Research paper

Nightmares mediate the association between traumatic event exposure and suicidal ideation in frontline medical workers exposed to COVID-19

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ABSTRACT

Background: Trauma experience increases the risk of suicidal ideation, but little is known about potentially psychological mechanisms underlying this relationship. This study aims to examine the relationship between coronavirus disease 2019 (COVID-19)-related traumatic event (CTE) exposure and suicidal ideation among hospital workers, and identify mediating roles of sleep disturbances in this relationship.
Methods: Workers in seven designated hospitals in Wuhan, China, were invited to participate in an online survey from May 27, 2020, to July 31, 2020. Participants completed a self-report questionnaire to evaluate demographic characteristics, level of CTE exposures, nightmare frequency, insomnia severity, symptoms of depression and anxiety, and suicidal ideation. A series of correlation analyses were performed, and a mediation model was generated to examine correlations between CTE exposure, sleep disturbances, and suicidal ideation.
Results: A total of 16,220 hospital workers were included in the final analysis, 13.3% of them reported suicidal ideation in the past month. CTE exposure was significantly associated with insomnia severity, nightmare frequency, and suicidal ideation. After controlling potential confounders, nightmares but not insomnia, depression, or anxiety were shown to be independent risk factors for suicidal ideation. Pathway analyses showed that the relationship between CTE exposure and suicidal ideation was fully mediated by nightmares (proportion mediated 66.4%) after adjusting for demographic characteristics and psychological confounders.
Limitations: Cross-sectional design precluded the investigation of causal relationships.

Conclusions: CTE exposure increases risk of hospital workers' suicidal ideation that is mediated by nightmares, suggesting nightmares intervention might be considered as a component when developing suicide prevention strategies.

1. Introduction

Suicide is a serious public health problem. Nearly 800,000 people die from suicide every year, making suicide among the top 20 leading causes of death worldwide (World Health Organization, 2019). Suicidal ideation is a particularly important predictor of future suicide attempts and suicide deaths (Hubers et al., 2018). Approximately 20% of individuals with suicidal ideation will make a suicide attempt within the first year after onset (Nock et al., 2013), and the risk of a completed suicide in people with suicidal ideation is more than three-times higher than those without suicidal ideation (Hubers et al., 2018). Hence, understanding profiles and risk factors of suicidal ideation might be useful for developing effective suicide prevention strategies.

Trauma is an extremely stressful life event. Associations between traumatic events (e.g., unexpected death of a loved one, physical or sexual assault, life-threatening accidents and illness, natural disasters, and childhood poly-traumatization) and suicidal behaviors (i.e., suicidal ideation, plans, and attempts) are generally consistent among different populations, including adolescents (Borges et al., 2008), the general population (Ásgeirsdóttir et al., 2018; Uwakwe et al., 2012), and military personnel (Belik et al., 2009). Traumatic life events were found to be associated with a 45% higher odds of subsequently reported suicidal ideation (Howarth et al., 2020). Furthermore, a significant dose-response relationship was found between the number of negative life events and suicidal behaviors (Yıldız, 2020). However, the mechanism by which traumatic events may predispose individuals to suicidal behaviors is still unclear.

Sleep disturbances are common symptoms in psychopathology and associated with both traumatic event exposure and suicidal ideation. Traumatic events are increasingly recognized as an important predisposing factor for sleep disturbances. Several studies have reported symptoms of insomnia and nightmares of individuals exposed to traumatic events (Babson and Feldner, 2010; Mysliwiec et al., 2018; Sinha, 2016). Additionally, sleep disturbances are independent risk factors for suicidal behaviors (Liu et al., 2020; Pigeon et al., 2012). Indeed, previous studies suggested a mediating role of sleep disturbances in the relationship between stressful life events and suicidal ideation (Berg et al., 2020; Liu et al., 2019). Hence, a reasonable expectation is a strong correlation between coronavirus disease 2019 (COVID-19)-related traumatic event (CTE) exposure, sleep disturbances, and suicidal ideation, especially during the stressful period that is associated with the COVID-19 pandemic.

COVID-19 pandemic with its rapid spread and high mortality rate has exerted a great negative impact on individual's mental health. Many studies reported that the prevalence of suicidal ideation was increasing significantly in different populations during COVID-19 pandemic (Brailovskaia et al., 2021; Dubé et al., 2021). Hospital workers are usually confronting with stressful working environments, which makes them at a higher risk of suicide relative to the general population (Dutheil et al., 2019; Que et al., 2020b; Schernhammer and Colditz, 2004). The COVID-19 pandemic emerged as a traumatic event that brought abrupt and unpredictably high levels of stress which in turn increase the suicide risk among hospital workers who suffered from more severe mental health consequences (Que et al., 2020a). A recent investigation of mental health problems among hospital workers during COVID-19 pandemic recruited 1173 frontline and 1173 non-frontline hospital workers including physicians, nurses, and other hospital workers. It was reported that 10.5% of this population had suicidal ideation, which was more common in frontline hospital workers (12.0%) than non-frontline workers (9.0%) (Cai et al., 2020). Given the

strong relationship between traumatic events and suicidal ideation with each other and with sleep disturbances, the purpose of the current study was to investigate a potential model of these factors among hospital workers under COVID-19 pandemic. Specifically, the current study assessed for the potential indirect effect of CTE exposure on suicidal ideation through sleep disturbances, which can provide potential targets for suicide prevention. The hypotheses of the present study were (1) CTE exposure, sleep disturbances, and suicidal ideation are positively correlated; (2) the level of CTE exposure is associated with the degree of risk of suicidal ideation among hospital workers; (3) sleep disturbances (insomnia and nightmare symptoms) have mediating effects on the relationship between CTEs and suicidal ideation.

2. Methods

2.1. Study design

This online cross-sectional study was conducted from May 27, 2020, to July 31, 2020. Hospital workers from seven tertiary hospitals that were designated to treat COVID-19 in Wuhan city, including Tongji Hospital affiliated with Huazhong University of Science and Technology, Wuchang Hospital affiliated with Wuhan University of Science and Technology, Union Hospital affiliated with Huazhong University of Science and Technology, Zhongnan Hospital of Wuhan University, Wuhan Mental Health Center, Wuhan Children's Hospital, and Renmin Hospital of Wuhan University, were invited to participate in this survey voluntarily. A self-administered survey on Questionnaire Star (https://www.wjx.cn/) was sent to all participants via a widely used social app, WeChat, which took hospital workers 10–20 min to complete. Participants received assessment reports of their mental health status and corresponding advice. All study procedures were approved by the Peking University Sixth Hospital Institutional Review Board.

2.2. Participants

A total of 35,891 healthcare workers clicked on the survey link, and 16,256 participants completed the survey. After excluding 36 individuals who refused to sign the informed consent, 16,220 valid questionnaires were included in the final analysis, with an effective response rate of 45.19%. The sample was comprised with 12,819 females (79.0%) and 3401 males (21.0%), and the median age of this sample was 31.0 years old (Table 1).

2.3. Measurements and covariates

2.3.1. Assessment of COVID-19-related CTEs

CTEs were assessed using a self-developed checklist that included nine questions: (1) direct contact with COVID-19-infected patients, (2) history of suspected or confirmed infection, (3) relatives infected with COVID-19, (4) colleagues infected with COVID-19, (5) witnessing death of COVID-19-infected patients, (6) witnessing breakdown of colleague, (7) insufficient personal protective equipment, (8) inadequate training on self-protection knowledge, and (9) quarantine experience. The participants were asked to report the number of CTEs they experienced during the COVID-19 pandemic. The total number of CTE exposures was ranged from 0 to 9. In quality analysis, we artificially defined 0–2 CTE exposures as the low CTE exposure group, 3–5 CTE exposures as the moderate CTE exposure group, and > 5 CTE exposures as the high CTE exposure group in the present study.

2.3.2. Insomnia severity and nightmare frequency

Insomnia severity was measured by the Insomnia Severity Index (ISI), which is a 7-item self-reported scale with total scores that range from 0 to 28 (Bastien et al., 2001). A higher score indicates greater insomnia severity. The Cronbach's α value of ISI was 0.94 in this study. An ISI score $\geq$ 15 indicates clinical insomnia symptoms (Morin et al., 2011). Additionally, the frequency of nightmares was assessed by an item that asked, "In the past month, how much were you bothered by repeated, disturbing dreams of the stressful experience?" (Bovin et al., 2016). This item was originated from PTSD Checklist for DSM-5 (PCL-5), which was used in assessing nightmare symptoms in previous study (Don Richardson et al., 2014). The response was on a 5-point Likert scale: 0 = not at all, 1 = a little bit, 2 = moderately, 3 = quite a bit, and 4 = extremely, which was analyzed as a continuous variable included in correlation and mediation regression models. Besides, nightmares were dichotomized as "not at all" (coded 0) and "other" (coded 1) in the logistic and mediation analysis.

2.3.3. Symptoms of depression and anxiety

Symptoms of depression and anxiety were assessed by the 9-item Patient Health Questionnaire (PHQ-9) and 7-item Generalized Anxiety Disorder Scale (GAD-7), respectively. The PHQ-9 is a 9-item self-reported questionnaire with scores of 0–27. Higher scores indicate more severe depressive symptoms. A PHQ-9 score $\geq$ 10 indicates clinical depressive symptoms (Kroenke et al., 2001). To minimize mixed effects on associations among insomnia, depressive symptoms, and suicidal ideation, PHQ-9 scores were modified by removing the item that assessed suicidal ideation and the item that assessed sleep disturbances, and we treated total scores of the remaining seven items as covariates in the adjusted analysis model when controlling depressive symptoms. The average item score for the remaining seven items was multiplied by 9 to create a modified PHQ-9 score. The correlation between the scores of original and modified versions of the scale was 0.988. We defined clinical depressive symptoms as modified scores $\geq$ 10 (Trockel et al., 2015). The GAD-7 is a 7-item self-reported questionnaire. Higher scores indicate more severe anxiety symptoms. A GAD-7 score $\geq$ 10 was

Table 1
Sociodemographic data and clinical characteristics of the participants stratified by CTE exposure (n = 16,220).

	Overall (n = 16,220)	CTE exposure Low exposure (n = 7813)	Moderate exposure (n = 7977)	High exposure (n = 430)	p
Continuous variable					
Median (IQR) age (years)	31.0 (27.0–38.0)	31.0 (27.0–38.0)	31.0 (27.0–37.0)	32.0 (28.0–39.0)	0.027
Median (IQR) years in practice	8.0 (4.0–14.0)	7.0 (4.0–14.0)	8.0 (4.0–13.0)	9.0 (5.0–15.0)	< 0.001
Median (IQR) ISI scores	5.0 (1.0–9.0)	4.0 (1.0–8.0)	6.0 (2.0–10.0)	9.0 (5.0–14.0)	< 0.001
Median (IQR) PHQ-9 scores	4.0 (1.0–8.0)	3.0 (0.0–6.0)	5.0 (1.0–9.0)	8.0 (4.0–11.0)	< 0.001
Median (IQR) GAD-7 scores	2.0 (0.0–6.0)	1.0 (0.0–5.0)	3.0 (0.0–7.0)	6.0 (2.0–9.0)	< 0.001
Categorical variables					
Gender					0.297
Male	3401 (21.0%)	1663 (21.3%)	1639 (20.5%)	99 (23.0%)	
Female	12,819 (79.0%)	6150 (78.7%)	6338 (79.5%)	331 (77.0%)	
Marital status					0.039
Married	10,657 (65.7%)	5141 (65.8%)	5215 (65.4%)	301 (70.0%)	
Separated/divorced	480 (3.0%)	218 (2.8%)	243 (3.0%)	19 (4.4%)	
Never married	5083 (31.3%)	2454 (31.4%)	2519 (31.6%)	110 (25.6%)	
Annual household income (¥)					< 0.001
$\leq$ 100,000	3793 (23.4%)	1952 (25.0%)	1732 (21.7%)	109 (25.3%)	
100,000–300,000	10,467 (64.5%)	4947 (63.3%)	5235 (65.6%)	285 (66.3%)	
> 300,000	1960 (12.1%)	914 (11.7%)	1010 (12.7%)	36 (8.4%)	
Smoking habit					0.030
No	15,520 (95.7%)	7443 (95.3%)	7667 (96.1%)	410 (95.3%)	
Yes	700 (4.3%)	370 (4.7%)	310 (3.9%)	20 (4.7%)	
Drinking habit					< 0.001
No	15,439 (95.2%)	7500 (96.0%)	7543 (94.6%)	396 (92.1%)	
Yes	781 (4.8%)	313 (4.0%)	434 (5.4%)	34 (7.9%)	
Occupation					< 0.001
Physician	3112 (19.2%)	1350 (17.3%)	1662 (20.8%)	100 (23.3%)	
Nurse	9405 (58.0%)	4066 (52.0%)	5043 (63.2%)	296 (68.8%)	
Technician	1466 (9.0%)	883 (11.3%)	572 (7.2%)	11 (2.6%)	
Other	2237 (13.8%)	1514 (19.4%)	700 (8.8%)	23 (5.3%)	
Media influence					< 0.001
Negative	3687 (22.7%)	1605 (20.5%)	1940 (24.3%)	142 (33.0%)	
Neutral	3526 (21.7%)	1999 (25.6%)	1471 (18.4%)	56 (13.0%)	
Positive	9007 (55.5%)	4209 (53.9%)	4566 (57.2%)	232 (54%)	
Suicidal ideation					< 0.001
No	14,055 (86.7%)	7085 (90.7%)	6679 (83.7%)	291 (67.7%)	
Yes	2165 (13.3%)	728 (9.3%)	1298 (16.3%)	139 (32.3%)	
Clinical insomnia symptoms					< 0.001
No	14,812 (91.3%)	7406 (94.8%)	7072 (88.7%)	334 (77.7%)	
Yes (ISI $\geq$ 15)	1408 (8.7%)	407 (5.2%)	905 (11.3%)	96 (22.3%)	
Nightmare symptoms					< 0.001
No	13,693 (84.4%)	7035 (90.0%)	6391 (80.1%)	267 (62.1%)	
Yes (Nightmare frequency $\geq$ 1)	2527 (15.6%)	778 (10.0%)	1586 (19.9%)	163 (37.9%)	
Clinical depressive symptoms					< 0.001
No	13,928 (85.9%)	7064 (90.4%)	6574 (82.4%)	290 (67.4%)	
Yes (PHQ-9 $\geq$ 10)	2292 (14.1%)	749 (9.6%)	1403 (17.6%)	140 (32.6%)	
Clinical anxiety symptoms					< 0.001
No	14,900 (91.9%)	7426 (95.0%)	7140 (89.5%)	334 (77.7%)	
Yes (GAD-7 $\geq$ 10)	1320 (8.1%)	387 (5.0%)	837 (10.5%)	96 (22.3%)	

CTE, COVID-19-related traumatic event; IQR, interquartile range; ISI, Insomnia Severity Index; PHQ-9, 9-item Patient Health Questionnaire; GAD-7, 7-item Generalized Anxiety Disorder Scale.

defined as clinical anxiety symptoms (Löwe et al., 2008). Cronbach's α value for PHQ-9 and GAD-7 in this study was 0.91 and 0.94, respectively.

2.3.4. Suicidal ideation

We assessed suicidal ideation by asking hospital workers, "During the past month, have you had thoughts of taking your own life?" This question is originated from an inventory developed by Meehan and colleagues (Meehan et al., 1992), and has been used extensively to assess suicidal ideation in other studies of medical professionals (Dyrbye et al., 2008; Shanafelt et al., 2011, 2015), working population (Shanafelt et al., 2021), as well as general population (Dyrbye et al., 2008; Kessler et al., 2005).

2.3.5. Other covariates

The annual family income was collected by asking respondents to make choice from following options: "≤ 100 thousands yuan", "100 – 300 thousands yuan", or "> 300 thousands yuan". The years in practice were collected based on participants' self-report. The habit of smoking was measured by asking the question, "Do you smoke 10 or more cigarettes per day for 6 or more months?" (Gray et al., 2015) The habit of drinking was measured by asking the question, "Do you drink regularly more than 14 units of alcohol (equivalent to six pints of beer or six glasses of wine) per week?" (Que et al., 2020a) Response options regarding these two questions were "yes" or "no". The media influence was measured by the question, "What was the influence of media report during the COVID-19 pandemic?" The response options were "negative", "neutral", and "positive".

2.4. Statistical analysis

Continuous variables that were non-normally distributed are presented as medians with interquartile ranges (IQRs). Categorical variables are presented as numbers and proportions (%). The Mann-Whitney test for continuous variables and trend χ^2 test for categorical variables were used to compare differences and tendencies in sociodemographic and clinical characteristics of participants in the different CTE exposure groups. Correlations among CTE exposure, sleep disturbances, mental health status, and suicidal ideation were analyzed using Spearman or Kendall's tau correlation analysis, depending on distributions of the dependent data. We examined associations between nightmares, insomnia, depression, anxiety, and suicidal ideation in the different CTE exposure groups using three logistic regression models. Model 1 was unadjusted. Model 2 was adjusted for sociodemographic characteristics, including age, gender, marital status, family income, ever smoking, ever drinking, years in practice, type of occupation, and media influence. Model 3 was further adjusted against other psychological problems. Mediation effects were analyzed using a 95% bias-corrected bootstrapping model with confidence intervals resampled 5000 times for each analysis. Unadjusted and adjusted mediation analyses were conducted using Mplus 8 software. All of the other analyses were performed using SPSS Statistics 20 software. All of the tests were two-sided. Values of $p < 0.05$ were considered statistically significant.

3. Results

3.1. Sample characteristics in different extent of CTE exposure

Of the 16,220 hospital workers, 7813 participants (48.2%) had low exposure, 7977 (49.2%) had moderate exposure, and 430 (2.7%) had high exposure Table 1. presents the sociodemographic and clinical characteristics of the different CTE exposure groups. The median age of high CTE exposure group was higher, but there was no significant gender difference among different CTE exposure groups. Years in practice were longer in high CTE exposure group. The ratio of married participants and nurse personnel was higher in high CTE exposure level.

The prevalence of drinking and smoking habits was more common in high CTE exposure. The proportion of low family income level was higher in high CTE exposure. The negative impact of media reports was more common in high CTE exposure group. Besides, the severity and prevalence of insomnia, nightmares, and depressive and anxiety symptoms increased significantly with an increase in CTE exposure. The prevalence of suicidal ideation was also higher among respondents with more CTE exposure.

3.2. Associations between CTE exposure, sleep disturbance, and suicidal ideation

Correlations between CTEs, insomnia severity, nightmare frequency, depressive and anxiety symptoms, and suicidal ideation are presented in Table 2. As predicted, the number of CTE exposures was positively associated with insomnia severity (β = 0.222, $p < 0.001$), nightmare frequency (β = 0.184, $p < 0.001$), depressive symptoms (β = 0.231, $p < 0.001$), anxiety symptoms (β = 0.216, $p < 0.001$), and suicidal ideation (β = 0.125, $p < 0.001$). We also found that insomnia severity (β = 0.309, $p < 0.001$), nightmare frequency (β = 0.455, $p < 0.001$), depressive symptoms (β = 0.358, $p < 0.001$), and anxiety symptoms (β = 0.371, $p < 0.001$) were positively associated with the risk of suicidal ideation.

3.3. Independent risk factor for suicidal ideation by level of CTE exposure

Table 3 and eTables 1–3 present the crude and multi-adjusted odd ratios (ORs) with 95% CIs of suicidal ideation stratified by CTE exposure and nightmares and insomnia, depression, and anxiety symptoms. Nightmares were associated with higher odds of suicidal ideation, regardless of the extent of CTE exposure. Compared with participants who had low CTE exposure and no nightmares, individuals with high CTE exposure and nightmares had a nearly 34-fold higher risk of suicidal ideation (OR = 33.98, 95% CI = 24.22–47.68), and the OR decreased but remained significant after controlling for sociodemographic characteristics and symptoms of insomnia, depression, and anxiety (OR = 8.14, 95% CI = 5.56–11.93). Insomnia, depression, and anxiety were significantly associated with a higher risk of suicidal ideation in different CTE exposure groups in the unadjusted model. However, insomnia was not a risk factor for suicidal ideation after controlling for sociodemographic characteristics, nightmare frequency, and symptoms of depression and anxiety (eTable1-3). Anxiety also was no longer a risk factor for suicidal ideation after controlling for sociodemographic characteristics, nightmare frequency, and symptoms of depression and insomnia (eTable 2). Moreover, depression remained a risk factor for suicidal ideation in the low CTE exposure group after controlling for sociodemographic characteristics, nightmare frequency, and symptoms of anxiety and insomnia (eTable 3).

3.4. Mediating effect of nightmares on CTE exposure and suicidal ideation

We also conducted a mediation model to explore the mediating effects of nightmare frequency on the relationship between CTE exposure and suicidal ideation. As shown in Table 4 and Fig. 1, in the unadjusted analysis with nightmares as a mediator, the total (β = 0.295, $p < 0.001$) and direct (β = 0.162, $p < 0.001$) effects of CTE exposure on suicidal ideation were significant, and the indirect effect (β = 0.133, $p < 0.001$) of CTE exposure on suicidal ideation that was mediated by nightmares was also significant. In the adjusted analysis with nightmares as a mediator, the total (β = 0.125, $p < 0.001$) and indirect (β = 0.083, $p < 0.001$) effects of CTE exposure on suicidal ideation were significant, whereas the direct effect of CTE exposure on suicidal ideation was no longer significant (β = 0.045, $p = 0.055$). Nightmares explained 66.4% of the association between CTE exposure and suicidal ideation. The results suggest that nightmares may fully account for the relationship between CTE exposure and suicidal ideation.

Table 2

Correlations, means and standard deviations among CTE exposure, sleep disturbances, emotional states, and suicidal ideation.

	CTE	Insomnia symptom	Nightmare frequency	Depressive symptom	Anxiety symptom	Suicidal ideation
CTE	–					
Insomnia symptom	0.222***	–				
Nightmare frequency	0.184***	0.399***	–			
Depressive symptom	0.231***	0.684***	0.403***	–		
Anxiety symptom	0.216***	0.670***	0.428***	0.817***	–	
Suicidal ideation	0.125***	0.309***	0.455***	0.358***	0.371***	–
Mean	2.65	6.07	0.20	5.13	3.45	0.13
SD	1.40	5.70	0.52	5.12	4.08	0.34
Min	0	0	0	0	0	0
Max	8	28	4	27	21	1

CTE, COVID-19-related traumatic event; SD, standard deviation. Kendall's tau correlation coefficients were used when dependent variables were dichotomous. Spearman correlation coefficients were used when dependent variables were continuous. ($n = 16,220$).

Table 3

Odds ratio (95% CI) of risk of suicidal ideation according to nightmares and CTE exposure.

CTE exposure	Model 1		Model 2		Model 3	
	No nightmares	Nightmares	No nightmares	Nightmares	No nightmares	Nightmares
Low	1 [Reference]	15.98 (13.41–19.06)	1[Reference]	15.62 (13.08–18.65)	1[Reference]	6.39 (5.25–7.77)
Moderate	1.64 (1.42–1.88)	17.37 (15.04–20.07)	1.56 (1.36–1.79)	16.47 (14.21–19.08)	1.18 (1.02–1.37)	5.38 (4.56–6.35)
High	2.58 (1.76–3.77)	33.98 (24.22–47.68)	2.36 (1.61–3.46)	31.03 (22.03–43.72)	1.36 (0.89–2.06)	8.14 (5.56–11.93)

CI, confidence interval; CTE, COVID-19-related traumatic event. Model 1: unadjusted logistic regression model. Model 2: adjusted for age, gender, marital status, family income, smoking status, drinking status, years in practice, type of occupation, and media influence. Model 3: adjusted for factors in Model 2, emotional states (PHQ and GAD scores), and insomnia symptoms (ISI scores). Nightmares were dichotomized as "not at all" (coded 0) and "other" (coded 1). ($n = 16,220$).

Table 4

Mediating effects of nightmares on the relationship between CTE exposure and suicidal ideation.

Model type	Model pathways	Point estimate	Product of coefficients		BC 95% CI		p	Mediating effects
			SE	Z	Lower	Upper		
Number of CTEs (continuous) → nightmare frequency (continuous) → suicidal ideation								
Model 1	Total effects	0.295	0.020	15.072	0.257	0.332	< 0.001	100.0%
	Direct effects	0.162	0.019	8.554	0.125	0.198	< 0.001	54.9%
	Indirect effects	0.133	0.007	19.370	0.120	0.148	< 0.001	45.1%
Model 2	Total effects	0.125	0.022	5.717	0.081	0.168	< 0.001	100.0%
	Direct effects	0.042	0.022	1.923	−0.002	0.084	0.055	33.6%
	Indirect effects	0.083	0.006	14.927	0.073	0.095	< 0.001	66.4%
Extent of CTEs (categorical) → nightmare exposure (categorical) → suicidal ideation								
Model 1	Total effects	0.652	0.049	13.319	0.558	0.749	< 0.001	100.0%
	Direct effects	0.276	0.015	19.013	0.284	0.469	< 0.001	42.3%
	Indirect effects	0.376	0.047	7.943	0.249	0.306	< 0.001	57.7%
Model 2	Total effects	0.261	0.055	4.785	0.152	0.369	< 0.001	100.0%
	Direct effects	0.081	0.054	1.510	−0.028	0.186	0.131	31.0%
	Indirect effects	0.180	0.011	16.074	0.157	0.202	< 0.001	69.0%

CTE, COVID-19-related traumatic events; BC, bias corrected, estimation of 5000 bootstrap samples. Model 1: unadjusted model. Model 2: adjusted for demographic characteristics and psychological status. ($n = 16,220$).

4. Discussion

As the main force for fighting against infectious disease pandemics, hospital workers may confront different CTEs during viral outbreaks. The present study found that CTE exposure increased the risk of suicidal ideation among hospital workers who were exposed to COVID-19. Besides, the results showed that the relationship between CTE exposure and suicidal ideation was mediated by nightmares whereas not by insomnia, which supports our hypothesis to some extent. To our knowledge, this is the first cross-sectional study to examine the relationship between CTE exposure and suicidal ideation and the potential mechanism that underlies this relationship among hospital workers who are exposed to COVID-19. The findings may contribute to the early identification and direct prevention of suicide that is related to infectious disease pandemics.

The prevalence of suicidal ideation in hospital workers was reported to range from 2.4% to 13.9% during the COVID-19 pandemic (Rogers et al., 2021). The present study found a prevalence of 13.3%. Similar to prior evidence (Borges et al., 2008; Howarth et al., 2020; Liu and Miller,

2014; Uwakwe et al., 2012), the present study showed that CTE exposure increased the risk of suicidal ideation among hospital workers who were exposed to COVID-19. Specifically, the more CTE exposure, the higher the risk of suicidal ideation, which was consistent with previous studies (Belik et al., 2007; Borges et al., 2008; Liu et al., 2019; Uwakwe et al., 2012). In the present study, the prevalence of suicidal ideation increased from 9.3% among hospital workers with low CTE exposure to 32.3% in those with high CTE exposure. To minimize the risk of pandemic-related suicidal ideation in hospital workers, systematic measures should be taken to avoid and minimize CTE exposure, such as better preparation to cope with future pandemics by equipping workers with sufficient protective supplies, improving self-protection awareness, and providing immediate psychological support and early interventions, such as counselling and psychology services, following infectious disease pandemic-related traumatic events exposure (Pollock et al., 2020; Trottier et al., 2021).

However, exposure to infectious disease pandemic-related traumatic events, such as exposure to infected patients and the sudden loss of family members, is almost inevitable for hospital workers. Hence,
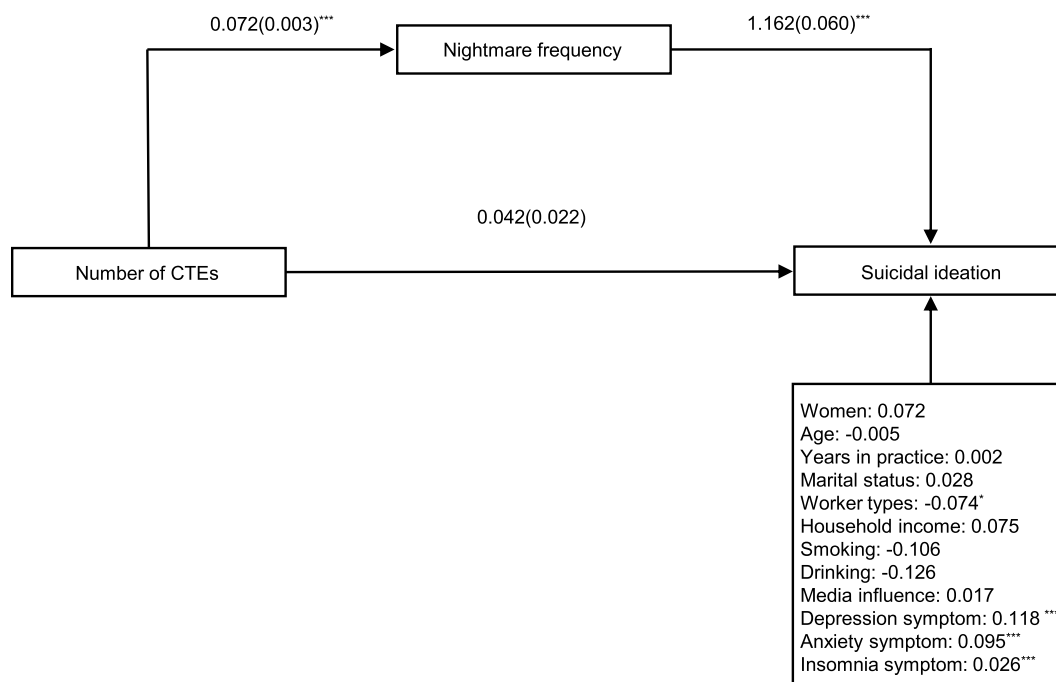
Fig. 1. Mediation model of nightmare frequency in the association between CTE exposure and suicidal ideation while controlling for demographic characteristics, insomnia symptoms, and emotional states. ($n = 16,220$)
CTEs = COVID-19 related traumatic events, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

understanding the psychological mechanisms that underlie the relationship between traumatic event exposure and suicidal ideation could reveal new promising targets for suicide prevention. Consistent with previous studies (Andrews and Hanna, 2020; Li et al., 2010; Littlewood et al., 2017; Russell et al., 2019), we also found that nightmares were an independent risk factor for suicidal ideation in different CTE exposure groups but not other factors (i.e., symptoms of depression, anxiety, and insomnia) after controlling potential confounders. The potential reason of this finding might be that the multi-collinearity of nightmares co-occurs with other psychopathological symptoms in clinical. One of the core symptoms of posttraumatic stress disorder is trauma-related nightmares, which usually develop following a traumatic event. The characteristics of such nightmares are influenced by the severity of trauma, an individual's psychological resiliency, and sleep duration and quality before and after the traumatic event (Brock et al., 2019; Mysliwiec et al., 2018). Increases in trauma severity and duration are typically associated with a higher risk of nightmares (Milanak et al., 2019; Secrist et al., 2020). The prevalence of nightmares in the present study increased from 10.0% in the low CTE exposure group to 37.9% in the high CTE exposure group.

Nightmares after exposure to trauma result from the dysfunction of a network of affective processes that serve an adaptive function that leads to trauma extinction (Nielsen and Levin, 2007). Based on currently accepted notions of trauma memory acquisition and extinction, repeated occurrences of the conditioned stimulus in the absence of the unconditioned stimulus in sleep leads to the formation of new extinction memories. One proposal is that nightmares may facilitate traumatic memory extinction (Mysliwiec et al., 2018; Nielsen and Levin, 2007). Moreover, physiological hyperarousal following trauma is involved in changes in neurocircuitry that controls emotional processes, including the prefrontal cortex and amygdala, which is a potential mechanism of nightmares (Hall Brown and Garcia, 2020). The occurrence of nightmares among the general population increased significantly after experiencing the COVID-19 pandemic, the greatest public health crisis since the influenza pandemic of 1918 (Kilius et al., 2021; Musse et al., 2020; Scarpelli et al., 2021). Approximately one-third to one-half of frontline hospital workers suffered from nightmares during the

COVID-19 outbreak (Lin et al., 2020; Stewart et al., 2021), which was higher than 15.6% in the present study. One possible reason for this difference is that our study was conducted 1–3 months after the major outbreak timepoint of COVID-19 in Wuhan. Although nightmares would recover from the withdrawal of CTE exposure, some hospital workers continue to suffer from nightmares for some time after the infectious disease pandemic is controlled. Hence, raising awareness about the negative impacts of trauma-related nightmares among hospital workers is important.

Nightmares are an important contributing factor to suicidality, which has a small-to-medium effect for prospective suicidal ideation ($d = 0.40$) and a medium effect for subsequent suicide attempts ($d = 0.64$) and suicide death ($d = 0.50$) (Liu et al., 2020). Emotional dysregulation and negative cognitive appraisals are factors that underlie the relationship between nightmares and suicidality (Andrews and Hanna, 2020). Previous research indicated that interventions that target nightmares may lower suicide risk. Prazosin treatment for nightmares was useful in preventing new and worsening suicidal ideation (Raskind et al., 2018). Additionally, interventions that target nightmare symptoms with psychotherapy, including imagery rehearsal therapy and exposure, relaxation, and rescripting therapy, may also decrease suicidal ideation (Cogan et al., 2019; Ellis et al., 2019). In the present study, nightmares fully mediated the relationship between CTE exposure and suicidal ideation, which indicates that nightmares may be an important component of suicidal ideation among hospital workers during infectious disease pandemics. Given that hospital workers might find it easier to seek help for nightmares than for suicidal ideation, timely interventions that target nightmares, such as pharmacological and psychological treatment (Yücel et al., 2020), especially for those who experience more traumatic events, may be effective for preventing suicide.

Although symptoms of depression, anxiety, and insomnia had no mediating effects on the relationship between CTE exposure and suicidal ideation in the present study, they were significantly associated with suicidal ideation. An estimated half of suicides in high-income countries can be attributed to mental illnesses (Fazel and Runeson, 2020). In the present study, symptoms of depression, anxiety, and insomnia in

hospital workers were common. Integrating early screening and timely interventions and support for individuals with COVID-19 pandemic-related psychological problems and suicidal behaviors would be beneficial for preventing suicide in hospital workers (Fazel and Runeson, 2020). For individuals at extremely high risk of suicide, priority access and the availability of mental healthcare, including the consideration of compulsory hospitalization and ensuring a safe environment with limited lethal means of suicide to guarantee safety, are optimum (Wang and Colucci, 2017).

5. Limitations

The present study has several limitations. First, the cross-sectional design precluded the investigation of causal relationships between variables of interest. The identified mediational pathways should be tested in future prospective studies. Although this study had covered the representative designated hospitals in Wuhan city and reached a large sample size, the relatively low response rate might limit the representativeness of the sample. Second, self-report items, not a valid instrument, were used to assess suicidal ideation and nightmares, which may introduce bias. The findings of this study should be interpreted carefully. Therefore, using validated scales or structured or semi-structured interviews would enhance diagnostic accuracy and further strengthen our understanding of the way in which sleep problems affect the relationship between trauma experience and suicidal ideation. Third, only insomnia and nightmare symptoms were included in the present study, and the effects of other sleep disturbances such as sleep deprivation and sleep apnea were not investigated. Fourth, we used a convenience sampling method to recruit participants from seven tertiary hospitals that were designated for the treatment of COVID-19 in Wuhan, and the representativeness of the sample might be limited. Fifth, only some of the COVID-19 related traumatic events were investigated in the present study, without assessing other valid and related potential confounders (e.g., experience of interpersonal tension, work-family imbalance, social media exposure, and workplace violence that occurred before and after COVID-19 outbreak). Last but not the least, CTE exposure can only account for a small part of suicidal ideation. Other risk factors are urgently need to be further explored in future studies.

6. Conclusions

Traumatic event exposure was significantly associated with suicidal ideation among hospital workers who were exposed to COVID-19, and the relationship could be fully mediated by nightmares but not insomnia, depression, or anxiety. The early assessment of nightmares and appropriate interventions among individuals with trauma experience may lower their suicide risk. Further research is needed to explore the neurobiological mechanisms of the nightmare-suicidal ideation link and effective treatments for nightmares to possibly reduce suicide risk.

CRediT authorship contribution statement

Jian-Yu Que: Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Le Shi:** Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Wei Yan:** Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Si-Jing Chen:** Investigation, Writing – review & editing. **Ping Wu:** Investigation, Writing – review & editing. **Si-Wei Sun:** Data curation, Writing – review & editing. **Kai Yuan:** Data curation, Writing – review & editing. **Zhong-Chun Liu:** Data curation, Writing – review & editing. **Zhou Zhu:** Data curation, Writing – review & editing. **Jing-Yi Fan:** Data curation, Investigation, Writing – review & editing. **Yu Lu:** Data curation, Writing – review & editing. **Bo Hu:** Data curation, Writing – review & editing. **Han Xiao:** Data curation, Writing – review & editing. **Zhi-Sheng Liu:** Data curation, Writing – review & editing. **Yi Li:** Data curation, Writing – review & editing. **Gao-Hua Wang:** Data curation, Writing – review & editing. **Wei Wang:** Data curation, Writing – review & editing. **Mao-Sheng Ran:** Investigation, Writing – review & editing. **Jie Shi:** Investigation, Writing – review & editing. **Yun Kwok Wing:** Investigation, Writing – review & editing. **Yan-Ping Bao:** Visualization, Investigation, Writing – review & editing. **Lin Lu:** Visualization, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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