Society of Medical Education & Research

2025, Volume 5, Page No: 265-276
ISSN: 3108-4818

International Journal of Social and Psychological Aspects of Healthcare

Temporal Variations in Risk Perception and Emotional Response of Healthcare Workers in China during the COVID-19 Pandemic

Veronica I. Morales[1]*, Juan P. Castillo[1], Daniela R. Vega[1]

[1]Department of Health Psychology, Faculty of Social Sciences, University of Chile, Santiago, Chile.

***E-mail** ✉ veronica.morales@outlook.com

Abstract

This study aimed to investigate the risk perception and negative emotional responses of Chinese healthcare workers (HCWs) during two distinct phases of the COVID-19 pandemic, and to identify potential intervention points for psychological support in high-stress environments. A repeated cross-sectional design was employed, including a cohort of Chinese HCWs assigned to frontline duties. Demographic information, such as gender, profession, and work location, was obtained via questionnaires. Risk perception was measured using a COVID-19–adapted risk perception scale, and the Chinese version of the Positive and Negative Affect Schedule (PANAS) was used to assess negative emotions. Results demonstrated that risk perception and negative emotions among HCWs differed across gender, professional role, work location, and pandemic phase. The dominant negative emotion varied between periods; however, negative emotions consistently correlated with risk perception, serving as a strong indicator of perceived risk. This research highlights variations in risk perception and emotional responses among HCWs during different stages of COVID-19, emphasizing the importance of continuous monitoring of psychological indicators to ensure occupational safety and mitigate future pandemic risks.

Keywords: Protection, Negative emotion, Risk perception, Healthcare worker, Pandemic, COVID-19

Introduction

On February 12, 2020, the World Health Organization officially designated the novel coronavirus as COVID-19. Due to its rapid transmission, the outbreak has not only raised significant public health concerns but has also imposed considerable psychological stress on the population. Studies indicate that Chinese medical personnel were particularly vulnerable to mental health burdens, affecting their attention, cognition, clinical decision-making, and even patient safety due to potential medical errors [1]. Frontline HCWs faced increased workloads and heightened risk of infection while performing life-saving duties. According to the National Health Commission of China, 1,716 HCWs were infected by February 11, 2020, and 11 had died as of February 24, 2020. Consequently, frontline HCWs encountered elevated occupational risks, making their perception of these risks a crucial element in pandemic response.

Risk perception is defined as an individual's understanding and evaluation of potential external threats, shaped by intuitive judgments and subjective experiences [2]. Accurately perceiving viral risks is essential for rapid behavioral adaptation and effective self-protective measures [3]. Given the importance of psychological and behavioral factors in pandemic containment, assessing individuals' responses and understanding how perceived risk evolves during a crisis is critical [4]. Public health emergencies that result in rapid and significant losses can substantially impact psychological well-being, closely linked to perceptions of danger [5]. Based on prior studies and literature analyses [6–8], HCWs' risk perception encompasses

Access this article online https://smerpub.com/

Received: 12 September 2025; **Accepted:** 09 December 2025

How to cite this article: Morales VI, Castillo JP, Vega DR. Temporal Variations in Risk Perception and Emotional Response of Healthcare Workers in China during the COVID-19 Pandemic. Int J Soc Psychol Asp Healthc. 2025;5:265-76. https://doi.org/10.51847/Tw0PKDaHVI

knowledge, feelings, and understanding of occupational risks and their characteristics. However, a universally accepted definition remains under discussion.

Koh *et al*. examined risk perception among Singaporean HCWs during the SARS outbreak, focusing on personal risk, family and social life, workload, and preventive behaviors [9]. The study revealed that most HCWs perceived high personal exposure risk, feared infection, and reported increased work stress. Research on factors influencing risk perception suggests six main dimensions: personal safety, physical functioning, occupational exposure, psychosocial concerns, organizational safety, and time pressure [10]. Core components of HCWs' risk perception include personal health risk, risk to others, social isolation, and acceptance of occupational hazards [11]. High perceived risk may influence workforce retention and willingness to care for infected patients [12], particularly when concerns about personal and family safety are prominent [13]. Conversely, low perceived risk can lead to noncompliance with protective measures, such as PPE use and vaccination, increasing both personal and nosocomial transmission risk [14]. Considering the nature of healthcare work and the uncertainty surrounding COVID-19, frontline HCWs face occupational exposure, prolonged shifts, and physical fatigue, making their risk perception highly susceptible to pandemic conditions.

In the context of epidemic outbreaks, few studies have explored healthcare workers' (HCWs) risk perception. Koh *et al*. employed qualitative interviews and found that exposure to infectious diseases significantly shapes nurses' perception of risk [9]. Additionally, prior research suggests that individuals' risk perception during public health crises is closely linked to policy support [15]. Theoretically, well-designed policies can enhance a sense of security, reducing anxiety and agitation. However, due to the rapid spread and latent characteristics of COVID-19, policies addressing the immediate needs of both the public and HCWs were insufficient, which may have influenced risk perception and contributed to adverse mental health outcomes [16]. A recent study by Diego *et al*. indicated that HCWs perceived restricted access to protective equipment and organizational support, highlighting that institutional safety significantly affected epidemic-related risk for HCWs [17]. Nevertheless, there remains a scarcity of research examining HCWs' risk perception specific to COVID-19, as well as their subsequent responses.

Multiple factors influence risk perception, arising not only from social and cultural contexts but also from individual differences. Evidence shows that HCWs' cognitive and decision-making capacities are affected by their emotional states [18, 19]. This understanding provides insight into HCWs' psychological status as expressed through emotions, which, as an individual trait, can shape perceptions of personal and organizational risks. Previous studies reported that distress and fear among HCWs often arise after exposure to infectious diseases [20, 21]. Being among the first to face such exposures, HCWs exhibited psychological disturbances, manifesting through negative emotions including fear, anxiety, anger, and depression [22, 23]. During the COVID-19 pandemic, online surveys revealed that symptoms of depression and anxiety were prevalent in the majority of HCWs, confirming the widespread presence of negative emotions [24–26]. A scoping review of 37 studies also demonstrated that even prior to COVID-19, HCWs experienced burnout, stress, and emotional burdens from caring for patients [27]. These feelings—fatigue, irritability, frustration, and exhaustion, combined with diminished support resources [28]—led to fewer positive emotions, lower work performance, and adverse outcomes affecting both patients and society. HCWs experiencing negative emotions are less able to manage work demands effectively, making risk avoidance necessary. Therefore, a deeper understanding of HCWs' negative emotions during COVID-19 and their relation to risk perception is essential to mitigate the impact of such emotions on risk judgments, improve self-protection, and enhance clinical care quality.

To investigate how the pandemic influenced HCWs' risk perception after COVID-19's outbreak, this study conducted repeated cross-sectional research on Chinese HCWs assigned to frontline roles. The study assessed both risk perception and emotional states. Two cross-sectional surveys were conducted within the same cohort: the first immediately after the outbreak, when HCWs were dispatched to the most affected regions in China, and the second upon the resumption of routine duties, when there were no new confirmed COVID-19 cases and HCWs had returned to regular positions. Three primary hypotheses were formulated:

1. HCWs' risk perception would decrease over time as their knowledge improved and protective measures became more effective.

2. After the peak of COVID-19, HCWs' overall negative emotions would decline, with variations in the dominant subtypes of negative emotions between the two periods.
3. Negative emotions would be significantly associated with risk perception in both periods, with differences in the patterns of associations between specific subtypes of negative emotions and risk perception across the two phases, suggesting that negative emotions substantially contribute to explaining risk perception.

This study aimed to examine the relationship between HCWs' negative emotions and perceived risk during a public health emergency, integrating emotional and cognitive-behavioral perspectives. Understanding the impact of emotional management on risk perception and self-protective behaviors can inform strategies to improve HCWs' mental health. Consequently, the findings provide potential intervention points for psychological support under stressful conditions.

Materials and Methods

Participants

This study was conducted across two separate periods during the COVID-19 pandemic. The first period spanned February 3–5, 2020, during which HCWs had been assigned to COVID-19 medical defense duties for 10–15 days under the national first-level emergency response. "Period 2" occurred from May 3–5, 2020, when all dispatched HCWs had returned to their regular work duties. Due to the critical nature of epidemic control, in-person interviews were not feasible; therefore, an online survey was conducted via a web-based platform. A strict sampling framework was not implemented; instead, links to the survey were shared with targeted groups through WeChat, and questionnaires meeting eligibility criteria were selected.

The study took place in a comprehensive hospital in Shanghai employing over 1,000 medical staff. The targeted participants were HCWs actively working with COVID-19 patients, excluding those in home isolation, resulting in approximately half of the total staff being eligible. The survey was overseen by the lead physician responsible for health surveillance in the temporary emergency medical team. This team was part of a WeChat group comprising nearly 550 frontline members. During the peak phase of the epidemic, all members were invited to complete the online questionnaire. From February 3–5, 238 responses were received, yielding a 43.3% response rate. After excluding random or incomplete responses, 220 questionnaires (92.4% valid) were considered qualified, with completion times ranging from 500 ms to 1,500 ms. The mean age of participants was 31.91 ± 7.0 years.

During Period 2, 320 questionnaires were submitted, and 304 met the eligibility criteria (95% valid) with a mean age of 30.75 ± 9.28 years; two responses were excluded for unqualified completion times. No significant age differences were observed between the two periods ($t = 1.56$, $p = 0.120$). Detailed between-group comparisons for both periods are presented in **Table 1.** Additionally, since Wuhan was the most severely affected region with HCW shortages, many HCWs in this cohort were dispatched from Shanghai. According to the group leader, no confirmed COVID-19 cases were included in our cohort, as all HCWs worked under protective measures. Dispatched personnel had frequent contact with confirmed cases, while non-dispatched members, located in low-risk areas, had limited exposure.

Table 1. Population characteristics stratified for the two study periods (1: peak of COVID-19; 2: post-resumption of work).

Characteristic	Period 2 (n = 304)	Period 1 (n = 220)	p value
Mean age (years)	30.42 ± 7.49	31.25 ± 7.01	0.120+
Gender			0.000×
Males	18 (5.9%)	38 (17.3%)	
Females	286 (94.1%)	182 (82.7%)	
Profession			0.000×
Physicians	19 (6.3%)	61 (27.7%)	
Nurses	285 (93.8%)	159 (72.3%)	
Deployment to Wuhan			0.002×
Not deployed	245 (80.6%)	151 (68.6%)	
Deployed	59 (19.4%)	69 (31.4%)	

+: p value for t-test; ×: p value for chi-square test.

Measures

Demographic questionnaire

This questionnaire collected information on gender, age, and profession. To assess exposure level, participants were also asked about contact with confirmed COVID-

19 patients and whether they had been assigned to Wuhan hospitals.

Risk perception questionnaire

HCWs' risk perception of COVID-19 was measured using an adapted version of the nursing staff risk perception questionnaire [10]. The self-report instrument included 14 items across six dimensions: personal safety risk (items 1–2), physical function risk (items 3–4), occupational exposure risk (items 5–7), psychosocial evaluation risk (items 8–10), organizational risk (items 11–12), and time pressure (item 13). Responses were rated on a 5-point scale from "never" to "almost always," with higher scores indicating greater perceived risk. The total score reflected overall risk perception. Participants were instructed to recall their experiences during COVID-19 when rating the risks. The adapted questionnaire demonstrated strong internal consistency (Cronbach's $\alpha = 0.905$), with dimensional α values ranging from 0.768 to 0.854. Although the shortened version no longer fit the six-dimension model well, it was reliable as a single-factor measure (CMIN/DF = 0.911 < 2; RMSEA < 0.05; NFI = 0.998). Risk perception was calculated using the weighted sum of dimensional scores.

Self-assessment questionnaire for negative emotions

The Chinese version of Watson and Tellegen's (1988) PANAS scale, validated cross-culturally [29, 30], was used to assess emotional state. The scale included 20 items, 10 positive and 10 negative, rated on a 5-point scale (1 = "very slight or none," 2 = "a little," 3 = "moderate," 4 = "relatively strong," 5 = "extremely strong"). Seven negative emotions were analyzed for the study: impatience, sadness, upset, tension, guilt, fear, and worry. Hostility, irritability, and shame were excluded, as they were less relevant to frontline HCWs and inconsistent with professional ethics. The short version showed strong reliability (Cronbach's $\alpha > 0.8$).

Procedure

The study was approved by the Ethics Committee of the Navy Medical University. Written informed consent was obtained from hospital management and from HCWs via personal emails. Data collection occurred online, with participants informed that their involvement was voluntary, confidential, and focused on their COVID-19 experiences. HCWs were recruited through hospital managers in Shanghai, who distributed survey links and emphasized anonymity. All submitted questionnaires were screened according to eligibility criteria: being an active HCW and completing the survey within the specified time frame.

Analytical procedures

Data management and statistical evaluation were performed using SPSS version 24.0. Subtypes of negative affect were indicated by scores on corresponding subscales, whereas overall risk perception was derived from the aggregation of five separate risk dimensions. Descriptive statistics included means and standard deviations (SD) for continuous measures. Given the normal distribution of these variables in large samples, independent t-tests were applied to detect group differences in affect and risk perception while accounting for categorical between-group factors. Furthermore, a multivariate analysis of covariance (MANCOVA) was conducted, incorporating seven distinct negative affect subtypes (Impatience, Sadness, Upset, Tension, Guilt, Fear, Caution) as dependent variables to assess variations across the two time points. In this model, differing demographic characteristics between samples were entered as covariates. Zero-order correlations were then calculated separately for each time point to examine associations between negative affect subtypes and risk perception. Fisher's z-test was employed to determine whether correlation coefficients differed significantly between the two periods. Subsequently, hierarchical regression analyses stratified by period were carried out to evaluate the predictive role of negative affect on risk perception levels, with between-group factors included as covariates in the initial step. Post hoc power calculations were performed using G*Power 3.1.9.2, with all tests set at $\alpha = 0.05$. For two-tailed tests at $p < 0.05$, the sample size of 220 yielded power of 0.95 and 0.99 for effect sizes $f^2 = 0.24$ and 0.29, respectively; the sample of 304 achieved power of 0.95 and 0.99 for effect sizes $f^2 = 0.21$ and 0.24.

Results and Discussion

Variations across groups in negative affect and risk perception between the two time points

Due to imbalances in the samples—specifically, a greater proportion of females relative to males, a higher representation of nurses compared to physicians (especially pronounced in the Period-2 cohort), and a limited number of dispatched personnel—group comparisons were conducted for key variables within

each period. As presented in **Table 2,** gender effects on total negative affect were generally non-significant, although in Period 2, females exhibited marginally higher worry than males (p = 0.017, d = 0.40). Occupational differences showed inconsistency across periods. In Period 1 alone, physicians reported elevated general risk perception (p = 0.027, d = 0.34) and higher negative affect, including impatience (p < 0.001, d = 0.51), sadness (p = 0.002, d = 0.52), upset (p = 0.01, d = 0.38), and tension (p = 0.012, d = 0.37) compared to nurses. In Period 2, no notable variation in risk perception emerged by deployment status (p = 0.209, d = 0.07); however, non-dispatched personnel displayed greater negative affect than those sent to Wuhan, encompassing impatience (p = 0.018, d = 0.32), sadness (p = 0.016, d = 0.30), tension (p = 0.003, d = 0.39), fear (p = 0.038, d = 0.25), and worry (t = 2.57, p = 0.011, d = 0.32). Identified intergroup variations influencing outcome measures were subsequently adjusted for as covariates in further analyses.

Table 2. Negative affect and risk perception during Period 1 (peak of COVID-19 outbreak) and Period 2 (post-resumption of work), stratified by gender, profession, and deployment to Wuhan.

Variable	**Period 2**				**Period 1**			
	Males Mean ± SD	**Females Mean ± SD**	**t**	**p**	**Males Mean ± SD**	**Females Mean ± SD**	**t**	**p**
Risk perception	32.72 ± 7.03	34.64 ± 9.92	0.42	0.421	38.95 ± 9.71	37.36 ± 9.48	0.94	0.350
Impatience	1.5 ± 0.92	1.66 ± 0.86	−0.75	0.452	1.79 ± 0.91	1.53 ± 0.83	1.71	0.088
Sadness	1.39 ± 0.70	1.41 ± 0.73	−0.09	0.925	1.61 ± 0.86	1.49 ± 0.82	0.75	0.453
Upset	1.83 ± 1.10	1.8 ± 0.92	0.13	0.897	1.92 ± 0.82	1.71 ± 0.93	1.31	0.192
Tension	1.33 ± 0.60	1.52 ± 0.82	−0.97	0.331	2.13 ± 1.00	1.87 ± 0.88	1.62	0.107
Guilt	1.11 ± 0.32	1.24 ± 0.57	−0.94	0.350	1.26 ± 0.50	1.32 ± 0.66	−0.49	0.626
Fear	1.22 ± 0.43	1.29 ± 0.64	−0.45	0.655	1.47 ± 0.80	1.64 ± 0.85	−1.13	0.259
Worry	1.11 ± 0.32	1.33 ± 0.70	−2.55	0.017	1.45 ± 0.72	1.51 ± 0.85	−0.43	0.666
Variable	**Period 2**				**Period 1**			
	Doctors Mean ± SD	Nurses Mean ± SD	t	p	Doctors Mean ± SD	Nurses Mean ± SD	t	p
Risk perception	32.58 ± 7.97	34.65 ± 9.88	−0.90	0.371	39.92 ± 9.45	36.75 ± 9.42	2.23	0.027
Impatience	1.47 ± 0.84	1.66 ± 0.86	−0.91	0.361	1.90 ± 1.00	1.45 ± 0.74	3.63	0.000
Sadness	1.32 ± 0.58	1.41 ± 0.74	−0.55	0.584	1.84 ± 1.00	1.39 ± 0.72	3.22	0.002
Upset	1.68 ± 1.00	1.81 ± 0.92	−0.59	0.555	2.00 ± 1.00	1.65 ± 0.86	2.60	0.010
Tension	1.26 ± 0.56	1.53 ± 0.82	−1.94	0.065	2.16 ± 1.00	1.82 ± 0.85	2.55	0.012
Guilt	1.11 ± 0.32	1.24 ± 0.57	−1.67	0.106	1.34 ± 0.60	1.30 ± 0.65	0.51	0.613
Fear	1.26 ± 0.56	1.29 ± 0.63	−0.17	0.868	1.74 ± 0.91	1.57 ± 0.80	1.36	0.175
Worry	1.21 ± 0.54	1.33 ± 0.70	−0.71	0.479	1.66 ± 0.89	1.44 ± 0.79	1.74	0.083
Variable	**Period 2**				**Period 1**			
	Shanghai (Returned) Mean ± SD	Wuhan Mean ± SD	t	p	Shanghai Mean ± SD	Wuhan Mean ± SD	t	p
Risk perception	34.87 ± 10.07	33.08 ± 8.36	1.26	0.209	37.43 ± 9.71	38.07 ± 9.13	−0.463	0.643
Impatience	1.7 ± 0.89	1.44 ± 0.70	2.39	0.018	1.60 ± 0.83	1.52 ± 0.87	0.66	0.510
Sadness	1.44 ± 0.76	1.24 ± 0.54	2.44	0.016	1.52 ± 0.86	1.49 ± 0.76	0.25	0.800
Upset	1.85 ± 0.94	1.63 ± 0.83	1.66	0.098	1.79 ± 0.95	1.64 ± 0.80	1.19	0.236
Tension	1.57 ± 0.85	1.29 ± 0.56	3.08	0.003	1.88 ± 0.96	2.00 ± 0.75	−1.00	0.318
Guilt	1.23 ± 0.53	1.24 ± 0.68	−0.11	0.914	1.28 ± 0.64	1.36 ± 0.64	−0.84	0.404
Fear	1.31 ± 0.66	1.17 ± 0.42	2.09	0.038	1.59 ± 0.87	1.67 ± 0.76	−0.63	0.527
Worry	1.36 ± 0.74	1.17 ± 0.42	2.57	0.011	1.54 ± 0.90	1.42 ± 0.65	1.09	0.279

Variations in negative affect and risk perception between the two time points

To address the initial two hypotheses, multivariate testing revealed a significant primary effect for time point [Wilks' $\lambda = 0.874$, $F(8, 513) = 9.21$, $p < 0.01$, $\eta\rho^2 = 0.13$]. Univariate follow-up results are detailed in **Table 3.** Covariates demonstrated significance: gender [$F(8, 513) = 2.71$, $p = 0.006$, $\eta\rho^2 = 0.04$], occupational category [$F(8, 513) = 3.45$, $p = 0.001$, $\eta\rho^2 = 0.05$], and deployment status [$F(8, 513) = 2.13$, $p = 0.032$, $\eta\rho^2 = 0.03$]. Following adjustment for these covariates, the time point exerted a significant influence on tension, fear, worry, and overall risk perception **(Table 3).** Levels of tension, fear, worry, and risk perception were markedly elevated in Period 1 relative to Period 2 (mean difference_tension = −0.38, $p < 0.001$; mean difference_fear = −0.30, $p < 0.001$; mean difference_worry = −0.16, $p = 0.024$; mean difference_risk perception = −2.76, $p = 0.002$). No meaningful variations emerged for impatience, sadness, upset, or guilt across the periods.

Table 3. Negative affect and risk perception stratified by Period 1 (peak of COVID-19 outbreak) and Period 2 (post-resumption of work).

Variable	Period 2 Mean ± SD	Period 1 Mean ± SD	F	p	ηρ²
Risk perception	34.83 ± 9.78	37.63 ± 9.51	9.446	0.002	0.018
Impatience	1.65 ± 0.86	1.58 ± 0.84	2.281	0.132	0.004
Sadness	1.40 ± 0.73	1.51 ± 0.83	0.493	0.483	0.001
Upset	1.81 ± 0.93	1.75 ± 0.91	1.173	0.279	0.002
Tension	1.51 ± 0.81	1.92 ± 0.90	22.739	0.000	0.042
Guilt	1.23 ± 0.56	1.31 ± 0.64	1.740	0.188	0.003
Fear	1.29 ± 0.62	1.61 ± 0.84	19.596	0.000	0.036
Worry	1.32 ± 0.70	1.50 ± 0.83	5.117	0.024	0.010

In the multivariate analysis of variance, gender, profession, and deployment status were included as covariates; ηρ² (partial eta squared) represents the proportion of variance accounted for by each predictor after partitioning out contributions from others.

Links between negative affect types and risk perception over the two time points

All subtypes of negative affect displayed significant associations with overall risk perception (all $p < 0.01$), and the magnitude of these relationships did not differ meaningfully between the two phases ($|z| < 1.96$). To further investigate the nuanced contributions of various negative affect components to risk perception in healthcare personnel, separate regression models were conducted for each phase, with aggregated risk perception designated as the criterion variable. In the initial block, categorical predictors were entered as dummy variables: gender (0 = female, 1 = male), occupational category (0 = physician, 1 = nurse), and deployment site (0 = Shanghai, 1 = Wuhan). The subsequent block assessed the unique contributions of the distinct negative affect subtypes **(Table 4).** Findings revealed that, after adjusting for intergroup covariates, worry emerged as the strongest predictor of risk perception during Phase 1 (B = 2.67, $p = 0.005$, SE = 0.95), whereas tension became the primary significant predictor in Phase 2 (B = 2.95, $p = 0.006$, SE = 1.06).

Table 4. Adjusted relationships involving gender, occupational role, deployment site, and specific negative affect subtypes (predictors) with overall risk perception (outcome), across Phase 1 (height of COVID-19 outbreak) and Phase 2 (following return to routine duties).

Predictor	Period 2 (N = 304)				Period 1 (N = 220)			
	B	SE	Beta	p	B	SE	Beta	p
Block 1	$R^2 = 0.006$				$R^2 = 0.026$			
Gender (1 = male)	0.29	3.58	0.01	0.935	2.15	2.40	0.09	0.370
Occupation (1 = nurse)	0.91	3.52	0.02	0.796	−4.43	2.03	−0.21	0.031
Location (1 = Wuhan)	−1.50	1.56	−0.06	0.334	0.28	1.38	0.01	0.839
Block 2	$R^2 = 0.273$				$R^2 = 0.274$			
Gender (1 = male)	1.62	3.13	0.04	0.604	−0.38	2.20	−0.02	0.862
Occupation (1 = nurse)	−0.08	3.07	0.00	0.981	−1.01	1.89	−0.05	0.595
Location (1 = Wuhan)	0.38	1.38	0.02	0.786	0.86	1.25	0.04	0.490

Impatience	0.73	0.88	0.06	0.407	0.19	1.16	0.02	0.869
Sadness	2.14	1.12	0.16	0.057	0.03	1.08	0.01	0.979
Upset	1.43	0.96	0.14	0.139	1.45	1.10	0.14	0.188
Tension	2.95	1.06	0.24	0.006	1.25	0.99	0.12	0.205
Guilt	−0.64	1.24	−0.04	0.606	−0.61	1.09	−0.04	0.575
Fear	0.56	1.50	0.04	0.708	1.46	1.20	0.13	0.226
Worry	−0.22	1.23	−0.02	0.856	2.67	0.95	0.23	0.005

** $p < 0.01$; Risk perception specified as the outcome variable.

Our results demonstrated that HCWs' risk perception and negative emotional responses varied according to gender, professional role, location, and pandemic period. The study also identified differences in how risk perception and negative emotions were associated across the two periods. Levels of tension, fear, worry, and overall risk perception were higher during Period 1 compared to Period 2. Notably, in Period 1, worry was the most significant negative emotion, indicating high risk perception, whereas in Period 2, tension became the predominant emotional indicator.

This study explored differences in risk perception and negative emotions, as well as variations in their associations among HCWs across two COVID-19 periods. The first hypothesis—that risk perception and negative emotions would decrease across successive periods—was supported, aligning with the course of the pandemic. These findings are consistent with longitudinal studies of SARS, which reported that risk perception initially increased and then plateaued [21, 31]. Public risk perception studies suggest that the novelty and uncertainty of COVID-19 disrupted cognitive safety systems, prompting increased information-seeking behaviors [32]. Risk perception, however, can be mitigated by effective vaccines or behavioral interventions, which likely reduce concern over time.

Regarding negative emotions, tension, fear, and worry significantly decreased from Period 1 to Period 2. During the peak of the pandemic, limited knowledge about the virus's origin and progression, along with delayed observable effects, resulted in heightened uncertainty and perceived public health threats [11]. Other studies also suggest that rising uncertainty amplifies risk perception through emotional appraisals [33]. As frontline responders, HCWs in high-risk areas experienced considerable tension, fear, and worry. In Period 2, protective measures had largely controlled the threat, and these negative emotions were alleviated, though not eliminated, as treatment options and vaccines were still in development. Interestingly, our study observed an increase in HCWs' feelings of upset in the later period, which mirrors findings in the German population showing sustained risk perception one month after the outbreak [34]. Persistent pandemic-related fear may reflect a long-term consequence rather than a pathological reaction [35], and anxiety related to COVID-19 has been shown to impose substantial daily life burdens [34, 36]. Practically, during the acute phase, tension, fear, and worry may hinder HCWs' rational assessment of protective behaviors for themselves and their patients. Coping strategies to manage these emotions can mitigate invisible losses and long-term consequences. In the later phase, effective emotional regulation can reduce perceived risks and enhance adherence to protective behaviors. Seeking support and acquiring knowledge further diminishes the negative effects of the pandemic. Monitoring risk perception and negative emotions among HCWs is thus essential to prevent potential resurgence.

Some between-group differences were noted. Female nurses and community health workers comprised most of the samples, reflecting their frontline role during China's COVID-19 response. Consequently, gender-related interpretations may be limited. However, prior research indicates that female HCWs are more susceptible to distress and depression [37, 38]. In Period 1, doctors exhibited higher negative emotions—including impatience, sadness, upset, and tension—and greater risk perception than nurses, likely due to high work stress and responsibility for patient care. This aligns with findings that experienced HCWs, such as nurses, are better equipped to handle crises [39]. In Period 2, nurses reported a higher risk perception than doctors, possibly because they had more direct patient contact and caregiving responsibilities.

Other studies indicate that being a nurse or frontline HCW increases risk factors for anxiety and depression [40], while HCWs continue to perform duties despite concern for personal and family safety [24]. Frontline HCWs often experience lower burnout and reduced

worry about illness due to perceived control and proximity to authority; however, prolonged work hours and unforeseen pandemic developments can increase stress, which may worsen negative emotional states and perception of risk [41–43].

In the later stage of COVID-19, undispatched HCWs reported higher impatience, sadness, tension, and worry than those dispatched to Wuhan, although their risk perception was similar. This may be attributed to greater psychological and material support provided to dispatched HCWs, consistent with findings by Cao *et al*., which indicated that family connection via technology was a key coping mechanism, rather than elevated burnout or distress [44]. Therefore, healthy coping strategies—including team support, organizational encouragement, and rational reflection—are critical for professional growth and resilience.

Future research should further examine differences between dispatched and non-dispatched HCWs to clarify the pandemic's impact on mental health, accounting for factors such as access to protective equipment and prior work experience. In our cohort, all HCWs were provided protective equipment and supplies, ensuring that concerns over PPE shortages were minimal compared to other countries where resources were limited [45]. Moreover, many Chinese HCWs volunteered for deployment to high-risk areas, bringing substantial medical expertise, which fostered a motivating organizational environment and encouraged junior staff. These factors may explain the relatively lower negative emotions among dispatched HCWs. Understanding these influences can offer valuable lessons for protecting frontline HCWs in future public health crises.

After adjusting for confounding variables such as gender, professional role, and location, further analysis of the relationship between negative emotions and risk perception supported our third hypothesis and highlighted the concept of emotion-driven risk perception. Research suggests that automatic incentive or alarm signals associated with intuitive "gut feelings" often occur before deliberate cognitive reasoning [46]. Similarly, cognitive processing theories underscore the significance of an emotion–cognition pathway [47, 48]. Negative emotions function in a dual capacity: as sources of information and as motivational forces. In acute-threat contexts like COVID-19, emotions may become particularly influential in their informational capacity, with individuals using negative feelings linked to a subject to evaluate that subject unfavorably. When experts provide uncertain or partially conflicting guidance, cognitive assessments of risk may be limited due to insufficient evidence-based information. Under such conditions, individuals are often compelled to rely on experiential judgment, which is heavily shaped by emotional state. Therefore, the uncertainty of COVID-19 induced negative emotions in HCWs, contributing to heightened perceptions of risk.

Our study provides insight into how emotions affect risk perception through a repeated cross-sectional design. The analysis indicated that worry was a key contributor to elevated risk perception immediately following the outbreak. However, the dominant components of negative emotions shifted as the pandemic progressed; in the second period studied, tension—reflecting the local context and severity of the pandemic—emerged as the primary driver of risk perception. The precise mechanisms through which emotions interact with risk-related cognition and behavior remain unclear. Only a limited number of studies examining risk perception's role in protective behaviors have incorporated emotion-based explanations [49–51]. The motivational function of negative emotions remains debated, partly due to limited opportunities to study the complexity of decision-making processes, which also complicates the interpretation of findings regarding the link between risk perception and protective behaviors. Employing multifactor models that integrate emotion-based frameworks could yield more comprehensive insights into how risk perceptions shape behavior.

Implications

HCWs operate under continuous psychological stress. Perceived risk, lack of control, elevated stress, and negative emotional arousal are all factors that threaten their well-being. Prolonged stress can lead to post-traumatic stress disorder, anxiety, and depression. If unmanaged, these conditions can have repercussions not only for HCWs but also for patients and healthcare systems, including physical health problems, impaired decision-making, reduced quality of care, absenteeism, and negative attitudes. Critically, negative emotions strongly influenced HCWs' risk perceptions, which are closely linked to protective behaviors. HCWs serve as intermediaries between health authorities and the public, shaping compliance with policies or vaccination programs, yet their perceptions are often guided by emotion and the tangible relevance of perceived risk. Even healthcare professionals can experience cognitive

dissonance when emotions conflict with rational assessments [52].

Therefore, it is crucial to implement targeted interventions to support HCWs during and after crises, preventing more severe consequences. Training in emotional coping strategies should be prioritized, enabling HCWs to integrate emotions with analytical reasoning while mitigating the negative bias in risk perception. Risk communication plans should account for HCWs' negative emotions, especially worry, and proactive measures should be enacted immediately after a crisis to alleviate emotional tension and enhance preparedness.

Limitations

This study has several limitations that should be acknowledged. First, data collection relied on mobile devices during COVID-19, which may have introduced sample bias. Frontline HCWs experienced heavy workloads during both periods, potentially missing survey invitations, or their phone usage was restricted to prevent virus transmission, resulting in lower response rates than anticipated. Additionally, both samples had disproportionate representation of females versus males and nurses versus doctors, particularly in Period 2. Future research should aim to recruit larger, more balanced samples.

Moreover, several potentially relevant factors, such as age differences and prior work experience, were not examined due to time constraints, limiting the generalizability of the results. Another limitation is the repeated cross-sectional design used to compare negative emotions and risk perception across two periods. Although between-group characteristics were relatively stable and controlled, participants in Period 1 and Period 2 were only "comparable" based on assumed relevant factors, rather than being strictly the same individuals. Because a strict longitudinal sample was not employed, analysis could not be restricted to participants present at both time points. While analyses were conducted on two separate subgroups rather than a pooled sample, unmeasured commonalities (e.g., age, education) may have influenced standard errors. Using fixed-effects approaches to control for time-specific influences may limit the analysis to static processes. Consequently, future research with larger, longitudinal designs could provide more rigorous validation of time-point comparisons.

Furthermore, this study provides only a snapshot of HCWs' emotional and cognitive responses during two periods of the pandemic. The complex interactions and multidimensional causality among factors could not be fully elucidated. For example, follow-up studies could more convincingly assess the effects of being forcibly dispatched to high-risk areas or experiencing shortages of personal protective equipment, which could help inform targeted support services for HCWs.

Conclusion

The key contribution of this study lies in its investigation of HCWs' risk perception and negative emotions across two COVID-19 periods. Findings indicated that both risk perception and negative emotions were influenced by the pandemic. The predominant negative emotions varied over time, but their relationship with risk perception remained stable, serving as a significant indicator. These results highlight the critical role of negative emotions in shaping HCWs' perception of risk while facing pandemic-related challenges in the Chinese context.

Importantly, the study emphasizes that understanding how pandemic-related risk perceptions evolve over time remains essential. This requires not only research initiated after future outbreaks but also long-term surveillance studies conducted prior to potential crises to capture the "true" dynamics of risk perception and emotional responses.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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