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Research article

The relationship between the frequency of headaches associated with the personal protective equipment and its influencing factors is mediated by depression: A cross-sectional study

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ABSTRACT

Background: To evaluate the factors affecting personal protective equipment (PPE) associated with headaches in healthcare workers during the first hit of coronavirus disease 2019 (COVID-19) outbreak in China in order to provide evidence for improving the prevention and treatment of PPE-associated headaches in frontline medical personnel.
Methods: In this cross-sectional study, the baseline characteristics and the prevalence of the PPE-associated headaches among frontline healthcare workers at Wuhan Taikang Hospital were objectively evaluated by means of a questionnaire survey. We obtained predictors of PPE-associated headaches frequency by multiple regression analyses. The path analysis model was applied to determine the interrelationships between the variables related to PPE-associated headaches frequency.
Results: Among the 520 participants, 436 (83.85 %) reported PPE-associated headaches during the anti-epidemic period. Compare with non-PPE-associated headache, age, PHQ-9 score >10, nurses, and PSQI>5were statistically significant found in participants with PPE-associated headaches. Multivariable linear regression showed that the occupation(nurse), pre-existing primary headache diagnosis, headache intensity and depression were risk factors for the frequency of PPE-associated headaches. The path analysis model observed that direct effects from occupation (nurse), pre-existing primary headache diagnosis, headache intensity and depression on the frequency of PPE-associated headaches. Depression indirectly mediated the effects of headache intensity and sleep quality on headache frequency. (All $P < 0.05$)
Conclusion: This study provided a path analysis model that illustrates the relationships between PPE-associated headaches frequency and its related factors among healthcare workers during the COVID-19 pandemic. It is crucial to the management of PPE-associated headaches to reduce its consequences for frontline healthcare workers.

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1. Introduction

Coronavirus disease 2019 (COVID-19) has become a major health problem around the world since its outbreak in Wuhan, in Hubei Province, China [1]. Up to date, according to WHO more than 770 million people confirmed COVID-19 cases have been reported worldwide, including over 6.5 million deaths. Of those, there have been nearly 100 million confirmed cases of COVID-19 with over 120,000 corresponding deaths in China [2]. Epidemiological and virological evidence shows that COVID-19 is mainly transmitted by symptomatic people to close contacts or direct contacts through respiratory droplets, viral-contaminated objects and their surfaces. COVID-19 was classified by the National Health Commission of China in January 2020 as a group B infectious disease, requiring the same protection measures for healthcare workers as with group A diseases [3].

In the event of outbreaks of infectious diseases related to airborne transmission, healthcare workers are required to wear personal protective equipment (PPE) during extended shifts. PPE refers to a variety of barrier equipment used to protect relevant personnel from contact with infectious factors, including head, face and respiratory protective equipment (respiratory head cover, masks), protective clothing, isolation clothing, surgical clothes, gloves, goggles, protective shoes (boots), etc [4]. Since the start of the outbreak of COVID-19 in Wuhan, the National Health Commission of China recommended that medical institutions take valid protective measures. It is important for healthcare workers in all hospitals and healthcare facilities to complete additional preventive measures, such as wearing PPE when they are interacting with suspected or confirmed COVID-19 patients [5].

During the COVID-19 outbreak, the frontline healthcare workers may always wear the PPE for more than 6–8 h at a time [6]. The bulky and discomfort of wearing PPE can be particularly prohibitive for frontline healthcare workers, especially if a long period of exposure to such equipment is necessary during the outbreaks of emerging infectious diseases. The frontline healthcare workers are the main force in combating COVID-19, but they are also prone to having headaches from wearing PPE. PPE-associated headaches are common in workplaces that use masks, protective masks, goggles, and protective clothing. However, the cause of these headaches is unclear, and they may occur due to mechanical pressure, hypercapnia, or hypoxia etc [7]. In recent years, some studies have found frequent and concurrent PPE-associated headaches in healthcare workers that negatively impact their work productivity and quality of life, with an incidence rate between 26.5 % and 90.7 % [6].

In the midst of the COVID-19 pandemic, there is an urgent need to explore PPE-associated headaches among frontline healthcare workers. We hypothesized that depression, anxiety and poor sleep quality may have contributed to the increased frequency of PPE-associated headaches among frontline healthcare workers. The purpose of this study is to better understand the factors affecting of PPE-associated headaches among frontline healthcare workers during the COVIID-19 pandemic and to provide evidence for improving PPE-associated headaches.

2. Methods

This cross-sectional study has been conducted between February 10th and April 15th, 2020 during the COVID-19 pandemic among healthcare workers in Wuhan Taikang Hospital, Hubei province, China. A total of 524 frontline healthcare workers consisting of doctors, nurses, and other paramedical staff were enrolled in this study. To ensure safety, all frontline healthcare workers were required to be mask-fitted and wear full PPE while dealing with suspected or confirmed COVID-19 infections during the first hit of COVID-19 outbreak in China. Of note, it is required that all frontline healthcare workers adhere to a 4-h rotation work schedule in Wuhan Taikang Hospital. All the participants were frontline medical staff involved in the medical care work of Wuhan Taikang Hospital and worked for more than 60 days. The exclusion criteria were as follows: (1) healthcare workers who had no close contact with COVID-19 patients (2) previous CT examination suggested intracranial organic lesions leading to secondary headache. As part of the study, each participant was asked to complete a self-administered questionnaire written in Chinese, which was sent directly to their personal smartphone. Our protocol was conducted according to the recommendations of guidelines proposed by the Institutional Review Board of the First Affiliated Hospital of Army Medical University and approved by the hospital ethics committee [(A) KY2022143]. Prior to the survey, questions were set up in advance, and the preset questionnaire was not submitted until all questions were answered by the respondents.

In this study, following the International Headache Society recommendations [8], PPE-associated headaches were defined either as "De Novo" headaches when they were not experienced before, or as "aggravated headaches" if they were pre-existing chronic headaches that were worsened by wearing PPE.

In the current study, the questionnaire was composed of four sections with a total of 50 questions. The first section comprised of twenty-six questions based on general information demographic characteristics (gender, age, ethnicity, occupation, subspecialty, and department of work), risk factors associated with headache, personal or family history related to headache, headache frequency, headache severity [The visual analog scale(VAS) [9], which goes from 0 to 10 severity points, was used to stratify the magnitude of the subjective experience of the headaches, with 0 meaning the absence of pain and 10 meaning the worst severity.], and specific symptoms of any headache disorder experienced before or after COVID-19 outbreak. The second part of the questionnaire was designed to determine participants' anxiety status using Generalized Anxiety Disorder 7-item Scale (GAD-7) [10]. The GAD-7 is a widely used anxiety screening scale to assess anxiety mood. The scale consists of seven items, each of which is rated on a scale of 0–3, with a total score range of 0–21. Higher scores indicate greater levels of anxiety. The scale has been shown to be reliable and valid in a number of studies. Previous studies have shown a great reliability of GAD-7 at an optimal cutoff value of 10 (Cronbach' alpha = 0.90), with a sensitivity of 86.2 % and a specificity of 95.5 %. Therefore, we regarded GAD-7> 10 scores as a cut-off for distinguishing anxiety. The third section consisted of Patient Health Questionnare-9 (PHQ-9) tests [11]. The PHQ-9 can be widely used to screen for depression in adults, diagnose depression, and measure the severity of depressive symptoms. The PHQ-9 is a self-report measure that takes approximately 5 min to complete. Several studies have found sensitivity and specificity for detecting depressive symptoms in adults when the PHQ-9 uses a cut-off score greater than 9. In this study, the PHQ-9 score greater than 10 was classified as depressive symptoms. The fourth section was Pittsburgh Sleep Quality Index (PSQI) to measure participants' sleep quality [12]. The PSQI is a self-report measure that assesses sleep quality over a one-month time frame. The PSQI consists of seven questions and ranges from 0 to 21, with higher PSQI scores indicating poorer subjective sleep quality. Scores can be used to compare the sleep quality of individuals and groups and can be used to identify sleep problems. The PSQI has been found to be reliable and valid, and has been used to measure the sleep quality of adults, children, and adolescents. In this study, a total PSQI score greater than 5 means a poor sleep quality.

The questionnaire was distributed and collected through the smartphone. The researcher explained the study purpose and anonymity to the study subjects who met the inclusion criteria, issued the questionnaire online after obtaining the consent, and the investigator checked it after submission. A total of 524 questionnaires were recovered, with a response rate of 100 %.

2.1. Statistical analysis

In the study, the results were analyzed statistically using the Statistical Package for Social Sciences (SPSS) software version 22.0. (V.22; SPSS Inc., Chicago, IL, USA). On the basis of demographic data, a descriptive analysis was conducted. Continuous variables were expressed by mean ± standard deviation (SD), while categorical variables are stated as numbers (n) and percentages (%). Among participants with or without headaches, Chi-squared analysis was performed to determine the relationship between demographic data and PPE-associated headaches. To investigate the relationships between these study variables and PPE-associated headaches onset, both univariate and multivariate logistic regression models were used. A significant difference ($P < 0.05$) was detected in the bilateral test.

According to a review of previous studies [13–15], we further conducted a hypothetical model to describing the relationship between headache intensity, pre-existing primary headache diagnosis, anxiety, depression, sleep quality, and occupation(nurses) to the frequency of PPE-associated headaches (As shown in Fig. 1). The hypothetical model is made up of four exogenous variables (nurses, headache intensity, sleep quality and pre-existing primary headache diagnosis) and three endogenous variables (anxiety, depression, and the frequency of PPE-associated headaches). In the hypothetical model, among the exogenous variables, occupation (nurses), headache intensity, sleep quality and pre-existing primary headache diagnosis directly affect PPE-associated headaches frequency, and among the endogenous variables, anxiety and depression directly affect PPE-associated headaches frequency. The anxiety is influenced by occupation(nurse), headache intensity, sleep quality, and pre-existing primary headache diagnosis, affects PPE-associated headaches frequency. Similarly, the depression is affected by exogenous variables (occupation, headache intensity, sleep quality, and pre-existing primary headache diagnosis), which is set to have a direct effect on PPE-associated headaches frequency. Based on previous studies that both anxiety and depression have a proven association with pain, and anxiety could be used as a

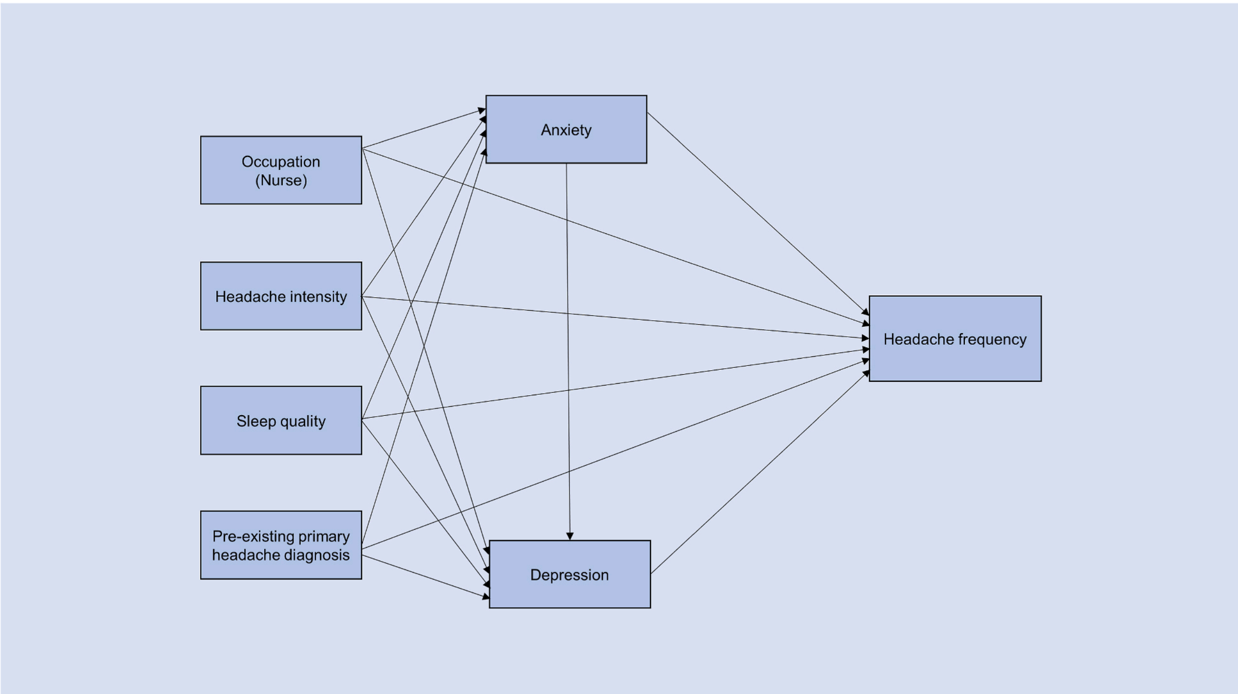

Fig. 1. Path diagram for the hypothetical model.

predictor of pain in depressed individuals. Therefore, this study assumed anxiety and depression as endogenous variables to explore the relationship between variables related to PPE-associated headaches frequency. In addition, using path analysis to validate the suitability of this hypothetical model, and a refined path-analysis model has been found.

The path analysis model is an extension of regression analysis that takes into account the relationships among independent variables, mediating variables, and dependent variables. It was hypothesized that all of these variables could directly influence on dependent variable (the frequency of PPE-associated headaches), whereas the independent outcomes (nurses, headache intensity, sleep quality and pre-existing primary headache diagnosis) could have indirect effects via the intermediary variables(anxiety and depression).We selected the best path model based on the fit indices, including a nonsignificant Chi-square(χ2) value ($P > 0.05$), the normed fit index (NFI)$\geq$0.9,the comparative fit index (CFI)$\geq$0.9,the goodness-of-fit index (GFI)$\geq$0.9,the adjusted goodness-of-fit index (AGFI)$\geq$0.9,the Root Mean-square Residual (RMR)$\leq$0.05,and the root mean-square error of the approximation (RMSEA)$\leq$0.05.The AMOS program (version 28.0, IBM Corp., Armonk, NY, USA) was used for the path and structural equation modeling components of the analysis with the maximum-likelihood method. In the bilateral test, the difference was statistically significant ($P < 0.05$).

3. Results

3.1. Baseline data of the sample

A total of 524 frontline healthcare workers were initially participated in this online survey. After excluding of 4 frontline healthcare workers with previous CT examination suggested intracranial organic lesions leading to secondary headache, 520 frontline healthcare workers were included for the final analysis in this study. As shown in Table 1, demographic characteristics and the prevalence rate of PPE-associated headaches in frontline healthcare workers can be found. All study respondents were mostly female (n = 411, 79.0 %) with an average age of 34.23 ± 6.49, mostly married (n = 386, 74.2 %), and were mainly Han (n = 470, 90.4 %) in Chinese ethnic groups. Among the participants in this study, 131 (25.2 %) were doctors, 372 (71.5 %) were nurses, and 17 (3.3 %) were other paramedical staff. The majority of healthcare workers in frontline (n = 289,55.6 %) settings hold medium or higher professional titles. The percentage PPE-associated headaches among frontline healthcare workers were 436/520 (83.85 %).

In addition, 436 respondents with PPE-associated headaches reported experiencing headache associated symptoms, including nausea (n = 183,42.0 %),vomit (n = 62,14.2 %), dizzy (n = 200,45.9 %), tinnitus (n = 34,7.8 %), osmophobia (n = 17,3.9 %), phonophobia (n = 58,13.3 %), photophobia (n = 28,6.4 %), red eye accompanied by tearing or sweating forehead (n = 59,13.5 %), visual rotation or a sense of self-motion (n = 34,7.8 %), and visual symptoms (n = 23,5.3 %)(Table 2).

Among frontline healthcare workers with PPE-associated headaches group, the main location of the headache was composed of forehead (n = 206, 47.2 %), posterior occiput (n = 76, 17.4 %), left neck (n = 2, 0.5 %), right neck(n = 2, 0.5 %), bilateral neck (n = 7, 1.6 %), left temporal area (n = 6,1.4 %), right temporal area (n = 5, 1.1 %), bilateral temporal area (n = 153, 35.1 %), left orbit(n = 2, 0.5 %),bilateral orbit (n = 59, 13.5 %), migratory symptoms (n = 12, 2.8 %), the whole head (n = 49,11.2 %),focal symptoms (n = 32, 7.3 %),and calvaria (n = 87, 20.0 %) (Table 3).

3.2. Factors associated with PPE-associated headaches among frontline healthcare workers

The influencing factors associated with PPE-associated headaches in frontline healthcare workers during the COVID-19 pandemic are represented in Table 4. Frontline healthcare workers aged 30–40 years were more likely to experience PPE-associated headaches

Table 1
Baseline characteristics of the included participants (n = 520).

Variables	Entire population (n = 520)
Age (years), mean (±SD)	34.23 ± 6.49
Sex	
Male, n (%)	109 (21.0)
Female, n (%)	411 (79.0)
Ethnic groups	
Han, n (%)	470 (90.4)
Yi, n (%)	13 (2.5)
Bai, n (%)	19 (3.6)
Others, n (%)	18 (3.5)
Marital status	
Married, n (%)	386 (74.2)
Single, n (%)	134 (25.8)
Healthcare professionals	
Doctors, n (%)	131 (25.2)
Nurses, n (%)	372 (71.5)
Other paramedical staff, n (%)	17 (3.3)
Professional title	
Junior, n (%)	231 (44.4)
Medium-grade, n (%)	207 (39.8)
Deputy senior or above, n (%)	82 (15.8)

Table 2
Concomitant symptoms of PPE-associated headache.

Variables	N = 436 (%)
Nausea, n (%)	183 (42.0)
Vomit, n (%)	62 (14.2)
Dizzy, n (%)	200 (45.9)
Tinnitus, n (%)	34 (7.8)
Osmophobia, n (%)	17 (3.9)
Phonophobia, n (%)	58 (13.3)
Photophobia, n (%)	28 (6.4)
Red eye accompanied by tearing or sweating forehead, n (%)	59 (13.5)
Visual rotation or a sense of self-motion, n (%)	34 (7.8)
Visual symptoms, n (%)	23 (5.3)

Table 3
The main location of the PPE-associated headache.

Variables	N = 436 (%)
Forehead, n (%)	206 (47.2)
Posterior occiput, n (%)	76 (17.4)
Left neck, n (%)	2 (0.5)
Right neck, n (%)	2 (0.5)
Bilateral neck, n (%)	7 (1.6)
Left temporal area, n (%)	6 (1.4)
Right temporal area, n (%)	5 (1.1)
Bilateral temporal area, n (%)	153 (35.1)
Left orbit, n (%)	2 (0.5)
Right orbit, n (%)	0 (0)
Bilateral orbit, n (%)	59 (13.5)
Migratory Symptoms, n (%)	12 (2.8)
The whole head, n (%)	49 (11.2)
Focal Symptoms, n (%)	32 (7.3)
Calvaria, n (%)	87 (20.0)

compared with other groups ($P < 0.05$). Nurses reported a higher rate of PPE-associated headaches compared with doctors or other paramedical staff ($P < 0.01$). Participants with PHQ-9 score >10 had higher percentage of PPE-associated headaches compared with other groups ($P < 0.05$). Frontline healthcare workers with PSQI score >5 who suffered higher rates of PPE-associated headaches as compared to other participants ($P < 0.05$). Moreover, an analysis of multivariable linear regression was conducted to analyze the contributing factors to the frequency of PPE-associated headaches in frontline healthcare workers. The results indicated that occupation(nurse) ($\beta = 0.111$, 95 % CI 0.021–0.194; $P = 0.015$), pre-existing primary headache diagnosis ($\beta = 0.127$, 95 % CI 0.045–0254; $P = 0.005$), headache intensity ($\beta = 0.259$, 95 % CI 0.037–0.079; $P < 0.001$) as well as depression ($\beta = 0.189$, 95 % CI 0.004–0.035; $P = 0.014$) were independently related to a higher frequency of PPE-associated headaches among frontline healthcare workers (Table 5).

The model of path-analysis between PPE-associated headache frequency and its related influencing factors.

The hypothetical path model's fit was examined in this study, and the results showed that the fit index was generally adequate at the recommended level with $\chi^2 = 0.042$, $\chi^2/df = 0.042$, $P = 0.838$; NFI = 1; CFI = 1; GFI = 1; AGFI = 0.999; RMR <0.001; RMSEA< 0.001. The correlation analysis revealed that headache frequency was related to anxiety and sleep quality, but there was no significant difference in the hypothetical path model. Moreover, neither occupation (nurse) nor pre-existing primary headache diagnosis was significantly affected for anxiety or depression in the hypothetical path model. Due to the presence of multicollinearity among the exogenous variables in the hypothetical model of this study led to a reduced significance of the exogenous variables including occupational (nurse), sleep quality, and pre-existing primary headache diagnosis. In order to make hypothetical path model more concise, we modified the model. The insignificant paths leading to the headache frequency were removed from anxiety and sleep quality. Then, the paths of occupation (nurse) and pre-existing primary headache diagnosis leading to the anxiety and the paths of occupation (nurse) and pre-existing primary headache diagnosis leading to the depression were removed.

The refined path-analysis model in Fig. 2 was used to illustrate the complex relationships between predictors and the frequency of PPE-associated headaches. As determined by pre-defined criteria, the refined path-analysis model fit the data extremely well, with $\chi^2 = 5.341$, $\chi^2/df = 1.335$, $P = 0.254$; NFI = 0.991; CFI = 0.998; GFI = 0.997; AGFI = 0.976; RMR = 0.025; RMSEA = 0.028.

According to the direct effects, there were significant paths from headache intensity (B = 0.277; $P = 0.01$) and sleep quality (B = 2.639; $P < 0.001$) on anxiety. The direct effects analysis also revealed that headache intensity (B = 0.178; $P = 0.005$), sleep quality (B = 1.602; $P < 0.001$) and anxiety (B = 0.754; $P < 0.001$) all had significant pathways to depression. Moreover, it should be noted that significant path from Occupation(nurse) (B = 0.085; $P = 0.048$), depression (B = 0.02; $P = 0.009$), pre-existing primary headache diagnosis (B = 0.149; $P = 0.005$) and headache intensity (B = 0.058; $P < 0.001$) exerted direct effects on PPE-associated headache frequency. However, anxiety (B = −0.005; $P = 0.522$) and sleep quality (B = −0.009; $P = 0.838$) did not exert direct effects on PPE-associated headache frequency. Based on this model, the amount of depression can be represented by all predictors ($R^2 = 0.657$).

Table 4
Demographic and clinical characteristics of respondents with and without PPE-associated headache.

Variables	Entire population (n = 520)		*P* values
	Without PPE-associated headache (n = 84)	With PPE-associated headache (n = 436)	
Sex (Female), n (%)	62 (73.8)	349 (80.0)	0.199
Age			0.028*
<30, n (%)	21 (25.0)	109 (25.0)	
30-40, n (%)	38 (45.2)	250 (57.3)	
>40, n (%)	25 (29.8)	77 (17.7)	
Healthcare professionals			0.004*
Doctors, n (%)	26(31.0)	105(24.1)	
Nurses, n (%)	51(60.7)	321(73.6)	
Other paramedical staff, n (%)	7(8.3)	10(2.3)	
Smoking, n (%)	5 (6.0)	35 (8.0)	0.513
Drinking, n (%)	13 (15.5)	67(15.4)	0.906
Coffee, n (%)	6 (7.1)	37 (8.5)	0.682
Past family history of headache, n (%)	15(17.9)	102(23.4)	0.266
Pre-existing primary headache diagnosis, n (%)	9(10.7)	66(15.1)	0.291
Analgesicss were used prior usage to PPE, n (%)	0	30(6.9)	<0.001*
GAD-7 Score,			0.678
≤10, n (%)	81(96.4)	416(95.4)	
>10, n (%)	3(3.6)	20(4.6)	
PHQ-9 score,			0.044*
≤10, n (%)	83(98.8)	406(93.1)	
>10, n (%)	1(1.2)	30(6.9)	
PSQI score,			0.003*
≤5, n (%)	35(41.7)	112(25.7)	
>5, n (%)	49(58.3)	324(74.3)	
Headache frequency (days/month), mean (SD)	–	6.67(2.642)	–
Headache durations (hours/during each episode), mean (SD)	–	4.58(2.112)	
Headache intensity (VAS scale), mean (SD)	–	3.92(1.878)	–
Mild headache, n (%)		205(47.02)	
Moderate to severe headache, n (%)		231(52.98)	

GAD-7, Generalized Anxiety Disorder 7-item Scale; PHQ-9, Patient Health Questionnare-9; PSQI, Pittsburgh Sleep Quality Index.

Table 5
Predictors determining the frequency of PPE-associated headache by multivariable linear regression analyses.

Variable	Multivariate Linear Regression Model				*P value*
	B	SE	β	95%CI	
Occupation (Nurse)	0.107	0.044	0.111	0.021–0.194	0.015
Pre-existing primary headache diagnosis	0.149	0.053	0.127	0.045–0.254	0.005
Headache intensity	0.058	0.011	0.259	0.037–0.079	<0.001
Anxiety (GAD-7 score)	−0.005	0.008	−0.047	−0.021–0.011	0.507
Depression (PHQ-9 score)	0.020	0.008	0.189	0.004–0.035	0.014
Sleep quality (PSQI score)	−0.001	0.006	−0.005	−0.012–0.011	0.927

GAD-7, Generalized Anxiety Disorder 7-item Scale; PHQ-9, Patient Health Questionnare-9; PSQI, Pittsburgh Sleep Quality Index.

In addition, the path analysis indicated that headache intensity (B = 0.017; $P < 0.01$) exerted an indirect effect on the PPE-associated headache frequency through the depression. Sleep quality (B = 0.078; $P < 0.01$) revealed an indirect effect on the PPE-associated headache frequency via the depression. The anxiety (B = 0.011; $P < 0.01$) exerted an indirect effect on the PPE-associated headache frequency through the depression. In contrast to the hypothesized path model, occupation (nurse) and pre-existing primary headache diagnosis did not have an indirect effect on PPE-associated headache frequency. In this refined path analysis model, all predictors accounted for the amount of PPE-associated headache frequency ($R^2 = 0.133$).

4. Discussion

In this study, we explored the factors affecting PPE-associated headaches among frontline healthcare workers at Taikang Hospital in Wuhan during the first hit of COVID-19 outbreak in China. The results revealed that 83.85 % frontline healthcare workers experienced PPE-associated headaches during the COVID-19 pandemic, including 12.69 % of aggravated headaches and 71.15 % of de novo headaches. We found that these headaches were more likely to occur in people with age 30–40, occupation (nurses), depression (PHQ-9 score >10), people with poor sleep quality (PSQI>5). Then, we further explored the potential factors associated with the frequency of PPE-associated headaches. Multivariate lines analysis revealed that occupation(nurse), pre-existing primary headache diagnosis,

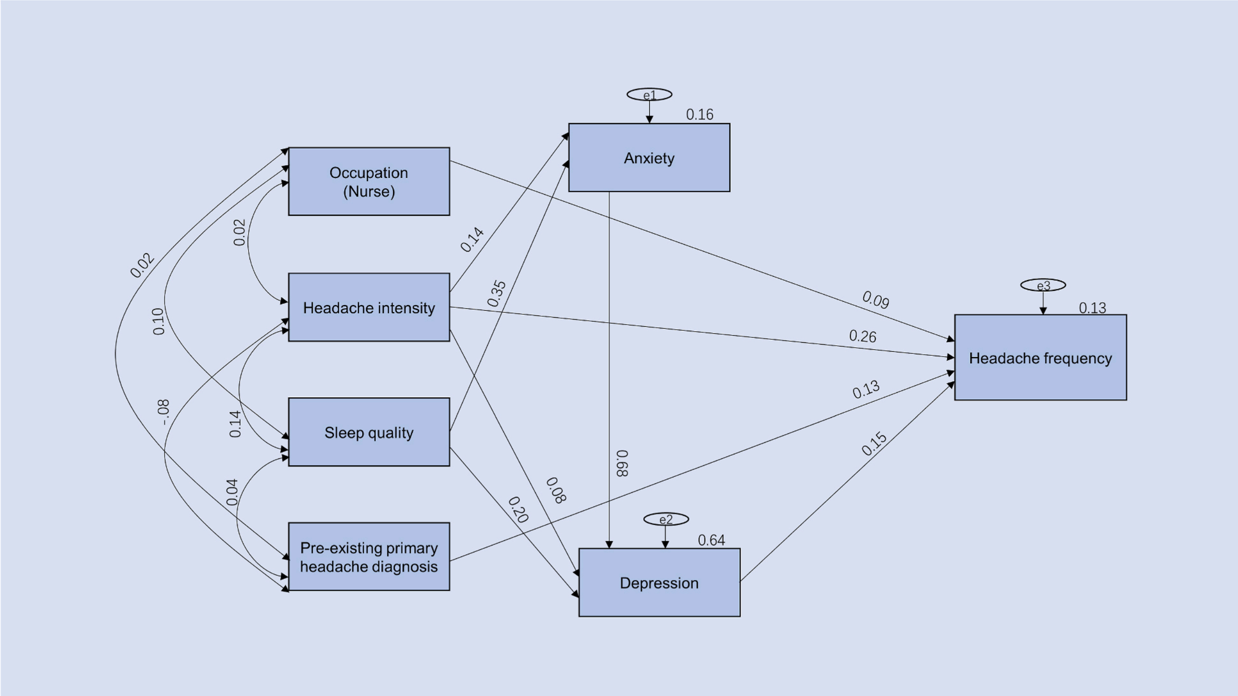

Fig. 2. The refined path-analysis model for the interrelationships between clinical variables and the frequency of PPE-associated headache. The numbers that appear along each path represent the standardized direct path coefficients. Correlations between the variables are indicated by double arrows, while standardized regression weights (parameter estimates) are represented by single arrows. The residual variances within variables not taken into consideration by the hypothesized path-analysis model are represented by error terms e1, e2and e3, respectively. All regression coefficients are statistically significant ($P < 0.05$).

headache intensity and depression (PHQ-9 score >10) were risk factors for the frequency of PPE-associated headaches among frontline healthcare workers. Of note, we provide a path analysis model that illustrates the relationships between PPE-associated headaches frequency and related factors among frontline healthcare workers. The main finding of our study is that the occupation(nurse), headache intensity, pre-existing primary headache diagnosis and depression directly contributed to increase the frequency of PPE-associated headaches among healthcare workers during COVID-19 pandemic. We also observed that depression, rather than anxiety, mediated the relationship between headache intensity and the frequency of PPE-associated headaches, poor sleep quality and the frequency of PPE-associated headaches, respectively.

Many theories and hypotheses have been proposed to account for the emergence of PPE-associated headaches. On the one hand, it is supposed that mechanical and physical forces from the respirator and safety goggles, along with the straps and bands attached to them, can lead to localised tissue damage or stimulate the sensory nerves in the face, head, and neck, which can cause discomfort [16]. Recently migraine has been associated with chronic neurovascular flogosis of extracranial trigger sites [17]. There is a possibility that the use of PPE mechanically exacerbates local inflammation and thus induce PPE-associated headache. On the other hand, psychological factors could significantly influence the susceptibility, onset, duration, and intensity of headaches within their broader context [18]. Previous research has uncovered that individuals with primary headaches tend to have a higher likelihood of also experiencing psychiatric conditions, particularly anxiety disorders and depression, when compared to the general healthy population [19]. The research findings indicate that patients who were experiencing both headaches and COVID-19 had a higher prevalence of anxiety related to the coronavirus, when compared to both healthy individuals and those who had not received a confirmed diagnosis of COVID-19 [20]. Several studies and meta-analysis research groups have reported the psychiatric factors for the PPE-associated headaches among frontline healthcare workers [6,21,22]. However, no previous study has determined the relationships between these variables that affect PPE-associated headaches frequency among frontline healthcare workers at the same time in this headache condition. To our knowledge, our survey is the first research to investigate the potential direct and indirect effects of depression, anxiety and sleep quality on headache frequency among frontline healthcare workers with PPE-associated headaches using path analysis.

It should be noted that, according to our research, nurses have a higher risk of developing a PPE-associated headaches. One reason for this is that nurses make up the majority of frontline healthcare workers, and they are primarily women. Studies have reported that women are more prone to have primary headaches than men [23]. Several studies have found that women are more likely to suffer PPE-associated headaches, but our study did not find a statistically significant difference [6]. However, our study also found that nurses had a higher frequency of PPE-associated headaches attacks than other occupations. This finding was consistent with those from a recent study by Dominguez-Moreno et al. [24], which analyzed the incidence of PPE-associated headache among healthcare workers during the current COVID-19 pandemic in Mexico and indicated that the occupation other than physician (mainly nurses) was an independent risk factor for PPE-associated headaches.

As we found, there was a significant association between sleep quality indirectly affecting the frequency of PPE-associated headaches through depression. This is an important finding, as it suggests that poor sleep quality (PSQI >5) may be a potential risk factor for developing PPE-associated headaches. In the COVID-19 pandemic, a lack of sleep quality is one of the most common complaints among frontline healthcare workers who have been afflicted with PPE-associated headaches. In Singapore and Italy healthcare workers-based studies, poor sleep has also been associated with the presence of PPE-associated headaches [25,26]. It should be noted, however, that these studies failed to demonstrate a link between PSQI and PPE-associated headaches, nor did they consider these symptoms in combination with psychological symptoms, including anxiety symptoms. According to our findings, a poor sleep quality exerts indirectly effect on the frequency of PPE-associated headaches through depression. A person's overall quality of life is influenced by the quality of their sleep [27]. Getting a poor night's sleep may alter the neuroendocrine stress response system and metabolic activity during sleep, impairing functions during the day [28]. Similarly, we speculated that sleep could contribute to headache-related effects by causing a poor quality of life in general. Sleep deprivation affects psychological and cognitive functions, which can worsen headache-related effects.

The present investigation revealed that PPE-associated headache attacks occurred substantially more frequently in frontline healthcare workers with pre-existing primary headache disorder. In the Ong et al. study [25], pre-existing headache affected the severity of headache associated with PPE, however, our study did not find a relationship between pre-existing primary headache and the severity of PPE-associated headaches. Additionally, more than half of those with PPE-associated headaches reported experiencing moderate to severe headaches intensity in our study. It has been shown that the modulatory pain process of pre-existing primary headache disorder involves an abnormal release of nociceptive molecules along with a malfunction of top-down pain modulatory pathways [29]. These changes can lead to sensitization of central and peripheral nociceptive pathways, resulting in a reduction in pain threshold [30]. This may be a potential reason for the higher frequency of PPE-associated headaches in frontline healthcare workers with primary headache disorders.

Furthermore, our study also found that depression (PHQ-9 score >10) as a relevant part of emotional aspects plays an important role in influencing the frequency of headache among frontline healthcare workers with PPE-associated headaches. It is believed that the majority of participants experienced tension-type headaches during the COVID-19 period, which are likely to be associated with PPE wearing, rather than migraine headaches [7]. Cathcart et al. study suggested that emotional stress was associated with increased mechanical pain hypersensitivity [31]. Due to this, an increased emotional load (stressful situation) may contribute to the excitation of the central nervous system, increasing PPE-associated headaches frequency. Depression was primarily thought to contribute to chronic pain through supra-spinal mechanisms and emotional modulation of pain, which may have a significant indirect effect on headache frequency [32,33]. In addition, the combined effect of depression and poor sleep quality may increase the frequency of PPE-associated headaches. Previous studies have demonstrated that depression and sleep deprivation were linked to reduced pain thresholds [34,35].

Although the intricate relationship between emotional distress and the occurrence of PPE-associated headaches is likely to be linked by some shared pathophysiological mechanisms, more studies are still needed to explore it in the future. There are several potential clinical implications. In this study, we firstly constructed a path analysis model to further explore the internal relationship between occupation (nurses), headache intensity, sleep quality, pre-existing primary headache diagnosis and depression influenced the frequency of PPE-associated headaches among frontline healthcare workers. Some studies have reported that emotional aspects and poor sleep quality seems to be the most common triggers for PPE-associated headaches [21,36]. Indeed, management of emotional aspects, depression, and sleep quality has clinical implications due to they represent modifiable risk factors involved in PPE-associated headaches. Therefore, proper management of these risk factors related to PPE-associated headaches appears to be necessary for decreasing the frequency of PPE-associated headaches among frontline healthcare workers.

The study has some limitations that need to be mentioned. Firstly, due to the cross-sectional nature of the study, causal interpretation is not possible. Our results indicate that depression (PHQ-9 score >10) is associated with the prevalence of PPE-associated headaches, but we cannot conclude that depression causes these headaches. Therefore, longitudinal designs need to be used in future studies. Secondly, this is a self-administered questionnaire survey and the responses reflect solely the opinions and perceptions of the respondents. Since the practices may not be verified through audits, they may not necessarily reflect actual practices. Finally, the sample size was small, but this was due to the difficulty of recruiting more participants in isolation hospitals during the first hit of COVID-19 outbreak in China.

5. Conclusion

In summary, this study investigates the prevalence and characteristics of PPE-associated headaches among frontline healthcare workers at Taikang Hospital in Wuhan during the first hit of COVID-19 outbreak in China. The occupation (nurses), headache intensity, pre-existing primary headache diagnosis and depression appeared to have direct effects on the frequency of PPE-associated headaches among frontline healthcare workers. Headache intensity and sleep quality may indirectly increase the frequency of PPE-associated headaches among frontline healthcare workers through depression. Not only may being aware of and avoiding trigger factors reduce the frequency of PPE-associated headaches, but it can also reduce the potential of medication overuse, ensuring the health of frontline healthcare workers and therefore improving their work efficiency. During COVID-19, the quality of health care could be improved by a greater focus on and better management of PPE-associated headaches among frontline healthcare workers.

Ethical approval and consent to participate

Our protocol was conducted according to the recommendations of guidelines proposed by the Institutional Review Board of the First Affiliated Hospital of Army Medical University and approved by the hospital ethics committee [(A)KY2022143].

Consent for publication

Not applicable.

Data availability statement

Supporting data regarding the extracted features are available upon request.

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CRediT authorship contribution statement

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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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List of abbreviations

COVID-19	coronavirus disease 2019
PPE	personal protective equipment
VAS	visual analog scale
GAD-7	generalized anxiety disorder 7-item scale
PHQ-9	patient health questionnare-9
PSQI	pittsburgh sleep quality index
SD	standard deviation
NFI	normed fit index
CFI	comparative fit index
GFI	goodness-of-fit index
AGFI	adjusted goodness-of-fit index
RMR	root mean-square residual
RMSEA	root mean-square error of the approximation
SE	standard error
CI	confidence intervals

References

[1] N. Zhu, D. Zhang, W. Wang, et al., A novel coronavirus from patients with pneumonia in China, 2019, N. Engl. J. Med. 382 (2020) 727–733.
[2] WHO. https://covid19.who.int.

[3] Special Expert Group for Control of the Epidemic of Novel Coronavirus Pneumonia of the Chinese Preventive Medicine A, [An update on the epidemiological characteristics of novel coronavirus pneumonia (COVID-19)], Zhonghua Liuxingbingxue Zazhi 41 (2020) 139–144.
[4] S. Saran, M. Gurjar, A.K. Baronia, et al., Personal protective equipment during COVID-19 pandemic: a narrative review on technical aspects, Expet Rev. Med. Dev. 17 (2020) 1265–1276.
[5] R. Ortega, M. Gonzalez, A. Nozari, R. Canelli, Personal protective equipment and covid-19, N. Engl. J. Med. 382 (2020) e105.
[6] P. Galanis, I. Vraka, D. Fragkou, A. Bilali, D. Kaitelidou, Impact of personal protective equipment use on health care workers' physical health during the COVID-19 pandemic: a systematic review and meta-analysis, Am. J. Infect. Control 49 (2021) 1305–1315.
[7] J.J.Y. Ong, A.C.Y. Chan, C. Bharatendu, H.L. Teoh, Y.C. Chan, V.K. Sharma, Headache related to PPE use during the COVID-19 pandemic, Curr. Pain Headache Rep. 25 (2021) 53.
[8] Headache Classification Committee of the International Headache Society (Ihs), The international classification of headache disorders, 3rd edition, Cephalalgia 38 (2018) 1–211.
[9] K.W. Faiz, [VAS–visual analog scale], Tidsskr. Nor. Laegeforen 134 (2014) 323.
[10] R.L. Spitzer, K. Kroenke, J.B. Williams, B. Löwe, A brief measure for assessing generalized anxiety disorder: the GAD-7, Arch. Intern. Med. 166 (2006) 1092–1097.
[11] K. Kroenke, R.L. Spitzer, J.B. Williams, The PHQ-9: validity of a brief depression severity measure, J. Gen. Intern. Med. 16 (2001) 606–613.
[12] D.J. Buysse, C.F. Reynolds 3rd, T.H. Monk, S.R. Berman, D.J. Kupfer, The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research, Psychiatr. Res. 28 (1989) 193–213.
[13] H.T. Chu, C.S. Liang, J.T. Lee, et al., Associations between depression/anxiety and headache frequency in migraineurs: a cross-sectional study, Headache 58 (2018) 407–415.
[14] K.A. Payne, S.F. Varon, A.K. Kawata, et al., The International Burden of Migraine Study (IBMS): study design, methodology, and baseline cohort characteristics, Cephalalgia 31 (2011) 1116–1130.
[15] E.C. Lim, R.C. Seet, K.H. Lee, E.P. Wilder-Smith, B.Y. Chuah, B.K. Ong, Headaches and the N95 face-mask amongst healthcare providers, Acta Neurol. Scand. 113 (2006) 199–202.
[16] A.V. Krymchantowski, Headaches due to external compression, Curr. Pain Headache Rep. 14 (2010) 321–324.
[17] E. Raposio, G. Raposio, D. Del Duchetto, E. Tagliatti, K. Cortese, Morphologic vascular anomalies detected during migraine surgery, J. Plast. Reconstr. Aesthetic Surg. 75 (2022) 4069–4073.
[18] F. Galli, O. Gambini, Psychopharmacology of headache and its psychiatric comorbidities, Handb. Clin. Neurol. 165 (2019) 339–344.
[19] C. Nimnuan, T. Asawavichienjinda, A. Srikiatkhachorn, Potential risk factors for psychiatric disorders in patients with headache, Headache 52 (2012) 90–98.
[20] A. Adiguzel, M. Akan, S. Ciplak, Investigation of the relationship between headache and anxiety during the late COVID-19 pandemic period: a prospective case-control study, Dicle Tip Dergisi 49 (2022) 92–101.
[21] A. Sahebi, N. Hasheminejad, M. Shohani, A. Yousefi, S. Tahernejad, A. Tahernejad, Personal protective equipment-associated headaches in health care workers during COVID-19: a systematic review and meta-analysis, Front. Public Health 10 (2022) 942046.
[22] J.L. Scheid, S.P. Lupien, G.S. Ford, S.L. West, Commentary: physiological and psychological impact of face mask usage during the COVID-19 pandemic, Int. J. Environ. Res. Publ. Health 17 (2020).
[23] K.G. Vetvik, E.A. MacGregor, Sex differences in the epidemiology, clinical features, and pathophysiology of migraine, Lancet Neurol. 16 (2017) 76–87.
[24] R. Dominguez-Moreno, V.A. Venegas-Gómez, L.A. Zepeda-Gutiérrez, et al., Headache related to personal protective equipment in healthcare workers during COVID-19 pandemic in Mexico: baseline and 6-month follow-up, Int. Arch. Occup. Environ. Health (2022) 1–10.
[25] J.J.Y. Ong, C. Bharatendu, Y. Goh, et al., Headaches associated with personal protective equipment - a cross-sectional study among frontline healthcare workers during COVID-19, Headache 60 (2020) 864–877.
[26] L. Rapisarda, M. Trimboli, F. Fortunato, et al., Facemask headache: a new nosographic entity among healthcare providers in COVID-19 era, Neurol. Sci. 42 (2021) 1267–1276.
[27] K.L. Nelson, J.E. Davis, C.F. Corbett, Sleep quality: an evolutionary concept analysis, Nurs. Forum 57 (2022) 144–151.
[28] D.J. Dijk, Slow-wave sleep deficiency and enhancement: implications for insomnia and its management, World J. Biol. Psychiatr. 11 (Suppl 1) (2010) 22–28.
[29] R.R. Ji, A. Nackley, Y. Huh, N. Terrando, W. Maixner, Neuroinflammation and central sensitization in chronic and widespread pain, Anesthesiology 129 (2018) 343–366.
[30] C.J. Schankin, A. Straube, Secondary headaches: secondary or still primary? J. Headache Pain 13 (2012) 263–270.
[31] S. Cathcart, J. Petkov, A.H. Winefield, K. Lushington, P. Rolan, Central mechanisms of stress-induced headache, Cephalalgia 30 (2010) 285–295.
[32] K. Zebenholzer, A. Lechner, G. Broessner, et al., Impact of depression and anxiety on burden and management of episodic and chronic headaches - a cross-sectional multicentre study in eight Austrian headache centres, J. Headache Pain 17 (2016) 15.
[33] E.L. Terry, J.L. DelVentura, E.J. Bartley, A.L. Vincent, J.L. Rhudy, Emotional modulation of pain and spinal nociception in persons with major depressive disorder (MDD), Pain 154 (2013) 2759–2768.
[34] Y.H. Chiu, A.J. Silman, G.J. Macfarlane, et al., Poor sleep and depression are independently associated with a reduced pain threshold. Results of a population based study, Pain 115 (2005) 316–321.
[35] B.L. Uhlig, M. Engstrøm, S.S. Ødegård, K.K. Hagen, T. Sand, Headache and insomnia in population-based epidemiological studies, Cephalalgia 34 (2014) 745–751.
[36] M. Chutiyami, U.M. Bello, D. Salihu, et al., COVID-19 pandemic-related mortality, infection, symptoms, complications, comorbidities, and other aspects of physical health among healthcare workers globally: an umbrella review, Int. J. Nurs. Stud. 129 (2022) 104211.