

Factors Affecting Intention to Leave Among ICU Healthcare Professionals in China: Insights from a Cross-Sectional Survey and XGBoost Analysis

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Background: The intention to leave among intensive care unit (ICU) healthcare professionals in China has become a concerning issue. Therefore, understanding the factors influencing the intention to leave and implementing appropriate measures have become urgent needs for maintaining a stable healthcare workforce.

Objective: This study aims to investigate the current status of intention to leave among ICU healthcare professionals in China, explore the relevant factors affecting this intention, and provide targeted recommendations to reduce the intention to leave among healthcare professionals.

Methods: A cross-sectional survey was conducted, involving ICU healthcare professionals from 3-A hospitals of the 34 provinces in China. The survey encompassed 22 indicators, including demographic information (marital status, children, income), work-related factors (weekly working hours, night shift frequency, hospital environment), and psychological assessment (using Symptom Checklist-90 (SCL-90)). The data from a sample population of 3653 individuals were analyzed using the extreme gradient boosting (XGBoost) method to predict intention to leave.

Results: The survey results revealed that 62.09% (2268 individuals) of the surveyed ICU healthcare professionals expressed an intention to leave. The XGBoost model achieved a predictive accuracy of 75.38% and an Area Under the Curve (AUC) of 0.77.

Conclusion: Satisfaction with income was found to be the strongest predictor of intention to leave among ICU healthcare professionals. Additionally, factors such as years of experience, night shift frequency, and pride in hospital work were found to play significant roles in influencing the intention to leave.

Keywords: ICU healthcare professionals, intention to leave, cross-sectional survey, extreme gradient boosting, XGBoost

Introduction

The ICU work environment is characterized by high intensity, and a single wrong decision can have serious consequences, leading to a higher risk of burnout among healthcare professionals.¹ In this highly tense and urgent work environment, healthcare professionals are also required to deal with critical medical conditions and emergencies, which can lead to prolonged periods of high stress. Consequently, this can have an impact on their intention to leave. Studies have shown that healthcare providers working in the ICU experience significantly higher levels of work burnout compared to other departments.² Moreover, as the level of work burnout increases, so does the intention to leave the job.³ Intention to leave

refers to the psychological and behavioral inclination of employees to leave their current organization or profession.^{4,5} Additionally, predicting the actual turnover intention of ICU medical staff has proved to be feasible.^{6,7}

Several work-related factors are associated with the intention to leave, such as work duration,⁸ work environment,⁹ and current working hours,^{10,11} as well as salary satisfaction and work pressure.^{12,13} However, there is still a lack of research on the factors associated with the intention to leave among ICU healthcare professionals. Investigating factors influencing the intention to leave among ICU healthcare professionals can assist hospital managers in taking preventive measures to address potential issues that may lead to employee turnover. Targeted actions should be implemented based on different circumstances.¹⁴ Therefore, accurately assessing the factors influencing the intention to leave among ICU healthcare professionals remains a critical concern.

In recent years, machine learning methods have gained recognition as predictive and analytical tools.¹⁵ The key distinction between machine learning and traditional statistics lies in the generation of models. Machine learning models are essentially created by algorithms based on data, making them more effective for complex data analysis compared to traditional methods.¹⁶ The greatest advantage of machine learning is its ability to evaluate all factors, including high-dimensional interactions, which may influence the intention to leave, even in complex data settings. XGBoost, through the fusion of gradient boosting tree algorithm and regularization techniques, exhibits remarkable capabilities in tackling high-dimensional data and enhancing model generalization.^{17,18} In addition, the incorporation of parallel computing technology leads to notable improvements in algorithmic efficiency and computational speed. By visualizing the importance of model features, the relative significance of variables can be explained, thereby identifying the factors with the greatest influence on the intention to leave.¹⁹ This study aims to analyze the intention to leave among ICU healthcare professionals in China and utilize machine learning to predict this intention, thereby identifying various factors that affect it. The findings will aid hospital decision-makers in understanding the intention to leave and other relevant factors and provide valuable insights for government policies aiming to retain healthcare professionals.

Methods

Study Design and Participants

This study used a cross-sectional survey method, which was conducted on the WeChat platform “Wenjuanxing” from December 13th to December 14th, 2018. ICU medical staff from top-level hospitals of the 34 provinces in China were contacted to participate in the survey. The survey included 22 indicators, covering the basic information of ICU medical staff (marital status, children, personal income, etc.), hospital work (weekly working hours, night shifts, hospital environment, etc.), SCL-90 psychological assessment, and intention to leave. A total of 3653 valid questionnaires were collected from ICU medical staff in China. Participation in the survey was voluntary and not mandatory. Participants who did not wish to participate or withdrew from the survey could choose not to participate or exit the survey at any time. This study was approved by the Ethics Committee of The Fourth Hospital of Hebei Medical University, with approval number of 20190436. Informed consent was received from all participants, and the study was performed in accordance with the Helsinki II declaration.

SCL-90 Evaluation of ICU Physicians’ Psychological Status

This study used the symptom checklist-90 (SCL-90) to evaluate the psychological status of ICU medical staff. The SCL-90 consists of 90 items, covering sensory experiences, emotions, thoughts, consciousness, behavior, and other aspects of mental health.²⁰ Each item is scored on a five-point scale, with 1–5 representing the severity of the symptom from “not at all” to “extremely”. When the total symptom index is between 1 and 1.5, it indicates no symptoms; between 1.5 and 2.5, it indicates mild symptoms; between 2.5 and 3.5, it indicates moderate symptoms; between 3.5 and 4.5, it indicates severe symptoms; and between 4.5 and 5, it indicates extremely severe symptoms. The total symptom index is calculated by dividing the total score of the SCL-90 by the total number of items (90).

Data Preprocessing and Feature Selection

The features used to build the predictive model were derived from the questionnaire survey data. These features include gender, education level, marital status, having children, work experience, job title, total number of beds in the ICU, whether the ICU has additional beds, nurse-to-bed ratio during night shifts, physician-to-bed ratio during night shifts, frequency of night shifts, weekly working hours, satisfaction with current income, satisfaction with work environment, sense of pride in working for the hospital, level of sympathy and care from the hospital towards doctors, influence of social opinions, total commuting time, length of annual leave, whether attending training courses, expected career prospects, occupation, and total symptom index.

In these features, variables are represented by numbers, all categorical features are transformed into dummy variables, and ordinal variables are represented by numbers indicating their degree. Furthermore, zero-importance feature screening is applied to identify the least important features, and zero-importance features beyond 99% of the total importance are filtered out.

Machine Learning Method for Building Predictive Model

The machine learning model used in this study is the eXtreme Gradient Boosting (XGBoost). After preliminary data preprocessing, the data are randomly divided into two parts: 80% of the total samples are used as the training set and 20% are used as the test set. The test set is used to train the model. During the model training process, 5-fold cross-validation is performed using different data splits. Grid search is applied to optimize the XGBoost model's hyperparameters. The hyperparameters to be tuned in this study are `n_estimators`, `max_depth`, `min_child_weight`, `subsample`, `colsample_bytree`, and `learning_rate`, with values ranging from 50 to 200, 3 to 7, 5 to 10, 0.5 to 1, 0.5 to 1, and 0.1 to 0.2, respectively.

Statistical Analysis

All analyses were performed using SPSS (version 26) and Python environments. First, the data were analyzed using frequency statistics in SPSS, and then radar charts were used to compare the factors. Feature importance was used to filter out zero-importance features, and the filtered features were used to build the machine learning model (XGBoost), resulting in ROC-AUC curves and feature importance plots. All of the above filtering and analysis steps were performed in the Python environment.

Results

Analysis of ICU Healthcare Workers' Characteristics and Intent to Leave

A total of 3653 ICU healthcare workers participated in this study, including 1273 (34.86%) males and 2380 (64.69%) females. The female participants showed a higher intent to leave at 59.50%. When considering the occupation, there were 1749 doctors (47.88%) and 1904 nurses (52.12%) included in the study. The doctors exhibited a higher intent to leave at 69.10%, which is 13.4% higher compared to the nurses' intent to leave at 55.7%. The general characteristics of the participants, including education level, professional title, and family situation, are presented in [Table 1](#). Among the healthcare workers with less than 10 years of work experience, working more than 60 hours per week, expressing dissatisfaction with income, low satisfaction with the working environment, and having low expectations for career prospects, the intent to leave rates were 63.88%, 70%, 81.20%, 81.20%, and 80.3% respectively. The distribution and attrition rates in other conditions are also displayed in [Table 1](#).

Correlation Analysis

Furthermore, as shown in [Figure 1](#), the correlation analysis of the 23 important features revealed significant positive correlations between marital status and having children, professional title and years of work experience. There were also correlations observed between years of work experience and pursuing further education, as well as between satisfaction with income and satisfaction with the work environment.

Table 1 Baseline Information of ICU Healthcare Personnel

Test Indicators	Group	Resignation Intention	Total
Gender	Female	963 (40.50%)	1417 (59.50%)
	Male	422 (33.20%)	851 (66.80%)
Education	Junior college	231 (41.50%)	326 (58.50%)
	Undergraduate	896 (38.80%)	1413 (61.20%)
	Master	201 (31.00%)	448 (69.00%)
	Doctoral	57 (41.30%)	81 (58.70%)
Marital status	Married	1018 (37.70%)	1681 (62.30%)
	Single	367 (38.50%)	587 (61.50%)
Whether have children	No	491 (38.00%)	80 (62.00%)
	Yes	894 (37.80%)	1468 (62.20%)
Working years	0–5 years	483 (38.60%)	767 (61.40%)
	6–10 years	379 (33.30%)	758 (66.70%)
	11–15 years	177 (33.90%)	345 (66.10%)
	Over 15 years	346 (46.50%)	398 (53.50%)
Title	Primary	747 (39.60%)	1141 (60.40%)
	Intermediate	369 (32.50%)	766 (67.50%)
	Deputy senior	193 (41.20%)	275 (58.80%)
	Senior	76 (46.90%)	86 (53.10%)
Total number of ICU beds	3–10	227 (31.80%)	487 (68.20%)
	10–15	258 (35.20%)	475 (64.80%)
	16–20	392 (41.30%)	557 (58.70%)
	Greater than 20	508 (40.40%)	749 (59.60%)
Whether there are additional beds in ICU	Almost none	491 (38.90%)	771 (61.10%)
	Occasionally	486 (38.30%)	783 (61.70%)
	Often	305 (39.00%)	478 (61.00%)
	Severe permanent additional beds	103 (30.40%)	236 (69.60%)
Nurse bed ratio in ICU night shift	1:1	69 (33.50%)	137 (66.50%)
	1:2	375 (40.60%)	549 (59.40%)
	1:3	528 (38.90%)	829 (61.10%)
	1:4	238 (37.30%)	40 (62.70%)
	>1:4	175 (33.10%)	353 (66.90%)
Physician bed ratio in ICU night shift	No fixed physician	40 (27.40%)	106 (72.60%)
	5–10	674 (37.50%)	1124 (62.50%)
	11–15	322 (38.60%)	512 (61.40%)
	16–20	248 (42.80%)	332 (57.20%)
	>20	101 (34.20%)	194 (65.80%)
Night shift frequency	Do not work	95 (53.10%)	84 (46.90%)
	2 days	73 (34.60%)	138 (65.40%)
	3 days	270 (38.10%)	439 (61.90%)
	4 days	446 (36.00%)	794 (64.00%)
	5 days	265 (34.50%)	504 (65.50%)
	6 days	165 (41.10%)	236 (58.90%)
	7 days	71 (49.30%)	73 (50.70%)
Number of working hours per week	Less than 40 hours	101 (56.10%)	79 (43.90%)
	40–60 hours	888 (41.20%)	1266 (58.80%)
	More than 60 hours	396 (30.00%)	923 (70.00%)
Satisfaction with current income	Very dissatisfied	138 (18.80%)	597 (81.20%)
	Dissatisfied	298 (28.00%)	766 (72.00%)
	General	657 (45.10%)	80 (54.90%)
	Satisfied	267 (72.40%)	102 (27.60%)
	Very satisfied	25 (89.30%)	3 (10.70%)

(Continued)

Table I (Continued).

Test Indicators	Group	Resignation Intention	Total
Satisfaction with working environment	Very dissatisfied	80 (18.80%)	345 (81.20%)
	Dissatisfied	233 (25.70%)	672 (74.30%)
	General	616 (38.60%)	978 (61.40%)
	Satisfied	402 (60.80%)	259 (39.20%)
	Very satisfied	54 (79.40%)	14 (20.60%)
Pride in hospital work	Feel tired	59 (17.70%)	275 (82.30%)
	No pride	272 (23.50%)	886 (76.50%)
	General pride	757 (43.40%)	988 (56.60%)
	Very proud	297 (71.40%)	119 (28.60%)
Degree of sympathy and care of the hospital for doctors	Very poor	65 (17.90%)	299 (82.10%)
	Poor	173 (22.20%)	607 (77.80%)
	General	726 (39.40%)	1117 (60.60%)
	Good	322 (61.70%)	20 (38.30%)
	Very good	99 (68.80%)	45 (31.20%)
Influence of social guidance	Very negative	107 (29.10%)	261 (70.90%)
	Overall negative	494 (32.20%)	1040 (67.80%)
	General	489 (39.10%)	763 (60.90%)
	Overall positive	258 (58.10%)	186 (41.90%)
	Very positive	37 (67.30%)	18 (32.70%)
Total commuting time	Less than 30 minutes	566 (37.30%)	951 (62.70%)
	30–60 minutes	567 (38.40%)	908 (61.60%)
	60–90 minutes	143 (36.10%)	253 (63.90%)
	90–120 minutes	69 (44.80%)	85 (55.20%)
	Greater than 120 minutes	40 (36.00%)	71 (64.00%)
Annual leave length	0 days	531 (34.20%)	1022 (65.80%)
	1–7 days	620 (40.10%)	925 (59.90%)
	8–14 days	173 (39.70%)	263 (60.30%)
	More than 14 days	61 (51.30%)	58 (48.70%)
Whether to study further	Yes	608 (37.20%)	1025 (62.80%)
	No	777 (38.50%)	1243 (61.50%)
Career prospects expectations	No hope at all	97 (19.70%)	396 (80.30%)
	Hopeless	162 (25.80%)	466 (74.20%)
	General	554 (36.40%)	968 (63.60%)
	More confident	425 (54.60%)	354 (45.40%)
	Full of confidence	147 (63.60%)	84 (36.40%)
Occupation	Doctor	541 (30.90%)	1208 (69.10%)
	Nurse	844 (44.30%)	1060 (55.70%)
Total symptom index	No symptoms	569 (49.00%)	593 (51.00%)
Slight symptoms	563 (34.30%)	1078 (65.70%)	1641 (44.92%)
Moderate symptoms	207 (31.10%)	459 (68.90%)	666 (18.23%)
Severe symptoms	41 (25.50%)	120 (74.50%)	161 (4.41%)
Very serious symptoms	5 (21.70%)	18 (78.30%)	23 (0.63%)

Feature Selection

In order to enhance the predictive and generalization ability of the model, feature selection was performed using PYTHON. A threshold of 0.99 was set to eliminate zero-importance features. The cumulative feature importance curve (Figure 2) shows that among the 23 features, there were no zero-importance features identified.

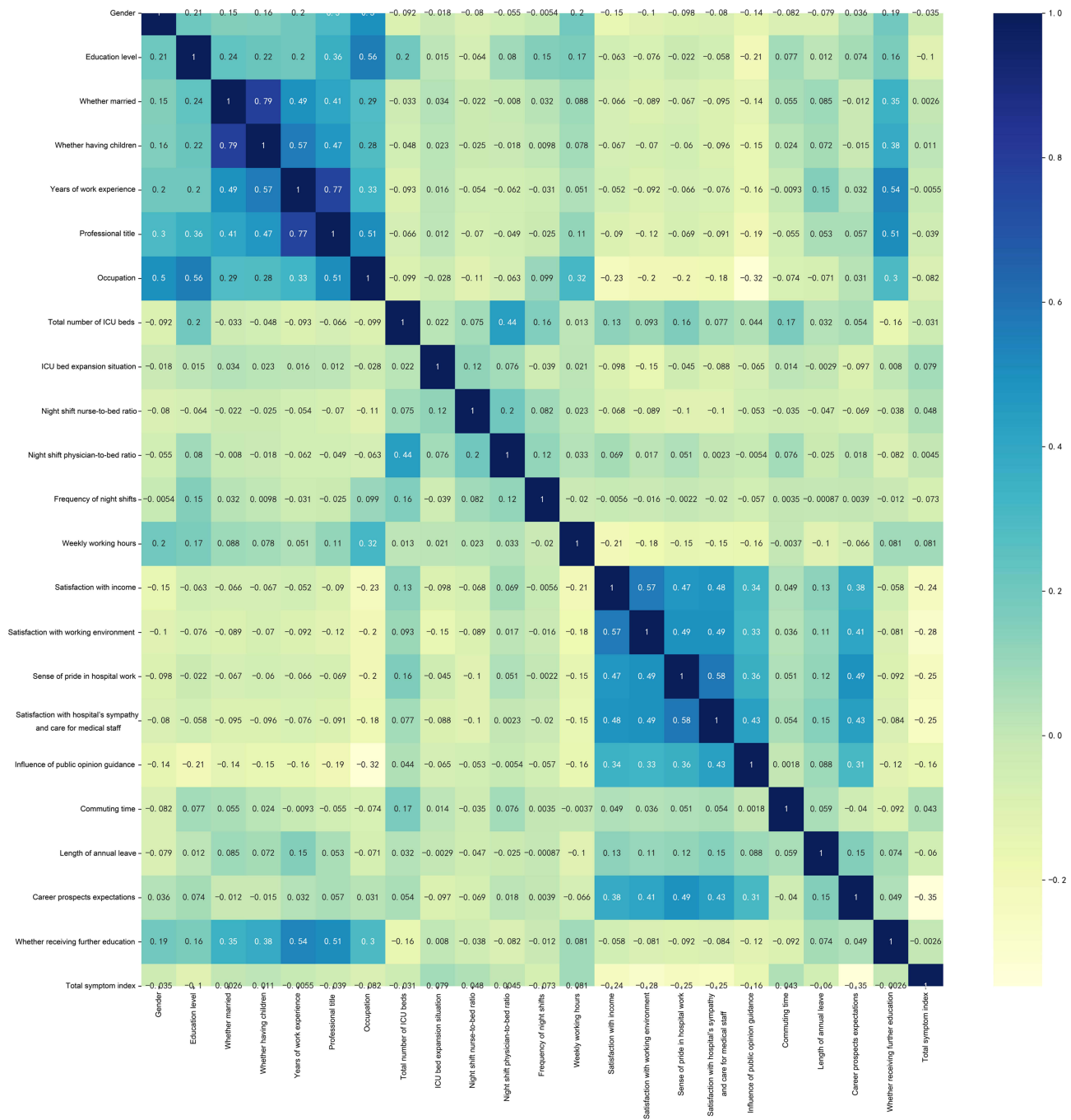


Figure 1 Correlation plot of all analysed features. ICU, Intensive Care Unit.

Performance Prediction

A machine learning model (XGBOOST) was constructed using 23 features extracted from a questionnaire survey data to predict psychological conditions. The ROC-AUC curve (Figure 3) demonstrates the predictive performance of the model. The accuracy of the prediction model was 75.38%, and the area under the ROC-AUC curve was 0.77.

Feature Importance

Figure 4 illustrates the feature importance results of the top 23 features for two prediction models trained using machine learning (xgboost). "Satisfaction with income" emerged as the most influential predictor in the prediction model for the

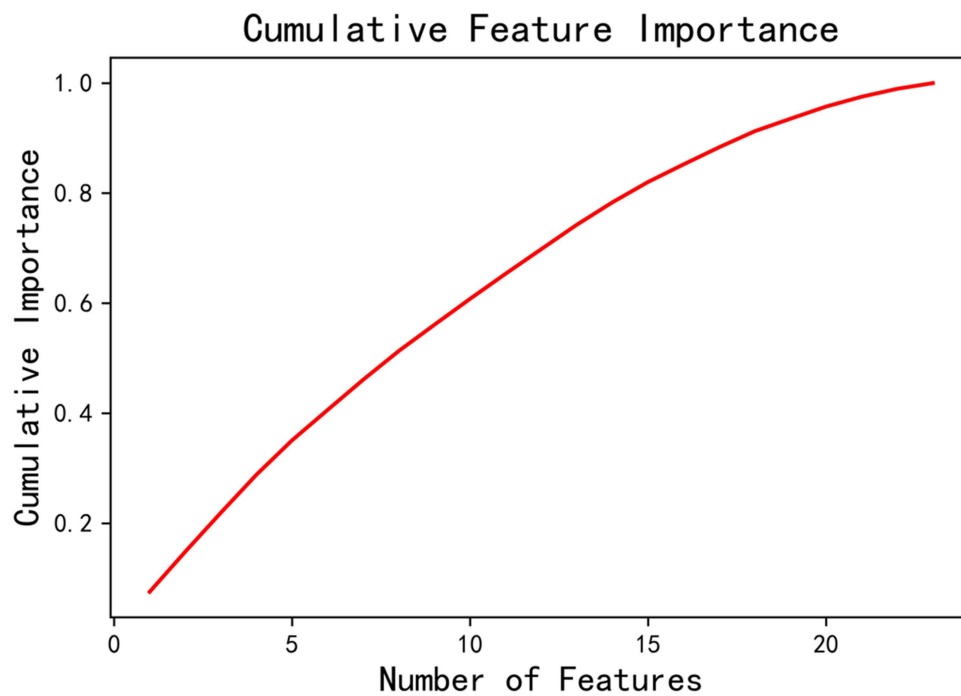


Figure 2 Cumulative importance versus the number of features.

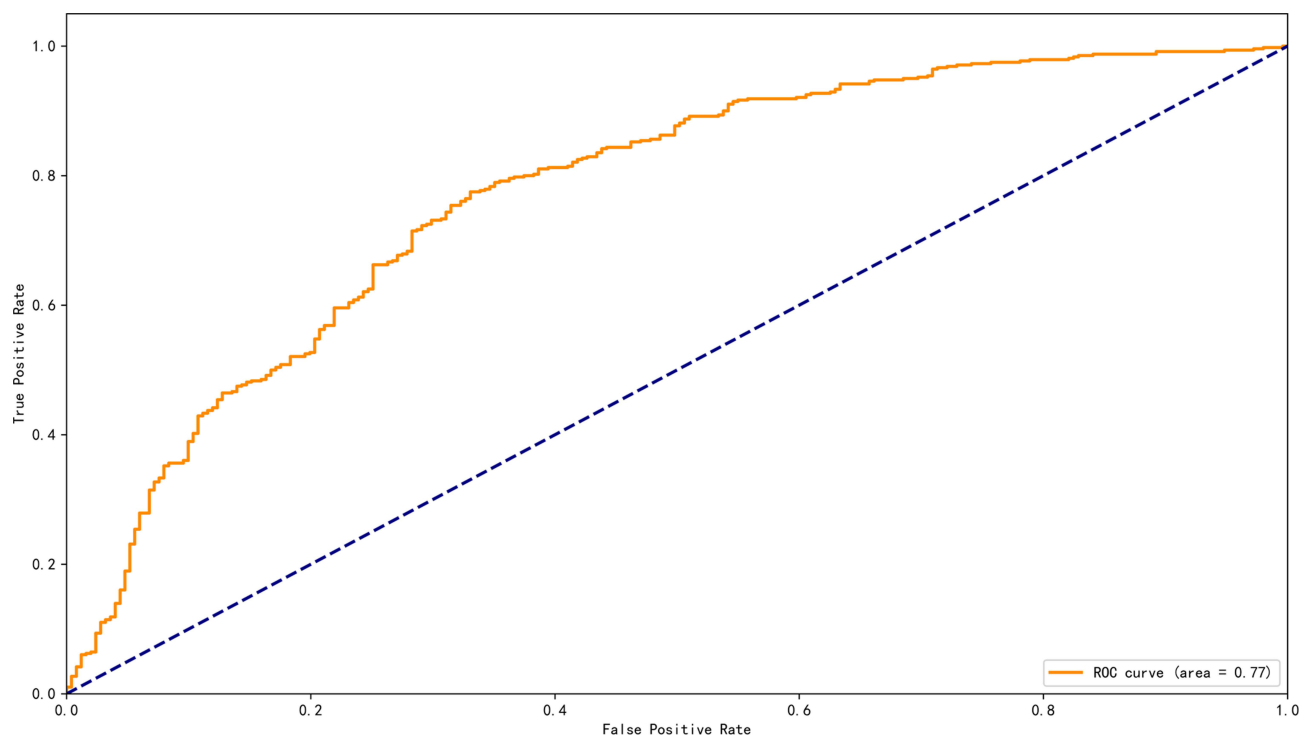


Figure 3 ROC-AUC Curve. AUC indicates area under the curve; ROC, Receiver operating characteristic.

experimental group, followed by years of work experience and frequency of night shifts. [Figure 5](#) represents the positive and negative relationships between the features, with red indicating positive correlation. The findings align with reality, as lower satisfaction with income corresponds to higher total symptom scores and a stronger intention to quit.

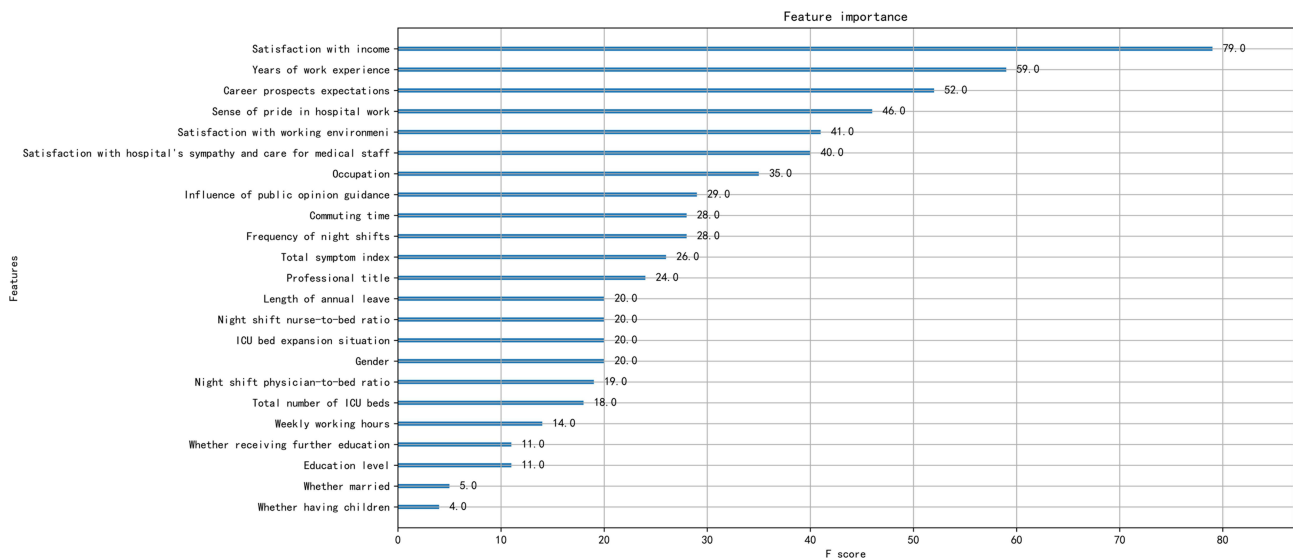


Figure 4 Feature Importance Plot.

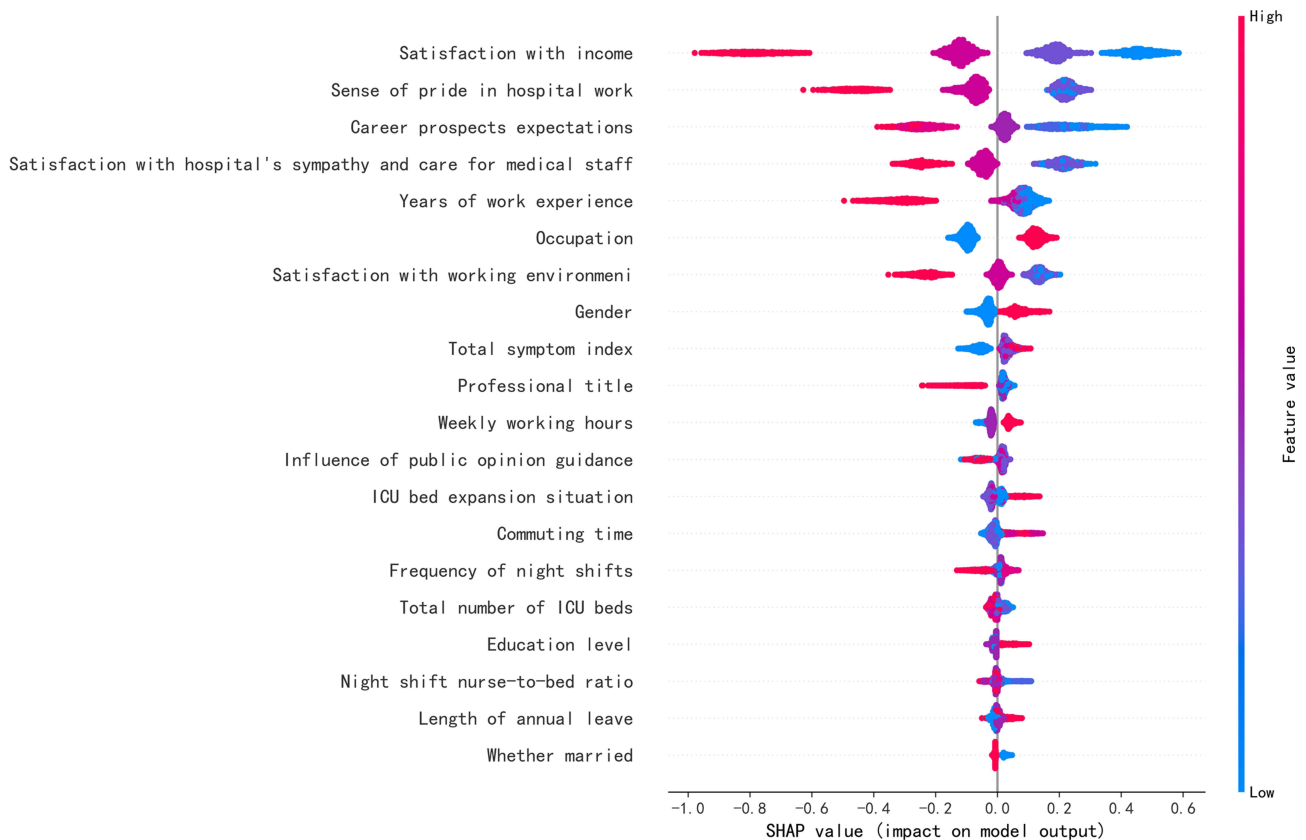


Figure 5 SHAP Plot. SHARP, SHapley Additive exPlanations. Features are ranked in descending order of their accountability for the prediction. Each dot in the visualization represents one datapoint of a feature. Its color is related to the real data value: high value in red and low value in blue. The impact of each value is associated with higher or lower prediction, represented by SHAP values on x-axis.

Discussion

In this study, we assessed the association between 23 factors and the turnover intention of ICU medical staff using a survey questionnaire and machine learning analysis. A total of 3653 ICU medical staff from 34 provinces in China were surveyed, and the results showed that 2268 (62.09%) of them had a turnover intention. Among them, male ICU medical

staff had a stronger turnover intention than females, which is consistent with the findings of Wang et al.²¹ Compared to previous studies focusing on identifying risk factors related to turnover intention among ICU medical staff, the current study, based on a questionnaire survey, can identify potential factors associated with turnover intention more effectively, allowing for better attention to be given to high-risk groups in order to reduce turnover intention.

The results of the study indicated that satisfaction with income was the most critical predictor of turnover intention, reflecting a positive correlation between turnover intention and income. This suggests that improving ICU medical staff's satisfaction with income is an effective way to reduce their intention to leave. This finding is consistent with previous research that identified low salary and compensation as significant factors leading to voluntary turnover.^{22,23} The lower the satisfaction with income, the more likely healthcare professionals are to have a tendency to leave.²⁴ Length of service was the second most important factor, as long-term work in the ICU environment can lead to professional burnout,¹ which can negatively impact the mental health of workers and lead to thoughts of leaving. Moreover, this may also be related to unfulfilled organizational commitment.²¹ In our study, only 31.81% of respondents were completely symptom-free, which is consistent with previous research.¹⁰ It has been found that night shifts can cause emotional fatigue and sleep deprivation among medical staff, making it an important factor influencing turnover intention, consistent with the results of this study.²⁵ Higher frequency of night shifts can contribute to various psychological issues. Therefore, reducing the frequency of night shifts may be a good approach to lower turnover intention. The feature importance results also revealed that night shift frequency is one of the strong protective factors against turnover intention for medical staff. Unlike other factors related to turnover intention for doctors, such as years of experience and pride in their work, night shift frequency and income are tangible and actionable factors. By establishing reasonable working time regulations and compensation systems, we can improve the well-being of doctors and reduce the likelihood of them leaving their current practice environment.

In this study, a sense of pride in working in a hospital was identified as the fourth most important predictor of turnover intention among ICU medical staff. Healthcare workers dedicate themselves to the frontline of medical care, silently working to fulfill their medical oath. Therefore, society as a whole should understand and support healthcare professionals. Recognition and appreciation from society are essential for healthcare staff to feel pride in their profession.²⁶

In all, turnover intention among ICU medical staff in China is relatively high. Factors such as satisfaction with income, length of service, night shift frequency, and pride in working in a hospital, have a significant impact on turnover intention among ICU medical staff, with satisfaction with income being the most important factor. Based on turnover intention and its influencing factors, it is recommended that hospitals create a better working environment, reduce the frequency of night shifts, and enhance staff's sense of identification and pride. In addition, healthcare professionals are a group that values psychological motivation. Therefore, hospital administrators and society at large should focus on providing positive motivation to healthcare professionals, enhancing their subjective well-being, and increasing their self-efficacy, thereby reducing turnover intention.

This study has several limitations. Firstly, it focuses solely on intensive care medical personnel in China, which may limit the generalizability of the findings to healthcare professionals in other countries or settings. Additionally, the study utilized a cross-sectional survey design, which restricts the establishment of causal relationships between identified factors and turnover intentions. Longitudinal studies would be beneficial for further exploring the dynamic changes of these intentions over time. Furthermore, this study employed machine learning techniques to predict turnover intentions based on identified factors. While these techniques can provide valuable insights, they are not without limitations. The performance of predictive models may vary depending on the quality and representativeness of the training data. Lastly, the data was collected in December 2018, predating the COVID-19 pandemic, however, they may also be unaffected by time, as the studied variables are interpersonal interactions within the work system.²⁷

Conclusion

Satisfaction with income, length of service, night shift frequency, and pride in working in a hospital are the main factors influencing turnover intention among ICU medical staff. Medical institutions should implement reasonable performance evaluation and compensation systems, reduce the frequency of night shifts, and enhance job satisfaction to decrease turnover intention among medical staff. System and policy reforms should be carried out to improve unreasonable

working conditions. Moreover, we consider XGBoost to be a practical tool for building predictive models, which can be extended to other research domains.

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Disclosure

Di Zhao is the lead contact author. The authors report no conflicts of interest in this work.

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