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Research article

The impact of eating behaviors during COVID-19 in health-care workers: A conditional process analysis of eating, affective disorders, and PTSD

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ABSTRACT

Objective: The incidence of post-traumatic stress disorder (PTSD) increased among healthcare workers (HCWs) during the outbreak of COVID-19. The purpose of this study was to examine the relationship between eating behavior and PTSD, considering the mediation effect of anxiety, depression and sleep.

Methods: A total of 101 HCWs completed a survey. The Food-Frequency Questionnaires (FFQ) were used to evaluate the diet. A special survey was conducted on the eating time of each shift mode. The PTSD Checklist-Civilian Version (PCL-C), Self-Rating Anxiety Scale (SAS), Self-Rating Depression Scale (SDS), Pittsburgh Sleep Quality Index (PSQI), and Morning-Evening Questionnaire (MEQ) were utilized to assess clinical symptoms.

Results: There was a statistically significant correlation between the night shift eat midpoint (NEMP) and PTSD symptoms, anxiety and depression as significant mediators. The last meal jet lag between night shift and day shift (NDLM) was related to PTSD symptoms significantly, and sleep and anxiety were significant mediators. The relationship between animal-based protein pattern and PTSD symptoms was statistically significant, and anxiety was the significant mediator.

Conclusions: The earlier the HCWs eat in the night shift, the lighter the symptoms of PTSD. This is mediated by improving anxiety, depression and sleep disorder. Furthermore, the consumption of animal protein could reduce symptoms of PTSD by improving anxiety.

1. Introduction

In December 2019, China experienced the first outbreak of severe acute respiratory syndrome corona virus 2 (SARS-CoV-2), a highly infectious virus that causes corona virus disease 2019 (COVID-19). As of 27 February 2022, there have been over 430 million documented cases of COVID-19, and over 5.9 million deaths [1]. With SARS-CoV-2 spreading rapidly, health systems around the world have faced unprecedented challenges in resourcing a health care response [2].

Healthcare workers (HCWs) may be at particular risk, working at the frontline of what was referred to as 'the war against COVID-19' [3, 4, 5]. That is, compared to other professions, HCWs are exposed to a high risk of infection, working under highly challenging conditions (e.g., increased work, exposure to negative emotions and mortality of patients, inadequate protection against contamination and sleep deprivation), while isolated from family and friends. Furthermore, previous studies on corona virus pandemics, severe acute respiratory syndromes (SARS) and Middle Eastern respiratory syndrome (MERS), have found a significant increase in symptoms of post-traumatic stress disorder (PTSD) among nurses who have come into contact with infected patients [6, 7]. Moreover, elevated levels of PTSD symptoms have been reported in HCWs from the current corona-virus outbreak worldwide [4, 8, 9, 10]. Therefore, it is necessary to pay attention to the PTSD risk of HCWs in the context of the current epidemic.

COVID-19 is widely acknowledged as a severe traumatic event [11]. As the front-line workers in the fight against the epidemic, HCWs are most obviously affected by the epidemic. Studies have found that the incidence rate of PTSD among HCWs after the outbreak of the epidemic is 25.1–71.5% [12]. Significantly higher than the average incidence rate of 3.9% before the outbreak [13]. However, we believe that COVID-19 is the acute stress leading to PTSD among HCWs. In normal humans, the HPA axis, with the signaling effector molecule glucocorticoids, is a center

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for coordinated oscillations of central rhythm and peripheral rhythms [14]. When acute stress occurs, the suprachiasmatic nucleus (SCN) maintains its intrinsic circadian rhythm, and peripheral rhythms appear phase delayed by modulation of the HPA axis to more effectively resist stress challenges [14]. When stress is stopped, the SCN returns its maintained initial principal phase through the HPA axis to the periphery [15]. The shift pattern of HCWs has changed their eating habits, sleep rhythm, and metabolism, putting HCWs under chronic stress for a long time. Furthermore, long-term chronic stress has been found to alter the stability of the SCN [16], resulting in an imbalance between central and peripheral rhythms, which makes health workers unable to combat challenges such as acute stress from COVID-19, thus contributing to the pathogenesis of PTSD.

PTSD is a psychiatric disorder caused by a terrifying event, perceived as a trauma, that affects the individual directly or indirectly the individual. PTSD is often associated with sleep disorder, anxiety and depression [17, 18]. The effect between sleep disturbances and mental disorders is often reciprocal. Psychiatric disorders such as PTSD, depression, and anxiety can cause sleep disturbances, and sleep disturbances can cause psychiatric disorders [19]. The relationship between PTSD and anxiety and depression is often reciprocal as well. Depression and anxiety may increase the risk of PTSD; PTSD may be a causal risk factor for anxiety and depression. Moreover, PTSD, anxiety, and depression may be independent disorders sharing common risk factors [20]. The initial hypothesis of this study was that symptoms of PTSD may be exacerbated by the presence of sleep disturbances, depression, and anxiety. To clarify the relationship between PTSD and sleep disorder, anxiety, depression and eating behavior in HCWs after the epidemic, the mediation model analysis was used following the cross-sectional study design.

2. Materials and methods

A cross-sectional study was used to investigate the association between eating behaviors and influence factors of PTSD in HCWs after the epidemic from April, 2020 and December, 2020. Due to the policy requirements in the early stage of the epidemic in Xi'an, by using the cluster sampling method, ten hospitals from grade 2 A hospitals in Xi'an, Shaanxi Province, China were selected. The questionnaires were distributed to HCWs at fever clinics and respiratory clinics. An individual in this study must meet the following inclusion criteria: (1) be aged between 20 and 50; (2) work at least one night shift each month; (3) have worked at least one year; (4) have consented to participate in the study voluntarily. The study was approved by China Clinical Trials Institutional Review Board (ChiCTR2000033364). All participants have signed informed consent.

During the survey, a trained investigator issued Food Frequency Questionnaires (FFQ) to HCWs to obtain their eating habits. This questionnaire has been verified in the Chinese population [21]. The questionnaire asked HCWs to recall how often they ate an average of one standard serving of food a month over the past three months, ranging from never to six times a day. The total amount of food consumed per month is calculated according to frequency and standard quantity.

Post-traumatic stress symptoms were evaluated with the PTSD Checklist-Civilian Version (PCL-C). PCL-C was developed based on the Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV) [22]. The scale has been verified in the Chinese population and has been proven to have good reliability and validity [23]. The total scores ranged from 17-85. With a PCL-C scores of 38 and 50 as the diagnostic cut-offs, scores in the range of 50–85 indicate more obvious PTSD symptoms, which may be diagnosed as PTSD. This diagnostic cut-off point (a score of 50) was used in the present study to identify PTSD symptoms [24].

Sleep [17], anxiety and depression [18] are closely related to PTSD, so this study also added PSQI, SAS and SDS scale. Pittsburgh Sleep Quality Index (PSQI) [25] is widely used to evaluate sleep quality, which can reflect the sleep status of respondents in the past month. The 19 items are divided into seven component scores that reflect the severity of various sleep problems in the following aspects: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medication and daytime dysfunction. The global PSQI score, ranging from 0 to 21, can be collected by summing the seven components after weighting them on a scale ranging from 0 to 3. The higher the score, the worse the quality of sleep.

Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS) are each composed of 20 items, the score of each item is 1–4 points, and the total score is 20–80 points as a result of the original score. Adding 1.25 to the original score calculates a standard score that ranges from 25-100. A score over 50 indicates anxiety or depression. Scores higher indicate more severe anxiety/depression [26, 27].

To observe the diet and sleep rhythm of HCWs. Each HCW was also asked to recall their diet rhythm during the night, rest and day shifts in the last month. And times for each meal were collected during day shift, night shift and rest day. The Morning-Evening Questionnaire (MEQ) [28] was used to observe the types of sleep of the HCWs. A total of 19 items are included in the MEQ, including sleep and wake times, preferred times for physical and mental activities, and subjective alertness levels. In order to indicate the preferred time for activities, multiple choice options are provided along with an ordinal scale. Scale scores range from 16 to 86, and five categories are proposed: definitely evening type (16–30), moderately evening type (31–41), intermediate type (42–58), moderately morning type (59–69), and definitely morning type (70–86).

3. Statistical analyses

Data coding, cleaning and analysis were performed using Amos 24.0 and R Project 4.0.1.

Eating time According to the collected daily feeding time of day shift, rest day and night shift, the time of last meal, eat duration [29], eat midpoint [30] and Last meal jet lag.

Eating midpoint is defined as the middle time point between the first and the last meal. This parameter was calculated for weekdays and weekends based on the methodology proposed to estimate the midpoint of sleep [31].

Eating midpoint (local time) = ([Timing of the last meal − Timing of the first meal]/2) + Timing of the first meal.

One study found that during night shift days, nurses usually ate the last meal later by nurses [32], so, last meal jet lag [30] was used to assess the delay or advance of the last meal during night shift.

last meal jet lag between night shift and day shift (h) = Time on night shift − Time on day shift (NDLM)

last meal jet lag between night shift and rest day (h) = Time on night shift − Time on rest day (NRLM)

last meal jet lag between rest day and day shift (h) = Time on rest day − Time on day shift (RDLM)

Eating pattern The daily food intake was calculated according to the results of FFQ scale. To facilitate the analysis, the daily food intake of some of the same types of food is combined. Three dietary patterns are determined by principal component analysis (Supplementary Table 1). The first pattern, called the plant-based protein pattern, was characterized by a high frequency of soybean, kernel, fresh beans, citrus, drupe, animal oil and melon. The second pattern, called the animal-based protein pattern, was characterized by a high frequency of egg, leaves, beef, mutton, pork, melon, freshwater fish and shrimp. The third pattern, called the relative vegetarian pattern, was characterized by a high frequency of eggplant, berry, fresh milk, leaves, kernel and rice. Each HCW gets a score for each of the three dietary patterns, and the higher the score, the closer to the dietary pattern. Dietary pattern scores were used for subsequent analysis.

Kruskal-Wallis tests were used to present demographic data, Wilcoxon rank sum test to compare the differences in dietary rhythms, and then conducted a Pearson's correlation analysis to discover the relationships between dietary rhythm, dietary content, PCL-C, PSQI, SAS, SDS and MEQ. Third, the PCL-C score was used as the dependent variable, the eating variables that were significantly associated with PCL-C were used as the independent variables, and the scale scores that were significantly associated with the independent and dependent variables were used as the mediating variables, and the mediating model was built. Because the effects between PTSD and anxiety, depression, and sleep are usually mutual, to test the results, three test models were built with SAS score as the dependent variable, PCL-C score as the mediator variable, and eating variables from the prior model as the independent variable. Finally, the mediation effect was tested based on bootstrap results. The indirect effect could be statistically significant if the 95% confidence interval (CI) with 5,000 bootstrapping re-samples did not include zero.

4. Result

4.1. Demographic and general characteristics

A total of 120 questionnaires were sent, 108 responses were received, and 101 of those were valid (Supplementary Figure 1). Among the valid questionnaire respondents, the average age was 30.23 ± 4.44 years (86.1% female), including 38 doctors (37.6%) and 63 nurses (62.3%). The average score of PCL-C was 31.41 ± 12.95, of which 11 (10.9%) exceeded the diagnostic criteria. The average score of PSQI was 6.23 ± 2.99, of which 9 (8.9%) exceeded the diagnostic criteria. The average score of SDS was 51.86 ± 12.34, of which 63 (62.4%) exceeded the diagnostic criteria. The average score of SAS was 40.19 ± 13.10, of which 25 (24.8%) exceeded the diagnostic criteria. The average score of MEQ was 47.21 ± 9.49. Among the scores of MEQ, there were definitely evening type 5, moderately evening type 19, intermediate type 63, moderately morning type 14 and definitely morning type 0.

Kruskal-Wallis tests revealed that occupation was closely related to PSQI, SAS and SDS. The PSQI, SAS and SDS scores of nurses were significantly higher than those of doctors. SDS and SAS scores for master's and Ph.D. degrees were significantly lower than those of other academic degrees. The SDS scores of HCWs aged 26–30 years were significantly higher than those of the other age groups. PCL-C analysis showed that sociodemographic characteristics were not related to PCL-C (Table 1).

The average eating frequency was 2.57 (SE 1.65, range 1–12) on night shift, 3.97 (SE 1.10, range 2–9) on day shift and 3.00 (SE 1.69, range 1–11) on rest day. In the Wilcoxon rank sum test, eating duration was not significantly different between night shift and rest day ($p = 0.30$). However, the eating duration of night shift (7.90/5.60 h) was significantly shorter than day shift (11.05/2.84 h) ($p < 0.001$). The eat midpoint on the night shift (15:21 ± 3:34) was significantly later than

Table 1. PCL-C, PSQI, SAS, SDS scores were analyzed by stratification according to sociodemographic characteristics.

Sociodemographic Characteristics	N	PCL-C	PSQI	SAS	SDS
Gender					
Man	14	28.64 ± 9.48	5.71 ± 1.54	37.14 ± 13.11	49.91 ± 12.28
Woman	87	31.85 ± 13.42	6.31 ± 3.16	40.68 ± 13.18	52.17 ± 12.47
P-value		0.55	0.65	0.23	0.54
Occupation					
doctor	38	28.76 ± 11.25	5.18 ± 2.39	36.74 ± 12.37	46.51 ± 11.39
nurse	63	33.00 ± 13.72	6.86 ± 3.16	42.26 ± 13.29	55.08 ± 11.95
P-value		0.12	0.00	0.01	0.00
Age					
≤25	12	33.50 ± 14.47	5.08 ± 2.07	43.13 ± 12.53	51.88 ± 11.76
26 to ≤30	47	31.13 ± 12.15	6.68 ± 2.75	40.82 ± 13.28	55.11 ± 10.98
31 to ≤35	27	33.48 ± 15.16	6.78 ± 3.6	41.25 ± 14.24	51.99 ± 12.16
>35	15	26.87 ± 9.37	4.73 ± 2.63	33.92 ± 10.32	41.42 ± 12.95
P-value		0.54	0.05	0.2	0.01
Education					
collage and high	8	28.25 ± 9.77	6.13 ± 3.44	40.31 ± 7.16	53.44 ± 15.17
undergraduate	70	33.37 ± 13.98	6.54 ± 3.00	42.21 ± 14.07	54.09 ± 11.78
master	19	26.79 ± 9.29	5.63 ± 2.85	34.54 ± 10.31	44.41 ± 11.51
doctor	4	25.25 ± 7.37	3.75 ± 1.71	31.25 ± 7.97	45.00 ± 8.23
P-value		0.21	0.19	0.04	0.02
BMI					
<18	8	39.75 ± 15.82	7.88 ± 3.14	49.84 ± 16.74	56.41 ± 8.88
18 to <24	71	29.97 ± 12.94	5.85 ± 3.04	38.59 ± 12.52	50.72 ± 12.62
≥24	22	33.00 ± 11.02	6.86 ± 2.59	41.82 ± 12.77	53.86 ± 12.61
P-value		0.10	0.09	0.08	0.41
Average of night shifts per month					
1~4	37	29.97 ± 14.55	6.27 ± 3.02	39.83 ± 15.81	49.86 ± 14.15
5~9	52	32.02 ± 11.39	6.29 ± 3.19	40.38 ± 10.29	53.51 ± 10.97
10~14	12	33.17 ± 14.8	5.83 ± 2.08	40.42 ± 16.29	50.83 ± 12.57
P-value		0.37	0.91	0.55	0.53
Working Year					
1~5	45	31.87 ± 12.94	6.09 ± 2.85	41.06 ± 13.80	52.67 ± 11.19
6~10	38	30.66 ± 13.53	6.42 ± 3.14	39.90 ± 13.69	52.24 ± 12.92
≥11	18	31.83 ± 12.37	6.17 ± 3.17	38.61 ± 10.67	49.03 ± 14.39
P-value		0.91	0.94	0.96	0.71

P-value from Kruskal–Wallis tests.

Table 2. Correlations, means and standard deviations among NDLM, NEMP, Animal-based protein, anxiety, depression, sleep and PTSD.

	PCL-C	SAS	SDS	PSQI	NDLM	NEMP	Animal-based protein
PCL-C	1.00						
SAS	0.83**	1.00					
SDS	0.51**	0.60**	1.00				
PSQI	0.56**	0.56**	0.50*	1.00			
NDLM	0.24*	0.42***	0.19	0.23*	1.00		
NEMP	0.21*	0.32**	0.25*	0.16	0.64**	1.00	
Animal-based protein	0.21*	0.20*	−0.24*	−0.23*	−0.08	−0.12	1.00
Mean ± SD	31.41 ± 12.95	40.19 ± 13.17	51.86 ± 12.41	6.23 ± 2.99	1.41 ± 3.80	15.35 ± 3.56	0.000 ± 1

NDLM, last meal jet lag between night shift and day shift; NEMP, Night shift eat midpoint; SD, standard deviation; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; p from Pearson correlation analysis.

that on the day shift (13:02 ± 1:39) and rest day (14:01 ± 2:05) ($p < 0.001$). Meanwhile, the time of the last meal on night shift (19:18 to 3:37) was significantly later than on day shift (17:53 to 2:44) as well as on rest days (18:24 to 2:50) ($p = 0.001$) (Supplementary Table 3).

4.2. Correlation of measured variables

Pearson correlation analysis showed that the night shift eat midpoint (NEMP) was positively correlated with SDS ($r = 0.25$, $P = 0.01$), SAS ($r = 0.32$, $P = 0.001$) and PCL-C ($r = 0.21$, $P = 0.03$) (Table 2). Time of last meal was positively correlated with SAS ($r = 0.23$, $p = 0.02$) on night shift (Supplementary Table 2). On day shift, time of last meal was negatively correlated with PSQI ($r = -0.20$, $p = 0.04$) and SAS ($r = -0.28$, $p = 0.01$) (Supplementary Table 2). On rest day, eat duration was negatively correlated with SAS ($r = -0.22$, $p = 0.03$) (Supplementary Table 2). The rest day eat midpoint (REMP) was negatively correlated with MEQ ($r = -0.21$, $p = 0.03$). NDLM was positively correlated with PSQI ($r = 0.23$, $p = 0.02$), SAS ($r = 0.42$, $p < 0.001$) and PCL-C ($r = 0.24$, $p = 0.02$) (Table 2). NRLM was positively correlated with PSQI ($r = 0.26$, $p < 0.01$) and SAS ($r = 0.32$, $p < 0.01$). Scores of plant-based protein pattern was negatively correlated with MEQ ($r = -0.28$, $p < 0.001$) (Supplementary Table 2). Scores of animal-based protein pattern was positively correlated with MEQ ($r = 0.21$, $p = 0.04$) (Supplementary Table 2), meanwhile negatively correlated with PSQI ($r = -0.23$, $p = 0.02$), SAS ($r = -0.20$, $p = 0.04$), SDS ($r = -0.24$, $p = 0.02$), PCL-C ($r = -0.20$, $p = 0.04$) (Table 2).

4.3. Establish structural model

According to the theoretical framework and the result of Pearson correlation analysis, two serial multiple mediation models and one multiple mediation model were constructed. The first serial multiple mediation model (Supplementary Figure 2) takes NEMP as independent variables, SDS and SAS as chain mediator variables, PCL-C as dependent variables (Model 1). The second serial multiple mediation model (Supplementary Figure 3) takes NDLM as independent variables, PSQI and SAS as chain mediator variables, PCL-C as dependent variables (Model 2). The multiple mediation model (Supplementary Figure 4) takes scores of animal-based protein pattern as independent variables, SDS, PSQI and SAS as mediator variables, PCL-C as dependent variables (Model 3). Bootstrapping results supported these three models.

Three test models were built with SAS score as the dependent variable, PCL-C score and another scale score which was significantly correlated with both independent and dependent variables (PSQI or SDS) as the mediator variable, and NEMP/NDLM/animal-based protein pattern as the independent variable, respectively, to test the result of mediation model. Model 4 takes NDLM as independent variables, PCL-C and SDS as chain mediator variables, SAS as dependent variables. Model 5 takes NEMP as independent variables, PCL-C and PSQI as chain mediator variables, SAS as dependent variables. Model 6 takes scores of animal-based protein pattern as independent variables, SDS, PSQI and PCL-C as mediator variables, SAS as dependent variables. Bootstrapping results supported these three models.

Table 3. The mediating effect of models.

Path	Estimate	Percentile 95% CI		P
		lower	upper	
Model 1				
NEMP → SDS → PCL-C	0.02	−0.10	0.15	0.66
NEMP → SAS → PCL-C	0.55	0.08	1.17	0.02
NEMP → SDS → SAS → PCL-C	0.42	0.11	0.85	0.01
Total indirect effects	0.99	0.40	1.79	0.00
Total	0.77	0.16	1.51	0.01
Model 2				
NDLM → PSQI → PCL-C	0.11	−0.01	0.37	0.12
NDLM → SAS → PCL-C	0.83	0.42	1.41	0.00
NDLM → PSQI → SAS → PCL-C	0.31	0.01	0.74	0.045
Total indirect effects	1.25	0.60	2.14	0.00
Total	0.82	0.15	1.57	0.02
Model 3				
Animal-based protein → SAS → PCL-C	−1.97	−4.39	−0.42	0.01
Animal-based protein → SDS → PCL-C	0.06	−0.41	0.52	0.78
Animal-based protein → PSQI → PCL-C	−0.41	−1.15	0.07	0.10
Total indirect effects	−2.32	−4.90	−0.69	0.00
Total	−2.65	−5.07	−0.91	0.00

Model 1, Serial multiple mediation model of effect of NEMP on PTSD; Model 2, Serial multiple mediation model of effect of NDLM on PTSD; Model 3, The multiple mediation model of effect of animal-based protein pattern on PTSD; NDLM, last meal jet lag between night shift and day shift; NEMP, Night shift eat midpoint.

4.4. Serial multiple mediation model of effect of NEMP on PTSD

In model 1, the total indirect effect was significant ($\beta = 0.99$, $p < 0.001$). The mediation effect of the path NEMP → SDS → PCL-C was nonsignificant ($\beta = 0.02$, $p = 0.66$). But the mediation effect of path NEMP → SAS → PCL-C ($\beta = 0.55$, $p = 0.02$) and path NEMP → SDS → SAS → PCL-C ($\beta = 0.42$, $p = p < 0.01$)) was significant (Table 3).

In this model, path coefficient analysis revealed no relationship between SDS and PCL-C (path coefficient = 0.03, $p = 0.66$). But other path coefficients were significant ($p < 0.05$) (Supplementary Figure 2 and Table 4). The total effect of NEMP on PTSD was significant ($\beta = 0.77$, $p = 0.01$) (Table 3). However, the direct effect of NEMP on PTSD was not significant (path coefficient = -0.22, $p = 0.27$) (Supplementary Figure 2 and Table 4), suggesting a complete mediation model.

Table 4. Path coefficients for mediation models.

Path	Unstandardized path coefficient	p (Percentile method)
Model 1		
NEMP → SDS	0.86	0.01
SDS → SAS	0.59	0.00
NEMP → SAS	0.68	0.02
NEMP → PCL-C	−0.22	0.27
SDS → PCL-C	0.03	0.66
SAS → PCL-C	0.82	0.00
Model 2		
NDLM → PSQI	0.18	0.045
PSQI → SAS	2.16	0.00
NDLM → SAS	1.05	0.00
NDLM → PCL-C	−0.43	0.04
PSQI → PCL-C	0.60	0.09
SAS → PCL-C	0.79	0.00
Model 3		
Animal-based protein → SAS	−2.65	0.01
Animal-based protein → SDS	−2.94	0.01
Animal-based protein → PSQI	−0.68	0.00
SAS → PCL-C	0.75	0.00
SDS → PCL-C	−0.02	0.78
PSQI → PCL-C	0.60	0.10
Animal-based protein → PCL-C	−0.33	0.62

Model1, Serial multiple mediation model of effect of NEMP on PTSD; Model2, Serial multiple mediation model of effect of NDLM on PTSD; Model3, The multiple mediation model of effect of animal-based protein pattern on PTSD; NDLM, last meal jet lag between night shift and day shift; NEMP, Night shift eat midpoint.

4.5. Serial multiple mediation model of effect of NDLM on PTSD

In model 2, both the total effect (β = 0.82, p = 0.02) and the total indirect effect (β = 1.25, p = 0.001) were significant. The mediation effect of the path NDLM → PSQI → PCL-C was nonsignificant (β = 0.11, p = 0.12). But the mediation effect of path NDLM → SAS → PCL-C (β = 0.83, p < 0.001) and path NDLM → PSQI → SAS → PCL-C (β = 0.31, p = 0.045) was significant (Table 3).

In this model, path coefficient analysis revealed no relationship between PSQI and PCL-C (path coefficient = 0.60, p = 0.09). But other path coefficients were significant (p < 0.05). The direct effect of NDLM on PTSD was significant (path coefficient = −0.43, p = 0.04) (Supplementary Figure 3 and Table 4), but opposite to the total effect, suggesting a suppressing effect [33].

4.6. The multiple mediation model of effect of animal-based protein pattern on PTSD

In model 3, the total indirect effect was significant (β = −2.32, p < 0.01). The mediation effect of the path animal-based protein pattern → SDS → PCL-C (β = 0.06, p = 0.78) and path animal-based protein pattern → PSQI → PCL-C (β = −0.41, p = 0.07) was nonsignificant. But the mediation effect of the path animal-based protein pattern → SAS → PCL-C (β = −1.97, p = 0.01) was significant, indicating that animal-based protein pattern may alleviate PTSD by alleviating anxiety (Table 3).

In this model, path coefficient analysis revealed no relationship between either SDS (path coefficient = −0.02, p = 0.78) or PSQI (path coefficient = 0.60, p = 0.10) and PCL-C. But other path coefficients were significant (p < 0.05) (Supplementary Figure 4 and Table 4). The total effect of animal-based protein pattern on PTSD was significant (β = −2.56, p < 0.01) (Table 3). But the direct effect of animal-based protein pattern on PTSD was not significant (path coefficient = −0.33 p = 0.62) (Supplementary Figure 4 and Table 4), suggesting a full mediation model.

4.7. Test models

The results of the test models suggested that the models were all significant. NEMP may improve PTSD, depressive symptoms, and consequently anxiety symptoms (model 4). NDLM may improve PTSD and, in turn, anxiety symptoms (model 5). Animal-based protein pattern can improve PTSD, depressive symptoms, and consequently anxiety (model 6) (For details, see Supplementary Table 4).

5. Discussion

Results from this trial found indicate that the PTSD was associated with eating behavior in HCWs after COVID-19. Eating earlier on night shift days in shift HCWs may alleviate PTSD by relieving anxiety and depression. Eating more animal protein may improve sleep and anxiety and further alleviate PTSD.

Since the outbreak of COVID-19 in late 2019, HCWs have been under more psychological pressure. As a result, HCWs are at a higher risk for depression, anxiety, insomnia, and stress than the general population [34, 35, 36]. In addition, consistent with the findings of this study, a large study of Chinese HCWs shows a higher risk of anxiety and depression among nurses [37]. Moreover, no association between PTSD and social factors such as age and gender among HCWs.

Previous studies have shown an association between meal timing irregularity, overtime work, and night shift work [38]. Additionally, night shift workers demonstrated behaviors of irregular meal timing and unhealthy eating habits [38]. This study found that the time of last meal and eat midpoint of the night shift was later than that of the day shift, indicating that the eating rhythm of the night shift moved backward as a whole. The current data cannot prove that this backward was related to COVID-19. However, it has been demonstrated that personal health problems, including obesity, blood glucose cholesterol, and blood pressure, were associated with irregular meal timing. These problems may lead to changes in leptin/ghrelin function, which might, in turn, lead to changes in mental health through metabolism [39].

When PTSD was used as the dependent variable for the night shift analysis alone, the results suggested that the earlier HCWs eat, the lighter the symptoms of depression and anxiety, and the lighter the PTSD. In terms of social jet lag, NDLM was also related to PTSD. The earlier advance of the last meal on the night shift predicted the lighter of PTSD symptoms compared to the day shift. Anxiety and depression play an essential role in the relationship between eating time and PTSD. A study of Canadian veterans suggests that anxiety and depression should be addressed when treating PTSD and pain [40]. Another study found that anxiety and depression play a critical mediating role in physical multimorbidity caused by PTSD [41]. In addition, another study shows that treating sleep problems during a COVID-19 pandemic can help reduce trauma-related symptoms [42]. It is confirmed that food intake is a powerful zeitgeber in alignment with the central circadian pacemaker [43]. Circadian rhythm is an essential regulator of various systems, such as monoamine signaling, immune function, HPA axis regulation, metabolic peptides, redox/mitochondria/apoptosis and neurogenesis. These systems play an important role in the development of emotional disorders such as anxiety and depression [44], and are also one of the factors that affect sleep. Therefore, eating time may theoretically be mediated by anxiety, depression and sleep to improve the symptoms of PTSD, which is also verified by the present study.

Collectively, these results could explain why shift workers have an increased risk of PTSD and highlight the importance of effective behavioral interventions, for example, meal timing to mitigate internal circadian misalignment during shift work schedules [45, 46]. But few studies have reported which diet is beneficial for PTSD. This study found that the animal-based protein pattern is associated with lighter PTSD, which is achieved by improving anxiety. Previous studies have supported that the Mediterranean diet based on vegetables, fruits, and fish is more beneficial to mental health [46]. However, this does not conflict with our findings. Additionally, research has shown that anxiety is associated with poor diet quality [47]. Therefore, the consumption of animal-based protein as a high-quality diet would be a possible intervention for anxiety and even PTSD. Shift work in HCWs, which is inevitably associated with decoupling the clock from the natural day-night cycles, has multiple detrimental effects on nutrient metabolism [48]. A high-quality diet with an animal-based protein pattern might regulate the nutrient-responsive pathways to provide feedback to circadian oscillators, which may be involved in PTSD proposed mechanism [44].

In the test models, when PTSD was used as the mediating variable and SAS as the dependent variable, the mediating effect still existed, which illustrated that eating behavior can directly ameliorate PTSD symptoms. This may be due to the interrelationship between PTSD and sleep, anxiety, and depression.

In summary, HCWs have been under chronic stress for a long time because of their profession and shift patterns. After COVID-19, the stress of shift HCWs suddenly increases and the likelihood of PTSD rises. This study provides novel evidence of prospective associations between high PTSD symptoms and eating behaviors. We suggest that eating earlier on night shift and eating more animal protein may alleviate PTSD. These findings add urgency to recent recommendations to implement an integrated approach to the treatment of PTSD workers under the impact of COVID-19.

6. Limitations

The present study has several limitations. First, the cross-sectional design precluded the investigation of causal relationships between variables of interest. Although the eating habits investigated are a long-term longitudinal process, the identified causal relationship between variables should be tested in future prospective studies. Second, in this study, cluster sampling was used to investigate the HCWs of the fever clinic and respiratory medicine department in 10 hospitals in Xi'an after the outbreak of COVID-19, but the small sample size limited the representativeness of the samples. Third, no relevant influencing factors were found in the sociodemographic analysis of PTSD, so this study did not assess confounders into the mediation model. Fourth, some factors during COVID-19, such as workload during a shift, the number of traumatic experiences in work, and stressful living beyond work due to the pandemic, also affect the psychological of HCWs, which was not investigated in this study. Last but not the least, eating behavior is not the only behavioral factor that affects emotion, and other positive factors need to be further explored in future studies.

Declarations

Author contribution statement

Zhen Yao: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Jun Chen; ZhenLiang Hui: Conceived and designed the experiments.

ShaoWei Li; Yanna Ma: Performed the experiments.

RuoXue Bai; Lan Li; Xu Zhang: Analyzed and interpreted the data.

XiaoXia Xie: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at Mendely Data under the accession number: 7709397904@qq.com; password : YAOzhen4568213.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

The clinical trial described in this paper was registered at China Clinical Trials Institutional Review Board under the registration number ChiCTR2000033364.

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