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ORIGINAL RESEARCH

Predictors of Probable Depression Onset and Remission in Hong Kong Adolescents: A Population-Based Longitudinal Study of Shared and Unique Modifiable Factors

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Background: The onset and remission of probable depression may be influenced by shared modifiable factors; however, direct comparisons of their predictors within the same cohort are lacking.

Methods: A one-year, two-wave longitudinal survey was conducted among 9222 Hong Kong secondary school students (grades 1–4) at baseline, with 7106 followed up. Data were collected using paper questionnaires in classrooms. Generalized linear mixed models, adjusted for age, gender, and school-level clustering, examined associations between baseline predictors at individual, interpersonal, and environmental levels and incidence/remission of probable depression. False discovery rate adjustments were applied. Subgroup analyses by age and gender were conducted for significant interactions. Sensitivity analyses using multiple imputation and inverse probability weighting were performed.

Results: Most predictors across three levels (eg, negative life events, interpersonal conflict, academic stress) showed opposing effects on incidence and remission (all $p < 0.01$). Interpersonal conflict and academic stress were key risk factors for incidence (AOR = 1.397) and barriers to remission (AOR = 0.742), respectively. School satisfaction and social capital were unique protective factors for incidence (AOR = 0.796 and 0.872). Negative life events and academic expectation stress had stronger adverse effects among older adolescents (≥15 years). Findings were robust in sensitivity analyses.

Conclusion: Incidence and remission of adolescent probable depression shared several common predictors with opposing effects. The unique protective effect of school satisfaction and social capital on incidence suggests their value in prevention. Age-specific interventions, such as enhancing coping skills and stress management, may promote depression remission among older adolescents.

Keywords: depression, incidence, remission, adolescents

Introduction

Adolescent depression has become a pressing global health concern,[1] imposing substantial burdens on individuals, families, and society.[2] Depression is the strongest single contributor to adolescent suicide and the third leading cause of death in this age group.[3] Early identification and prevention of depression are essential for reducing adolescent suicide and preventing adverse outcomes in adulthood, such as poorer health, increased criminal behaviour, impaired social functioning, and higher rates of illicit drug use.[4]

The incidence of adolescent depression has shown an increasing trend from 1990 to 2019.[5] In Hong Kong, the incidence of probable depression (defined by the Center for Epidemiological Studies Depression Scale (CESD)≥16) in adolescents was 46.6% in 2020.[6] Identifying potentially modifiable risk/protective factors of depression onset during adolescence is critical to guide the development of prevention programs. Many cross-sectional and longitudinal studies have assessed the relationship between various modifiable factors and adolescent depression.[7] According to the socio-

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ecological model,[8] these factors can be categorized into three levels: individual (eg, psychological resilience[9] and coping skills[10]), interpersonal (eg, family/peer support[11]) and environmental (eg, school environment).[12] These levels are equally important for understanding individuals' health development and guiding interventions. However, to our knowledge, only six studies (Supplementary Table 1) have examined modifiable factors of depression onset in adolescents. Five of them, conducted in the Americas, Oceania, and Europe, primarily aimed to develop and validate predictive indices for adolescent depression onset. These studies tested a wide range of factors, including psychosocial variables (eg, cognitive styles and problematic behaviours), clinical information (eg, structural magnetic resonance imaging,[13] hormonal and neural functioning[14]), and parental mental health and personality.[13] However, to obtain the optimal predictive model (eg, with the highest area under the receiver operating characteristic curve), these studies usually excluded independently significant but less contributing predictors. Therefore, it is hard to comprehensively understand the significant predictors for adolescent depression onset. One study from China (N=4100 secondary students)[6] assessed several individual and interpersonal factors, and found that negative life events, loneliness, and social anxiety significantly predicted depression onset in adolescents. No environmental factors were examined in this study. Besides, methodological heterogeneity across these studies (eg, different depression measures and follow-up periods) makes it difficult to synthesize findings.

Remission from probable depression is possible among adolescents, especially among those with mild depressive symptoms.[15] One Hong Kong study reported that 23.2% of adolescents with probable depression (defined by the CESD ≥16) remitted within one year.[16] Given the limited availability of mental health services, especially in low- and middle-income countries, and the episodic nature of depressive symptoms during adolescence, it is neither practical nor necessary for all adolescents with probable depression to receive formal clinical treatment. Identifying its modifiable predictors may promote natural remission from probable depression without intensive intervention, thereby supporting more efficient, tiered allocation of mental health resources. However, modifiable factors contributing to probable depression remission remain poorly understood. Only two studies were identified: One study[15] found that adolescents with poor general health and family relations were less likely to remit from moderate/severe depressive symptoms. This study did not clarify whether the independent variables were assessed using validated measures, which might threaten the validity of the findings and make them difficult to replicate and interpret. Another longitudinal study[16] identified several predictors at individual (eg, self-esteem, positive affect) and interpersonal-levels (family support). While neither of them examined environmental factors from school, community and society, which are closely related to adolescent mental health.[17,18]

The onset and remission of probable depression may share common predictors. For instance, negative life events, loneliness, and social anxiety were both reported to predict incidence[6] and remission[16] of probable depression in different cohort studies. However, differences in study designs, samples, and measurements make direct comparisons difficult. The potential overlaps and distinctions between predictors of onset and remission remain unclear. A single study examining modifiable predictors for both outcomes simultaneously is warranted. Understanding shared and unique predictors can facilitate the development of cost-effective interventions that have both prevention and treatment functions. In addition, developmental differences across adolescence and well-documented gender disparities in depression (ie, higher prevalence among females)[19] suggest that the predictors for depression incidence and remission may vary across age and gender groups. Examining their potential moderating effects helps identify subgroup-specific patterns of predictors and inform the development of tailored prevention and intervention strategies for adolescent depression.

This population-based longitudinal study aims 1) to provide the prevalence, incidence, and rates of remission and persistence of probable depression among Hong Kong adolescents; 2) to identify shared and unique modifiable predictors of onset and remission; and 3) to explore whether age and gender moderate these relationships. Predictor selection was guided by theories that have been commonly used to explain adolescent depression, including the Stress-coping Theory,[10] the Hopelessness Theory,[20] and the Vulnerability-resilience Stress Theory.[21] A comprehensive review of the longitudinal factors of adolescent depression was conducted. Predictors were included if they: (1) were modifiable and could inform selective prevention programs; (2) showed evidence of longitudinal associations with adolescent depression; (3) demonstrated relatively large effect sizes; and (4) though not well-studied, were culturally relevant to the Hong Kong context (eg, academic stress[22] and satisfaction with local social development). Details of included predictors were shown in Supplementary Table 2. Briefly, a total of 16 predictors were included, including seven at individual (eg, self-esteem), three at interpersonal (eg, interpersonal support), and six at environmental levels (eg, academic expectation stress). We

hypothesized that factors related to acute stress and interpersonal triggers would be more strongly associated with depression onset, whereas factors related to chronic stress and coping resources would be more strongly associated with remission. In addition, age and gender would moderate these relationships.

Methods

Study Design and Participants

A one-year two-wave longitudinal study with stratified random sampling was conducted in Hong Kong secondary schools from October 2020 to October 2023. For each participating school, the time interval between baseline and follow-up survey was one year. The overall data collection spanned three years because schools were recruited in batches and the COVID-19 pandemic slowed the progress of school-based surveys. The sampling frame encompassed 391 local, non-international secondary schools. Nine of Hong Kong's 18 districts were randomly selected, with two schools randomly chosen from each of these districts. Then, an additional school was randomly selected from each of the remaining nine districts. To achieve the target sample, 41 schools were invited, of which 27 agreed to participate, resulting in a school-level participation rate of 65.9%. The flowchart was shown in Supplementary Figure 1. An invitation Email was sent to selected schools to explain the objectives, significance and logistics of the study. Replacements of schools were made upon refusals. The inclusion criteria included: 1) secondary students from Grades 1–4; (2) students' and parental consent; (3) Chinese speaking. Students in Grades 5 and 6 were not invited because they were preparing for the public exam and had difficulty following up. Exclusion criteria included: 1) having cognitive impairment to complete the survey independently; 2) having severe mental problems that need immediate action (eg, suicidal ideation). The anonymous, structured, paper-based questionnaire survey was conducted in classroom settings by two experienced research assistants (RAs), in the absence of teachers, which took around 15 minutes. RAs briefed students about the background and administration of the questionnaire and stood by for inquiries. Students received bookmarks as a token of appreciation.

Measures

Outcome

Probable Depression

The 20-item Center for Epidemiological Studies Depression Scale (CESD)[23] was used to measure depressive symptoms over the last week, which has been widely used in Chinese adolescents.[16] Responses are rated on a 4-point scale from 0 (less than one day) to 3 (5–7 days/week), with total scores ranging from 0 to 60. The cut-off of 16 or higher was defined as probable depression.[16] Previous studies[24,25] found this cut-off significantly related to clinical assessments of depression, which has been used to predict clinical diagnoses of depression. It is a standard cut-off that has been used by prior studies in Hong Kong adolescents.[16] The Cronbach's α in the study was good (0.911 at baseline and 0.914 at follow-up). Incidence was defined as the proportion of adolescents who developed probable depression at one-year follow-up among those without probable depression at baseline. Remission referred to the proportion of adolescents who had probable depression at baseline but remitted at one-year follow-up.

Modifiable Predictors

Individual-Level Factors

The study included seven individual-level factors, measured by well-validated scales (Supplementary Table 2 for details). Specifically, self-esteem was assessed by five positive items of the Rosenberg Self-Esteem Scale (RSE),[26] since previous research has suggested that the RSE is better specified as a single positive dimension to reduce overlap between measures and response bias to negatively-worded items.[27,28] Dysfunctional attitudes were measured with six items from the Dysfunctional Attitude Scale Form A (DAS-A) on a 7-point Likert scale.[29] Hopelessness was evaluated using the 4-item Beck Hopelessness Scale (BHS) on a 6-point Likert-type scale.[30] Coping strategies were examined using the short version of the Cognitive Emotion Regulation Questionnaire (CERQ),[31] which evaluates adolescents' positive and negative coping responses to stressful, threatening, or traumatic life events. Psychological resilience was measured with the 2-item abbreviated Connor-Davidson Resilience Scale (CD-RISC2),[32] with higher scores suggesting greater

psychological resilience. Problem behaviour was assessed using an adapted Problem Behaviour Scale (PBS),[33] including drinking or drug addiction, smoking, poor sleep quality, obesity, breaking items of oneself or others, running away from home, and skipping school. Negative life events were evaluated with the 27-item Adolescent Self-Rating Life-event Checklist (ASRLE),[34] which measures stress across four domains (ie, family, school, interpersonal, and individual).

Interpersonal Factors

Three interpersonal-level factors were included: Interpersonal support was measured by a four-item scale, with two items focused on family support and two on peer support.[35] Interpersonal conflict with family and peers was assessed using the Network of Relationships Inventory-conflict subscale (NRI-CS).[36] Parental psychological control was evaluated by the 8-item Psychological Control Scale-Youth Self-Report (PCS-YSR),[37] which measures tactics such as guilt induction, invalidation of feelings, and love withdrawal. These scales have been validated in previous studies among Chinese adolescents[35,38,39] and also demonstrated satisfactory reliability in the current study.

Environmental Factors

Six environmental-level factors were included. Academic expectation stress from parents, teachers, and the self was examined using the 9-item Academic Expectations Stress Inventory (AESI).[40] Academic stress related to school, class, workload, homework, tests, and academic performance was assessed with the 6-item Students' Academic Stress Scale (SASS).[41] Both scales have been validated in Chinese adolescents[41,42] and showed good reliability in the current study. Additionally, adolescents' satisfaction with their school and Hong Kong's social development, social capital, and community group participation were each assessed with a single question.

Background Factors

Sociodemographic factors included age, gender, living arrangement, parents' education levels, impacts of COVID-19, and participation in extracurricular activities regarding mental health promotion were collected.

Data Matching

Information, including school, grade, class, date of birth, and the last three digits of HKID, was collected at both baseline and follow-up for data matching. First, students' school, grade, class, and date of birth were used to match data for the first round. For participants not matched, school, grade, class, and the last three digits of the HKID were used to match for the second round. Any remaining unmatched participants were manually reviewed to identify any incorrect information or typos on the above-mentioned matching variables.

Statistical Analyses

Participant characteristics were compared between those who completed the one-year follow-up and those who did not. Chi-square and *t*-tests were used to assess differences in categorical and continuous variables, respectively. Weighted prevalence, incidence and remission rates based on the age and gender distribution from the Hong Kong Census were reported.[43] The univariable generalized linear mixed model (GLMM) evaluated the longitudinal association between baseline predictors and probable depression incidence/remission at one-year follow-up, adjusting for cluster effects within schools. As all background factors (living arrangement, parental education, COVID-19 impacts, participation in mental health promotion activities) tested in univariable models were non-significant, they were not included in multivariable models. Age and gender were retained in the multivariable analyses regardless of significance, given their known links with depression onset and remission.[35] Continuous variables were z-score normalized to standardize the scale. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported using the standardized data.

To explore the potential moderation role of age and gender, one-by-one interaction terms of significant predictors identified in multivariable GLMMs with age/gender were tested. Subgroup analyses by age/gender were then conducted on predictors with significant interactions. Given the non-normal distribution of age, the median value (14 years old) was used to divide adolescents into two groups in subgroup analyses. The same cutoff has been previously used to define

younger and older adolescents.[44] To reduce the Type I error due to multiple tests (17 predictors × 2 outcomes × 2 moderators), adjusted p-values were calculated using the False Discovery Rate (FDR) method.

Two sensitivity analyses were conducted. First, we assumed that the missing data were missing at random (with $p<0.05$ of Little's test). To mitigate possible biases caused by missing data, multiple imputations (MI) were implemented. Missing values ranged from 0.9% for living arrangements to 6.6% for community group participation. Therefore, ten imputations were created based on the rule of thumb that the number of imputations should be at least as large as the percentage of missing data.[45] All variables with missing data (Table 1) were included in the imputation model. Second, inverse probability weighting (IPW) was used to reduce selection bias due to loss to follow-up. Weights were calculated by logistic regression based on background factors that significantly differed between adolescents who completed the one-year follow-up and those who dropped out (Table 1). As the estimated probabilities did not produce extreme weights in the current sample, additional stabilization or truncation procedures were not applied.

Table 1 Characteristics at Baseline of Participants Who Completed 1-Year Follow-Up and Those Who Did Not

	Total Baseline Sample (N=9222), n (%)	**Lost to Follow Up (n = 2116), n (%)**	**Completed Follow Up (n = 7106), n (%)**	***p*** [b]
Age (years) [a]	14.40 (1.42)	14.53 (1.49)	14.32 (1.37)	**<0.001**
≤14	5996 (54.0)	2193 (50.9)	3803 (56.0)	**<0.001**
≥15	5107 (46.0)	2117 (49.1)	2990 (44.0)	
Gender				
Male	5503 (49.6)	2235 (55.9)	3268 (46.0)	**<0.001**
Female	5600 (50.4)	1762 (44.1)	3838 (54.0)	
Mother's educational level				
Primary school or below	611 (5.5)	232 (5.8)	379 (5.3)	0.118
Middle school	4787 (43.1)	1761 (44.1)	3026 (42.6)	
College or above	2031 (18.3)	691 (17.3)	1340 (18.9)	
Do not know	3674 (33.1)	1313 (32.8)	2361 (33.2)	
Father's educational level				
Primary school or below	849 (7.6)	321 (8.0)	528 (7.4)	0.092
Middle school	4960 (44.7)	1808 (45.2)	3152 (44.4)	
College or above	1847 (16.6)	620 (15.5)	1227 (17.3)	
Do not know	3447 (31.0)	1248 (31.2)	2199 (30.9)	
Living with parents				
Both parents	8335 (75.1)	2938 (73.5)	5397 (75.9)	**0.011**
Mother only	1615 (14.5)	619 (15.5)	996 (14.0)	
Father only	516 (4.6)	212 (5.3)	304 (4.3)	
Neither	542 (4.9)	199 (5.0)	343 (4.8)	
Missing	95 (0.9)	29 (0.7)	66 (0.9)	
Impacts of COVID-19				
Negative	4513 (48.9)	1230 (50.6)	3283 (48.3)	**0.038**
No impacts	3375 (36.6)	831 (34.2)	2544 (37.5)	
Positive	1149 (12.5)	314 (12.9)	835 (12.3)	
Missing	185 (2.0)	54 (2.2)	131 (1.9)	
Participation in mental health promotion activities				
No	1536 (16.7)	286 (11.8)	1250 (18.4)	**<0.001**
Yes	7686 (83.3)	2143 (88.2)	5543 (81.6)	
Depression				
No	4270 (38.5)	1476 (36.9)	2794 (39.3)	**0.014**
Yes	6833 (61.5)	2521 (63.1)	4312 (60.7)	

(*Continued*)

Table 1 (Continued).

	Total Baseline Sample (N=9222), n (%)	Lost to Follow Up (n = 2116), n (%)	Completed Follow Up (n = 7106), n (%)	*p* [b]
Individual-level factors				
Self-esteem [a]	13.94 (3.05)	13.81 (3.17)	14.02 (2.97)	**0.001**
Dysfunctional attitudes [a]	21.43 (7.27)	21.56 (7.42)	21.36 (7.18)	0.168
Hopelessness [a]	10.68 (3.64)	10.83 (3.71)	10.59 (3.60)	**0.001**
Cognitive emotion regulation				
Positive coping [a]	16.35 (3.14)	16.32 (3.25)	16.36 (3.08)	0.500
Negative coping [a]	12.90 (2.69)	12.93 (2.77)	12.88 (2.65)	0.345
Psychological resilience [a]	4.60 (1.76)	4.57 (1.79)	4.63 (1.74)	0.085
Problem behaviour [a]	8.24 (1.21)	8.31 (1.29)	8.19 (1.16)	**<0.001**
Negative life events [a]	29.87 (22.29)	30.59 (22.57)	29.47 (22.12)	**0.014**
Interpersonal-level factors				
Interpersonal support [a]	21.77 (8.70)	21.47 (8.91)	21.93 (8.57)	**0.007**
Interpersonal conflict [a]	14.84 (5.69)	15.07 (5.91)	14.72 (5.56)	**0.002**
Parental psychological control	17.12 (6.06)	17.05 (6.23)	17.16 (5.96)	0.382
Environmental factors				
Academic expectation stress [a]	28.25 (9.12)	27.89 (9.28)	28.46 (9.01)	**0.002**
Academic stress [a]	18.33 (3.98)	18.19 (4.02)	18.40 (3.95)	**0.007**
School satisfaction [a]	3.46 (0.92)	3.41 (0.96)	3.50 (0.90)	**<0.001**
Social capital [a]	4.82 (2.62)	4.76 (2.61)	4.85 (2.62)	0.109
Satisfaction with HK [a]	4.40 (2.46)	4.32 (2.49)	4.45 (2.44)	**0.007**
Community group participation [a]	0.55 (0.65)	0.57 (0.65)	0.54 (0.65)	0.055

Notes: [a] data was shown as mean (SD). [b] P values are for the comparison between participants who completed the one-year follow-up and those who lost to follow-up. Bolded p-values indicate $p < 0.05$.
Abbreviation: SD, standard deviation.

Ethical Standards Statement

The study procedures were carried out in accordance with the Declaration of Helsinki. Ethics approval [reference number: 2018.625] was obtained from the Ethics Committee of the corresponding author's affiliation. Informed consents were obtained from both participants and their parents. Participants reporting serious mental health problems at baseline or follow-up (eg, suicidal ideation) would be referred to school social workers for appropriate support. Information on available support services, including contacts for the research team, local service providers, and trusted online resources, was also provided at the end of the questionnaire. After the study, school-based reports and tailored professional recommendations were provided to each participating school.

Results

Demographic Characteristics

A total of 12,582 students were invited to participate in this study, with 73.3% [9222/12,582] completing the baseline survey. Subsequently, 77.1% [7106/9222] of them completed the one-year follow-up (54.0% female, and mean (SD) age 14.32 (1.37) years). The majority (75.9%) of participants were living with both parents, and less than one-fifth had parents with a college degree or higher. Significant differences were observed between participants who completed the follow-up and those who lost to follow-up, including age, gender, parental education, and living arrangement (all $p<0.05$) (Table 1). The final analytic sample included 6793 participants with complete data on CESD at both baseline and follow-up. The prevalence of probable depression was 60.7% (weighted: 60.5%) at baseline and 75.8% (weighted: 75.5%) at follow-up. Among participants without probable depression at baseline, 57.9% (1547/2672) (weighted: 58.3%) developed probable depression at follow-up. Among those with probable depression at baseline, 12.5% (517/4121) (weighted: 13.2%) remitted at follow-up (Figure 1A).

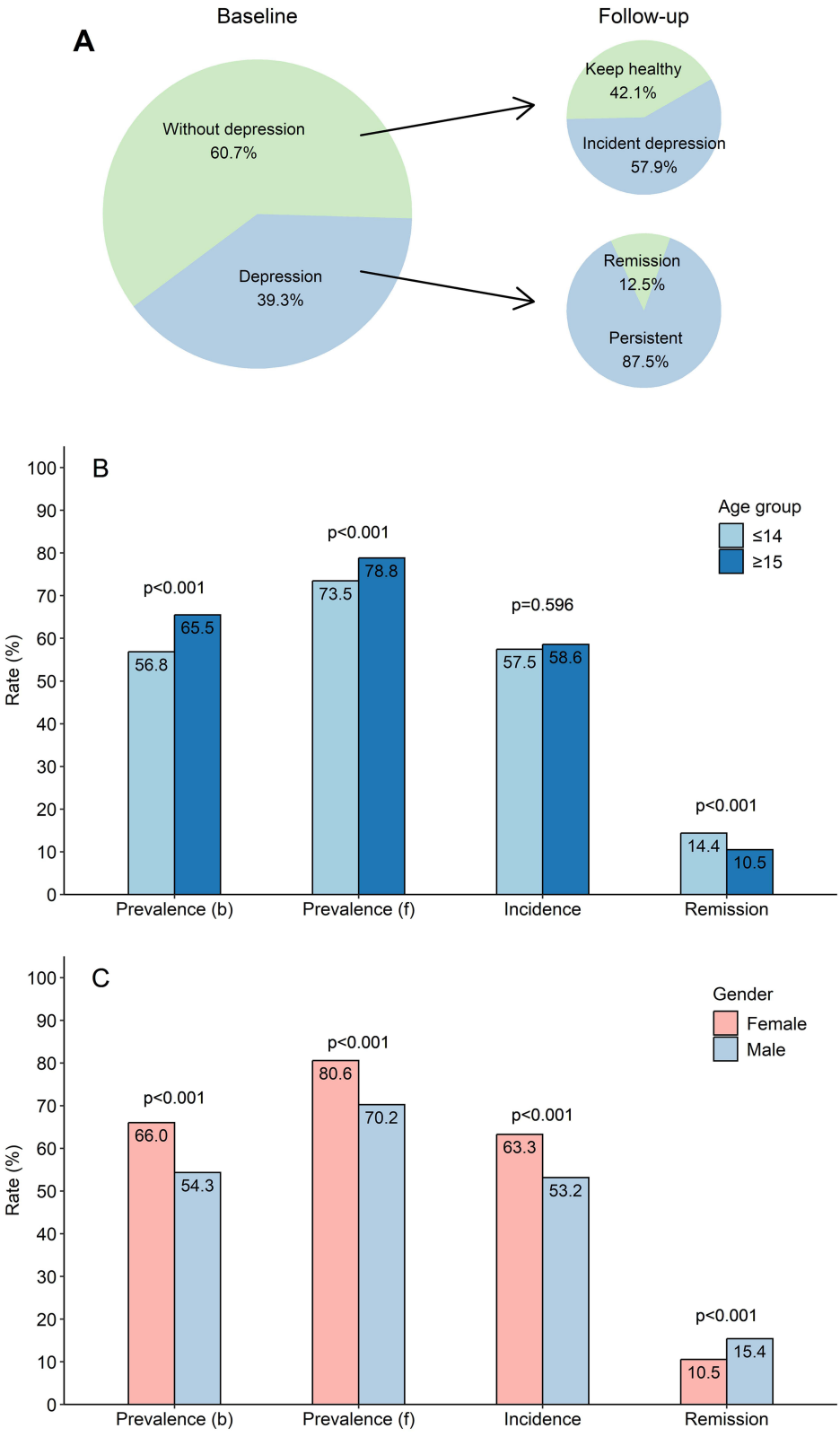

Figure 1 Conversion rates of depression in total sample (**A**), across age groups (**B**) and gender (**C**).
Notes: Prevalence (b) means the prevalence of depression at baseline; prevalence (f) means the prevalence of depression at one-year follow-up; *p* values were estimated by Chi-square test; the sample sizes used to estimate the incidence and remission rates are 2672 and 4121, respectively.

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Modifiable Predictors of Incidence and Remission

In multivariable GLMMs, most factors showed opposing effects with the incidence and remission of probable depression (ie, predictors with adjusted odds ratio (AOR)>1 for incidence tend to have AOR<1 for remission, and vice versa). For incidence, potent risk factors included hopelessness, problem behavior, negative life events, interpersonal conflict, and academic stress (AORs ranging from 1.342 to 1.397), while school satisfaction was a strong protective factor (AOR=0.796, all adjusted p<0.001). For remission, potent barriers included dysfunctional attitudes, negative life events, academic expectation stress and academic stress (AORs ranging from 0.742 to 0.792, all adjusted p<0.001). Notably, school satisfaction (AOR = 0.796) and social capital (AOR = 0.872; both adjusted p<0.05) emerged as unique protective factors for incidence but not for remission, representing the only factors with differential effects across outcomes.

Detailed results of the multivariable GLMMs are shown in Table 2, with univariable analyses in Supplementary Table 3. Sensitivity analyses using MI (Supplementary Table 4) and IPW (Supplementary Table 5) confirmed the robustness of these findings.

Moderation Role of Age and Gender

As shown in Figure 1B, the prevalence of probable depression was higher among adolescents aged 15 years or older compared to those 14 years or younger, both at baseline (65.5% vs. 56.8%, p<0.001) and follow-up (78.8% vs. 73.5%, p<0.001). Conversely, the remission rate was lower in the older age group (10.5% vs. 14.4%, p<0.001). Figure 1C indicates that female adolescents had higher probable depression prevalence at baseline and follow-up, as well as higher incidence and lower remission rates compared to males (all p<0.001).

Age and gender did not show significant interaction effects with the key predictors of probable depression onset (all adjusted p>0.05). For remission, only age exhibited significant interactions with negative life events and academic expectation stress (both adjusted p<0.05). Tables 3 and 4 present the interaction effects of age and gender, respectively. Sensitivity analyses

Table 2 Multivariable Analyses of Baseline Predictors for Depression Incidence and Remission Rate

	Incidence (N = 2672)			Remission (N = 4121)		
	AOR (95% CI)	***p***	**Adjusted *p***	**AOR (95% CI)**	***p***	**Adjusted *p***
Individual-level factors						
Self-esteem	0.804 (0.729, 0.886)	**<0.001**	**<0.001**	1.139 (1.029, 1.260)	**0.012**	**0.017**
Dysfunctional attitudes	1.295 (1.181, 1.419)	**<0.001**	**<0.001**	0.792 (0.714, 0.879)	**<0.001**	**<0.001**
Hopelessness	1.366 (1.236, 1.509)	**<0.001**	**<0.001**	0.815 (0.735, 0.904)	**<0.001**	**<0.001**
Cognitive emotion regulation						
Positive coping	1.053 (0.976, 1.137)	0.181	0.192	0.959 (0.870, 1.058)	0.408	0.434
Negative coping	1.174 (1.081, 1.274)	**<0.001**	**<0.001**	0.859 (0.776, 0.949)	**0.003**	**0.005**
Psychological resilience	0.832 (0.767, 0.903)	**<0.001**	**<0.001**	1.181 (1.068, 1.306)	**0.001**	**0.002**
Problem behavior	1.362 (1.212, 1.530)	**<0.001**	**<0.001**	0.883 (0.803, 0.970)	**0.010**	**0.015**
Negative life events	1.342 (1.199, 1.502)	**<0.001**	**<0.001**	0.778 (0.700, 0.864)	**<0.001**	**<0.001**
Interpersonal-level factors						
Interpersonal support	0.854 (0.786, 0.927)	**<0.001**	**<0.001**	1.170 (1.055, 1.297)	**0.003**	**0.005**
Interpersonal conflict	1.397 (1.257, 1.554)	**<0.001**	**<0.001**	0.866 (0.787, 0.951)	**0.003**	**0.005**
Parental psychological control	1.175 (1.076, 1.283)	**<0.001**	**<0.001**	0.829 (0.755, 0.910)	**<0.001**	**<0.001**
Environmental factors						
Academic expectation stress	1.288 (1.183, 1.401)	**<0.001**	**<0.001**	0.744 (0.671, 0.826)	**<0.001**	**<0.001**
Academic stress	1.343 (1.228, 1.469)	**<0.001**	**<0.001**	0.742 (0.670, 0.822)	**<0.001**	**<0.001**
School satisfaction	0.796 (0.729, 0.869)	**<0.001**	**<0.001**	1.074 (0.974, 1.185)	0.151	0.171
Social capital	0.872 (0.804, 0.945)	**0.001**	**0.001**	1.091 (0.988, 1.205)	0.086	0.104
Satisfaction with HK	0.830 (0.766, 0.900)	**<0.001**	**<0.001**	1.138 (1.028, 1.260)	**0.013**	**0.017**
Community group participation	1.075 (0.899, 1.285)	0.429	0.759	0.973 (0.789, 1.199)	0.796	0.917

Notes: All models were estimated based on standardized data, and adjusted for age, gender and cluster effects within schools. Adjusted p: p values adjusted for multiple testing using False Discovery Rate (FDR). Bolded p-values indicate p < 0.05.
Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

Table 3 Interactions of Significant Predictors with Age for Depression Incidence and Remission Rate

	Incidence (N = 2672)			Remission (N = 4121)		
	AOR (95% CI)	***p***	**Adjusted *p***	**AOR (95% CI)**	***p***	**Adjusted *p***
Individual-level factors						
Self-esteem*age	0.946 (0.859, 1.042)	0.261	0.804	1.029 (0.926, 1.144)	0.594	0.702
Dysfunctional attitudes*age	0.966 (0.881, 1.059)	0.459	0.984	0.909 (0.816, 1.012)	0.082	0.178
Hopelessness*age	1.068 (0.968, 1.178)	0.191	0.804	1.052 (0.945, 1.172)	0.352	0.508
Negative coping*age	0.938 (0.861, 1.022)	0.144	0.804	0.932 (0.840, 1.034)	0.186	0.345
Psychological resilience*age	0.968 (0.893, 1.049)	0.429	0.984	0.989 (0.891, 1.097)	0.831	0.831
Problem behavior*age	1.013 (0.902, 1.138)	0.829	0.990	1.014 (0.921, 1.117)	0.770	0.831
Negative life events*age	0.966 (0.861, 1.084)	0.558	0.990	0.793 (0.712, 0.883)	**<0.001**	**<0.001**
Interpersonal-level factors						
Interpersonal support*age	0.990 (0.914, 1.072)	0.799	0.990	0.881 (0.795, 0.977)	**0.016**	0.069
Interpersonal conflict*age	0.995 (0.891, 1.110)	0.923	0.990	0.940 (0.851, 1.037)	0.217	0.353
Parental psychological control*age	1.001 (0.914, 1.095)	0.990	0.990	0.903 (0.822, 0.993)	**0.034**	0.088
Environmental factors						
Academic expectation stress*age	0.985 (0.907, 1.069)	0.711	0.990	0.833 (0.756, 0.919)	**<0.001**	**<0.001**
Academic stress*age	0.991 (0.910, 1.080)	0.840	0.990	0.895 (0.812, 0.987)	**0.026**	0.084
School satisfaction*age	1.087 (1.000, 1.181)	0.050	0.735	-	-	-
Social capital*age	0.954 (0.878, 1.037)	0.268	0.804	-	-	-
Satisfaction with HK*age	0.997 (0.923, 1.077)	0.936	0.990	0.960 (0.866, 1.064)	0.436	0.567

Notes: All models were estimated based on standardized data, and adjusted for age, gender and cluster effects within schools. Adjusted p: p values adjusted for multiple testing using False Discovery Rate (FDR). Bolded p-values indicate $p < 0.05$.
Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

Table 4 Interactions of Significant Predictors with Gender for Depression Incidence and Remission Rate

	Incidence (N = 2672)			Remission (N = 4121)		
	AOR (95% CI)	***p***	**Adjusted *p***	**AOR (95% CI)**	***p***	**Adjusted *p***
Individual-level factors						
Self-esteem*gender	0.911 (0.746, 1.114)	0.363	0.933	1.110 (0.907, 1.358)	0.312	0.490
Dysfunctional attitudes*gender	0.946 (0.786, 1.139)	0.560	0.933	1.019 (0.828, 1.254)	0.857	0.857
Hopelessness*gender	0.982 (0.800, 1.204)	0.858	0.961	0.833 (0.678, 1.025)	0.084	0.292
Negative coping*gender	0.936 (0.790, 1.109)	0.445	0.933	1.149 (0.939, 1.405)	0.177	0.460
Psychological resilience*gender	1.067 (0.905, 1.257)	0.442	0.933	1.040 (0.851, 1.272)	0.700	0.827
Problem behaviour*gender	1.152 (0.910, 1.459)	0.241	0.933	0.895 (0.741, 1.081)	0.248	0.461
Negative life events*gender	1.217 (0.953, 1.554)	0.115	0.933	0.832 (0.673, 1.029)	0.090	0.292
Interpersonal-level factors						
Interpersonal support*gender	1.055 (0.892, 1.247)	0.531	0.933	1.302 (1.061, 1.599)	**0.012**	0.078
Interpersonal conflict*gender	1.023 (0.821, 1.275)	0.840	0.961	0.972 (0.804, 1.176)	0.770	0.834
Parental psychological control*gender	0.907 (0.760, 1.083)	0.280	0.933	1.125 (0.933, 1.357)	0.217	0.461
Environmental factors						
Academic expectation stress*gender	0.980 (0.830, 1.157)	0.813	0.961	1.045 (0.852, 1.282)	0.672	0.827
Academic stress*gender	0.991 (0.827, 1.186)	0.918	0.961	0.906 (0.741, 1.109)	0.339	0.490
School satisfaction*gender	0.909 (0.760, 1.087)	0.296	0.933	-	-	-
Social capital*gender	0.977 (0.829, 1.150)	0.776	0.961	-	-	-
Satisfaction with HK*gender	1.004 (0.852, 1.183)	0.961	0.961	1.301 (1.060, 1.596)	**0.012**	0.078

Notes: All models were estimated based on standardized data, and adjusted for age, gender and cluster effects within schools. Adjusted p: p values adjusted for multiple testing using False Discovery Rate (FDR). Bolded p-values indicate $p < 0.05$.
Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

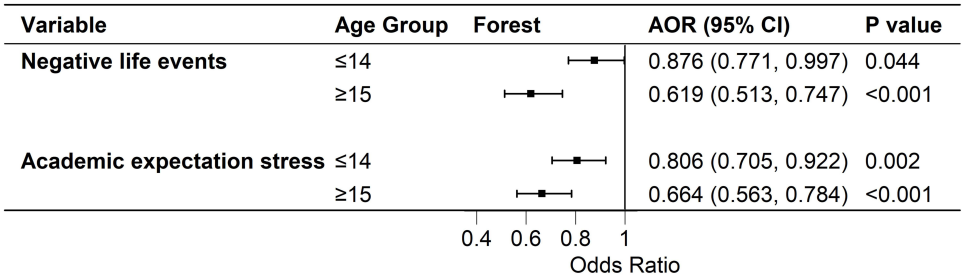

Figure 2 Subgroup analyses of depression remission by age.
Notes: Estimates were based on standardized data in subgroup analyses by age; all models adjusted for gender in analyses.
Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

using MI and IPW (Supplementary Tables 6–9) confirmed the robustness of the findings. As shown in Figure 2, negative life events and academic expectation stress had stronger negative impacts on remission among older adolescents.

Discussions

This study revealed a concerning situation of probable depression among adolescents in China. The prevalence (60.7%) and incidence (57.9%) were higher than pre-pandemic estimates in Hong Kong (prevalence: 33.4%;[46] incidence: 53.0%[47]) and the US[15] (prevalence: 28%) (defined by the same cutoff of CESD). One possible explanation is the stringent public health measures in Hong Kong during COVID-19, where adolescents spent prolonged time at home for remote learning, sharing limited living space. Living in crowded environments with reduced outdoor activity and peer interaction has been linked to higher depression risk.[48,49] In addition, the CES-D cutoff of 16, while sensitive for screening, might yield higher rates of "probable depression" by capturing subthreshold cases. Conversely, the remission rate (12.5%) was lower than the pre-pandemic estimate (23.2%).[16] This might be attributed to pandemic-related disruptions, such as reduced access to mental health services,[50] and increased academic pressure due to school closures and online learning,[51] which might hinder the natural recovery. Other non-pandemic factors might also contribute to the high incidence and low remission rates observed in this study, such as differences in sampling characteristics and changes in adolescents' willingness to report mental health symptoms. Future studies are needed to validate these findings and to explore the underlying mechanisms. Older adolescents had a similar incidence but lower remission than younger adolescents, which was possibly due to their greater academic stress[52] and reduced perceived support from family and teachers.[53] Female adolescents also showed higher incidence and lower remission, consistent with evidence that girls are more prone to persistent depressive symptoms.[15] These findings highlight the grim situation of adolescent probable depression in China, particularly among older and female adolescents.

This study found that the incidence and remission of probable depression shared several individual- and interpersonal-level predictors with opposing effects. Similarly, remission predictors identified by previous studies,[15,16] such as self-esteem, family support and reduced negative events, were also found to be inversely related to incidence.[7,14] It indicates that through enhancing these shared predictors, established psychosocial interventions for depression, such as cognitive-behavioural therapy,[54] family-based therapy,[55] and interpersonal psychotherapy,[56] may also be effective in preventing depression onset among adolescents. Future research should explore whether the mechanisms linking the common factors to onset versus remission are truly symmetrical or involve distinct pathways. Notably, interpersonal conflict was a particularly important factor among the potent predictors of incidence, with a clinically meaningful effect size: each SD increase was associated with nearly a 40% rise in the risk of developing probable depression. This highlights the importance of enhancing interpersonal skills (eg, communication and conflict resolution) to prevent depression. For remission, decreased academic stress was a particularly potent predictor. Given that academic stress is a well-established risk factor in Asian contexts where academic achievement is highly emphasized,[8] adolescents with probable depression may benefit from strategies aimed at reducing academic stress, such as strengthening stress management skills, providing academic support, and fostering a positive school environment.

It is interesting to find that school satisfaction and social capital were unique protective factors for incidence but not for remission. This suggests that positive school and social environment may help prevent probable depression but have limited effects on alleviating internalizing symptoms (eg, hopelessness and anhedonia). A longitudinal study in the US[57] also found that adolescents in more favorable school environments (eg, greater teacher support and structured discipline) in 9th grade had lower depression by 11th grade. Similarly, a nationally representative cross-sectional study in England[58] reported that adolescents with low social capital, such as low neighbourhood involvement, were nearly twice as likely to report poor health. It is probably because once probable depression is established, negative cognitive biases may prevent adolescents from perceiving or benefiting from positive environmental features. In addition, internalizing symptoms may reduce adolescents' engagement with school and community environments, thereby weakening the potential benefits of these resources. It is also possible that a higher intensity of environmental positivity is required to facilitate recovery than for prevention of probable depression. Given their unique role in preventing onset, enhancing school satisfaction and social capital should be prioritized in prevention strategies. For example, school-based programs could incorporate initiatives to enhance school connectedness (eg, teacher-student mentorship programs and positive school climate campaigns) and strengthen social capital (eg, community service activities and peer support networks). Future longitudinal studies are needed to further examine specific dimensions of school environment (eg, safety, structure, and disciplinary styles)[57] and social capital (eg, resources from household, school and neighbourhood relationships).[59,60]

Age significantly moderated the effects of negative life events and academic expectation stress on remission. Subgroup analyses showed that younger adolescents were less affected by these barriers to remission, consistent with their higher remission rates in our sample. One possible explanation is that younger adolescents may experience lower cumulative stress exposure and fewer entrenched maladaptive coping patterns, making their depressive symptoms more reversible.[61] In contrast, older adolescents often face more persistent academic pressure and developmental challenges, which may hinder recovery. The finding that age moderated remission but not incidence may also reflect the greater entrenchment of stress exposure and maladaptive coping patterns in older adolescents. While stressors can trigger probable depression at any age, recovery may require overcoming more accumulated stress and rigid coping responses in older adolescents, making them more sensitive to barriers. These findings highlight the need for age-specific interventions. In particular, stress management training, especially for academic expectation stress, should be prioritized for senior secondary students. Moreover, teachers and parents maintaining realistic academic expectations may help reduce stress and facilitate natural remission of probable depression in older adolescents.

Limitations

Several limitations should be noted. First, although the CES-D is a well-validated screening instrument, it is not a clinical diagnostic tool. Therefore, outcomes in this study refer to probable depression based on the cut-off of ≥16, rather than clinically diagnosed Major Depressive Disorder (MDD). Accordingly, "remission" refers to scoring below the cut-off at follow-up, which does not necessarily indicate clinical remission from MDD and may partly reflect natural symptom fluctuation and regression to the mean. The high prevalence and incidence may also be influenced by the high sensitivity of this cut-off. Second, remission models did not adjust for baseline CES-D scores, as these might act as mediators between predictors and remission. Adjusting for the baseline score might result in overadjustment and obscure meaningful predictors. Besides, from a prognostic perspective, our aim was to estimate the total predictive effect of baseline characteristics on natural remission, rather than their effects conditional on identical baseline severity. However, not adjusting for baseline severity may have led to overestimation of the observed associations; results of remission should be interpreted with caution. Third, several environmental predictors (ie, school satisfaction, social capital, satisfaction with Hong Kong's social development, and community group participation) were measured using single items, which have unknown reliability and may not capture the full complexity of multidimensional constructs. This may have attenuated observed effect sizes and could partially explain the null findings for these factors in relation to remission. Similarly, the PBS showed low internal consistency (Cronbach's $\alpha = 0.569$ at baseline), which might have underestimated the true effects of problem behaviors on outcomes and increased the risk of Type II error. Fourth, all measures were based on adolescent self-report. This introduces the potential for shared method variance, which may inflate associations between predictors and outcomes due to common rater effects, response biases (eg, social desirability, negative affectivity), and consistent reporting contexts. Future studies would benefit from multi- informant

approaches (eg, parent and teacher reports of behavior, clinical interviews) and objective measures where feasible (eg, school records for attendance, administrative data for community participation). Fifth, the study's generalizability is constrained by its school-based sampling frame. Adolescents who had dropped out of school or were absent on survey days, populations that likely have higher rates of depression and different risk profiles, were excluded from participation. As a result, the prevalence and incidence of depression may be underestimated, and the findings may be less applicable to the most vulnerable adolescents not engaged in the education system. Besides, individual-level data on students who declined participation or did not return parental consent were not collected, as surveys were only administered to assenting students with parental permission. Consequently, we were unable to compare participants and non-participants, which may introduce non-response bias. Future studies should consider collecting basic demographic information from non-participants to better evaluate generalizability. Finally, while the longitudinal design strengthens temporal inference relative to cross-sectional studies, it does not establish causation. Unmeasured confounders (eg, genetic vulnerability, treatment, temperament, comorbid mental health conditions and parental mental health) may explain some of the observed associations. Furthermore, depression is a recurrent condition that waxes and wanes over time; a single follow-up assessment cannot capture the full trajectory of the disorder, including relapse, chronicity, or late remission. Longer-term studies with multiple assessments are needed to understand how these predictors influence depression course over development.

Conclusions

The incidence and remission of adolescent probable depression shared several common modifiable predictors with opposing effects. For incidence, key risk factors included hopelessness, problem behaviors, negative life events at individual level, interpersonal conflict at interpersonal level, and academic stress, school satisfaction (protective factor) at environmental level. For remission, major barriers included dysfunctional attitudes, negative life events at individual level, and academic expectation stress, academic stress at environmental level. Notably, school satisfaction and social capital were unique predictors of incidence, suggesting that enhancing these factors should be prioritized in prevention strategies. Older adolescents were more susceptible to the adverse effects of negative life events and academic expectation stress on remission. These findings highlight the need for age-specific interventions, particularly those that strengthen coping skills and stress management among older adolescents with probable depression.

Data Sharing Statement

The data that support the findings of this study are available on request from the corresponding author.

Ethical Standards Statement

The study procedures were carried out in accordance with the Declaration of Helsinki. Ethics approval was obtained from the Ethics Committee of The Chinese University of Hong Kong [reference number: 2018.625]. Informed consents were obtained from both participants and their parents.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no conflict of interest.

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