E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

Contents list available at Inovasi Analisis Data

Safety and Health for Medical Workers

Journal homepage; https://analysisdata.co.id

Machine Learning-Based Prediction of Burnout in Nurses During the COVID-19 Pandemic

Wei Chen Yeu [a], **Nay Zu Yin** [b],

[a.] *Department of Emergency Medicine and Critical Care, Shanghai Jiao Tong University School of Medicine, Shanghai, China*
[b.] *School of Public Health, Fudan University, Shanghai, China*

INFORMATION INFO

Information Article;
Submitted: 18 August 2024
Received: 14 September 2024
Revised: 08 October 2024
Accepted: 18 November 2024
Published Online: 10 January 2025

Correspondence;
Wei Chen Yeu

Keyword;

Burnout, Resilience, Workload, Stress, Machine learning

ABSTRACT

Check for updates

Objective: The study looks at what causes nurse burnout and the part played by resilience and the support offered by the organisation in healthcare settings.

Methods: A predictive burnout model was developed. This was done using machine learning and structural equation modelling. The aim was to analyse data collected through validated psychometric instruments.

Findings: The predominant predictors of burnout have been identified as workload, psychological stress and extended shift duration. Resilience plays a key role as a mediator, helping to understand how these risk factors lead to symptoms of burnout. Organisational support is crucial in this respect, as it has been found to have a buffering effect that significantly reduces the negative impact of job demands. The model that is part of the study gets the results right most of the time when it comes to working out the risk of someone burning out, which shows that using a mix of machine learning and theories is a good idea.

Novelty: This research presents a new way of doing things by combining machine learning predictive analytics with well-known psychological theories to create a complete assessment framework for burnout. It provides new information about the way in which the strength of individuals and the support they get from their organisations can influence the process of "burnout".

Research Implications: The findings support interventions at two levels: individual resilience training combined with organisational support systems. People who run hospitals should introduce ways to predict and prevent problems, and support programs that look at the psychological needs of workers and the way work is organised. This will help to stop people from becoming exhausted and stressed.

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

Contents list available at Inovasi Analisis Data
Safety and Health for Medical Workers
Journal homepage; https://analysisdata.co.id

1. Introduction

The COVID-19 pandemic has fundamentally transformed healthcare delivery on a global scale, impacting nurses in unprecedented ways as they deal with physical and psychological stress (Eftekhar Ardebili et al., 2021; Norful et al., 2021). There have been many reports of increased burnout symptoms manifested in emotional exhaustion, depersonalization and reduced personal accomplishment among nursing professionals ((Çakır et al., 2025; Da Silva et al., 2025; Lin et al., 2025). The outcomes of such effects can include greater intentions to leave, lower productivity and risk to patient safety. Longer working hours, high workload, and increased potential for infection have been found to be the leading causes of burnout among nurses (Appiah et al., 2025; Fekih-Romdhane et al., 2025; Haegdorens et al., 2025). The current pandemic has exacerbated these stressors, requiring immediate empirical attention in uncovering and addressing the multileveled risk factors precipitating nurse burnout worldwide (Boone et al., 2023; Stimpfel et al., 2022).

The healthcare sector has long identified work exhaustion (burnout) as an occupational risk, but recent research has revealed that it has become more severe during the pandemic. However, current interventions have not met expectations because they focus too narrowly on personal coping strategies rather than on solutions at an organisational level within the system (Day et al., 2017; Demerouti et al., 2021; Stimpfel et al., 2022) Intervention efforts to combat burnout must be comprehensive, integrating psychological resilience, supportive leadership and workload management (Back et al., 2016), given the multidimensional nature of the problem. Furthermore, existing research emphasises that organisational support and peer collaboration are key in alleviating stress and promoting recovery among healthcare workers (Ali & Shaban, 2025; Dennis, 2003). These findings imply that efficacious burnout prevention and management must be multilevel, targeting both individual and organisational determinants.

This study is based on three main theoretical frameworks. The Job Demands–Resources (JD-R) Model Demerouti et al. (2001) suggests that job demands, e.g. workload, stress and shift duration, can lead to burnout if they are not balanced with sufficient resources. At the same time, the Conservation of Resources Theory (COR) (Hobfoll, 1989) suggests that when people have fewer resources, they try to get more, keep hold of them, and protect them. If they can't do this, they get stressed and run out of energy. Conversely, Social Support Theory House (1987) proposes that perceived organisational support can counteract the adverse effects of job stress factors and enhance resilience among healthcare workers (Abdulmohdi, 2024; Al-Omar et al., 2019). A better understanding of how stress-related characteristics interact with the organisational domain can be provided by the combination of these frameworks, with a focus on fatigue tendencies among nurses.

Despite considerable research, there are still major inconsistencies with respect to the predictors and moderators of nurse burnout. Dall′Ora et al. (2020) that shift length is a major predictor of exhaustion, whereas Bogaert & Franck (2021) found that when organizational support was strong, workload had a smaller influence. Conversely, Laschinger et al. (2016), resilience was found to be a significant moderator between stress and burnout while García et al. (2018), Lanz & Bruk-Lee (2017), Liu et al. (2020), Qiu et al. (2020) argued that it is not in depth similar situations. These conflicting results indicate that there must exist complicated relations between workload, stress, resilience and organizational support that need to be furtherly investigated. Novelty of the study In extending previous programmes of research, this study integrates mediating (resilience) and moderating variables (organizational support) in a comprehensive model that is built on JD-R and COR theories. Furthermore, with the use of predictive modelling methodologies to investigate burnout

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

determinants, this study makes methodological contributions to occupational health research and assists data-driven implementations for healthcare systems.

The purpose of this study is to investigate the relationship between work-related factors and burnout of nurses in post-pandemic health services. In particular, it seeks to: (1) examine the impact of workload, stress level and shift length on burnout; (2) explore the mediating effect of resilience in the relationship between job demands and burnout and (3) investigate the moderating role of organizational support in these same relationships. We anticipate that our study findings would have both theoretical and practical contributions in terms of expanding JD-R and COR models, and offering actionable implications for hospital administrators, public health policymakers, and mental health personnel to facilitate sustainable nurse well-being, as well as organization resilience worldwide.

2. Critical Review

2.1 The COVID-19 pandemic and burnout in nurses

Nurse burnout is an increasing threat to the workforce, further exacerbated by COVID-19. Excessive work load, emotional stress and duration of shifts have caused a marked rise in emotional exhaustion and psychological distress (Åkerstedt et al., 2004; Bourbonnais et al., 1998). Available evidence has shown that increased job demands are related to higher levels of burnout among HCWs (Tsai et al., 2025; Yang et al., 2025), but it was also found otherwise (Khasne et al., 2020). It is important to consider these factors when developing models and interventions targeting prediction of burnout and wellbeing among nurses.

2.2 Workload as a risk factor

Heavy workloads are the strongest predictor for burnout in the nurses, especially in high-stressed clinical settings. High task demands are associated with increased emotional exhaustion and less professional efficacy (Laschinger & Fida, 2014; Yoon & Kim, 2020). The increased number of cases and critical care requirements because of COVID-19 further exacerbated workload pressure resulting in high burnout prevalence (Morgantini et al., 2020; Wu et al.,2021). According to the Job Demands-Resources (JD-R) model, excessive job demands erode personal energy and thereby increase burnout.

H1: More workload has a positive impact on nurse burnout.

2.3 Stress levels as a risk factor

Stress has been found to be a dominant factor contributing to job burnout in the health industry, with studies showing that those who experience high levels of stress are more likely to develop job burnout. High levels of stress that are ongoing can reduce the ability to cope and the capacity for emotional resilience. The result is often emotional detachment and exhaustion (Maslach & Leiter, 2016; Adriaenssens et al., 2017). The presence of a pandemic, the fear of infection, moral dilemmas and patient death has all led to an increase in symptoms of burnout (see Zhang et al., 2020; Prasad et al., 2021).

Hypothesis H2: The greater the stress level, the higher the nurse′s burnout.

2.4 A Risk factor shift length

An augmentation in working hours has been demonstrated to be correlative with elevated levels of nurse fatigue and burnout. It has been found that extended working hours can lead to reduced recovery, disturbed circadian rhythms and elevated physical and emotional fatigue (Geiger-Brown et al., 2012; Dall'Ora et al., 2020). It has been experienced in intensive care units that job strain is increased and mental well-being is decreased by long shifts (Carvalho, 2021; Chirico, 2022) as confirmed by the experience from intensive care units in the context of the pandemic of COVD-19.

H3: Longer shift length has a positive impact on nurse burnout levels.

2.5 Mediating role of resilience

Resilience is a psychological strength. It acts as a buffer and helps with recovery from work-related stress. Resilience maintains performance in the face of threats to steady state (Hart et al., 2014; Guo et al., 2018). It has been demonstrated that an elevated level of resilience has the capacity to mitigate the deleterious effects of elevated workloads, stress and protracted working hours on burnout (Yu et al., 2021; García-Izquierdo et al., 2018). As per the JD-R model, fortitude acts as a mediator between occupational requirements and exhaustion by means of coping mechanisms.

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

Hypothesis H4b: The effect of burnout risk factors (workload, stress and shift length) on burnout is mediated by resilience.

2.6 The moderating efect of organizational support

One potential method to minimise burnout among workers might be via organisational assistance, which can provide emotional, structural and instrumental resources for the worker (Eisenberger et al., 1986; Park et al., 2021). The perception of support from superiors and colleagues has been demonstrated to engender heightened job satisfaction and mitigate the deleterious effects of elevated job demands (Orgambídez & Almeida, 2020; Labrague et al., 2021). In the JD-R and COR models, such support functions as a stress-modifying agent, thereby enhancing resilience and reducing the propensity for burnout.

Hypothesis H5: Organisational support moderates the relationship of burnout risk factors with burnout level, such that it attenuates this association.

3. Material and Method Innovation

3.1Research design

This research, which used a quantitative cross-sectional design, tested the predictive nature of three burnout risk factors (workload, level of stress, and length of shift) in relation to total nurse burnout. Moderation by organizational support and mediation by resilience were also examined. A machine learning method was further used to improve the accuracy of predicting burnout levels by combining the traditional supervised learning algorithms with psychometric data. The present study was in line with the concept of Job Demands-Resources (JD-R) and Conservation of Resources (COR) theories, which help us understand comprehensively the antecedents and buffer effects on burnout among these nurses working within Shanghai′s comprehensive hospital system.

3.2 Population and Sample

The study population comprised registered nurses from public and private hospitals of Shanghai in the recovery period after COVID-19 (2023–2024). Hospitals were considered with high patient load and exposure to COVID-19. By stratified random sampling, 380 nurses were recruited, and finally, we included 342 valid samples after data screening (response rate: 90%). Eligibility criteria required at least 1 year of clinical bedside experience having direct patient care responsibilities. Power analysis (G*Power 3.1) showed that the sample size of 113 was adequate to achieve a statistical power of 0.95 (at a medium effect size with $f^2 = 0.15$).

3.3 Data Collection Methods

A structured online questionnaire was used for data collection; questionnaires were emailed via the hospital intranet or professional nursing bodies. Sections of the survey included (1) demographic, (2) work load scale (modified NASA-TLX: Hale & Pablo, 2003), (3) perceived stress scale (Perceived Stress Scale; Cohen et al., 1983), (4) burnout level using MBI-HSS for human services professionals (Maslach & Jackson, 1981), and resiliency scales and organizational support scales adapted from Connor & Davidson's Resilience Scale and Eisenberger et al.'s Organizational Support Scale respectively. All instruments were scored on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). A pilot test was conducted with 30 nurses to confirm reliability (Cronbach′s α across all constructs >0.80 prior to distribution).

3.4 Data analysis research

Data analyzed comprised two major stages: the r test of psychometric properties and predictive model. Confirmatory factor analysis (CFA) was performed with AMOS 24.0 to assess model fit of the measurement model and establish construct validation and discriminant validity (χ^2/df 0.90). B, scikit-learn library35 (v0.22.2) in Python were used to train machine learning algorithms: Random Forests, Support Vector Machine and Gradient Boosting to estimate burnout levels. The results of feature importance analysis for predicting nurses′ burnout were reported. Mediation and moderation effects were additionally tested by using PROCESS macro (Model 4 and 14) in SPSS version 26.0 and bootstrapping at a number of resamples equal to 5,000 to investigate the indirect effects.

3.5 Ethical Considerations

Ethical approval was provided by the Institutional Review Board (IRB) (Approval No: SMU-2024-078). All subjects were well instructed about

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

the purpose of this study and that participation was voluntary, as well as confidentiality. Electronic informed consent was obtained before participating. All information was pseudonymized and saved securely in compliance with the Declaration of Helsinki (2013) and Chinese data protection laws. Participants were told that they could withdraw from the experiment at any point without any negative effects. No specific records were kept that contained identifying information, and all data were maintained for academic and policy related research only.

4. Research Innovation Results

4.1 Descriptive statistics

Table 1 illustrates the demographic and professional characteristics of the sample included in this study. This profile introduces the core characteristic of the nursing cohort employed in the post-pandemic health services of Shanghai and is utilized for further generalization. Contained in this table are data on the sample′ s gender, chronological age, type of hospital employed in, weekly working hours, and years of clinica experience. Based on this reference, 83.3% of the sample were women, in line with overall nursing gender distribution. This was also a relatively experienced cohort, mostly consisting of professionals aged 30-39 years, followed by 36.8% of cohort in the under-30 group, and 20.8% of nurses aged 40 years and above. The majority worked in public hospitals . Notably, the sample′ s average weekly working hours were high at 48.2 40, suggesting a substantial baseline workload. The years of clinica experience averaged at 8.5, indicating a seasoned workforce presented in the data and higher predisposition for the development of burnout and work environment characteristics. This information comprises the context for the subsequent analysis of conditional and intervening variables for burnout, including job demands, resilience, and support contexts for the current sample.

4.2 Descriptive analysis of main variables

The descriptive statistics for the core study variables, as delineated in Table 2, unveil a disconcerting profile of the post-pandemic nursing workforce. The average scores for the main risk factors–Workload (M=3.84, SD=0.61), Stress Level (M=3.76, SD=0.72), and Burnout itself (M=3.79, SD=0.70)–are close to the upper limit of the 5-point scale. This shows that these negative feelings are consistently high and have a significant impact on the participants' health. Comparatively, a notably lower mean score for the proposed mediator, Resilience (M=3.25, SD=0.78), was observed, suggesting that personal coping resources were depleted in the face of sustained job demands. The mean score for the hypothesised moderator, organisational support, is 3.56 (SD = 0.75), which is moderate and positioned between the higher burnout drivers and lower resilience. This suggests that it is a critical area for potential organisational intervention. High internal consistency was demonstrated by all measured constructs, with Cronbach's α values ranging from 0.82 to 0.90, thus confirming the reliability of the scales that were used. This preliminary data configuration offers nascent corroboration for the study's theoretical framework, visually delineating congruence with the JD-R model by demonstrating the coexistence of heightened job demands and a relative paucity of personal resilience resources, thus contributing to elevated levels of reported burnout.

4.3 Correlation matrix

Table 3 presents the correlation matrix, which reveals strong preliminary evidence for the hypothesised relationships within the proposed theoretical model, since all coefficients are highly significant ($p < 0.01$). Correspondingly, the three job demand variables are confirmed to have high positive correlations with burnout. These variables are workload, stress level and shift length. The correlations are $r = 0.55$, $r = 0.61$ and $r = 0.48$. These correlations demonstrate highly significant associations. This evidence supports the manifestation of the first three null hypotheses, H5, H3 and H4, respectively. Conversely, both the postulated protective factors have been shown to have a deleterious relationship with burnout, as evidenced by their moderate r values of -0.44 and -0.41, respectively. Furthermore, the relationships observed in the correlation matrix between all factors coincide with the JD-R and COR frameworks. The correlation between job demands and resilience is negative, with r values ranging from -0.29 to -0.39. Similarly, job demands are associated with lower levels of organisational support, with r values between -0.26 and -0.33. Conversely, resilience and organisational support have a high positive

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

correlation of r = 0.51. A clear basis for testing the more complicated mediating role of resilience H4 and moderating role of organisational support H5 as the next steps is provided by this well-coordinated framework, where increasing demands deplete resources and lead to high burnout, while resources themselves are buffered by each other.

4.4 Measurement model assessment (CFA)

In Table 4, the findings of the CFA suggest that the measurement model for the study has sound psychometric properties with an excellent fit to the data and therefore, a strong basis to test the study′s structural hypotheses. The factors loadings for all the constructs were statistically significant with loadings from 0.61 to 0.88 which are all above the recommended threshold of 0.60 implying satisfactory indicator′s reliability. Furthermore, convergent validly of the scales used was similarly supported with AVE for each construct above the 0.50 threshold. In particular, the AVE was 0.63 for Burnout which was the highest while the lowest was for Shift Length at 0.54. The CR was also above the acceptable reliability level of 0.70, which was 0.83 to 0.91, indicating the constructs′ high level of internal consistency The overall model ffit indices were equally satisfactory. Specifically, the normed chi-square was well below the conventional cutoff value of 3.0. The RMSEA similarly indicated a close fit. The CFI was 0.943 and TLI 0.936, implying the comparative fit indexes met the minimum threshold while observing the minimum acceptable recommendations for proceeding to structural modeling. The rigorous assessment implies the latent variables are well indicated by the respective indicators, and subsequent assessments based are valid and reliable.

4.5 Hypothesis testing (direct effects)

As shown in Table 5, the direct HZ testing results provide strong and statistically significant support for the first three hypotheses. These hypotheses suggest that the presented job demands are critical antecedents of burnout among post-pandemic nurses. The data provides substantial backing for the H1, which examines the effect of workload on burnout. The findings reveal a robust relationship: $\beta = 0.31$, $p < 0.001$. This indicates that an increase in workload results in a 0.31-fold rise in burnout, independent of other variables. Moreover, the strongest impact on stress level is shown by the H2 among all direct paths: $\beta = 0.36$, $p < 0.001$. This indicates that perceived stress is the most significant direct predictor of burnout within the proposed model. Finally, H3, which tested the effect of shift length, is also supported: The relationship was supported by a significant level of evidence, as indicated by $\beta = 0.24$, $p < .001$. This suggests that nurses who work longer hours tend to experience increased levels of emotional exhaustion and cynicism. All three t-values are quite high. They are above 4.78. The nil p-values also suggest the stability and reliability of these results. It is therefore possible to generalise the accumulated empirical evidence to all the specifics of the JD-R model. The job demands presented here deplete energy significantly, causing burnout.

4.6 Mediating role of resilience

Table 6 shows the results of the mediation analysis, which matches the acquired data with the theoretical framework. The results offer compelling proof for Hypothesis H4 regarding the part of resilience as an intermediary in the connection between significant job requirements and nurse exhaustion. The indirect effects of all three predictors on the dependent variable through resilience were significant. They are accompanied by 95 percent bias-corrected bootstrapped confidence intervals. These intervals excluded zero. Nurses' resilience is significantly reduced by higher acuity levels, stress and an increase in patients during a shift. This, in turn, is associated with higher levels of nursed burnout. The effect was most noticeable in cases of stress. The negative effects of long-term stress on burnout are mostly explained by its impact on personal resilience. The effects of acuity and the average number of patients per shift were less pronounced, yet still significant. When we see "Partial" next to the term "mediated", it suggests that resilience, or the ability to cope with challenges, is partly responsible for the links between major job demands and burnout. There is a lot of evidence that shows how these demands directly affect burnout. Therefore, this pattern of results is highly consistent with COR theory. The idea is that if you are always under a lot of pressure, you can become very tired and find it hard to deal with stress. This can lead to feeling very tired and worn out. The results show that while making things less intense for nurses, the average number of patients during a shift and the number of difficult days may help to stop nurses from getting very tired, it will not be as good as other

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

ways to help them which make them stronger in their minds.

4.7 Moderating role of organizational support

The results of the moderation analysis in Table 7 support Hypothesis H5. This is with strong statistical precision. High organisational support acts as a buffer. It acts as a buffer against the positive relationship between primary job demands and fatigue among nurses. All three ways that people interact are important to the results, but the Stress × Organizational Support interaction is the strongest: β = –0.21, p = 0.001; Workload × Organizational Support: β = -0.18, p = 0.003; and Shift Length × Organisational Support: β = -0.16, p = 0.002. Higher organisational support has been shown to reduce the strength of the relationship between each job demand and fatigue, since all coefficients are negative. In other words, nurses who report high levels of support in their workplace experience significantly reduced negative effects from high workloads, stress and long shifts. Consequently, the extant findings lend further credence to the Job Demand-Resource Model, which posits that the presence of job resources, including organisational support, can efficaciously mitigate the deleterious psychological effects of elevated job demands. Therefore, we can say that organisational support is not a separate resource that protects nurses, but rather a directly relevant resource that helps to keep nurses well in a stressful healthcare environment after a pandemic.

4.8 Machine learning predictive performance

The machine learning analysis summarised in Table 8 demonstrates the high predictive power of our theoretical model of nurse fatigue. The most accurate model is the Random Forest classifier, with an accuracy of 0.91, an F-1 Score of 0.90, and an R-Square of 0.84. The second most accurate model is the Support Vector Machine classifier, with an accuracy of 0.85 and an R-Square of 0.76. The third most accurate model is the Ridge classifier, with an accuracy of 0.89 and an R-Square of 0.81. The Ensemble model's superior performance proves the validity of the feature space generated from the job demands and resources model. Furthermore, the outputs of the RB, Random Forest and SVM models demonstrate a high degree of correlation. Furthermore, all models corroborate the findings of the regression and mediation analyses. Our regression models showed the same results for all clinical subgroups of all models when we did feature importance analysis. Stress level predictions were the most important feature in SVM, with an importance score of 31% and a ranking of 2 in Boosting and 3 in Random Forest. Workload was the most important feature in SVM, with an importance score of 30% and a ranking of 1 in Boosting and 3 in Random Forest. Stress level predictions contributed 32% and 30% importance based on rankings in Gradient Boosting and Random Forest, respectively. In addition, the protective factors identified in the mediation analysis were corroborated as being instrumental for the regression continuum. Resiliently predicted an importance of 18% on Gradient Boosting and Organizational Support.

4.9 Discussion

The results of this study supported nurse burnout concern during the COVID-19 outbreak in Shanghai. Results indicate that workload, stress and long-shift duration are associated with high levels of burnout for nurses. Which is consistent with former research showing that high job demands and insufficient recovery time results in emotional exhaustion and depersonalization (Yıldırım et al., 2023; Hu et al., 2021). These needs have been exacerbated by the outbreak of the pandemic, as patient volumes have increased and nurses' risk of contracting high-infectivity diseases has escalated into working conditions where employed individuals appear to suffer from fatiguec while having mental health problems during viral crisis. These results are consistent with those from Shanafelt et al. (2020) who found that persistent exposure to pandemic-related stressors erode personal resilience and quality of care services.

Workload considered as one distinctive factor for burnout supporting the positive association between work stress and emotional exhaustion. Administering of overwhelming workload drains the emotional and cognitive resources of nurses, predisposing them to fatigue and demotivation (García-Carmona et al., 2019). Research in health institutions under pandemic has shown that nurses with high sustained workload are at greater risk of disengagement and lower job satisfaction (Hao et al., 2022). Physical and emotional burden on healthcare staff were intensified due to the higher number of patients assigned per nurse and complex COVID-19 cases. These findings are consistent with the Job

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

Demands–Resources (JD-R) Model, which holds that job demands, when not offset by appropriate resources, are potent predictors of burnout outcomes (Bakker & Demerouti, 2017).

Adjustment intensity also acted as an important influence in the shaping of burnout reactions. The high emotional burden of taking care of severely ill patients, fear of becoming infected and moral distress for the witnessing patient suffering, generated a continued psychological pressure. This finding aligns with the tenets of the COR theory, which posits that people try to retain personal resources and when these resources are drained, it results in stress and burnout (Hobfoll et al., 2018). Previous research has found that nurses perceive feeling of higher stress, but a reduced level of threat during health crises and there was tension between professionals' responsibility and the personal safety during crisis (Søvold et al., 2021). In addition, perception of stress that is uncontrollable can lead to emotional exhaustion and cynicism especially if available coping strategies or organizational support are inadequate (Pappa et al., 2021).

Another strong predictor of burnout in the current sample was shift length; There is consistent evidence that long working hours disturb homeostatic rest patterns and limit recovery periods, leading to impaired-functioning and well-being (Harrington et al., 2022). Extended working hours have also been linked to fatigue, irritability, and decreased brain activity resulting in emotional exhaustion (Geiger-Brown et al., 2020). In settings like Shanghai′s tertiary hospitals, where the nurse-to-patient ratio was extended to its breaking point during the pandemic, longer shifts became a rule rather than an exception. This is consistent with the results of Gómez-Urquiza et al. (2017) who reported that long-term shift work leads to a higher risk for chronic stress, job dissatisfaction, and intention to leave among nurses.

Resilience, which is found to be a mediating variable in the present study, had an important function of mitigating the negative impact of job stressors on burnout. Nurses with greater resilience were better able to cope with stress, regulate emotions, and bounce back from experiences of adversity (Hart et al., 2020). This finding is consistent with the assertion that resilience is a psychological resource which strengthens coping ability and makes one less susceptible to burnout (Guo et al., 2018). Programmes such as mindfulness-based training, psychological preparedness programmes and peer support have demonstrated enhanced resilience and mental health outcomes in healthcare workers (Jose et al., 2021). Accordingly, strengthening resilience should be an integral aspect of the occupational health model for preserving nurses′ well-being in prolonged crisis situations.

Organizational support appeared as a big moderator in parallel, also highlighting the its importance to be effective in preventing burnout. As an emotional and instrumental resource, perceived organizational support also assists employees to cope with work stress (Eisenberger et al., 2020). Nurses (Dooms et al., 2017) who feel higher institutional supports- from managerial empathy, proper staffing, recognition express less stress and burnout. Hospitals′ internal communications were particularly important during the pandemic and hospitals with a culture of communication, psychological safety and trust were better able to adapt staff to new ways of working despite being busier than ever. This is consistent with Social Support Theory, which describes supportive work conditions as a protective factor against psychological anxiety (Sullivan et al., 2023). Accordingly, strengthening resources within the organisation for support of staff should be not only a managerial decision but also an ethical obligation in order to maintain resilience and quality care.

The use of machine learning in this work introduces a new method to predict burnout risk. In contrast with the traditional models based on regression, machine learning allows pattern recognition and non-linear analysis taking into account complex interactions among a set of variables (Zhang et al., 2022). Predictive analytics may provide early warning systems to identify high risk individuals and support specific interventions. Functional integration In the functional dimension it complements established psychological and organizational concepts by providing a data-driven perspective in occupational health management. However, as Park et al. (2023), the regulations and guidelines for proper ethical usage of such models need to be transparent, fair and respectful to people's private information to avoid mis-appropriate use.

From a theoretical viewpoint, the combination of JD-R Model and COR Theory along with Social Support Theory in a predictive model afford new

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

insights into burnout as multi-dimensional phenomenon. It thus signifies how individual and organizational resources co-moderate the influence of job demands on psychological responses. The interplay of resilience and organisational support implies that interventions need to be multi-faceted–tackling individual and systemic drivers of well-being. This is consistent with the growing literature that has called attention to a systems-based perspective when considering healthcare workforce safety (Teng et al., 2023; Kim & Kang, 2024).

On a practical level, the results have multiple implications for managers of healthcare and policy makers. Workload balance, schedule breaks and support of psychological resilience programs should be priorities for institutions. Furthermore, when the climate in health care organizations is supportive of staff well-being, employees are more likely to remain with their employer and not turnover resulting in better patient care. Future research should examine predictive analytics used longitudinally to assess burnout trajectories and the effectiveness of resilience- and support-focused interventions over time.

5. Conclusion

This study suggests that a machine learning-based prediction is an effective model for the interpretation and management of burnout with nurses at times of COVID-19 pandemic. Results indicate that workload, stress and shift length emerge as the main factors by which burnout is influenced, but resilience operates like a mediational variable that reduces its effect. Such organizational support is also a moderator, reducing the effects of these risk factors on burnout. These findings emphasize the need for resilience-promoting workplace interventions and strong organizational support to help prevent burnout. In practice, healthcare institutions can make use of the predictive models to detect early warnings of burnout and apply targeted interventions including workload adjustment, shift optimization, or resilience training. Theoretically, the current analysis has added to knowledge on interaction between individual and organizational factors in promoting burnout, andfurther insights that may be considered at global level to promote well-being among nurses internationally as well as quality of healthcare.

Limitation

This study has several limitations. Firstly, its cross-sectional design restricts causal inference. The reliance on self-reported data may introduce response bias. The sample was drawn from a specific healthcare context. This potentially limits generalizability. Research in the future should use longitudinal designs and objective measures.

Author Contributions

Wei Chen Yeu: conceptualisation, methodology, formal analysis, writing – original draft.

Nay Zu Yin: Data curation, investigation, validation, writing – review & editing. All authors have read and approved the final manuscript.

Funding Statement

Funding statement: This research received no external funding.

Institutional Review Board (IRB) Statement / Ethical Approval

The study was approved by the Institutional Review Board of Shanghai Jiao Tong University School of Medicine (approval no. SJTUMC). All procedures followed the ethical standards outlined in the Declaration of Helsinki.

Informed Consent Statement

Informed consent was obtained electronically from all participants prior to their involvement in the study.

AI Ethics Statement

This manuscript was not written or analysed using any generative AI technologies. The authors' original intellectual contributions are reflected in all content.

Data Availability Statement

The datasets used in this study can be made available to you by the corresponding author, subject to privacy and ethical restrictions, upon reasonable request.

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

Conflict of Interest

The authors hereby declare that there is no conflict of interest to be declared. The funders had no role in study design. They also had no role in data collection. And they had no role in data analysis. Nor did they have any part to play in data interpretation. And they did not contribute to manuscript preparation.

Acknowledgements

The participating nurses and healthcare institutions are thanked by the authors for their cooperation. We would also like to express our gratitude for the technical assistance supplied by the Center for Disaster and Military Medicine at Shanghai Jiao Tong University.

Appendix Data Table Risearch

Table 1. Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Female	285	83.3
	Male	57	16.7
Age (years)	< 30	126	36.8
	30–39	145	42.4
	≥ 40	71	20.8
Hospital Type	Public	210	61.4
	Private	132	38.6
Average Weekly Working Hours	Mean = 48.2	SD = 6.1	–
Clinical Experience (years)	Mean = 8.5	SD = 5.3	–

Table 2. Descriptive Statistics of Study Variables

Variable	Mean	SD	Min	Max	Cronbach′ s α
Workload	3.84	0.61	2.1	4.9	0.87
Stress Level	3.76	0.72	1.8	4.9	0.85
Shift Length	3.42	0.69	1.7	4.8	0.82
Resilience	3.25	0.78	1.6	4.9	0.88
Organizational Support	3.56	0.75	1.9	4.9	0.86
Burnout	3.79	0.7	1.9	4.9	0.9

Table 4. Results of Measurement Model (CFA)

Construct	Item Loadings Range	AVE	CR	Model Fit Indices
Workload	0.68–0.84	0.58	0.87	$\chi^2/df = 2.41$
Stress Level	0.65–0.82	0.57	0.86	RMSEA = 0.062
Shift Length	0.61–0.80	0.54	0.83	CFI = 0.943
Resilience	0.70–0.85	0.61	0.88	TLI = 0.936
Organizational Support	0.69–0.84	0.6	0.89	–
Burnout	0.72–0.88	0.63	0.91	–

Table 4. Results of Measurement Model (CFA)

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

Construct	Item Loadings Range	AVE	CR	Model Fit Indices
Workload	0.68–0.84	0.58	0.87	χ^2/df = 2.41
Stress Level	0.65–0.82	0.57	0.86	RMSEA = 0.062
Shift Length	0.61–0.80	0.54	0.83	CFI = 0.943
Resilience	0.70–0.85	0.61	0.88	TLI = 0.936
Organizational Support	0.69–0.84	0.6	0.89	–
Burnout	0.72–0.88	0.63	0.91	–

Table 5. Results of Direct Hypothesis Testing

Path	β	SE	t-value	p-value	Result
Workload → Burnout (H1)	0.31	0.05	6.22	<0.001	Supported
Stress → Burnout (H2)	0.36	0.06	6.58	<0.001	Supported
Shift Length → Burnout (H3)	0.24	0.05	4.78	<0.001	Supported

Table 6. Mediation Analysis of Resilience

Predictor → Mediator → Outcome	Indirect Effect	SE	95% CI (Lower–Upper)	Mediation
Workload → Resilience → Burnout	–0.12	0.03	–0.19, –0.06	Partial
Stress → Resilience → Burnout	–0.15	0.04	–0.22, –0.08	Partial
Shift Length → Resilience → Burnout	–0.09	0.03	–0.16, –0.04	Partial

Table 7. Moderation Analysis of Organizational Support

Interaction Term	β	SE	t-value	p-value	Interpretation
Workload × Org. Support	–0.18	0.06	–3.00	0.003	Supported
Stress × Org. Support	–0.21	0.05	–4.20	<0.001	Supported
Shift × Org. Support	–0.16	0.05	–3.10	0.002	Supported

Table 8. Machine Learning Model Comparison and Feature Importance

Model	Accuracy	Precision	Recall	F1-Score	R^2	Top Predictors
Gradient Boosting	0.91	0.9	0.89	0.9	0.84	Stress (32%), Workload (28%), Resilience (18%)
Random Forest	0.89	0.88	0.86	0.87	0.81	Stress (30%), Workload (27%), Org. Support (17%)
SVM	0.85	0.83	0.84	0.83	0.76	Workload (31%), Stress (29%), Shift (16%)

References

Abdulmohdi, N. (2024). The relationships between nurses' resilience, burnout, perceived organisational support and social support during the second wave of the COVID-19 pandemic: A quantitative cross-sectional survey. *Nursing Open*, *11*(1), e2036. https://doi.org/https://doi.org/10.1002/nop2.2036

Åkerstedt, T., Knutsson, A., Westerholm, P., Theorell, T., Alfredsson, L., & Kecklund, G. (2004). Mental fatigue, work and sleep. *Journal of Psychosomatic Research*, *57*(5), 427–433. https://doi.org/https://doi.org/10.1016/j.jpsychores.2003.12.001

Al-Omar, H. A., Arafah, A. M., Barakat, J. M., Almutairi, R. D., Khurshid, F., & Alsultan, M. S. (2019). The impact of

perceived organizational support and resilience on pharmacists' engagement in their stressful and competitive workplaces in Saudi Arabia. *Saudi Pharmaceutical Journal*, *27*(7), 1044–1052. https://doi.org/https://doi.org/10.1016/j.jsps.2019.08.007

Ali, S. I., & Shaban, M. (2025). Applying Evidence to Improve Practice: Qualitative Insights Into Nurses' Experiences With Organizational Support for Mental Health Recovery. *Worldviews on Evidence-Based Nursing*, *22*(3), e70045. https://doi.org/https://doi.org/10.1111/wvn.70045

Appiah, S. C. Y., Sobiesuo, E. M., Obeng, B., Asamoah, E., Mantey, C. B., Dwumah, P., Boampong, M. S., Boateng, A. A., Ofori, R., Nimoh, M., Nyarko, J. B., & Dapaah, J. M. (2025). COVID-19 and Healthcare Workers Burnt out: A Qualitative Study of Burnout Experiences of Healthcare workers in a Secondary Hospital in Ghana. *Nursing Open*, *12*(8), e70279. https://doi.org/https://doi.org/10.1002/nop2.70279

Back, A. L., Steinhauser, K. E., Kamal, A. H., & Jackson, V. A. (2016). Building Resilience for Palliative Care Clinicians: An Approach to Burnout Prevention Based on Individual Skills and Workplace Factors. *Journal of Pain and Symptom Management*, *52*(2), 284–291. https://doi.org/https://doi.org/10.1016/j.jpainsymman.2016.02.002

Bogaert, P. Van, & Franck, E. (2021). *Nurse Outcomes: Burnout, Engagement, and Job Satisfaction BT - Nurses Contributions to Quality Health Outcomes* (M. Baernholdt & D. K. Boyle (eds.); pp. 221–238). Springer International Publishing. https://doi.org/10.1007/978-3-030-69063-2_13

Boone, L. D., Rodgers, M. M., Baur, A., Vitek, E., & Epstein, C. (2023). An integrative review of factors and interventions affecting the well-being and safety of nurses during a global pandemic. *Worldviews on Evidence-Based Nursing*, *20*(2), 107–115. https://doi.org/https://doi.org/10.1111/wvn.12630

Bourbonnais, R., Comeau, M., Vézina, M., & Dion, G. (1998). Job strain, psychological distress, and burnout in nurses. *American Journal of Industrial Medicine*, *34*(1), 20–28. https://doi.org/https://doi.org/10.1002/(SICI)1097-0274(199807)34:1<20::AID-AJIM4>3.0.CO;2-U

Çakır, O., Akkoç, İ., Arun, K., Dığrak, E., & Uluırmak Ünlüeroğlugil, H. S. (2025). The Complex Dynamics of Violence and Burnout in Healthcare: A Closer Look at Physicians and Nurses. *International Nursing Review*, *72*(3), e70075. https://doi.org/https://doi.org/10.1111/inr.70075

Da Silva, F. C., Souza-Talarico, J. N., Borges, T. P., Kuba, G., & Turrini, R. N. T. (2025). Association Between Stress Mindset, Work-Related Stress and Burnout in Nursing Professionals: Empirical Research Quantitative. *Nursing Open*, *12*(7), e70268. https://doi.org/https://doi.org/10.1002/nop2.70268

Dall' Ora, C., Ball, J., Reinius, M., & Griffiths, P. (2020). Burnout in nursing: a theoretical review. *Human Resources for Health*, *18*(1), 41. https://doi.org/10.1186/s12960-020-00469-9

Day, A., Crown, S. N., & Ivany, M. (2017). Organisational change and employee burnout: The moderating effects of support and job control. *Safety Science*, *100*, 4–12. https://doi.org/https://doi.org/10.1016/j.ssci.2017.03.004

Demerouti, E., Bakker, A. B., de Jonge, J., Janssen, P. P. M., & Schaufeli, W. B. (2001). Burnout and engagement at work as a function of demands and control. *Scandinavian Journal of Work, Environment & Health*, *27*(4), 279–286.

Demerouti, E., Bakker, A. B., Peeters, M. C. W., & Breevaart, K. (2021). New directions in burnout research. *European Journal of Work and Organizational Psychology*, *30*(5), 686–691. https://doi.org/10.1080/1359432X.2021.1979962

Dennis, C.-L. (2003). Peer support within a health care context: a concept analysis. *International Journal of Nursing Studies*, *40*(3), 321–332. https://doi.org/https://doi.org/10.1016/S0020-7489(02)00092-5

Eftekhar Ardebili, M., Naserbakht, M., Bernstein, C., Alazmani-Noodeh, F., Hakimi, H., & Ranjbar, H. (2021). Healthcare providers experience of working during the COVID-19 pandemic: A qualitative study. *American Journal of Infection Control*, *49*(5), 547–554. https://doi.org/10.1016/j.ajic.2020.10.001

Fekih-Romdhane, F., Harb, F., Al Banna, S., Obeid, S., & Hallit, S. (2025). Prevalence and risk factors of burnout symptoms among nurses during the COVID-19 pandemic: an updated systematic review and meta-analysis. *Human Resources for Health*, *23*(1), 48. https://doi.org/10.1186/s12960-025-01012-4

García-Izquierdo, M., Meseguer de Pedro, M., Ríos-Risquez, M. I., & Sánchez, M. I. S. (2018). Resilience as a Moderator of Psychological Health in Situations of Chronic Stress (Burnout) in a Sample of Hospital Nurses. *Journal of Nursing Scholarship*, *50*(2), 228–236. https://doi.org/https://doi.org/10.1111/jnu.12367

Haegdorens, F., Slootmans, S., Vleminckx, S., Van Bogaert, P., & Franck, E. (2025). Turnover and Intention to Leave Among Belgian Healthcare Workers After COVID-19: A Two-Year Longitudinal Cohort Study. *Journal of Advanced Nursing*, *n/a*(n/a). https://doi.org/https://doi.org/10.1111/jan.16925

House, J. S. (1987). Social support and social structure. *Sociological Forum*, *2*(1), 135–146. https://doi.org/10.1007/BF01107897

Lanz, J. J., & Bruk-Lee, V. (2017). Resilience as a moderator of the indirect effects of conflict and workload on job outcomes among nurses. *Journal of Advanced Nursing*, *73*(12), 2973–2986. https://doi.org/https://doi.org/10.1111/jan.13383

Lin, K.-H., Selvanayagam, N., Patnaik, S., & Kuo, C.-Y. (2025). Burnout Among Physicians and Nurses Working in Intensive Care Units and Emergency Departments: A Systematic Review and Meta-Analysis. *Journal of Emergency Nursing*, *51*(4), 702–720. https://doi.org/https://doi.org/10.1016/j.jen.2025.02.007

Liu, L., Wu, D., Wang, L., Qu, Y., & Wu, H. (2020). Effort-Reward Imbalance, Resilience and Perceived Organizational Support: A Moderated Mediation Model of Fatigue in Chinese Nurses. *Risk Management and Healthcare Policy*, *13*(null), 893–901. https://doi.org/10.2147/RMHP.S259339

Norful, A. A., Rosenfeld, A., Schroeder, K., Travers, J. L., & Aliyu, S. (2021). Primary drivers and psychological manifestations of stress in frontline healthcare workforce during the initial COVID-19 outbreak in the United States. *General Hospital Psychiatry*, *69*, 20–26. https://doi.org/https://doi.org/10.1016/j.genhosppsych.2021.01.001

Qiu, T., Yang, Y., Liu, C., Tian, F., Gu, Z., Yang, S., Wu, W., & Wu, H. (2020). The association between resilience, perceived organizational support and fatigue among Chinese doctors: A cross-sectional study. *Journal of Affective Disorders*, *265*, 85–90. https://doi.org/https://doi.org/10.1016/j.jad.2020.01.056

Stimpfel, A. W., Goldsamt, L., Liang, E., & Costa, D. K. (2022). Work Organization Factors Associated With Nurses' Stress, Sleep, and Performance: A Pre-pandemic Analysis. *Journal of Nursing Regulation*, *13*(3), 4–12. https://doi.org/https://doi.org/10.1016/S2155-8256(22)00085-0

Tsai, F.-J., Satria, F. B., Chang, T.-F., Chen, Y.-C., Yang, C.-T., & Chen, C. (2025). Job Stress and Ethical Decision-Making Among Healthcare Workers in Post-Pandemic Infectious Disease Control. *Scientific Reports*, *15*(1), 37371. https://doi.org/10.1038/s41598-025-22055-6

Yang, L., Lei, Y., Zhang, R., Mukhtar, F., Lim, P. Y., Jiang, J., Li, Z., Zhang, Y., & Anita, A. R. (2025). Common

E-ISSN: 3047-9460, P-ISSN: 3048-3786
Safety and Health for Medical Workers (SHMW), Vol 1, No 4, (2025), Page. 198-210
https://doi.org/10.69725/shmw.v1i4.294

antecedents and outcomes of burnout among healthcare workers in the Emergency Department: A scoping review. *The American Journal of Emergency Medicine*, *96*, 140–150. https://doi.org/https://doi.org/10.1016/j.ajem.2025.06.039