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<https://doi.org/10.1057/s41599-023-02252-2>

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Developmental trajectories of depression, anxiety, and stress among college students: a piecewise growth mixture model analysis

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Mental health issues are becoming increasingly common among college students, but not all students follow the same developmental trends of mental health. This study aims to identify the developmental trajectories of depression, anxiety, and stress among college students and the related factors for different trajectory classes. The data were collected from a longitudinal survey of college students over four consecutive years, and 2473 students were included in the analysis. The study used a piecewise growth mixture model to determine the subtrajectories, and a multinomial logistic regression model was constructed to investigate the related factors affecting students in subtrajectories. The results revealed that subtrajectories include the low and stable class, increasing class, decreasing then stable class, increasing then decreasing class, and decreasing and high class. The decreasing and high class only presents in the trajectories of anxiety and stress. Regarding related factors, high BMI and high sleep hours were identified as related factors for the increasing class of depression; gender and high sleep hours were associated with the increasing class of anxiety; and hometown location was related to the increasing class of stress. Extroversion personality, relationship with classmates, siblings, and father's education level are related factors for other subtrajectories. Considering that college students experience multiple trajectories of depression, anxiety, and stress, mental health education and psychological intervention should be carried out for students in each class.

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Introduction

Psychological problems such as depression, anxiety, and stress have attracted growing attention in recent years. The incidence of common psychological disorders such as depression and anxiety has increased by at least 25% since the COVID-19 pandemic, with women and young people being the most affected (Collabo, 2021). The average age of onset for mental illness is also decreasing, yet most young people are hesitant to seek help for their psychological problems (Sarokhani et al., 2013).

Among young people, the psychological problems of college students are becoming common worldwide. It is estimated that 12–50% of college students have at least one common psychological disorder, and they have more serious mental health problems such as depression, anxiety, and stress than their peers who do not attend college (Bruffaerts et al., 2018; Cvetkovski et al., 2019). In the United States, a study of 26 universities in 2007 and 2009 reported that 17.3% of students were screened positive for depression, 4.1% for panic disorder, 7% for generalized anxiety, 6.3% for suicidal ideation, and 15.3% for nonsuicidal self-injury behaviors (Eisenberg et al., 2013). In China, ~35% of college students suffer from depression above the normal level, ~38% to 43% have anxiety problems, and ~20–30% experience high levels of stress (Liu et al., 2019). Compared with other age groups, college students deserve more attention in terms of their mental health since they face a crucial transition from adolescence to adulthood (Zarrett and Eccles, 2006). During their college years, students need to handle heavy academic pressure independently while thinking about future career planning, having higher risks of poorer mental health (Beiter et al., 2015; Eccles et al., 2003; Liu et al., 2022b). College students are an important targeted group of psychological services among young people.

Although the prevalence of depression, anxiety, and stress is high, the subgroups that deviate from the overall trend receive more attention. Existing studies have covered some age groups and analyzed their developmental trajectories of depression, anxiety, and stress, including adolescents, adults, and the elderly. Vella et al. (2019) specified the trajectories of mental health among children aged 4 to 12 as low difficulty, improvers, decliners, early decliners, early improvers, and high difficulty. Among adolescents, Crocetti et al. (2009) classified a low anxiety class with symptoms relieved over time and a high anxiety class with symptoms deteriorated. Schmeelk-Cone and Zimmerman (2003) identified four trajectories of stress among African-American adolescents, namely high, increasing, decreasing, and low. Using the growth mixture model (GMM), Colman et al. (2007) investigated anxiety and depression symptoms from the ages of 13, 15, 36, 43 to 53 and identified six trajectory classes, i.e., absence of symptoms, repeated moderate symptoms, adult-onset moderate symptoms, adolescent symptoms with the good adult outcome, adult-onset severe symptoms, and repeated severe symptoms over the life course. In the context of COVID-19, four trajectories of depression and five trajectories of anxiety were discovered among adults in England (Saunders et al., 2021). These studies considered the individual heterogeneity of the developmental trajectories and identified participants who deviated from the overall trend (von Eye et al., 2006).

Existing studies of college students mainly have focused on the overall changes in mental health. Cooke et al. (2006) investigated the psychological well-being of college students in the first year and noticed that students suffered from more significant strain as they entered university. Moreover, students' anxiety levels were significantly aggravated and could not return to preuniversity levels although the situation eased by the end of the semester. Bewick et al. (2010) expanded the scope from preregistration to the junior year. The strain on college students was still the heaviest in the first

semester of the freshman year and decreased significantly in the second semester of the freshman and junior years. In the whole scope of the four academic years, some studies stated that students' mental health worsened in the first two years, mainly manifested as decreased self-esteem and deteriorated depression, anxiety, and stress, but was alleviated in the junior and senior years (Bayram and Bilgel, 2008; Conley et al., 2020; Liu et al., 2019). However, not all students follow the same trend, and a few studies have investigated the heterogeneity of students' mental health. We believe that existing studies overlooked the multiple changes in depression, anxiety, and stress among college students. Compared with the variable-centered model, the person-centered model is more compelling in longitudinal studies of mental health (Gao et al., 2021). Therefore, this study aims to identify the developmental trajectories of depression, anxiety, and stress among college students, which will be of great importance to the prevention and education of mental illness among college students in the future.

To further analyze the typical characteristics of subtrajectories and provide effective interventions, we first reviewed some factors associated with depression, anxiety, and stress that prior studies have identified, which can be categorized into internal factors and external factors. Internal factors include gender, personality, lifestyle, etc., and external factors include family background and relationships with classmates. First, in the internal factors, gender is a significant related factor for identifying trajectory classes of depression, anxiety, and stress, and Dekker et al. (2007) identified six different developmental trajectories of depression for males and females. Second, for personality, some studies have proposed that extroverted persons might initially have a high level of anxiety but then quickly decrease, and children with fewer mental problems are likely to be more sociable (Saunders et al., 2021; Vella et al., 2019). Third, regarding lifestyle, body mass index (BMI) (Abdel Wahed and Hassan, 2017; Luppino et al., 2010; Wang et al., 2019), physical activity (Cao et al., 2023), and sleep hours (Baglioni et al., 2016; Beiter et al., 2015; Ghrouz et al., 2019) are associated with individuals' depression, anxiety, and stress. Fourth, family background (Cao and Liu, 2022; Liu et al., 2023b) also affects individuals' mental health state including hometown location (Gruebner et al., 2017), siblings (Downey and Condron, 2004; Lawson and Mace, 2010), and parents' education level (Lund et al., 2019; Wege et al., 2016; Yu et al., 2022). Last, relationships with classmates are essential sources of social support for individuals, and students with poor relationships with classmates usually have more severe symptoms of depression and anxiety (Allen et al., 2006; Shao et al., 2020). In general, extroversion, good sleep, healthy BMI, good social relationships, hometown in urban areas, siblings, and high parental education are usually identified as protective factors for depression, anxiety, and stress, which can promote resilience and are associated with lower negative outcomes. However, poor sleep, unhealthy BMI, poor social relationships, hometown in rural areas, no siblings, and parents with low education levels are regarded as risk factors for depression, anxiety, and stress in some studies, which are usually associated with higher negative outcomes, and people with multiple risk factors are more likely to suffer from psychological problems.

Although college students' overall trajectories of mental health have been analyzed in previous studies, the trajectories of the groups with depression, anxiety, and stress problems were not investigated thoroughly. Moreover, there are few studies on the developmental trajectories of depression, anxiety, and stress among Chinese college students, especially tracking the development of students' mental status throughout the university for four consecutive years. In this way, the study can provide critical evidence for future studies on Chinese college students. The sophomore year is a turning point in college when students gradually adapt to the college environment and clearly

understand their academic goals and future career choices (Liu et al., 2019). Some studies supported this view that students' mental health worsened in the first two years but improved in the last two years (Bayram and Bilgel, 2008; Conley et al., 2020). However, some sophomores who do not adjust to the college environment may become dissatisfied with the college experience and suffer from more severe problems in the following years (Dipeolu et al., 2022). Therefore, the study chose the sophomore year as the change point (knot) for mental health and explored the developmental trajectories of depression, anxiety, and stress of college students during the four years. Additionally, identifying related factors for their developmental trajectories will help specify the characteristics of these subgroups for targeted interventions. It is worth noting that these college students deviating from the general trend should become the focus in the prevention of mental diseases. Therefore, to provide critical evidence on Chinese college students, the study identified the developmental trajectories of depression, anxiety, and stress and explored the related factors for the subtrajectories.

Methods

Participants and procedures. The data of this study came from the Beijing College Students Panel Survey (BCSPS) (Li, 2013). The samples were representative of college students in Beijing with a stratified, multistage, and probability proportional to size sampling method, and biases caused by human factors and potential selective factors were excluded as much as possible (Gao et al., 2022; Liu et al., 2022a; Zhang et al., 2022). This panel survey has been used in many studies (Liu et al., 2023c; Liu et al., 2023d; Luo et al., 2022; Zhu, 2020). The present study selected students who enrolled in 2008 and analyzed their information during the four academic years. The baseline survey collected 2473 valid samples, and high response rates were maintained in the following three years, with 95.27%, 94.66%, and 90.58%, respectively.

Measures

Depression, anxiety, and stress. The Depression Anxiety Stress Scale-42 (DASS-42) consists of three subscales, with 14 items each. It uses a four-point Likert scale to assess the severity of an individual's depression, anxiety, and stress in the past week, with 0 indicating "did not apply to me at all", 1 "applied to me to some degree, or some of the time", 2 "applied to me to a considerable degree, or a good part of the time", and 3 "applied to me very much, or most of the time" (Lovibond and Lovibond, 1995). DASS-42 has a stable factor structure and good reliability in its application, and it can reliably and validly assess the mental health of Chinese individuals (Antony et al., 1998; Wang et al., 2020).

The depression scale in DASS-42 assesses the individual's dysphoria, hopelessness, etc. According to the total score summed by the scores of relevant items, the severity of depression has five levels: normal (0–9), mild (10–13), moderate (14–20), severe (21–27), and extremely severe (28–42) (Lovibond and Lovibond, 1995). The missing data rates were 5.22%, 0.90%, and 3.57%, and the reliability coefficients of the depression scale in the four years were 0.89, 0.90, 0.93, and 0.94, respectively. The anxiety scale in DASS-42 evaluates an individual's autonomic arousal, skeletal muscle effects, etc. According to the total score, the severity of anxiety includes normal (0–7), mild (8–9), moderate (10–14), severe (15–19), and extremely severe (20–42) (Lovibond and Lovibond, 1995). The missing data rates were 5.63%, 0.34%, and 3.57%, and the reliability coefficients of the anxiety scale in the four years were 0.82, 0.85, 0.90, and 0.92, respectively. The stress scale in DASS-42 estimates the individual's difficulty relaxing,

nervous arousal, etc., and the severity of stress is classified into normal (0–14), mild (15–18), moderate (19–25), severe (26–33), and extremely severe (34–42) according to the total score (Lovibond and Lovibond, 1995). The missing data rates were 5.30%, 0.77%, and 3.57%, and the reliability coefficients of the stress scale in the four years were 0.88, 0.88, 0.91, and 0.93, respectively.

Related factors. According to the related factors of mental health in previous studies, the variables collected in the baseline survey include gender, extroversion personality, BMI, sleep hours, relationship with classmates, hometown location, siblings, father's education level, and mother's education level. Gender is regarded as a dummy variable (female = 0, male = 1). The degree of extroversion personality is measured by a question ("Do you think you are introverted or extroverted?"), and the choices range from introversion (=1) to extroversion (=9). BMI is calculated based on an individual's height and weight. A BMI below 18.5 is considered low (=0), between 18.5 to 24 is considered normal (=1), and above 24 is considered high (=2) (Gallagher et al., 2000). As the optimal sleep hours for young people is 7–9 h, sleep duration within this range is regarded as normal (=1), less than 7 hours is low (=0), and higher than 9 hours is high (=2) (Hirshkowitz et al., 2015). The relationship with classmates is measured by a question ("How did you get along with your classmates in college?"), and the choices range from very unfamiliar (=1) to very familiar (=5). Hometown location and siblings are both dummy variables (hometown location: rural = 0, urban = 1; siblings: yes = 0, no = 1). The years of formal education that the fathers and mothers have received correspond to their education level, and the study uses the number of years that most Chinese take (never accept formal education = 0, primary school = 6, middle school = 9, senior high school and equivalent education level = 12, bachelor's degree or associate degree = 16, master's degree and above = 19).

Data analysis. The piecewise growth mixture model was used to identify college students' developmental trajectories of depression, anxiety, and stress in Mplus 8.3. The growth mixture model can estimate the average growth curve of each subtrajectory and analyze the correlation with independent variables (Boscardin et al., 2008; Ram and Grimm, 2009). This study increased the latent classes from the baseline models of depression, anxiety, and stress until the models best fit the data (Asparouhov and Muthen, 2014). The trajectories were raised to six latent classes, and the classes were determined according to the model fit statistics and trajectory classes in previous studies. Generally, lower Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Sample Size Adjusted Bayesian Information Criterion (SABIC) indicate better model fit, and BIC is the most widely used index in the test (Nylund et al., 2007). Entropy is not specifically used for model selection initially since a high entropy value does not necessarily indicate better internal homogeneity of subtrajectories. However, the model fit is usually poor with a low entropy value (Feldman et al., 2009; Lubke and Muthen, 2007). In addition, an entropy value lower than 0.6 indicates that the accuracy of classification is less than 80%, while an entropy value above 0.8 indicates that the accuracy of classification is more than 90% (Lubke and Muthen, 2007). The LoMendel-Rubin Likelihood Ratio Test (LMR-LRT) and Bootstrapped Likelihood Ratio Test (B-LRT) compare the k and k-1 models, and when the k model is statistically significant, it indicates that the k model fits better than the k-1 model (Lo et al., 2001).

The multinomial logistic regression model was constructed in Stata 16.0 to explore the related factors for subtrajectories of depression, anxiety, and stress, with the subtrajectories as

dependent variables, and gender, extroversion personality, BMI, sleep hours, relationship with classmates, hometown location, siblings, father's education level, and mother's education level as independent variables (Asparouhov and Muthen, 2014).

Results

Descriptive statistics. Approximately 47.15% were females, 53.85% were males, and the average age was 19.60 ± 0.89 . The average score of extroversion personality was 5.60 ± 1.65 , and that of the relationship with classmates was 3.61 ± 0.83 . A total of 71.95% of the students had a normal BMI, 19.19% had a low BMI, and 8.86% had a high BMI. The average sleep hours of students were 7.41 ± 0.84 , with 82.15% of the students normal, 10.42% low, and 7.43% high. In terms of family background, more students came from urban areas than rural areas, and more students did not have siblings. The average years of the father's education were 13.41 ± 3.60 , and the average years of the mother's education were 12.49 ± 4.08 . The statistics in the baseline survey are listed in Appendix A.

Determination of trajectory classes. To determine the trajectory classes of depression, anxiety, and stress, six latent classes of trajectories were tested. In Table 1, the AIC, BIC, and SABIC decreased with latent classes increasing, and the B-LRT of all models was statistically significant ($p < 0.05$). In the depression and anxiety trajectories, the entropy values were higher than 0.8. In the stress trajectories, the entropy values were higher than 0.7.

In the depression trajectories, the 2-class, 4-class, and 6-class models were statistically significant in LMR-LRT, indicating that 2-class, 4-class, and 6-class models fit better than 1-class, 3-class, and 5-class models, respectively. Considering all fitting indexes, the 4-class model was the most suitable. Furthermore, we noticed that previous studies also identified depression trajectories into four classes (Bonanno et al., 2012; Xiang and Cheng, 2019).

In the anxiety trajectories, the LMR-LRT was only statistically significant in the 2-class model ($p < 0.05$), but the AIC, BIC, and SABIC of other models were better than those of the 2-class model. Combined with the classification of prior studies, the five trajectory classes of anxiety fit well and were chosen as the proper model (Saunders et al., 2021).

In the stress trajectories, although the AIC, BIC, and SABIC decreased with the increase of the latent classes, the decreasing trend slowed down significantly after the 5-class model, and the difference between the 5-class model and the 6-class model was slight. Therefore, the 5-class model showed the best fitness and five trajectory classes of stress were chosen.

Trajectory classes of depression, anxiety, and stress. The trajectories of depression are shown in Fig. 1. It should be noted that I represents the intercept, S1 denotes the slope of the first piece, and S2 stands for the slope of the second piece. Class 1 accounted for 79.34% of the students, and the average scores in the four years remained within the normal range. Thus, this class was named the low and stable class. Class 2 accounted for 8.61%, and the average scores in the first two years were in the normal range, while their depression symptoms deteriorated to severe degrees in the last two years. Thus, the study named it the increasing class. Class 3 accounted for 8.25%. These students presented severe depression in their freshman year, relieved significantly in their sophomore year, and remained mildly depressed for the last two years. This class was named the decreasing then stable class. Class 4 accounted for 3.80%. Students in this class showed mild depression during the freshman year, then deteriorated and showed severe depression during the sophomore year, and the symptoms gradually decreased during the junior and senior years

Table 1 Fit indices for growth mixture models of developmental trajectories with 2-6 latent classes.

	Depression trajectories			Anxiety trajectories			Stress trajectories			
	2-class model	3-class model	4-class model	5-class model	6-class model	2-class model	3-class model	4-class model	5-class model	6-class model
AIC	59,361	59,025	58,761	58,578	58,394	57,221	56,959	56,742	56,620	56,486
BIC	59,459	59,147	58,906	58,747	58,586	57,320	57,081	56,887	56,789	56,678
SABIC	59,405	59,081	58,827	58,654	58,481	57,266	57,014	56,808	56,697	56,573
Entropy	0.89	0.87	0.87	0.88	0.88	0.85	0.83	0.83	0.84	0.82
LMR-LRT	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p = 0.24$	$p = 0.24$	$p = 0.17$	$p = 0.24$
B-LRT	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Mixture proportion (%)	87.90	82.25	79.34	78.73	74.93	88.80	83.70	80.92	79.95	64.70
	12.10	9.06	8.61	6.35	9.94	11.20	10.11	8.61	6.67	19.09
		8.69	8.25	6.02	5.34		6.19	5.46	5.82	5.82
			3.80	5.42	5.26			5.01	4.77	4.37
				3.48	3.44				2.79	3.88
					1.09					2.14

AIC Akaike information criterion, BIC Bayesian information criterion, SABIC sample size adjusted Bayesian information criterion, LMR-LRT Lo-Mendell-Rubin adjusted likelihood ratio test, B-LRT bootstrapped likelihood ratio test.

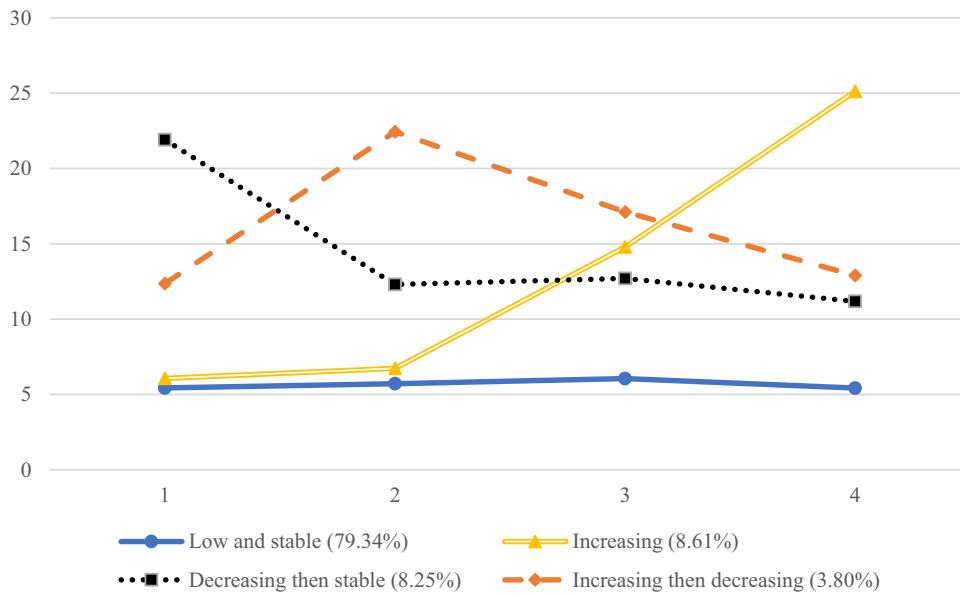


Fig. 1 Piecewise growth mixture model of depression. Trajectory classes of depression.

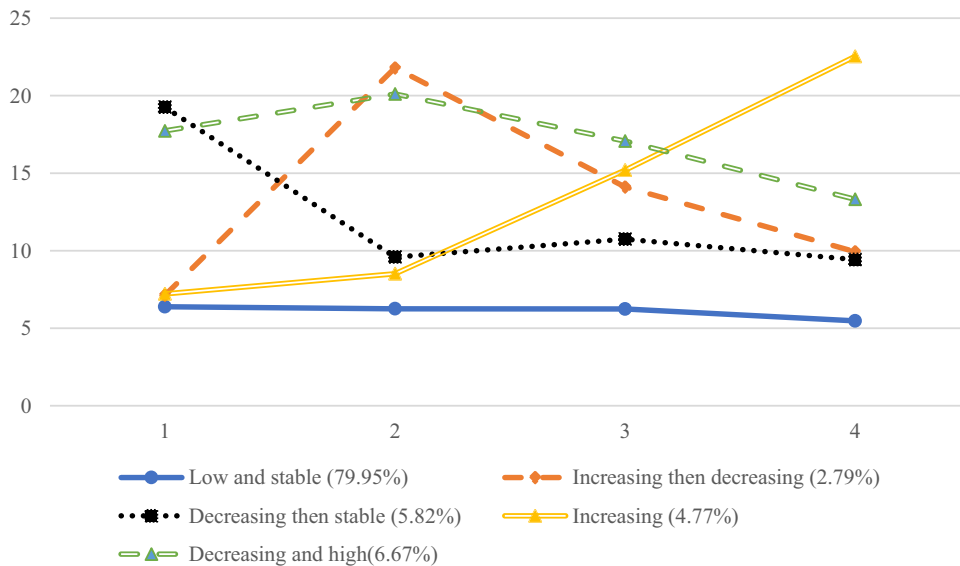


Fig. 2 Piecewise growth mixture model of anxiety. Trajectory classes of anxiety.

although their depression levels were still higher than those in the freshman year. This class was named the increasing then decreasing class.

The trajectories of anxiety are shown in Fig. 2. Class 1 accounted for 79.95% of the students and was regarded as the low and stable class. Class 2 accounted for 2.79%, belonging to the increasing then decreasing class. Class 3 accounted for 5.82%, and this class was categorized as the decreasing then stable class. Class 4 accounted for 4.77%, belonging to the increasing class. Class 5 accounted for 6.67%. Although the anxiety symptoms declined in the junior and senior years, the average scores remained in the range of severe anxiety until they dropped to moderate anxiety in the last year, and the average score in the last year was higher than that of other classes. Therefore, this class was named the decreasing and high class.

The trajectories of stress are shown in Fig. 3. Class 1 accounted for 76.35%, which could be classified as the low and stable class. Class 2 accounted for 13.10%, being defined as the decreasing and high class. Class 3 accounted for 4.65%, being classified as the

increasing then decreasing class. Class 4 represented 2.99%, belonging to the decreasing then stable class. Class 5 accounted for 2.91%, which was described as the increasing class.

Related factors for trajectory classes. With the low and stable class as the reference class, multinomial logistic regression models were used to analyze the factors associated with subtrajectories of depression, anxiety, and stress.

The results of the depression model (Table 2) show that students' hometown location ($RRR = 1.99, p = 0.01$), low sleep hours ($RRR = 1.92, p = 0.01$), and relationship with classmates ($RRR = 0.75, p = 0.01$) were statistically significant in the decreasing then stable class. In other words, students from urban areas and with low sleep hours were more likely to belong to the decreasing then stable class. Additionally, increasing these students' relationships with classmates by one rank decreased their likelihood of entering this class by 25%, making them more likely to enter the low and stable class. In the increasing then decreasing class,

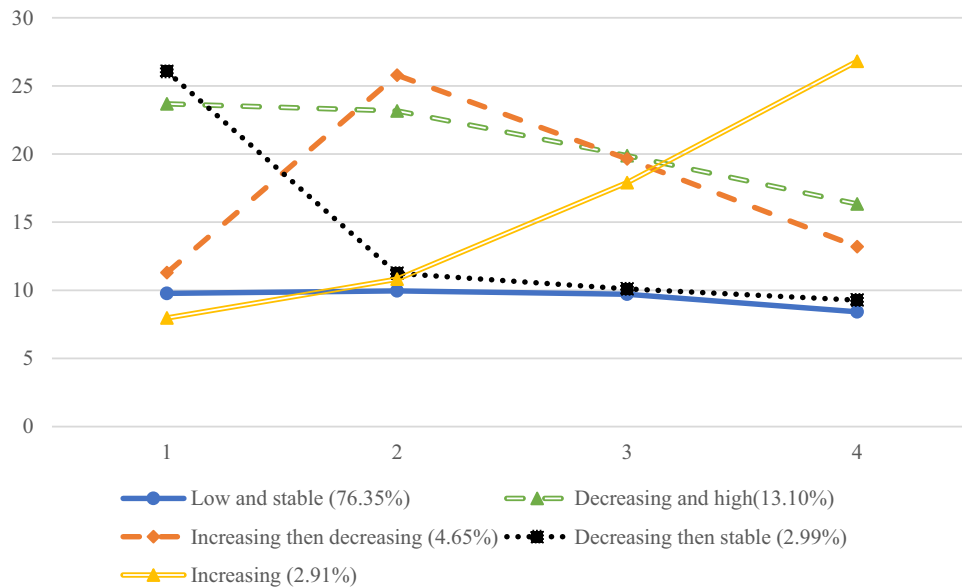


Fig. 3 Piecewise growth mixture model of stress. Trajectory classes of stress.

Table 2 Multinomial logistic regression analysis of predictors for classes of depression trajectory.

	Decreasing then stable (vs. Low and stable)			Increasing then decreasing (vs. Low and stable)			Increasing (vs. Low and stable)		
	RRR	95% CIs	p value	RRR	95% CIs	p value	RRR	95% CIs	p value
Gender: Men (vs. Women)	1.05	(0.73;1.50)	0.80	1.42	(1.02;1.98)	0.04*	1.37	(0.84;2.30)	0.21
Age	1.06	(0.87;1.29)	0.55	0.92	(0.77;1.09)	0.33	1.04	(0.81;1.33)	0.78
Siblings: No (vs. Yes)	1.01	(0.66;1.56)	0.96	1.08	(0.73;1.59)	0.71	0.99	(0.56;1.75)	0.98
Extroversion personality	0.96	(0.87;1.07)	0.48	0.96	(0.87;1.06)	0.45	1.04	(0.90;1.20)	0.62
Hometown location: Urban (vs. Rural)	1.99	(1.18;3.35)	0.01*	0.90	(0.57;1.41)	0.64	1.05	(0.54;2.06)	0.89
Father's education level	0.94	(0.88;1.01)	0.10	1.00	(0.94;1.06)	0.98	1.04	(0.95;1.15)	0.39
Mother's education level	1.02	(0.96;1.09)	0.50	1.01	(0.95;1.07)	0.77	0.99	(0.91;1.08)	0.85
BMI									
Low (vs. Normal)	1.21	(0.79;1.85)	0.38	1.48	(1.01;2.17)	0.05*	0.95	(0.50;1.78)	0.87
High (vs. Normal)	0.86	(0.46;1.62)	0.64	1.42	(0.86;2.34)	0.18	2.11	(1.12;3.96)	0.02*
Sleep hours									
Low (vs. Normal)	1.92	(1.18;3.11)	0.01*	1.58	(1.00;2.50)	0.05*	1.00	(0.45;2.22)	0.99
High (vs. Normal)	1.27	(0.71;2.28)	0.43	0.62	(0.31;1.23)	0.17	2.31	(1.22;4.37)	0.01*
Relationship with classmates	0.75	(0.61;0.93)	0.01*	0.84	(0.70;1.01)	0.07	0.95	(0.72;1.26)	0.72

Figures with * are statistically significant at $p < 0.05$. Cragg and Uhler's $R^2 = 0.23$. RRR relative-risk ratios, 95% CIs 95% confidence intervals.

students were more likely to be males ($RRR = 1.42, p = 0.04$) and have a low BMI ($RRR = 1.48, p = 0.05$) and low sleep hours ($RRR = 1.58, p = 0.05$). Finally, high BMI ($RRR = 2.11, p = 0.02$) and high sleep hours ($RRR = 2.31, p = 0.01$) contributed significantly to the increasing class, indicating that students with high BMI and sleep hours were 1.11 and 1.31 times more likely to be classified as the increasing class than students with normal BMI and sleep hours, respectively.

In the anxiety model (Table 3), siblings ($RRR = 1.77, p = 0.03$), extroversion personality ($RRR = 1.15, p = 0.02$), and father's education level ($RRR = 1.09, p = 0.04$) were statistically significant in the decreasing then stable class. In the increasing class, students were more likely to be males ($RRR = 1.83, p = 0.01$) and have high sleep hours ($RRR = 1.87, p = 0.04$), which were 83% and 87% more likely than females and students with average sleep hours, respectively. However, no significant related factors were found for the increasing then decreasing class and the decreasing and high class.

In the stress model (Table 4), hometown location ($RRR = 3.41, p = 0.01$) and low sleep hours ($RRR = 2.62, p = 0.00$) were statistically significant in the decreasing then stable class. In the increasing class, hometown location ($RRR = 2.25, p = 0.05$) was statistically significant, and students from urban areas were 1.25 times more likely to be in the increasing class than those from rural areas. In the decreasing and high class, low sleep hours ($RRR = 1.89, p = 0.00$) also had a statistically significant impact. However, the increasing then decreasing class did not find variables with significant correlation.

Discussion

Based on the piecewise growth mixture model, this study identified the developmental trajectories of depression, anxiety, and stress among college students, complementing previous studies focusing on their overall changes in mental health and providing a sample of Chinese college students. The four subtrajectories of

Table 3 Multinomial logistic regression analysis of predictors for classes of anxiety trajectory.

	Decreasing then stable (vs. Low and stable)			Increasing then decreasing (vs. Low and stable)			Increasing (vs. Low and stable)			Decreasing and high (vs. Low and stable)		
	RRR	95% CIs	p value	RRR	95% CIs	p value	RRR	95% CIs	p value	RRR	95% CIs	p value
Gender: Men (vs. Women)	1.06	(0.72;1.56)	0.76	1.37	(0.80;2.32)	0.25	1.83	(1.17;2.84)	0.01*	0.98	(0.68;1.41)	0.91
Age	1.01	(0.82;1.24)	0.94	1.07	(0.81;1.41)	0.66	1.05	(0.84;1.32)	0.65	0.91	(0.75;1.11)	0.37
Siblings: No (vs. Yes)	1.77	(1.07;2.93)	0.03*	1.48	(0.76;2.89)	0.25	1.35	(0.81;2.24)	0.25	1.05	(0.68;1.63)	0.83
Extroversion personality	1.15	(1.02;1.29)	0.02*	1.07	(0.91;1.25)	0.43	1.02	(0.90;1.15)	0.80	0.96	(0.86;1.07)	0.45
Hometown location: Urban (vs. Rural)	0.86	(0.48;1.53)	0.60	1.38	(0.63;3.02)	0.43	1.01	(0.56;1.81)	0.98	1.30	(0.77;2.20)	0.32
Father's education level	1.09	(1.00;1.18)	0.04*	1.05	(0.95;1.17)	0.35	0.95	(0.88;1.04)	0.27	1.02	(0.95;1.10)	0.56
Mother's education level	0.99	(0.92;1.06)	0.68	0.98	(0.89;1.07)	0.59	1.05	(0.97;1.13)	0.20	0.99	(0.93;1.05)	0.77
BMI												
Low (vs. Normal)	1.09	(0.68;1.73)	0.73	1.56	(0.86;2.81)	0.14	0.91	(0.52;1.59)	0.74	1.14	(0.74;1.75)	0.56
High (vs. Normal)	0.60	(0.28;1.29)	0.19	0.46	(0.14;1.52)	0.21	0.94	(0.48;1.84)	0.86	0.72	(0.37;1.40)	0.33
Sleep hours												
Low (vs. Normal)	0.96	(0.53;1.74)	0.89	1.53	(0.76;3.10)	0.23	0.57	(0.24;1.33)	0.20	1.51	(0.92;2.48)	0.10
High (vs. Normal)	1.09	(0.56;2.12)	0.80	0.82	(0.29;2.32)	0.71	1.87	(1.04;3.37)	0.04*	0.98	(0.51;1.90)	0.95
Relationship with classmates	0.84	(0.67;1.05)	0.13	1.02	(0.74;1.39)	0.92	0.92	(0.72;1.17)	0.49	0.85	(0.69;1.04)	0.12

Figures with * are statistically significant at $p < 0.05$. Cragg and Uhler's $R^2 = 0.12$. RRR relative-risk ratios, 95% CIs 95% confidence intervals.

Table 4 Multinomial logistic regression analysis of predictors for classes of stress trajectory.

	Decreasing then stable (vs. Low and stable)			Increasing then decreasing (vs. Low and stable)			Increasing (vs. Low and stable)			Decreasing and high (vs. Low and stable)		
	RRR	95% CIs	p value	RRR	95% CIs	p value	RRR	95% CIs	p value	RRR	95% CIs	p value
Gender: Men (vs. Women)	1.06	(0.62;1.81)	0.82	0.85	(0.56;1.29)	0.45	1.62	(0.93;2.81)	0.09	0.95	(0.72;1.26)	0.73
Age	1.14	(0.87;1.50)	0.34	1.00	(0.80;1.25)	0.99	1.13	(0.85;1.49)	0.40	1.04	(0.89;1.20)	0.63
Siblings: No (vs. Yes)	0.89	(0.47;1.68)	0.72	1.56	(0.93;2.63)	0.10	0.73	(0.40;1.36)	0.33	1.20	(0.86;1.68)	0.28
Extroversion personality	1.00	(0.86;1.18)	0.96	1.00	(0.89;1.14)	0.94	1.08	(0.92;1.28)	0.33	0.95	(0.87;1.03)	0.19
Hometown location: Urban (vs. Rural)	3.41	(1.46;7.95)	0.01*	1.00	(0.55;1.84)	1.00	2.25	(1.01;5.01)	0.05*	1.25	(0.84;1.86)	0.27
Father's education level	1.02	(0.92;1.13)	0.68	1.06	(0.97;1.15)	0.17	0.97	(0.87;1.07)	0.53	1.02	(0.97;1.08)	0.39
Mother's education level	0.97	(0.89;1.06)	0.51	0.98	(0.91;1.05)	0.53	1.03	(0.93;1.14)	0.55	0.98	(0.94;1.03)	0.48
BMI												
Low (vs. Normal)	1.53	(0.84;2.79)	0.17	1.58	(0.99;2.51)	0.06	1.38	(0.73;2.60)	0.32	1.17	(0.84;1.64)	0.35
High (vs. Normal)	1.05	(0.43;2.57)	0.92	1.51	(0.79;2.90)	0.21	1.21	(0.53;2.78)	0.65	0.98	(0.61;1.57)	0.93
Sleep hours												
Low (vs. Normal)	2.62	(1.39;4.94)	0.00*	1.69	(0.96;2.97)	0.07	0.51	(0.16;1.67)	0.27	1.89	(1.29;2.77)	0.00*
High (vs. Normal)	1.30	(0.54;3.17)	0.56	0.99	(0.46;2.10)	0.97	1.66	(0.76;3.61)	0.20	1.18	(0.73;1.89)	0.50
Relationship with classmates	0.87	(0.64;1.18)	0.37	0.82	(0.64;1.03)	0.09	1.05	(0.77;1.45)	0.75	0.87	(0.74;1.02)	1.00

Figures with * are statistically significant at $p < 0.05$. Cragg and Uhler's $R^2 = 0.14$. RRR relative-risk ratios, 95% CIs 95% confidence intervals.

depression are the low and stable, decreasing then stable, increasing, and increasing then decreasing. Both anxiety and stress trajectories fall into five classes, i.e., low and stable, decreasing then stable, increasing then decreasing, increasing, and decreasing and high. The trajectories in this study are consistent with some findings in previous studies. For instance, the low and stable class supported that most college students' depression, anxiety, and stress were within the normal range. Both the increasing then decreasing class and decreasing and high class provided evidence that some students faced serious symptoms of depression, anxiety, and stress when they entered college at first but eased up in their junior and senior years (Bayram and Bilgel, 2008; Bruffaerts et al., 2018; Liu et al., 2019). These students spent the first two years adjusting to the transition to college, recovering

and growing in the last two years, which not only emphasized the significance of the sophomore year but also called for caution about mental health in the first two years of college. Similarly, students in the decreasing then stable class experienced severe symptoms in their freshman year, which were then relieved significantly and remained stable, which was consistent with some findings that some students had the highest psychological strain in the first year, and their symptoms gradually subsided in the second semester of the first year (Bewick et al., 2010; Cooke et al., 2006). In the increasing class, their symptoms of depression, anxiety, and stress increasingly deteriorated over the four years probably because of their increasingly high academic and employment pressure (Cvetkovski et al., 2019; Shao et al., 2020; Yu et al., 2022). Overall, these different developmental trajectories

revealed the complex psychological states of students during their college years, and students' mental states fluctuated in different stages. For instance, entering college can be considered the first time most students leave their families and become independent. Changes in living and learning environments inevitably lead to some students' psychological maladaptation. The sophomore year is also a critical stage when students adapt to college life and their psychological conditions improve accordingly. It should also be noted that some students' psychological conditions may deteriorate at this stage. Furthermore, when it gets closer to graduation, problems such as employment after graduation plague most students, which also worsens students' psychological condition.

Gender, extroversion personality, sleep hours, and BMI were examined as the internal factors associated with subtrajectories of depression, anxiety, and stress. First, men are more likely to belong to the increasing then decreasing class of depression and the increasing class of anxiety. The results support some findings that the proportion of male students experiencing different degrees of depression is significantly higher than that of female students (Gao et al., 2020). Compared with female students, male freshmen are usually less able to adapt to the new environment, which may cause males to have higher levels of depression and anxiety when they enter college. Second, extroverted students are more likely to enter the decreasing then stable class of anxiety, and Saunders et al. (2021) reported a similar trajectory among adults. Extroverted students are thought to be less likely to experience psychological problems, which may reflect the finding that extroverted students' mental health improves quickly as they adjust to college life, but the relationship between mental problems in the freshman year and extroversion personality is not clear. Third, in lifestyle, both low and high sleep hours are related factors in some subtrajectories of depression, anxiety, and stress. Consistent with previous studies, sleep is considered a sensitive indicator of mental health. People are more prone to suffer from sleep problems when they have psychological fluctuations, and lack of sleep even worsens their psychological problems (Baglioni et al., 2016; Beiter et al., 2015; Cao and Liu, 2023). Thus, when individuals experience abnormal sleep, they may enter all subtrajectories other than the low and stable class. Apart from that, long sleep duration is also regarded as a related factor in this study, which is usually overlooked. Hypersomnia is one of the main symptoms of atypical depression, which has different symptoms from typical depression (Matza et al., 2003). This suggests that targeted prevention and treatment should be carried out for different types of mental problems. Furthermore, students with both low and high BMI are correlated with classes in the depression trajectories. This finding supports the findings that nonnormal BMI is associated with depressive symptoms among students (Luppino et al., 2010; Wang et al., 2019). Moreover, nonnormal BMI is related to a consistently poor diet or lifestyle, leading to increasing depression during college.

Relationships with classmates, hometown location, siblings, and father's education level were identified as external factors correlated with trajectory classes of depression, anxiety, and stress. First, students who are not familiar with their classmates usually belong to the decreasing then stable class in the depression trajectories, which corresponds to the findings of Shao et al. (2020). This finding highlights the role of social support for mental health, with peer relationships being an important source of social support that students can receive in college. Therefore, being unfamiliar with classmates is not conducive to their initial adjustment to life, which explains why we noticed that students in the decreasing then stable class experienced severe psychological problems in their freshman year. In addition, family background plays a role in students' mental health. The correlation between family location and the classes of depression and stress is probably related to the negative impact of

urbanization and modernization (Buttazzoni et al., 2022). Students without siblings are more likely to experience a decreasing then stable level of anxiety, supporting the finding that the social interaction of siblings can positively affect individual mental health (Lawson and Mace, 2010). A higher father's education level is correlated with anxiety trajectories in the study, which may be related to the fact that academic families bring more academic pressure to children (Yu et al., 2022). Family background is a correlated factor of students mainly entering the decreasing then stable class. These students' poor mental health status in their freshman year may be related to their maladjustment after leaving the family environment. With the adjustment to college life, mental health gradually returned to the normal range.

In the study, the developmental trajectories of depression, anxiety, and stress were identified, and the trajectories were prevalent among college students, which indicated the differentiation of student development and the significance of using GMM to classify the population. Using GMM to identify trajectories provides a new perspective for traditional psychological theory. For instance, Erik Erikson's stage theory focuses on the overall psychological development in a period and less on individuals who deviate from the overall trend. From a psychological perspective, different trajectories are of great significance for identifying the characteristics of individuals in a group, which will facilitate interventions for specific groups. The overall development trend of mental health can only identify the general characteristics, but GMM focuses on the internal differences, which can classify the trajectories based on the differences in the group. In practice, identifying the students' characteristics will facilitate the practical prevention of mental illness, especially among the students in the increasing class, mental health education and psychological intervention need to be taken in advance (Liu et al., 2023a). For students who are in the decreasing then stable class and increasing then decreasing class, it should be ensured that their symptoms gradually decrease as expected. Students in the decreasing and high class are also the focus of preventing psychological problems, and their psychological symptoms in the later years of college should be receive more attention.

There are still some limitations of this study. First, although the sample of the study is highly representative of college students in Beijing, the generalizability of the findings needs to be cautious among college students nationwide in China. Second, the DASS-42 used in this study is a self-report scale, which may result in possible bias in the measure of depression, anxiety, and stress among college students. Third, some variables in the survey were measured using a single question; thus, the self-reported results should be further examined.

Conclusions

First, four trajectories of depression, five trajectories of anxiety, and five trajectories of stress among college students are identified. The subtrajectories of depression include the low and stable class, the increasing class, the decreasing then stable class, and the increasing then decreasing class. The trajectories of anxiety can be categorized as the low and stable class, the increasing class, the increasing then decreasing class, the decreasing then stable class, and the high and decreasing class. This classification also applies to the trajectories of stress.

Second, the study found that gender, relationship with classmates, hometown location, BMI, and sleep hours are related factors affecting entry into different trajectories of depression. Gender, extroversion personality, siblings, father's education level, and high sleep hours are corresponding factors for dividing different trajectories of anxiety. Hometown location, low sleep hours, and high sleep hours are factors influencing the classification of different trajectories of stress.

It is practical to classify the developmental trajectories of depression, anxiety, and stress and identify relevant factors for taking preventive measures among targeted students. Especially for students with factors associated with the high and decreasing class and the increasing class, psychological intervention needs to be taken in advance.

Data availability

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

Received: 19 February 2023; Accepted: 17 October 2023;

Published online: 26 October 2023

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Acknowledgements

The authors would like to acknowledge and thank the National Survey Research Center, Renmin University of China, for the support in data collection.

Author contributions

Author XL designed the study and wrote the protocol. Authors XL and YZ undertook the statistical analysis. Authors YZ, XL, WG, and XC wrote the first draft of the manuscript and managed the literature analyses. Author WG polished the full text. All authors read and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

The ethical approval was acquired from the Ethics Committee of Tianjin University (TJUE-2022-017).

Informed consent

The written consent was obtained from all participants before the study.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1057/s41599-023-02252-2>.

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