Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Journal of Affective Disorders 301 (2022) 260–267

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research paper

Self-reported anxiety level and related factors in senior high school students in China during the outbreak of coronavirus disease 2019

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ARTICLE INFO

Keywords:
Anxiety
Coronavirus disease 2019
Senior high school students

ABSTRACT

Background: The outbreak of COVID-19 has been a big challenge for senior high school students in China who are facing tremendous pressure of the highly competitive College Entrance Examination.
Methods: To evaluate the psychological impact of the event in the population, we conducted an anonymous online survey among senior high school students in China between 26 Feb and 4 March, 2020. Information collected included demographic characteristics, attitude toward medical study, infection of COVID-19 in acquaintances, anxiety symptoms evaluated using the GAD-7, and health literacy level measured using the IDSHL.
Results: Of 21,085 participants, 3,575 (17.0%), 943 (4.5%) and 448 (2.1%) reported with mild, moderate, and severe anxiety. Female, higher academic year, worse self-evaluated academic performance, negative attitude toward medical study, living in Hubei province and having acquaintance infected with COVID-19 were significantly associated with anxiety level, while higher education level of mother and higher IDSHL score were associated with a lower risk. The score of IDSHL, particularly of the domain "infectious disease prevention", was associated with the GAD-7 score in a linear pattern (β=-0.0371, $p<0.01$).
Limitations: Limitations included the cross-sectional study design unable to infer the casual relationship, anonymous survey, selection bias and self-reported anxiety disorder levels.
Conclusions: The results suggested that COVID-19 outbreak may increase anxiety level in senior high school students in China. The anxiety related factors observed in this study may help to identify vulnerable individuals and develop interventions.

1. Introduction

Anxiety, an abnormal and overwhelming sense of apprehension and fear, is common among adolescents (Yang et al. 2021). It is estimated that in China 13.99% of middle school students were troubled by anxiety (Wang et al. 2019). Anxiety is usually caused by chronic stress, specifically for Chinese senior high school students, the tremendous pressure of the highly competitive College Entrance Examination. The outbreak of coronavirus disease 2019 (COVID-19) may have aggravated the stress and increase anxiety level in this population. Since anxiety during adolescence not only leads to concurrent adjustment problems, but also impedes future adaptive psychosocial development (Maldonado et al. 2013), it is essential to understand the prevalence and the main determinants of anxiety symptoms in high school students during the epidemic of COVID-19, and thus develop specific psychological crisis interventions for this vulnerable population and their counterparts in other countries.

The outbreak of COVID-19 was first reported in Wuhan, the capital city of Hubei province of China, and subsequently spread to all 34 provinces, municipalities and autonomous regions of the country (Wang, Horby, et al. 2020). In response to the outbreak, Chinese government adopted a variety of drastic public health measures, including

Abbreviations: COVID-19, Coronavirus disease 2019; IDSHL, The infectious disease-specific health literacy scale; OR, Odds ratio; CI, Confidence interval; IQR, Interquartile range; GAD, The generalized anxiety disorder screener; WHO, World health organization; SARS, The severe acute respiratory syndrome; H1N1, Influenza A.

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https://doi.org/10.1016/j.jad.2022.01.056
Received 22 October 2021; Received in revised form 20 December 2021; Accepted 11 January 2022
Available online 14 January 2022

coronavirus testing, quarantine, contact tracing, travel restriction, social distancing and home confinement. On 23th January of 2020, China imposed a lockdown of the population in Wuhan as well as the entire Hubei province, leading to a significantly decreased growth rate and increased doubling time of cases (Lau et al. 2020). Nevertheless, due to the rapid spreading of COVID-19 from person to person through respiratory droplets (Miller and Englund 2020), together with the exponentially increasing number of cases, unpredictable widespread of the disease and lack of effective methods to control at that time (Pan et al. 2020), the stressful public health emergency aroused public panic and mental health problems in Chinese population (Wang, Pan, Wan, Tan, Xu, Ho, et al. 2020; Wang, Pan, Wan, Tan, Xu, McIntyre, et al. 2020), particularly in COVID-19 patients (Guo et al. 2020), medical health workers (Zhang, Wang, et al. 2020; Lai et al. 2020), and college students (Cao et al. 2020; Huckins et al. 2020).

Several studies have examined the psychological status of adolescences in China during the epidemic of COVID-19 (Zhang, Ye, et al. 2020; Zhou et al. 2020; Hou et al. 2020; Yang et al. 2020; Xu et al. 2021; Chen et al. 2021). The prevalence of anxiety symptoms (mild to serve) was 38.42% among junior and senior high school students in Henan province of China during Feb 4-12, 2020 (Xu et al. 2021) and was 37.4% among those from 21 provinces and autonomous regions of China during March 8-15, 2020 (Zhou et al. 2020). Chen et al (Chen et al. 2021) found that the prevalence of anxiety (mild to serve) among adolescents from 34 provinces of China increased from 19.0% during Feb 20-27, 2020 to 36.7% during April 11-19, 2020, indicating the impact of the stage of COVID-19 outbreak. The risk factors for anxiety identified in the surveys were also much different from each other.

Bronfenbrenner's Process-Person-Context-Time (PPCT) theory of human development offers a useful framework to better understand the development of anxiety in adolescents during the COVID-19. The first concept 'process' in the PPCT theory refers to dynamic interactions of a child (individual) with immediate environment (typically the persons, objects, and symbols in the school and home environment) (Bronfenbrenner and Ceci 1994) and social contexts outside the immediate environment (Bronfenbrenner 1977), through which development occurs. Guided by the theory, Berg, et al (Berg et al. 2018) found proximal processes of poor adolescent family relationships and frequent peer contact to be associated with an increased likelihood of heavy episodic drinking in adulthood. According to the theory, the potential risk and protective factors for the psychiatric disorder can be identified from the proximal processes in individuals, immediate environment and social contexts.

To better understand mental health status in Chinese senior high school students, we conducted an online survey in the populations in early stage of COVID-19 pandemic (between 26th February and 4th March, 2020). We analyzed the data based on the PPCT theory, aiming to test the hypotheses of:

1) The outbreak of COVID-19 may increase anxiety level in Chinese senior high school students. Specially, the prevalence of anxiety observed in this survey may be at a high level, and the anxiety level would be correlated with epidemic status of COVID-19 which is indicated with the percentage of accumulated regional COVID-19 case accounting for the national accumulated cases, and the number of daily reported new cases in each region; and
2) The potential risk and protective factors for the psychiatric disorder would be identified from the proximal processes of the individuals, the immediate environment and the social contexts. Specifically, anxiety level in Chinese senior high school students may be associated with sex, attitude toward medical study, score of each domain of IDSHL (individuals), academic year, self-evaluated academic performance (school environment), educational levels of parents (family environment) or living in Hubei province, having acquaintance infected with COVID-19 (social contexts).

2. Methods

2.1. Participants and Procedure

This cross-sectional survey was conducted during the period between 26th February and 4th March of 2020, when COVID-19 was well-controlled in China with less than 600 daily reported cases, while the number of cases increased rapidly in other countries (**Fig. 1**). The survey was also taken place between the date (January 30, 2020) that the COVID-19 was declared as a Public Health Emergency of International Concern by the World Health Organization (WHO) and the date (March 11, 2020) that the COVID-19 was proclaimed as a pandemic (Mahase 2020; Cucinotta and Vanelli 2020).

As the Chinese Government recommended travel restriction, social distancing, closure of public places including schools, and home confinement, we conducted an online survey using electronic self-administered questionnaires designed as student-version and parent-version using the online survey tool Sojump (Shanghai Information Co.). The questionnaires were released through WeChat platform (Tencent Corp). Specifically, the online questionnaires were forwarded to the principals of several key senior high schools by the Admissions Office of the Shanghai Medical College of Fudan University, and then to the head teachers of classes by the principals. Finally, head teachers released the students' and parents' version of questionnaires to the corresponding WeChat groups consisting of students or parents only. All the students and the parents were asked to answer the questions voluntarily and anonymously after reading informed consent at the forepage of the questionnaires. All principals and head teachers were also encouraged to forward the online questionnaires to their colleagues in other key senior high schools in China.

This study was approved by the Institutional Review Board of the Fudan University School of Public Health (IRB00002408 & FWA00002399). Informed consent was presented at the forepage of questionnaire, but signature was waived because the questions were answered anonymously. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000.

2.2. Measures and Instruments

2.2.1. Questionnaire-based information

We used the survey data from the students only in this analysis. The data was downloaded from the Sojump system, including the data collected using the questionnaire and the auto-recorded date and time of completing the questionnaire.

The information collected by the student-version of self-administered questionnaire included: 1) demographic characteristics, including sex, date of birth, name of high school, academic year, and self-evaluated performance level; 2) education levels and occupations of parents; 3) degree preferences, including the willingness to learn medicine (prior and post COVID-19 outbreak), preferred medical career (clinician, public health practitioner, pharmacist, nurse or others), and main motivations for selecting or unselecting medical study; 4) infection of COVID-19 in acquaintances; 5) health literacy level on infectious diseases assessed using the Infectious Disease-specific Health Literacy Scale (IDSHL), and 6) anxiety level evaluated using the Chinese version of the Generalized Anxiety Disorder Screener (GAD-7).

2.2.2. The IDSHL

The IDSHL developed by *Tian et al* (Tian et al. 2016) was used to assess health literacy level of the students on infectious diseases. The scale was developed, tested and validated in Chinese population in 2014. This self-reported scale includes 28 items and has proved to be an efficient, psychometrically sound and user-friendly measure for infectious disease-specific health literacy. The total score of the scale ranges

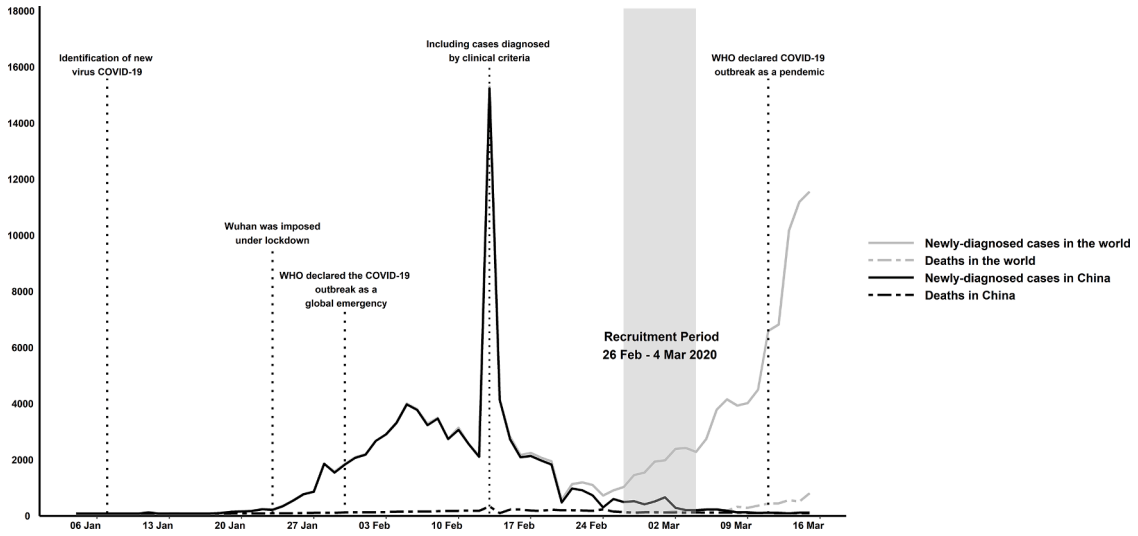

Fig. 1. Period of the survey and timeline of the epidemic of COVID-19. **Abbrev:** COVID-19, coronavirus disease 2019.

from 0 to 100. Higher score corresponds to a higher the level of health literacy. Of the 28 items, 22 were scored according to the difficulty level of questions and were classified into 4 domains: 1) infectious disease-related knowledge and values; 2) prevention of infectious diseases; 3) management or treatment of infectious diseases; and 4) identification of pathogens and infection sources. In the present study, the IDSHL demonstrated good internal consistency (Cronbach's $\alpha = 0.758$).

2.2.3. The Chinese version of GAD-7

The Chinese version of GAD-7 was used to measure anxiety level of the students (Spitzer et al. 2006). The scale has been used in Chinese population and proved with good retesting reliability and validity (Cronbach's alpha=0.90) (Tong et al. 2016). It is a brief self-reported questionnaire to measure seven symptoms during the past two weeks, each of which was rated on a four-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). The anxiety level was then assessed as minimal (score of 0-4), mild (score of 5-9), moderate (score of 10-14), and severe (score of 15-21). Those who had a GAD-7 score of 5 points or above were considered with anxiety, and those with a score of 10 or greater were identified as cases with generalized anxiety disorder. In this study, Cronbach's alpha for the scale was 0.913, indicating high internal consistency.

2.2.4. COVID-19 epidemic data

The number of COVID-19 cases across China was obtained through the website of National Health Commission of the People's Republic of China (http://www.nhc.gov.cn/xcs/xxgzbd/gzbd_index.shtml), while the number of cases around the world was derived from the World Health Organization (WHO) COVID-19 Situation Reports (https://covid19.who.int/table). The obtained data includes the number of accumulated cases in the participants' provinces of China and across the country (until 4th March, 2020), and the number of daily reported new cases and deaths nationally and internationally (from 6th January to 16th March, 2020). Differences may exist between the reporting jurisdictions and the number from the website of WHO due to the time of reporting and the update of the website. The key events that occurred in the early period of COVID-19 pandemic were also derived from the COVID-19 Timeline Report of the WHO and the National Health Commission of the People's Republic of China.

2.3. Data analysis

All data analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). Categorical variables were presented as the number and proportion, while continuous variables were described as medians and interquartile ranges (IQR). Chi-square (χ^2) test was used to compare the difference in anxiety level by characteristics of the students. The regional correlation of anxiety level with the number of COVID-19 cases during the period of survey was illustrated in diagrams and evaluated using Pearson correlation analysis. Univariate ordinal logistic regression with the outcome variable (anxiety level) of four categories-multinomial and ordinal (minimal, mild, moderate and severe) was adopted to calculate odds ratios (ORs) and 95% confidence intervals (CIs) of anxiety level with sex, academic year, self-evaluated academic performance, attitude toward medical study before and after COVID-19 outbreak, parents' education level, region, diagnosis of COVID-19 in acquaintances and IDSHL score. Multivariable stepwise regression was applied to examine magnitude of the associations for each significant variable with the level of anxiety. The significance level of the Wald Chi-square for an effect to enter or stay in the model was set as 0.05. Both simple and multivariable linear regression were used to estimate β coefficients and 95%CIs of the GAD-7 score with the score of each domain in IDSHL. All tests were two-tailed, and a p value less than 0.05 was considered statistically significant.

3. Results

3.1. Characteristics and anxiety levels in participants of the study

From 21,141 surveys that were delivered, 56 students were excluded due to unclear locations. The effective number of participants were 21,085 students from 233 senior high schools in 24 provinces, municipalities and autonomous regions (96 cities), including 776 students from Wuhan, the capital city of Hubei province suffering the most from the COVID-19 outbreak in China. The geographic distribution of participants is illustrated in Fig. 2.

As shown in Table 1, of 21,085 respondent students, 52.9% were females, 3.8% came from Hubei province. The distribution of students in the Year 1, Year 2, graduate year, and the re-sit graduate year were 33.3%, 31.8%, 33.1%, and 1.8%, respectively. According to self-evaluation, 69.7% of the students had predicted academic performance qualified for top-tier universities. Only 1.6% of the students claimed to have had acquaintance with diagnosed COVID-19 cases. According to the students' report, 36.0% of the fathers and 33.4% of the mothers had junior college degree or above. The median score of the IDSHL in the students was 73 (out of 100). Of all participants, 4966 (23.6%) were regarded as with anxiety, with 17.0% (n = 3575) reported with mild anxiety, 4.5% (n = 943) with moderate anxiety and 2.1% (n =

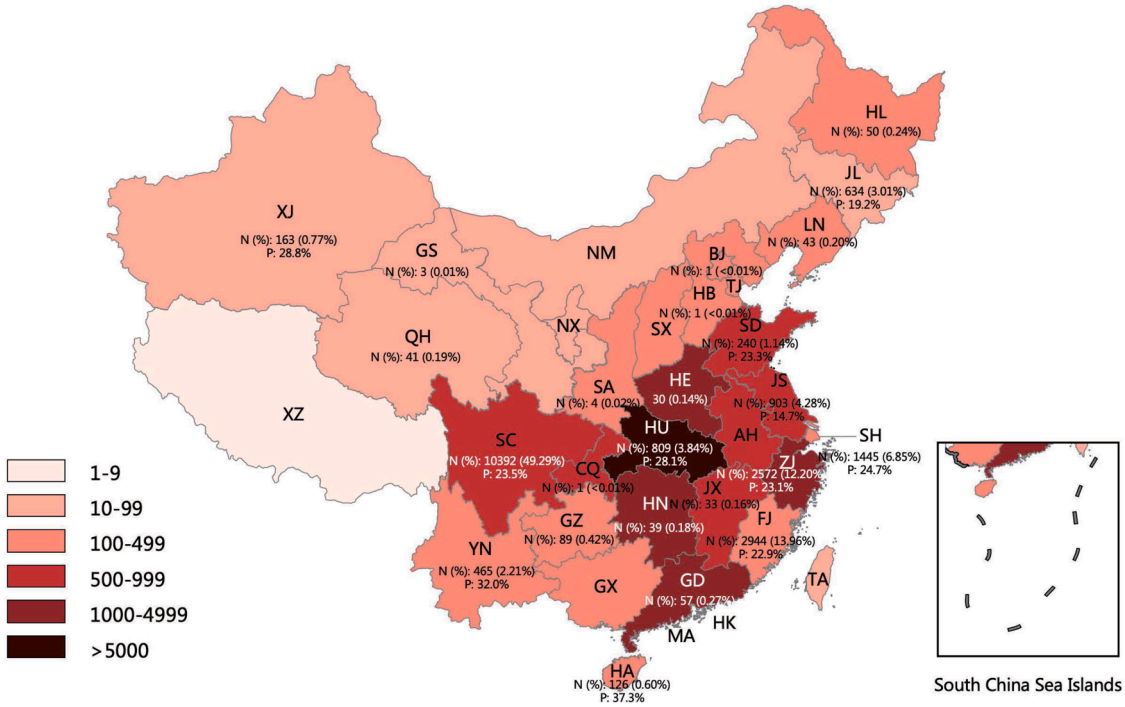

Fig. 2. Geographic distribution of participants and prevalence of anxiety across regions in China. *The color legends refer to the cumulative number of COVID-19 cases (up to the 4th March of 2020) in respective regions. **Abbrev**: N (%), number and percentage of participants; P, Prevalence of anxiety; COVID-19, coronavirus disease 2019. AH, Anhui; BJ, Beijing; CQ, Chongqing; FJ, Fujian; GD, Guangdong; GS, Gansu; GX, Guangxi; GZ, Guizhou; HA, Hainan; HB, Hebei; HE, Henan; HK, Hong Kong; HL, Heilongjiang; HN, Hunan; HU, Hubei; JL, Jilin; JS, Jiangsu; LN, Liaoning; MA, Macao; NM, Inner Mongolia; NX, Ningxia; QH, Qinghai; SA, Shaanxi; SC, Sichuan; SD, Shandong; SH, Shanghai; SX, Shanxi; TA, Taiwan; TJ, Tianjin; XJ, Xinjiang; XZ, Tibet; YN, Yunnan; ZJ, Zhejiang; JX, Jiangxi.

448) with severe anxiety.

Table 1 further shows the significant differences in anxiety levels by sex, academic year, self-evaluated academic performance, attitudes towards medical study before and after the COVID-19 outbreak, parent's education levels, regions, diagnosis of COVID-19 in acquaintances, and the IDSHL score.

3.2. Correlations of anxiety levels with epidemic status of COVID-19 across regions

The prevalence of anxiety was mapped against the accumulated number of reported COVID-19 cases in China until 4th March of 2020 by regions (Fig. 2). To investigate the relationship between the prevalence of anxiety and epidemic status of COVID-19, we conducted correlation analyses using the percentage of accumulated regional COVID-19 case accounting for the national accumulated cases and the number of daily reported new cases in each region to indicate the epidemic status of COVID-19. In order to establish a more robust correlation, only provinces or regions with participant number of more than 100 were included. We did not observed a significant correlation of the prevalence of anxiety with the percentage of accumulated regional cases over the study period ($r = 0.15$, $p = 0.67$) and with the number of daily reported new cases ($r = -0.42$, $p = 0.31$) across regions. Excluding data in Hubei province due to the strong interference in the region did not change the results substantially, with correlation coefficients of -0.41 ($p = 0.24$) and 0.16 ($p = 0.71$), respectively.

3.3. Factors associated with anxiety levels in senior high school students

As shown in Table 2, students who were female, living in Hubei province, or having acquaintance infected with COVID-19 were at a higher level of anxiety, with OR (95%CI) being 1.25 (1.17, 1.33), 1.29 (1.10, 1.50), 1.95 (1.55, 2.43), respectively. The ascending academic year was associated with the levels of anxiety, with OR (95%CI) being 1.10 (1.02, 1.20), 1.78(1.64, 1.92) and 1.99 (1.58-2.47) for students in the Year 2, 3 and 4 (re-sit of graduate year) relative to those in the Year 1. Self-evaluated academic performance was also associated with a higher anxiety level. Compared with top tier students, the ORs (95%CI) were 1.24 (1.15, 1.34), 1.30 (1.10, 1.54), and 1.17 (1.01, 1.35), respectively, for the second, third and other tier students. Higher educational level of parents and higher score of IDSHL were significantly associated with a lower level of anxiety.

We further established a multivariate ordinal logistic regression model through a stepwise approach, and found that attitude towards medical study after COVID-19 outbreak, fathers' education levels and living in Hubei province were no longer significantly associated with the anxiety level (Table 2)

3.4. Associations of score in each domain of IDSHL with the GAD-7 score

We performed univariate and multivariable linear regression analyses to evaluate the associations of the score in each domain of IDSHL with anxiety levels in our subjects. As shown in Table 3, of the four domains of IDSHL, only the score in the domain "*Identification of pathogens and infection sources*" was not associated with the GAD-7 score. On the other hand, higher scores in domains "*infectious disease-related knowledge and values*" (β=-0.0094, p=0.02), "*prevention of infectious diseases*" (β=-0.0414, $p<0.01$) and "*management or treatment of infectious diseases*" (β=-0.0151, $p<0.01$) were significantly and negatively associated with the GAD-7 score. The inverse associations remained unchanged after adjusting for sex, academic year, self-evaluated academic performance, attitude towards learning medicine before COVID-19 outbreak, mother's educational level and having acquaintance infected with COVID-19. Further mutual adjustment of the scores in IDSHL domains, however, observed only a significant inverse association between the score of the domain "*prevention of infectious diseases*" and the score of the GAD-7 ($\beta = -0.0371$, $p < 0.01$).

Table 1
Generalized anxiety disorder level according to the characteristics of participants.

	Total (N, %)	Generalized anxiety disorder level (N, %)				*p* for chi square tests
		Minimal	Mild	Moderate	Severe	
All subjects	21085 (100.0)	16119 (76.4)	3575 (17.0)	943 (4.5)	448 (2.1)	
Sex						*<0.0001*
Male	9933 (47.1)	7801 (78.6)	1550 (15.6)	390 (3.9)	192 (1.9)	
Female	11152 (52.9)	8318 (74.6)	2025 (18.2)	553 (4.9)	256 (2.3)	
Academic year						*<0.0001*
Year 1	7032 (33.3)	5663 (80.5)	1045 (14.9)	218 (3.1)	106 (1.5)	
Year 2	6698 (31.8)	5293 (79.0)	1035 (15.5)	249 (3.7)	121 (1.8)	
Graduate year	6984 (33.1)	4911 (70.3)	1414 (20.2)	451 (6.5)	208 (3.0)	
Resit of graduate year	371 (1.8)	252 (67.9)	81 (21.8)	25 (6.8)	13 (3.5)	
Academic performance						*<0.0001*
Top tier	14699 (69.7)	11409 (77.6)	2385 (16.2)	608 (4.2)	297 (2.0)	
Second tier	4678 (22.2)	3445 (73.6)	884 (18.9)	237 (5.1)	112 (2.4)	
Third tier	687 (3.3)	499 (72.6)	134 (19.5)	43 (6.3)	11 (1.6)	
others	1021 (4.8)	766 (75.0)	172 (16.9)	55 (5.4)	28 (2.7)	
Attitude toward medial study before COVID-19 outbreak						*0.0003*
Positive	3682 (17.5)	2913 (79.1)	561 (15.3)	137 (3.7)	71 (1.9)	
Negative	14706 (69.7)	11111 (75.6)	2570 (17.5)	697 (4.7)	328 (2.2)	
Neutral	2697 (12.8)	2095 (77.7)	444 (16.5)	109 (4.0)	49 (1.8)	
Attitude toward medical study during COVID-19 epidemic						*0.0002*
Positive	6249 (29.7)	4900 (78.4)	972 (15.6)	257 (4.1)	120 (1.9)	
Negative	11121 (52.7)	8396 (75.5)	1935 (17.4)	525 (4.7)	265 (2.4)	
Neutral	3715 (17.6)	2823 (76.0)	668 (18.0)	161 (4.3)	63 (1.7)	
Father's education level						*0.03*
Primary school or below	1727 (8.2)	1274 (73.8)	329 (19.0)	86 (5.0)	38 (2.2)	
High school or technical school	11765 (55.8)	8957 (76.1)	2038 (17.3)	522 (4.5)	248 (2.1)	
Junior college or above	7593 (36.0)	5888 (77.6)	1208 (15.9)	335 (4.4)	162 (2.1)	
Mother's education level						*0.0007*
Primary school or below	2868 (13.6)	2106 (73.4)	551 (19.2)	139 (4.9)	72 (2.5)	
High school or technical school	11167 (53.0)	8532 (76.4)	1913 (17.1)	494 (4.4)	228 (2.1)	
Junior college or above	7050 (33.4)	5481 (77.7)	1111 (15.8)	310 (4.4)	148 (2.1)	
Region						*0.01*
Non-Hubei	20276 (96.2)	15537 (76.6)	3418 (16.9)	898 (4.4)	423 (2.1)	
Hubei	809 (3.8)	582 (71.9)	157 (19.4)	45 (5.6)	25 (3.1)	
Acquaintance diagnosed with COVID-19						*<0.0001*
No	20757 (98.4)	15909 (76.6)	3505 (16.9)	914 (4.4)	429 (2.1)	
Yes	328 (1.6)	210 (64.0)	70 (21.4)	29 (8.8)	19 (5.8)	
IDSHL score						*<0.0001*
≤73	10759 (51.0)	8078 (75.1)	1884 (17.5)	542 (5.0)	255 (2.4)	
>73	10326 (49.0)	8041 (77.9)	1691 (16.4)	401 (3.9)	193 (1.8)	

Abbrev: N, number; COVID-19, coronavirus disease 2019; IDSHL, Infectious Disease-specific Health Literacy Scale.

4. Discussion

In this large-scale cross-sectional survey conducted between 26 Feb and 4 March, 2020, a period corresponding to the recovering stage after the peak of the COVID-19 outbreak in China, we found that the prevalence of anxiety disorder in senior high school students of China was 23.6% (mild 17.0%, moderate 4.5%, and severe 2.1%). The prevalence was lower than 28.8% in general population during the peak of the epidemic (Jan 31 to Feb 2, 2020) (Wang, Pan, Wan, Tan, Xu, Ho, et al. 2020) and between the 19% observed in Feb 20-27, 2020 and the 36.7% during April 11 to 19, 2020 among Chinese secondary school students. The prevalence was also lower than 37.4% in junior and high school students around China during the later phase of the outbreak of COVID-19 (March 8-15, 2020) (Zhou et al. 2020).

The reasons for anxiety in Chinese senior high school students may be more complicated than in general population. First, the outbreak of COVID-19 triggered anxiety in the whole society due to fear of getting the virus or even dying from the fatal disease with limited knowledge then. It is of note that the prevalence of anxiety was not significantly correlated with the percentage of accumulated regional cases or the number of daily reported new cases. This may be explained by the well-contained outbreak in China during the period of survey, and suggests that it may be the fatality of COVID-19 that caused anxiety in students. Previous studies also showed that anxiety and health concerns were raised by outbreak of fatal diseases such as the severe acute respiratory syndrome (SARS) in 2003, avian influenza in 2006, influenza A (H1N1) in 2009/2010 and the Ebola in 2014/2016 (Main et al. 2011; Saadatian-Elahi et al. 2010;Lau et al. 2010; Jalloh et al. 2018). Over 50% of respondents reported with anxiety or worries during the periods of the outbreaks (Bults et al. 2011; Goulia et al. 2010; Jalloh et al. 2018;Lau et al. 2010). Second, the growing academic pressure caused by the COVID-19 outbreak may aggravate anxiety. The senior high school students, as the candidates of college entrance, have been struggling for the College Entrance Examination, the most competitive examination in China. Their routines and normal pace of learning were disrupted by the sudden outbreak of COVID-19. Due to the closure of schools, all students had to attend online homeschool instead of classroom study. The changes in teaching and learning, as well as the challenge of self-discipline, long screen time, lack of interaction with teachers and other students, could worsen existing anxiety, a typical emotional reaction in the situation of huge academic pressure. Finally, long-term social distancing and home confinement, the main measures taken to prevent spreading of COVID in China, could cause negative emotional responses like feelings of loneliness and helplessness, particularly for those lacking family support (Tang et al. 2021) and even undergoing increased domestic violence and abuse due to long time family bonding. Closure of schools during COVID-19 epidemic took away school-based supports from these vulnerable students, exposing them to risks of developing mental health problems. Lack of social activities has been suggested to predispose adolescents to psychiatric disorder (Butler et al. 2016). Sustained anxiety may lead to physiological dysfunction, and progress to physical and mental diseases (Batelaan et al. 2016; Liu et al. 2017).

Table 2
Ordinal logistic regression analyses for underlying factors associated with student's generalized anxiety disorder level.

	Univariate ordinal logistic regression analyses			Multivariate ordinal logistic regression analyses		
	β	SE	OR (95% CI)	β	SE	OR (95% CI)
Sex						
Male	Ref.		Ref.	Ref.		Ref.
Female	0.22	0.03	1.25 (1.17, 1.33)	0.21	0.03	1.23 (1.15, 1.31)
Academic year						
Year 1	Ref.		Ref.	Ref.		Ref.
Year 2	0.10	0.04	1.10 (1.02, 1.20)	0.09	0.04	1.09 (1.01, 1.19)
Graduate year	0.57	0.04	1.78 (1.64, 1.92)	0.61	0.04	1.84 (1.70, 1.99)
Resit of graduate year	0.69	0.11	1.99 (1.58, 2.47)	0.64	0.11	1.90 (1.51, 2.37)
Academic performance						
Top tier	Ref.		Ref.	Ref.		Ref.
Second tier	0.21	0.04	1.24 (1.15, 1.34)	0.18	0.04	1.20 (1.11, 1.30)
Third tier	0.26	0.09	1.30 (1.10, 1.54)	0.23	0.09	1.26 (1.06, 1.50)
others	0.16	0.07	1.17 (1.01, 1.35)	0.18	0.08	1.20 (1.03, 1.39)
Attitude toward medical study before COVID-19 outbreak (n, %)						
Positive	Ref.		Ref.	Ref.		Ref.
Negative	0.20	0.04	1.23 (1.13, 1.34)	0.22	0.05	1.25 (1.14, 1.36)
Neutral	0.08	0.06	1.08 (0.96, 1.22)	0.12	0.06	1.13 (1.00, 1.28)
Attitude toward medical study during COVID-19 epidemic (n, %)						
Positive	Ref.		Ref.			
Negative	0.17	0.04	1.18 (1.10, 1.27)			
Neutral	0.13	0.05	1.14 (1.03, 1.25)			
Father's education level						
Primary school or below	Ref.		Ref.			
High school or technical school	-0.12	0.06	0.88 (0.79, 0.99)			
Junior college or above	-0.20	0.06	0.82 (0.73, 0.93)			
Mother's education level						
Primary school or below	Ref.		Ref.	Ref.		Ref.
High school or technical school	-0.16	0.05	0.86 (0.78, 0.94)	-0.12	0.05	0.89 (0.81, 0.98)
Junior college or above	-0.23	0.05	0.80 (0.72, 0.88)	-0.15	0.05	0.86 (0.78, 0.96)
Region						
Non-Hubei	Ref.		Ref.	Ref.		Ref.
Hubei	0.25	0.08	1.29 (1.10, 1.50)			
Acquaintance diagnosed with COVID-19						
No	Ref.		Ref.	Ref.		Ref.
Yes	0.67	0.11	1.95 (1.55, 2.43)	0.67	0.11	1.96 (1.56, 2.46)
IDSHL score						
≤73	Ref.		Ref.	Ref.		Ref.
>73	-0.16	0.03	0.85 (0.80, 0.90)	-0.14	0.03	0.87 (0.82, 0.93)

Abbrev: N, number; COVID-19, coronavirus disease 2019; IDSHL, Infectious Disease-specific Health Literacy Scale; β, beta coefficient; SE, standard error; OR, odds ratio; CI: confidence interval; Ref., reference group.

Although prevalence of anxiety is moderate in our subjects, these speculations are somewhat supported by the anxiety-related factors identified in this study according to the PPCT theory, which included sex, attitude toward medical study and IDSHL score (individuals), academic year, self-evaluated academic performance (school environment),

Table 3
Associations between score of the GAD-7 score and the score of each domain for IDSHL scale.

IDSHL domains	The GAD-7 score		
	β_u	β_a	β_m
Infectious disease-related knowledge and values	-0.0094*	-0.0093*	-0.0025
Infectious disease prevention	-0.0414**	-0.0366**	-0.0371**
Management or treatment of infectious diseases	-0.0151**	-0.0127**	-0.0073
Identification of pathogens and infection sources	-0.0075	-0.0061	0.0108

β_u=standardized coefficients of univariate regression analyses; β_a=standardized coefficients adjusted for sex, academic year, academic performance, attitude toward learning medicine before COVID-19 outbreak, mother's education level and acquaintance with COVID-19 cases; β_m=standardized coefficients adjusted for the above variables and other IDSHL domains. *$P < 0.05$. **$P < 0.01$.
Abbrev: IDSHL, Infectious Disease-specific Health Literacy Scale; GAD-7, the Generalized Anxiety Disorder Scale; β, beta coefficient.

educational levels of parents (family environment) or living in Hubei province, having acquaintance infected with COVID-19 (social contexts).

For individual factors, female students were more likely to be anxious in this study, which is consistent with previous studies, in which female is an important risk factor for anxiety (Putwain 2007). Interestingly, we found that higher IDSHL score was negatively related with anxiety level, indicating the power of knowledge in releasing psychiatric disorder. Particularly, high score on *prevention of infectious diseases*, one of the domains of the IDSHL, was significantly associated with low risk of anxiety. This domain includes interpreting indicators of at-risk groups, rational decision-making skills, disinfection, sterilization, insecticidal skills, self-protection skills against infectious disease, personal hygienic behaviors, relevant policies and laws, physical exercise, and nutrition and food hygiene (Tian et al. 2016), all of which help to prevent infecting any pathogens including coronavirus, and thus release anxiety in students.

Regarding school environment, students who were in higher academic year or with worse self-evaluated academic performance showed a higher level of anxiety disorder, suggesting the role of academic pressure. The results may help to explain the low prevalence of anxiety in our subjects. All participants of the survey were from key senior high schools who were strictly selected and highly competitive for the College Entrance Examination, and thus may suffer less anxiety symptoms, even though the outbreak of COVID-19 may have aggravated the anxiety.

Protection of higher education levels of parents indicate the importance of family support for our subjects. Relationships with parents form the immediate family environment for a persons' development. Parents influence their children via their own knowledge, attitudes and response to the COVID-19 outbreak and related anxiety. Strong family support helps to release adolescents' anxiety caused by huge academic pressure and the outbreak, particularly through open and constructive communication with well-educated parents. Interestingly, we observed a significant association of student's anxiety with mothers' education level, but not with fathers' in multivariable ordinal logistic regression analyses. The highly correlated educational level between mothers and fathers may partly contributed to the results, and indicate more important influence of mothers on adolescent students.

The positive association of living in Hubei province–a region completely locked down–with anxiety level prove the adverse impact of social isolation. The students having acquaintance infected with COVID-19 were more likely to be anxious, supporting the direct effect of COVID-19 on anxiety level in students. However, due to lack of prevalence of anxiety before the outbreak of COVID-19 in our subjects, it is unclear whether the outbreak of COVID-19 have increase anxiety in the population.

The potential risk and protective factors of anxiety level in our subjects implicate the direct and indirect impacts of the COVID-19 outbreak and provide clues to develop interventions for this specific population. First of all, the most vulnerable students can be identified based on their social-demographic characteristics and then can be intervened extensively through more active interactions with their teachers, peers, family members and social workers. More importantly, due to the positive effect of health literacy on anxiety level, it would be effective to popularize knowledges on infectious disease by health education and promotion in students.

The strengths of the study include the large sample size, the application of the PPCT theory in identifying and explaining the potential risk and protective factors for anxiety, the timing of the investigation, the widely distributed study participants, the detailed information collection and the intensive analyses of the data. However, there are several limitations in this study. First, the nature of cross-sectional study design limited the validity of the study in causal inference. Second, the subjects were not randomly selected, which may lead to selection bias. However, the large sample size covered 233 senior high schools, 96 cities and 24 provinces, slightly released our concerns on the issue. Third, the anxiety symptoms were self-reported by students, which may not be accurate as those assessed by professional psychologists. Misclassification bias could not be avoided. Finally, the participants of the survey were anonymous. Therefore, we could not implement related interventions in our subjects and follow-up them to evaluate the effectiveness of the interventions

In conclusion, this study shows a moderate anxiety level in key senior high school students in China during the outbreak of COVID-19 and identifies related factors that can be used to detect vulnerable individuals and develop specific interventions. As the COVID-19 pandemic is ongoing, our findings may provide important implications for China and other countries to deal with the mental health problem in senior high school students.

CRediT authorship contribution statement

Lei Wang: Formal analysis, Writing – original draft. **Yeerzhati Yeerjiang:** Data curation, Writing – original draft. **Hai Feng Gao:** Supervision, Writing – review & editing. **Jian Feng Pei:** Data curation, Writing – review & editing. **Ruo Xin Zhang:** Formal analysis, Writing – review & editing. **Wang Hong Xu:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

ALL authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stockownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Acknowledgements

The authors gratefully acknowledge all research members, teachers, parents and students participating in this research.

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