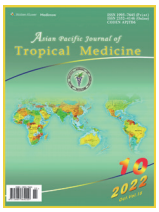

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Posttraumatic stress symptom trajectories of Chinese university students during the first eight months of the COVID-19 pandemic and their association with cognitive reappraisal, expressive suppression, and posttraumatic growth

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ABSTRACT

Objective: To identify the moderating effects of cognitive reappraisal (CR) and expressive suppression (ES) on the relationship between posttraumatic stress (PTS) symptoms and posttraumatic growth (PTG) in university students.

Methods: The survey included 1 987 Chinese university students who completed questionnaires on PTS symptoms in February 2020, with three follow-up surveys at two-month intervals until August 2020. We assessed CR and ES at February 2020 and PTG at August 2020. Growth mixture modeling was used to classify the PTS symptom trajectories. Multinomial logistic regression was used to recognize the predictors of class membership. The relationships among PTS symptoms, CR, ES, and PTG were examined using multi-group path analysis.

Results: Sex, SARS-CoV-2 infection of a family member or friend, number of siblings, CR, and ES were significantly associated with PTS symptoms. Three latent classes were identified: 'Increasing PTS' (n=205, 10.0%) who had rapid deterioration of PTS symptoms, 'Moderate PTS' (n=149, 8.0%) who had a high level of PTS symptoms at the beginning and slightly increasing, and 'Persistent Minimal PTS' (n=1 633, 82.0%), who had slow resolution of PTS symptoms over time. Male, SARS-CoV-2 infection of a family member or friend, and having a lower CR and a higher ES, were more likely to have 'Increasing PTS'. PTS at February 2020 predicted PTG only in 'Increasing PTS' class, and both CR and ES had moderating effects on the conversion between them.

Conclusions: Most students recovered from posttraumatic stress of COVID-19 pandemic, but a small proportion expeienced increasing PTS symptoms, and those with this condition may benefit from emotional regulation intervention.

KEYWORDS: COVID-19 pandemic; Posttraumatic stress symptoms; Cognitive reappraisal; Expressive suppression; Posttraumatic growth; Chinese university students

Significance

The impact of COVID-19 pandemic on posttraumatic stress is heterogenous in general residents. This study found that the trajectories of COVID-19 posttraumatic stress in Chinese university students were identified as Increasing (rapid deterioration of PTS symptoms), Moderate (a high level of PTS symptoms at the beginning and slightly increasing), and Persistent minimal (slow resolution of PTS symptoms over time) classes. This longitudinal study demonstrated that posttraumatic stress predicted posttraumatic growth only in 'Increasing posttraumatic stress' class and cognitive reappraisal and expressive suppression played moderating effect between the posttraumatic stress and posttraumatic growth in this class, respectively.

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1. Introduction

COVID-19 has spread globally and affected the work and life of all mankind. Since this COVID-19 outbreak, researchers around the world have placed a great deal of importance on mental health conditions of infected people and frontline healthcare workers and the student group, who gained greater level of mental health problems than the employed, farmers, unemployed, and retired[1]. Moreover, a longitudinal study presented that, unlike the symptoms decline in adult, both depression and anxiety in students kept an increasing trend across the first 16 weeks of home isolation[2]. Identifying clinically relevant trajectory patterns and correspondingly predictors would help to make use of the limited mental health intervention resource more productively for the high-risk groups. However, the trajectories of PTS symptoms in university students in the context of COVID-19 was unknown. Especially, Wang and colleagues presented that the college students had higher incidence of PTS symptoms than anxiety and depression[3]. What's more, a study showed that the university students' prevalence of COVID-19-related posttraumatic stress disorder (PTSD) reached as high as 30.8%[4], which was higher than the medical practitioners (11.4%)[5]. The whole of 2020 had gone through phases of detecting and responding to the outbreak (before 19th January), initial containment of the spread of the epidemic (before 20th February), initial remission period (before 17th March), victory in the battle to defend Wuhan and Hubei (before 28th April), followed by universal epidemic prevention and control. These phases suggest the benefits of learning from the first eight-month trajectory of PTS symptoms in students[6]. Identifying the COVID-19-related PTS trajectories, figuring out the students whose PTS symptoms would deteriorate, and understanding the modifiable risk factors are important for developing a roadmap to prevent or mitigate PTS.

As the most commonly examined emotion regulation (ER) strategies, cognitive reappraisal (CR) is regarded to alter dysfunctional thinking patterns before emotions become fully activated and one becomes emotionally stressed, while expressive suppression (ES) increases or prolongs the duration of negative emotion[7]. Higher CR and lower ES could reduce worse mental health outcomes and foster beneficial psychological changes in individuals by identifying and challenging negative trauma-related cognitions and rebuilding understanding of the world ultimately decreasing the severity of PTS symptoms[8]. CR might also benefit individuals through a dynamic adjustment to COVID-19 pandemic restrictions despite the current uncontrollable and uncertain nature of the pandemic[9]. ES risks promoting PTS symptoms by inducing incongruence and discrepancy, which might lead to negative feelings about oneself[7]. However, study by Seligowski *et al.*[10] showed a moderate effect size for ES and worrying but no effects for CR on PTS symptoms, suggesting that more researches are needed to understand the correlation between PTS and CR, PTS and ES.

Posttraumatic growth (PTG) is the result of positive thinking following the adverse events, which refers to those energetic changes that excel the original level of psychological functioning, moreover, it needs time[11]. Nowadays, the PTS and PTG still remain an elusive relationship. Several studies have noted that the correlation between PTS and PTG depends on the third variable, as the two being mutually independent[12,13]. For example, the interaction between resilience/perceived distance-to-death and PTS predicted PTG in female survivors of childhood sexual abuse[14,15]; however, other studies of survivors of Hurricane Katrina and the Israel-Gaza conflict, revealed a positive relationship between PTS and PTG[16,17]. It should also be noted that the PTS symptoms and the positive changes after a stressful experience were not antagonistic relationships. People can positively shift their thinking even during ongoing distress to redefine their personal strengths and philosophies and look at possibilities to deal with severe challenges and social relationships and to plan for the future[18]. Studies focusing on university students showed that trauma exposure could promote students' personal growth[19,20]. The outbreak of COVID-19 has brought a series of harm to mental health, as reflected by PTS among the general population and university students; however, it has also helped people to make positive changes, such as spend more time with loved ones, slow the life pace, and improve their physical health, which are highly related to PTG domains[4,21]. A study focused on discharged COVID-19 patients reported that individuals' PTSD was positively related to PTG[18], while another study by Tomaszek[22] presented the opposite case, as the more PTS symptoms, the less PTG. More researches are needed to clarify the relationship between PTS and PTG in students in the context of COVID-19. In the face of stressful situations, CR helps reduce negative emotions, thereby increasing positive emotions that result in PTG[7]. For example, through reconsideration of stressful situations as opportunities for growth, one could enhance positive emotional experiences without necessarily minimizing the threat as less severe or consequential. However, reducing negative moods also decreases the motivation they provide; therefore, one may be less likely to engage in PTG. These patterns suggested a complex relationship between PTS and PTG and that CR can distinguish the PTS class but is not negatively related to PTS[23]. Though a study has suggested a loose relationship between ES and PTG[24], whether ES is a moderator between PTS and PTG remains to be seen .

University students are reporting an increasing number of psychological problems in recent years, particularly regarding the COVID-19 pandemic. Thus, it would be necessary to examine the PTS trajectories, even more, to identify modifiable risk factors, which may help us understand COVID-19's effects on university students and guide prevention and intervention plans for high-risk populations. The current study aims to evaluate PTS symptoms of the COVID-19

outbreak on university students, explore the PTS trajectories, determine whether CR, ES, and demographic variables can predict class membership, explore the relationship between PTS and PTG in different trajectories, and test whether CR or ES moderates the relationship between PTS and PTG in different trajectories.

2. Subjects and methods

2.1. Participants

This study was a longitudinal follow-up investigation that was approved by the Ethics Committee of Hainan Medical University (No. HYLL2020006). The data collection was carried out during the first 8 months after the COVID-19 outbreak in China in 2020 (T1, baseline, February; T2, 2-month follow-up, April; T3, 4-month follow-up, June; T4, 6-month follow-up, August). The participants came from 31 provinces, autonomous regions and municipalities, were all college students studying in Hainan Province, China, and were recruited by social media through WeChat. The respondents were first asked to read an informed consent, and they only participated in the survey if they agreed. The responses from 2 134 students were collected. A total of 1 987 (93.1%) participants who provided data for the four time periods (T1-T4) were included in this study.

The demographic information of each participant, including sex, age, and academic year in university was collected. Based on the guiding principles of emergent psychological crisis intervention in COVID-19[25], the populations affected by COVID-19 were divided into the following four levels: level 1, patients with severe symptoms of COVID-19, front-line medical workers, researchers of Centers for Disease Control and Prevention, or administrative staff; level 2, patients with mild symptoms of COVID-19, close contacts, suspected COVID-19 patients, or patients with fever who were admitted to the hospital for treatment; level 3, individuals related to the level 1 and level 2 group members, such as family members, colleagues, friends, and rescuers, including commanders, administrative staff, and volunteers; and level 4, residents of affected areas, susceptible groups, and the general public. In addition, the participants were asked whether they had a family member or friend suspected of having COVID-19.

2.2. Measurements

2.2.1. Posttraumatic stress symptoms

The Chinese version of the PTSD checklist for DSM-5 (PCL-5) was used to measure the PTS symptoms[26]. Each item of the 20-item self-report scale was scored as 0 (not at all) to 4 (very seriously). Therefore, the total symptom score ranged from 0 to 80; higher scores indicate more serious PTS symptoms. We assessed PTS symptoms at T1, T2, T3 and T4. Reliability statistics for the PCL-5 indicated a good internal consistency for the total score (α=0.98, 0.99, 0.99 and 0.98, respectively).

2.2.2. Cognitive reappraisal and expressive suppression

The Chinese version of the Emotion Regulation Questionnaire (ERQ) consists of 10 items that measure two factors: CR (6 items) and ES (4 items)[27]. Each item of the ERQ was scored as 1 (completely disagree) to 7 (completely agree), and a higher total score indicates more frequent use of the CR or ES. We assessed CR and ES only at T1. This ERQ showed Cronbach's α values of 0.95 and 0.90 for CR and ES, respectively.

2.2.3. Posttraumatic growth

The Chinese-Posttraumatic Growth Inventory (PTGI) was used to measure PTS symptoms; it consists of 20 items that measure 5 factors: relating to others, new possibilities, personal strength, spiritual change, and appreciation of life[28]. Each item of the PTGI was scored as 1 (none) to 6 (a heavy great degree), with more total score indicating a higher tendency of posttraumatic growth. We assessed PTG at T4. This PTGI showed good validation with a Cronbach's α value of 0.95.

2.3. Statistical analyses

Data were analyzed using SPSS 21 (IBM Corp., Armonk, NY). Growth mixture modeling (GMM) was conducted in Mplus 7[29]. The significance threshold was set at 0.05.

Using SPSS, t tests and Chi-square tests, with Bonferroni corrections for multiple tests, were employed to reveal whether the variables of participants who completed the four assessments (T1-T4) were significantly different from the variables of those who did not complete the four assessments. Zero-order correlations were used to determine the degree of correlation between variables. Using Mplus, the TECH13 option was carried out in conjunction with TYPE=MIXTURE to establish two-sided tests of model fit for multivariate skewness and kurtosis (Mardia's measure of multivariate kurtosis).

The GMM was used to investigate whether distinct PTS trajectories exist, which allowed for differences in growth parameters across unobserved subpopulations or classes, and more, the intercept and slope variance parameters were allowed to vary within classes[29,30]. Multiple fit indices were used together to determine the appropriate class solution. The best model was chosen by determining which model had the lowest values for the Akaike Information Criteria, the Bayesian Information Criteria (BIC), the sample-size adjusted BIC, and highest entropy values[30]. In addition, the Lo-Mendell-Rubin-

likelihood ratio test (LMR-LRT) and the bootstrapped likelihood ratio test (BLRT) were used to compare the estimated model and a model with k-1 subgroup, with k set at the number of subgroups[30]. A low and significant *P*-value resulting from the LMR-LRT and BLRT indicated that the estimated model was superior to a model with one less subgroup. The fit indices in combination with theoretical interpretability guided the final model selection.

The multinomial logistic regression analysis in SPSS was used to understand how the classes differed in terms of the scores of the baseline CR, ES and background variables in univariate and multivariate analysis respectively, the most likely class membership being used as the dependent variable, the CR, ES and demographic variables being used as the independent variable. To account for these multiple comparisons, the Bonferroni α adjustment set the significance level for each univariate model to $P<0.017$ ($\alpha/3$).

The multigroup structural equation modeling was modeled to ask whether PTS symptoms at baseline predicted the PTG level at the final stage, and whether CR and ES had a moderating effect on the relationship between them, respectively, in each PTS symptom trajectory class, the PTS symptoms being used as independent variable, the CR/ES being used as moderating variable, the PTG being used as dependent variable. The following fit indices were used in measurement invariance to determine an adequate fit: comparative fit index (CFI)>0.90, Tucker-Lewis index (TLI)>0.90, root mean square error of approximation (RMSEA)<0.09, standardized root mean squared residual (SRMR)<0.08, and a *Chi*-squared value-to-degrees of freedom ratio of less than 3: 1[31].

3. Results

3.1. Demographic characteristics of the participants

The demographics, CR, ES, and PTG in total and for the three PTS trajectory classes were presented in Table 1. The participants in this study averaged 19 years old, the majority were freshmen (48.3%), female students (68.4%), students with no exposure to COVID-19 (97.3%), students with no family or friends being healthcare workers (72.9%), students with no family or friends having been infected with COVID-19 (98.9%), or students having 1 sibling (37.5%).

There were no differences between the participants who completed the four assessments (T1-T4) and those who did not. None of the participants had any missing data. Prior to conducting statistical analyses, the distributions of each variable were carefully examined; if the assumptions of normality were not met, then the maximum likelihood estimation with robust standard errors was proposed to deal with the data.

Zero-order correlations of dichotomous and continuous background variables, PTS (at T1-T4), CR, ES, and PTG are presented in Table 2. Sex was significantly associated with PTS symptoms at T3 and T4 (both $P<0.05$), as males have significantly more PTS symptoms than females. Whether the participant's family or friends had been infected with COVID-19, and number of siblings were significantly associated with PTS symptoms at all the time points.

CR was significantly negatively associated with PTS symptoms at all the four time points in the expected direction. ES was significantly positively associated with PTS symptoms at T3 and T4. PTG had no relationship with PTS symptoms at any time point.

3.2. Growth mixture modeling

Table 3 shows the goodness-of-fit indices for the four models. BIC, adjusted BIC, and entropy criteria suggested that a four-class model had the best overall fit. However, the VLMR-LRT results did not strongly support the four-class model being better than the three-class model. Considering model parsimony/interpretability and BIC as the most reliable goodness-of-fit indicator, the three-class model was chosen as the final model.

The PTS symptom trajectories and characteristics for the three-class solution are illustrated in Figure 1 and Table 1. Each class was given a description fitting of its trajectory. Approximately 8.0% (n=149) of participants fell into the 'Moderate PTS', which had a high intercept (*i.e.*, a high level of PTS symptoms at T1; β=12.53, SE=0.98, $P<0.001$) and a slightly increasing slope (β=1.87, SE=0.45, $P<0.001$). The 'Increasing PTS' comprised approximately 10.0% (n=205) of the study samples, with a high intercept (β=11.23, SE=0.89, $P<0.001$) and a large increasing slope (β=9.55, SE=0.33, $P<0.001$), indicating rapid deterioration of PTS symptoms over time. The largest portion of the sample (approximately 82.0%, n=1 633) fell into the 'Persistent minimal PTS' and was characterized by a low intercept (β=4.93, SE=0.19, $P<0.001$) and a small decreasing slope, indicating slow resolution of PTS over time (β=-1.09, SE=0.05, $P<0.001$).

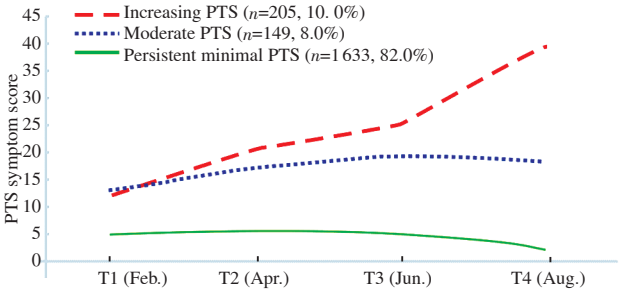

Figure 1. Three-class Growth Mixture Model for posttraumatic stress symptoms from February 2020 (T1) to August 2020 (T4) (n=1 987). PTS: posttraumatic stress. Increasing PTS: a large increasing slope, indicating rapid deterioration of PTS symptoms over time; Moderate PTS: a high level of PTS symptoms at the beginning and a slightly increasing slope; Persistent minimal PTS: a small decreasing slope, indicating slow resolution of PTS symptomsover time.

Table 1. Demographics, cognitive reappraisal, expressive suppression, and posttraumatic growth of the students categoried by the posttraumatic stress trajectory classes.

Variables	Total (n=1 987)	Increasing PTS (n=205, 10.0%)	Moderate PTS (n=149, 8.0%)	Persistent minimal PTS (n=1 633, 82.0%)
Age, years^	19.85 (1.39)	19.84 (1.35)	19.93 (1.43)	19.84 (1.39)
Sex				
Male	627 (31.6)	109 (53.2)	52 (34.9)	466 (28.5)
Female	1 360 (68.4)	96 (46.8)	97 (65.1)	1 167 (71.5)
Academic year				
First	960 (48.3)	94 (45.9)	72 (48.3)	794 (48.6)
Second	707 (35.6)	78 (38.0)	48 (32.2)	581 (35.6)
Third or fourth	320 (16.1)	33 (16.1)	29 (19.5)	258 (15.8)
COVID-19 exposure				
Level 1	0 (0)	0	0	0
Level 2	2 (0.1)	0	1 (0.7)	1 (0.1)
Level 3	51 (2.6)	6 (2.9)	3 (2.0)	42 (2.5)
Level 4	1 934 (97.3)	199 (97.1)	145 (97.3)	1 590 (97.4)
Whether the participant's family or friends are healthcare workers				
Yes	539 (27.1)	43 (21.0)	37 (24.8)	459 (28.1)
No	1 448 (72.9)	162 (79.0)	112 (75.2)	1 174 (71.9)
SARS-CoV-2 infection of a family member or friend				
Someone diagnosed	1 (0.1)	0	0	1 (0.1)
Someone suspected	3 (0.2)	1 (0.5)	0	2 (0.1)
No infection	1 965 (98.9)	198 (96.6)	145 (97.3)	1 622 (99.3)
Unclear	18 (0.8)	6 (2.9)	4 (2.7)	8 (0.5)
Number of siblings				
0	430 (21.6)	40 (19.5)	26 (17.5)	364 (22.3)
1	746 (37.5)	86 (42.0)	61 (40.9)	599 (36.7)
2	496 (25.0)	48 (23.4)	41 (27.5)	407 (24.9)
3	213 (10.7)	20 (9.8)	11 (7.4)	182 (11.1)
≥4	102 (5.2)	11 (5.3)	10 (6.7)	81 (5.0)
CR^		24.91 (3.41)	27.48 (5.72)	28.54 (7.20)
ES^		16.51 (2.30)	17.71 (3.94)	16.71 (4.91)
PTG^		51.94 (14.53)	49.09 (21.09)	49.72 (27.55)

^Data were expressed as mean (SD), others, n (%). Except for PTG (being collected at T4, August 2020), the above information was collected at baseline (T1, February 2020). CR: cognitive reappraisal; ES: expressive suppression; PTG: posttraumatic growth; PTS: posttraumatic stress. COVID-19 exposure were divided into the following four levels: level 1, patients with severe symptoms of COVID-19, front-line medical workers, researchers of Centers for Disease Control and Prevention, or administrative staff; level 2, patients with mild symptoms of COVID-19, close contacts, suspected COVID-19 patients, or patients with fever who were admitted to the hospital for treatment; level 3, individuals related to the level 1 and level 2 group members, such as family members, colleagues, friends, and rescuers, including commanders, administrative staff, and volunteers; and level 4, residents of affected areas, susceptible groups, and the general public. Increasing PTS: rapid deterioration of PTS symptoms; Moderate PTS: a high level of PTS symptoms at the beginning and slightly increasing; Persistent minimal PTS: slow resolution of PTS symptoms over time.

Table 2. Correlations of posttraumatic stress at the baseline, 2-month, 4-month, and 6-month follow-up, with cognitive reappraisal and expressive suppression at baseline, posttraumatic growth at the 6-month follow-up.

Variables	T1-PTS	T2-PTS	T3-PTS	T4-PTS	CR	ES	PTG	Age	Sex	Academic year	a1	a2	a3	a4
T1-PTS	1													
T2-PTS	0.52***	1												
T3-PTS	0.43***	0.50***	1											
T4-PTS	0.38***	0.50***	0.56***	1										
CR	-0.05**	-0.06***	-0.07***	-0.10***	1									
ES	0.03	0.03	0.04*	0.04*	0.50***	1								
PTG	-0.01	-0.01	0.02	0.02	0.22***	0.12***	1							
Age	0.01	0.01	0.02	-0.01	-0.01	-0.02	-0.04*	1						
Sex	-0.02	-0.05	-0.04*	-0.07***	0.07***	-0.05**	-0.01	-0.03	1					
Academic year	-0.01	-0.01	-0.02	0.01	0.01	0.01	0.10***	- 0.56***	-0.01	1				
a1	-0.01	-0.01	0.01	-0.02	-0.03	-0.01	-0.04*	-0.02	0.04	0.05*	1			
a2	-0.03	0.01	0.02	0.03	-0.02	0.01	-0.01	0.01	0.03	0.05*	0.12***	1		
a3	0.05**	0.05*	0.05**	0.06**	-0.02	0.02	-0.01	0.01	-0.01	-0.02	0.04	-0.01	1	
a4	0.05**	0.05**	0.07***	0.07***	-0.03	-0.01	0.01	0.07***	0.09***	0.05**	0.03	0.04	0.01	1

CR: cognitive reappraisal; ES: expressive suppression; PTG: posttraumatic growth; PTS: posttraumatic stress. T1: baseline, T2: 2-month follow-up, T3: 4-month follow-up, T4: 6-month follow-up. Sex (1=male, 2=female); Academic year (1=first year, 2=second year, 3=third or fourth year); a1: COVID-19 exposure (1=Level 1, 2=Level 2, 3=Level 3, 4=Level 4); a2: family or friends of the participants are healthcare workers (1=Yes, 2=No); a3: SARS-CoV-2 infection of a family member or friend (1=Someone diagnosed, 2=Someone suspected, 3=No infection, 4=Unclear); a4: number of siblings (1=0, 2=1, 3=2, 4=3, 5=4); $^{*}P$<0.05, $^{**}P$<0.01, $^{***}P$<0.001.

Table 3. Fit indices for latent class growth analysis examining posttraumatic stress from baseline to the 6-month follow-up (T4) (n=1 987).

Number of classes	No. of free para-meters	Log-likelihood	AIC	BIC	Adjusted BIC	Entropy	VLMR-LRT *P*-value	BLRT *P*-value	Class percentages
1	9	-28887.69	57793.39	57843.74	57815.15	NA	NA	NA	100
2	12	-27789.80	55603.60	55670.73	55632.60	0.96	0.000	0.000	12/88
3	**15**	**-27340.16**	**54710.32**	**54794.23**	**54746.58**	**0.98**	**0.037**	**0.042**	**8/10/82**
4	18	-27146.38	54328.76	54429.46	54372.27	0.98	0.115	0.117	2/7/9/82

Final solutions are in bold. AIC: Akaike information criterion; BIC: Bayesian information criterion; VLMR: Vuong-Lo-Mendell-Rubin test; BLRT: bootstrap likelihood ratio test.

Table 4. Univariate analyses of cognitive reappraisal, expressive suppression, and different classes of posttraumatic stress.

Variables	Increasing PTS *vs.* Persistent minimal PTS		Moderate PTS *vs.* Persistent minimal PTS		Increasing PTS *vs.* Moderate PTS	
	B (SE)	*OR* (95% *CI*)	B (SE)	*OR* (95% *CI*)	B (SE)	*OR* (95% *CI*)
CR	-0.07 (0.01)	0.93 (0.91-0.95)***	-0.02 (0.01)	0.98 (0.95, 1.00)	-0.05 (0.01)	0.95 (0.92-0.98)**
ES	-0.01 (0.01)	0.99 (0.96-1.02)	0.05 (0.02)	1.05 (1.01-1.09)*	-0.06 (0.02)	0.94 (0.90-0.98)*

CR: cognitive reappraisal; ES: expressive suppression; PTS: posttraumatic stress. Increasing PTS: rapid deterioration of PTS symptoms over time; Moderate PTS: a high level of PTS symptoms at the beginning and a slightly increasing slope; Persistent minimal PTS: slow resolution of PTS over time. $^{*}P$<0.05, $^{**}P$<0.01, and $^{***}P$<0.001.

Table 5. Multinomial logistic regression coefficients for demographic variables, cognitive reappraisal, expressive suppression, and different classes of posttraumatic stress.

Variables	Increasing PTS *vs.* Persistent minimal PTS		Moderate PTS *vs.* Persistent minimal PTS		Increasing PTS *vs.* Moderate PTS	
	B (SE)	*OR* (95% *CI*)	B (SE)	*OR* (95% *CI*)	B (SE)	*OR* (95% *CI*)
CR	-0.23 (0.03)	0.80 (0.75-0.84)***	-0.13 (0.03)	0.88 (0.83-0.93)***	-0.10 (0.04)	0.90 (0.84-0.98)*
ES	0.28 (0.04)	1.32 (1.21-1.45)***	0.20 (0.04)	1.22 (1.13-1.33)***	0.08 (0.06)	1.08 (0.96-1.21)
Sex	-0.85 (0.15)	0.42 (0.31-0.58)***	-0.14 (0.18)	0.86 (0.60-1.24)	-0.71 (0.22)	0.49 (0.32-0.76)**
SARS-CoV-2 infection of a family member or friend	1.48 (0.58)	4.41 (1.42-13.67)*	1.54 (0.61)	4.66 (1.42-15.31)*	-0.05 (0.68)	0.95 (0.25-3.57)

CR: cognitive reappraisal; ES: expressive suppression; PTS: posttraumatic stress. Increasing PTS: rapid deterioration of PTS symptoms over time; Moderate PTS: a high level of PTS symptoms at the beginning and slightly increasing; Persistent minimal PTS: slow resolution of PTS over time. $^{*}P$<0.05, $^{**}P$<0.01, and $^{***}P$<0.001.

3.3. Class differences in cognitive reappraisal and expressive suppression

The 'Increasing PTS' class reported significantly lower mean scores of CR compared with the other classes (Table 4). As for ES, the 'Moderate PTS' class was significantly higher than the 'Increasing PTS' and 'Persistent minimal PTS' classes.

The backward selection method suggested that of the demographic variables, only sex (P=0.001) and whether the participant's family or friends had been infected with COVID-19 (P=0.010) significantly contributed to the model; therefore, they were retained in the final model.

Table 5 presents the parameter estimates for the multivariate class comparisons. CR contributed a unique variance to the distinction between the three classes. ES uniquely distinguished both the 'Increasing PTS' and 'Moderate PTS' classes from the 'Persistent minimal PTS' class. The 'Increasing PTS' class reported a higher ratio of males than the other two classes. Compared with the 'Persistent minimal PTS' class, both the 'Increasing PTS' and 'Moderate PTS' classes were uniquely predicted by having family or friends infected with COVID-19.

3.4. Relationships among posttraumatic stress symptoms, cognitive reappraisal, and expressive suppression

To test this hypothesis, the model had to first meet the assumptions of measurement invariance. This was the case for both PTS and PTG measures, while the CR and ES measures did not have a latent factor structure, hence they were not subjected to invariance testing. The first-order confirmatory factor analysis scalar model for the PTS scale was a good fit to the data with all indices (χ^2: df=2.31, RMSEA=0.04; CFI=0.94; TLI=0.92; SRMR=0.06). The scalar model did not significantly differ from the metric model (χ^2=53.12, df=40, P>0.05), supporting the assumption of measurement invariance. In addition, the first-order confirmatory factor analysis scalar model for the PTG scale was a good fit to the data with all indices (χ^2: df=2.43, RMSEA=0.06; CFI=0.97; TLI=0.96; SRMR=0.02). The scalar model did not significantly differ from the metric model (χ^2=46.39, df=40, P>0.10), supporting the assumption of measurement invariance.

A multi-group path analysis tested the hypothesis that PTS symptoms predicted PTG, and CR and ES moderated the relationship between PTS symptoms and PTG. The models

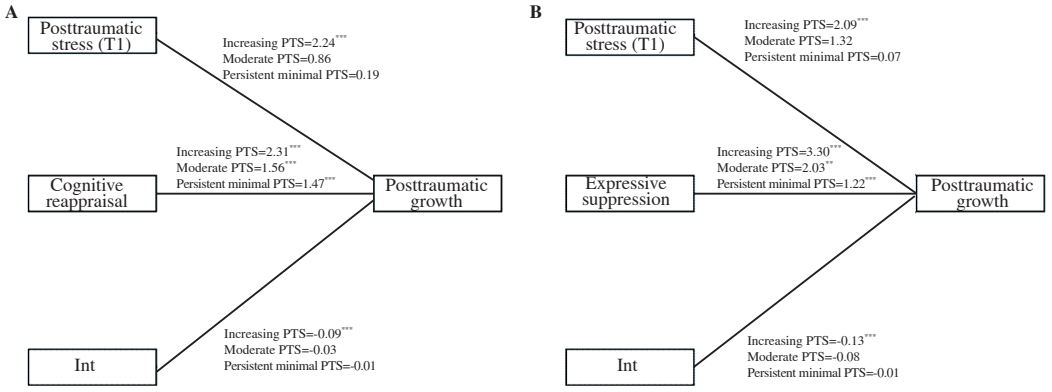

Figure 2. Multi-group path analysis of the relationship between posttraumatic stress (PTS) symptoms and cognitive reappraisal/expressive suppression on posttraumatic growth. (A) Int=posttraumatic stress (T1, February)×cognitive reappraisal; (B) Int=posttraumatic stress (T1, February)×expressive suppression. Unstandardized coefficients are reported. $^{*}P<0.05$, $^{**}P<0.01$, and $^{***}P<0.001$. Increasing PTS: rapid deterioration of PTS symptoms over time; Moderate PTS: a high level of PTS symptoms at the beginning and a slightly increasing slope; Persistent minimal PTS: slow resolution of PTS over time.

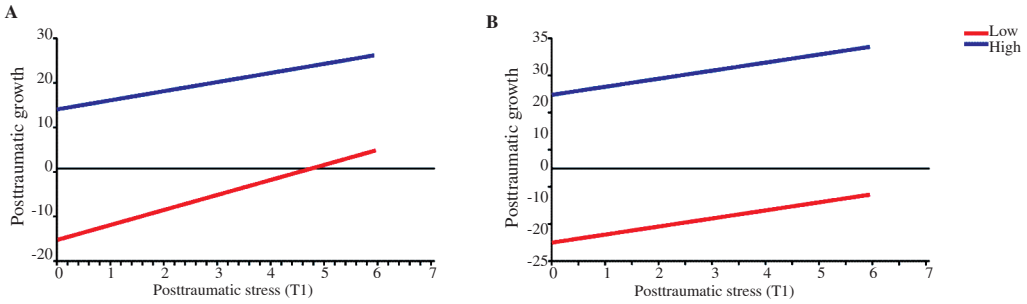

Figure 3. Posttraumatic stress and cognitive reappraisal (A) and expressive suppression (B) interact to predict posttraumatic growth among people who had rapid deterioration of posttraumatic stress symptoms over time (Increasing PTS).

were all a good fit to the data for CFI>0.95, TLI>0.95, χ^2: *df*<3, RMSEA<0.02, and SRMR<0.02. The PTS symptoms predicted PTG (β=2.24, SE=0.55, *P*<0.001; Figure 2), and this relationship was moderated by CR in the 'Increasing PTS' class (β=-0.09, SE=0.02, *P*<0.001; Figure 2). The moderating influence of CR on the direct association between PTS and PTG is summarized in Figure 3. Note that the strength of the PTS and PTG direct effect is lessened with increasing levels of CR. Moreover, the PTS symptoms predicted PTG (β=2.09, SE=0.53, *P*<0.001; Figure 2), and this relationship between PTS symptoms and PTG was moderated by ES in the 'Increasing PTS' class (β=-0.13, SE=0.03, *P*<0.001; Figure 2). The moderating influence of ES on the direct association between PTS and PTG is summarized in Figure 3, indicating that the strength of the PTS and PTG direct effect is lessened with increasing levels of ES.

4. Discussion

This study investigated the trajectories of PTS intensity among 1 987 Chinese university students in the first eight months after the COVID-19 outbreak. Three PTS trajectory classes were identified: 'Increasing PTS' (*n*=205, 10.0%), 'Moderate PTS' (*n*=149, 8.0%), and 'Persistent Minimal PTS' (*n*=1 633, 82.0%). The last class suggested a strong adaptability and ability to deal with the COVID-19 emergency by the majority of students. We also observed that a small but statistically significant portion of students experienced moderate levels of symptomatology from the beginning of COVID-19 pandemic, and accompanied with increasing symptomatology. This study did not match with the former that observed four PTS trajectories: resistance, resilient, chronic, and delayed[32]. It is possible that at the first stage of the COVID-19 pandemic, individuals generated moderate to serious levels of emotional exhaustion. Over time, other deleterious consequences emerged, for example people felt loneliness because of social distancing, concerned about their well-being and that of loved ones, held negative feelings about a high rate of hospitalized patients and deaths, and worried about the absence of vaccines. The global spread of COVID-19 enhanced emotional exhaustion and contributed to the absence of the "resistance" class of the PTS trajectory. However, considering the regional differences of COVID-19 in China[33], for example, at the beginning of the pandemic, Hubei Province was the most serious province, Anhui,

Hunan, Jiangxi, Henan, Zhejiang, Guangdong, and Jiangsu Province were the second ones, which followed by Chongqing Municipality, Shandong and Sichuan Province, and, the PTS trajectories needed more validation.

CR and ES from the first assessment (T1) were used to predict PTS class membership following the pandemic outbreak. We observed CR levels increase from the classes 'Increasing PTS' to the 'Moderate PTS' class to the 'Persistent Minimal PTS' class. This finding suggests that a lower level of CR predicts intensity and chronicity PTS symptoms, while a higher CR level may suggest the stronger emotional well-being of students who received supportive interactions through their networks. The highest ES level in the 'Moderate PTS' class compared to 'Increasing PTS' and 'Persistent Minimal PTS' classes, which both show similar ES levels, suggested that ES is the 'Moderate PTS' class predictor. Additionally, our study suggests that CR and ES could be used together to identify 'Increasing PTS' class and 'Persistent Minimal PTS' classes in which CR is more sensitive. Our finding was similar to study by Lai *et al.* that a higher CR predicted fewer PTS symptoms[34] but inconsistent with Tyra *et al*. who reported the highest ES predicted PTS severity[35], suggesting that more studies are needed.

We further analyzed the relationship between PTS at T1 and PTG at T4 in the three PTS classes, as well as the effects of CR and ES on that. We observed that CR and ES were positively correlated with PTG in the three classes, and PTS could predict PTG in the 'Increasing PTS' class, which was similar to the reports by Lowe *et al.* showing that more PTSD symptoms were associated with stronger PTG experiences[16]. It was also supported by Zuo *et al.* that, when comparing with other provinces, the residents in Hubei province received more positive benefits from the same perceived social support in the first stage of COVID-19 pandemic[36]. Our data from the first eight months of the pandemic suggested that students experiencing more PTS may have engaged in the coping process, as PTG is a positive developmental change in cognitive emotional understanding of oneself and the world. It should be noted that since PTS and PTG development is a lifelong process, follow-up studies with these students will draw a clearer picture of the relationship between PTS and PTG and identify other factors that work on it. The correlation between CR and the three classes in our study is consistent with previous study showing that CR provided protection when injury occurred[34]. Students may use CR to alter emotion-forming patterns due to COVID-19 pandemic stress, thereby decreasing maladaptive cognitions and boosting their PTG[9]. Furthermore, we observed a strong modulating effect of CR, ES in the 'Increasing PTS' class but not in the other two classes, which is different from results reported by Zhou *et al.*[24], who found no direct effect of ES on PTG among adolescents after an earthquake. This difference may be due to the different pressures presented by the two events, as the COVID-19 outbreak was sudden and posed more severe stress that affected the PTS trajectories. It was reported that under traumatic stress, individuals who accessed ER strategies quickly and accurately, capture emotions comprehensively and clearly, might be less likely to get in the "increasing PTS" class[10].

Except for the factors that have been found to contribute to students' PTS symptoms, such as sex, academic year, family, and friends[3,37], the siblings and whether family members or friends being healthcare workers were also included in this study as the context-level predictors. We found that male sex was predictive of PTS severity, which was inconsistent with reports by Zhen *et al.*[23] and Jiang *et al.*[37], who found that males did not tend to engage in immersive thinking about trauma. Another explanation is that male students might be distracted from traumatic events at the beginning, but following the pandemic outbreak and the concern of an uncertain future of the pandemic, male students' belief system switched to a negative assumption. Unlike Wang *et al.*[3] who showed that being sophomore and senior students have higher risks to experience mental health problems, we found that the grade in university did not predict PTS severity. This difference may be due to the safe environment and relaxed atmosphere in Hainan Province, whose number of confirmed cases have kept lower than the average level of 31 provinces in China. What's more, Hainan Province is famous for slow pace of life, which protect students from the academic and employment pressure[6]. We also observed that family members or friends who had been infected with COVID-19 were the strongest predictor of the 'Increasing PTS' class. This was consistent with the conclusions of other studies which cited COVID-19 as having raditaion-like side effects[1,4]. The medical workers and patients in Wuhan had more serious anxiety and depressive symptoms than those in non-Hubei areas[38]; the patients who had typical COVID-19 symptoms presented higher negative emotion level than the mild or common individuals[39]; the public displayed awful mental states during COVID-19 outbreaks and gradual improvements as outbreaks subsided[40]. Unexpectedly, family members or friends who were healthcare workers were not a predictor of the 'Increasing PTS' class. The COVID-19 pandemic caused panic during the initial stages with rapid increases in patients, lack of medical supplies, and isolation due to social-distancing policies, these were alleviated by the objective information healthcare workers provided[41].

Our study sheds light on PTS, emotion regulation strategies, and their roles in predicting and moderating PTG following the pandemic outbreak. It should be noted that some limitations remain. First, we measured PTG only during the last assessment, thus we do not know how the changes in PTS affected PTG throughout the pandemic. Second, the current study samples were limited to Chinese university students in Hainan province, and future studies need to examine a more diverse sample. Third, we did not consider the co-occurring risk factors, such as negative events, history of depression and anxiety, which may have affected the results of our findings. Future studies could consider direct interviews of participants about their PTS and administer assessments of social, domestic, and occupational functioning. These could add

more conclusive data about of emotion regulation strategies to psychopathology.

In conclusion, we observed three distinct PTS trajectories (Increasing PTS, Moderate PTS and Persistent Minimal PTS) among university students in the first eight months after the COVID-19 outbreak in Hainan province, China. CR and ES can be used to identify the low or high PTS classes and classes with fast, slow, or no resolution of their PTS. The severity of PTS was associated with more PTG; CR, ES played a modulating role in the relationship between PTS and PTG separately, suggesting that professional psychological intervention focusing on emotion regulation should be provided for the 'Increasing PTS' class.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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Authors' contributions

HJJ performed the analytic calculations, the numerical simulations, and wrote the first draft of the manuscript. Both JN and ZYL contributed to the final version of the manuscript. JY developed the theoretical formalism, and supervised the project.

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