ORIGINAL RESEARCH

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

Jiangnan Wu^{1,*}, Chao Zhang^{2,*}, Feng He^{3,*}, Yuan Wang⁴, Liangnan Zeng⁵, Wei Liu⁶, Di Zhao⁷, Jingkun Mao¹, Fei Gao⁸

¹Department of Artificial Intelligence, Tianjin University of Technology, Tianjin, People's Republic of China; ²Sixth Department of Oncology, Hebei General Hospital, Shijiazhuang, People's Republic of China; ³The Second Hospital of Hebei Medical University, Shijiazhuang, People's Republic of China; ⁴Department of Neurosurgery, Tangshan Gongren Hospital, Tangshan, People's Republic of China; ⁵Department of Nursing, Chengdu Fifth People's Hospital, The Fifth People's Hospital Affiliated to Chengdu University of Traditional Chinese Medicine, Chengdu, People's Republic of China; ⁶Hebei Psychological Counselor Association, Shijiazhuang, People's Republic of China; ⁷Department of Neurosurgery, The Fourth Hospital of Hebei Medical University, Shijiazhuang, People's Republic of China; ⁸Hebei General Hospital, Shijiazhuang, People's Republic of China

*These authors contributed equally to this work

Correspondence: Di Zhao; Fei Gao, Tel +86-13363833833; +86-13933173693, Email 179381749@qq.com; 27909361@qq.com

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

2543

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.

| 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%) | 4 (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%) |
| Number of used in a bound of a sub- | 7 days | / I (49.30%) | 73 (50.70%) |
| Number of working hours per week | Less than 40 hours | 101 (56.10%) | /9 (43.90%) |
| | 40-60 hours | 000 (41.20%) 294 (20.00%) | 1200 (30.00%) |
| Satisfaction with current income | Nory dissatisfied | 138 (18 80%) | 597 (81 20%) |
| | very dissatistied | 298 (28 00%) | 766 (72 00%) |
| | General | 657 (45 10%) | 80 (54 90%) |
| | Satisfied | 267 (72 40%) | 102 (27 60%) |
| | Very satisfied | 207 (72.70%) 25 (89 30%) | 3 (10 70%) |
| | very satisfied | 23 (07.30%) | 5 (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%) | 1534 (41.99%) |
| | 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%) |
| | I—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.

| Gender - | · | 0. 21 | 0. 15 | 0. 16 | 0. 2 | 0. 5 | 0.0 | -0. 092 | -0. 018 | -0. 08 | -0. 055 | -0. 0054 | 0. 2 | -0. 15 | -0. 1 | -0. 098 | -0. 08 | -0. 14 | -0. 082 | -0. 079 | 0. 036 | 0. 19 | -0. 035 | | - 1.0 |
|---|----------|---------------|----------------|------------------------|-------------------------|-------------------|--------------|-------------------------|----------------------------|------------------------------|-----------------------------------|--------------------------|---------------------|-------------------------|-----------------------------------|-------------------------------|---|------------------------------------|---------------|-----------------------|------------------------------|-------------------------------------|--------------------|--|--------|
| Education level - | 0. 21 | 1 | 0. 24 | 0. 22 | 0. 2 | | | 0. 2 | 0. 015 | -0. 064 | 0. 08 | 0. 15 | 0. 17 | -0. 063 | -0. 076 | -0. 022 | -0. 058 | -0. 21 | 0. 077 | 0. 012 | 0. 074 | 0. 16 | -0. 1 | | |
| Whether married - | 0. 15 | 0. 24 | 1 | 0. 79 | 0. 49 | | 0. 29 | -0. 033 | 0. 034 | -0. 022 | -0. 008 | 0. 032 | 0. 088 | -0. 066 | -0. 089 | -0. 067 | -0. 095 | -0. 14 | 0. 055 | 0. 085 | -0. 012 | | 0. 0026 | | |
| Whether having children - | 0. 16 | 0. 22 | 0. 79 | | | | 0. 28 | -0. 048 | 0. 023 | -0. 025 | -0. 018 | 0. 0098 | 0. 078 | -0. 067 | -0. 07 | -0.06 | -0. 096 | -0. 15 | 0. 024 | 0. 072 | -0. 015 | | 0. 011 | | - 0. 8 |
| Years of work experience - | 0. 2 | 0. 2 | 0. 49 | 0. 57 | 1 | 0. 77 | | -0. 093 | 0. 016 | -0. 054 | -0. 062 | -0. 031 | 0. 051 | -0. 052 | -0. 092 | -0. 066 | -0. 076 | -0. 16 | -0. 0093 | 0. 15 | 0. 032 | | -0. 0055 | | |
| Professional title - | | | | | | | 0. 51 | -0. 066 | 0. 012 | -0. 07 | -0. 049 | -0. 025 | 0. 11 | -0.09 | -0. 12 | -0. 069 | -0. 091 | -0. 19 | -0. 055 | 0. 053 | 0. 057 | | -0. 039 | | |
| Occupation - | | | 0. 29 | 0. 28 | 0. 33 | 0. 51 | 1 | -0. 099 | -0. 028 | -0. 11 | -0. 063 | 0. 099 | | -0. 23 | -0. 2 | -0. 2 | -0. 18 | -0. 32 | -0. 074 | -0. 071 | 0. 031 | | -0. 082 | | |
| Total number of ICU beds - | -0. 092 | 0. 2 | -0. 033 | -0. 048 | -0. 093 | -0. 066 | -0. 099 | 1 | 0. 022 | 0. 075 | 0. 44 | 0. 16 | 0. 013 | 0. 13 | 0. 093 | 0. 16 | 0. 077 | 0. 044 | 0. 17 | 0. 032 | 0. 054 | -0. 16 | -0. 031 | | - 0. 6 |
| ICU bed expansion situation - | -0. 018 | 0. 015 | 0. 034 | 0. 023 | 0. 016 | 0. 012 | -0. 028 | 0. 022 | 1 | 0. 12 | 0. 076 | -0. 039 | 0. 021 | -0. 098 | -0. 15 | -0. 045 | -0. 088 | -0. 065 | 0. 014 | -0. 0029 | -0. 097 | 0. 008 | 0. 079 | | |
| Night shift nurse-to-bed ratio - | -0. 08 | -0. 064 | -0. 022 | -0. 025 | -0. 054 | -0. 07 | -0. 11 | 0. 075 | 0. 12 | 1 | 0. 2 | 0. 082 | 0. 023 | -0. 068 | -0. 089 | -0. 1 | − 0. 1 | -0.053 | -0. 035 | -0. 047 | -0. 069 | -0. 038 | 0. 048 | | |
| Night shift physician-to-bed ratio - | -0. 055 | 0. 08 | -0. 008 | -0. 018 | -0. 062 | -0. 049 | -0. 063 | 0. 44 | 0. 076 | 0. 2 | 1 | 0. 12 | 0. 033 | 0. 069 | 0. 017 | 0. 051 | 0. 0023 | -0. 0054 | 0. 076 | -0. 025 | 0. 018 | -0. 082 | 0. 0045 | | - 0. 4 |
| Frequency of night shifts - | -0. 0054 | 0. 15 | 0. 032 | 0. 0098 | -0. 031 | -0. 025 | 0. 099 | 0. 16 | -0. 039 | 0. 082 | 0. 12 | 1 | -0. 02 | -0. 0056 | -0. 016 | -0. 0022 | -0. 02 | -0.057 | 0. 0035 | -0. 00087 | 0. 0039 | -0. 012 | -0. 073 | | |
| Weekly working hours - | 0. 2 | 0. 17 | 0. 088 | 0. 078 | 0. 051 | 0. 11 | | 0. 013 | 0. 021 | 0. 023 | 0. 033 | -0. 02 | 1 | -0. 21 | -0. 18 | -0. 15 | -0. 15 | -0. 16 | -0. 0037 | -0. 1 | -0. 066 | 0. 081 | 0. 081 | | |
| Satisfaction with income - | -0. 15 | -0. 063 | -0. 066 | -0. 067 | -0. 052 | -0.09 | -0. 23 | 0. 13 | -0. 098 | -0. 068 | 0. 069 | -0. 0056 | -0. 21 | 1 | 0. 57 | 0. 47 | 0. 48 | 0. 34 | 0. 049 | 0. 13 | 0, 38 | -0. 058 | -0. 24 | | - 0. 2 |
| Satisfaction with working environment - | -0. 1 | -0. 076 | -0. 089 | -0. 07 | -0. 092 | -0. 12 | -0. 2 | 0. 093 | -0. 15 | -0. 089 | 0. 017 | -0. 016 | -0. 18 | 0. 57 | 1 | | | | 0. 036 | 0. 11 | | -0. 081 | -0. 28 | | |
| Sense of pride in hospital work - | -0. 098 | -0. 022 | -0. 067 | -0.06 | -0. 066 | -0. 069 | -0. 2 | 0. 16 | -0. 045 | -0. 1 | 0. 051 | -0. 0022 | -0. 15 | 0. 47 | 0. 49 | 1 | | | 0. 051 | 0. 12 | 0. 49 | -0. 092 | -0. 25 | | |
| Satisfaction with hospital's sympathy and care for medical staff | -0. 08 | -0. 058 | -0. 095 | -0. 096 | -0. 076 | -0. 091 | -0. 18 | 0. 077 | -0. 088 | -0. 1 | 0. 0023 | -0. 02 | -0. 15 | | | 0. 58 | 1 | | 0. 054 | 0. 15 | 0. 43 | -0. 084 | -0. 25 | | - 0 0 |
| Influence of public opinion guidance - | -0. 14 | -0. 21 | -0. 14 | -0. 15 | -0. 16 | -0. 19 | -0. 32 | 0. 044 | -0. 065 | -0. 053 | -0. 0054 | -0. 057 | -0. 16 | | | 0. 36 | 0. 43 | 1 | 0. 0018 | 0. 088 | 0. 31 | -0. 12 | -0. 16 | | 0.0 |
| Commuting time - | -0. 082 | 0. 077 | 0. 055 | 0. 024 | -0. 0093 | -0. 055 | -0. 074 | 0. 17 | 0. 014 | -0. 035 | 0. 076 | 0. 0035 | -0. 0037 | 0. 049 | 0. 036 | 0. 051 | 0. 054 | 0. 0018 | 1 | 0. 059 | -0. 04 | -0. 092 | 0. 043 | | |
| Length of annual leave - | -0. 079 | 0. 012 | 0. 085 | 0. 072 | 0. 15 | 0. 053 | -0. 071 | 0. 032 | -0. 0029 | -0. 047 | -0. 025 | -0. 00087 | -0. 1 | 0. 13 | 0. 11 | 0. 12 | 0. 15 | 0. 088 | 0. 059 | 1 | 0. 15 | 0. 074 | -0.06 | | |
| Career prospects expectations - | 0. 036 | 0. 074 | -0. 012 | -0. 015 | 0. 032 | 0. 057 | 0. 031 | 0. 054 | -0. 097 | -0. 069 | 0. 018 | 0. 0039 | -0. 066 | 0. 38 | 0. 41 | 0. 49 | 0. 43 | | -0.04 | 0. 15 | 1 | 0. 049 | -0. 35 | | 0. 2 |
| Whether receiving further education - | 0. 19 | 0. 16 | 0, 35 | 0, 38 | 0. 54 | 0. 51 | 0, 3 | -0. 16 | 0. 008 | -0. 038 | -0. 082 | -0. 012 | 0. 081 | -0. 058 | -0. 081 | -0. 092 | -0. 084 | -0. 12 | -0. 092 | 0. 074 | 0. 049 | 1 | -0. 0026 | | |
| Total symptom index - | -0. 035 | -0, 1 | 0. 0026 | 0. Q11 | -0. Q055 | -0. 039 | -0. 082 ⊊ | -0. 031 ₽ | 0. 079 E | 0. Q48 운 | 0. Q045 .9 | -0. 073 | 0. Q81 ≌ | -0.24 | -0.128 | -0₄25 ¥ | -0₄25 È | -0,16 8 | 0. Q43 | -0.106 g | -0.135 g | -0. 0026 | - X6 | | |
| | Gend | Education lev | Whether marrie | Whether having childre | Years of work experienc | Professional titl | Occupatio | Total number of ICU bed | ICU bed expansion situatio | Night shift nurse-to-bed rat | Night shift physician-to-bed rati | Frequency of night shift | Weekly working hour | Satisfaction with incom | tisfaction with working environme | Sense of pride in hospital wo | atisfaction with hospital's sympath and care for medical staff | nfluence of public opinion guidanc | Commuting tim | Length of annual leav | Career prospects expectation | Whether receiving further education | Total symptom inde | | |

Figure I 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.

| | | | | Feat | ure importance | | | |
|---|-----|------|------|------|----------------|------|------|------|
| Satisfaction with income | | | | | | | | 79.0 |
| Years of work experience | | | | | | | 59.0 | |
| Gareer prospects expectations | | | | | | 52 0 | | |
| Sense of pride in hospital work | | | | | 46.0 | 0110 | | |
| Satisfaction with working environment | | | | | 41.0 | | | |
| infaction with hospital's sympathy and care for medical staff | | | | | 40.0 | | | |
| Occupation - | | | | 35.0 | | | | |
| Influence of public opinion muidance | | | | 29.0 | | | | |
| Commuting time - | | | -2' | 0 | | | | |
| Frequency of night shifts - | | | -2' | 0 | | | | |
| Total symptom index - | | | 26.0 | | | | | |
| | | | 24.0 | | | | | |
| length of annual leave t | | | 20.0 | | | | | |
| Night shift nurse-to-hed ratio | | | 20.0 | | | | | |
| | | | 20.0 | | | | | |
| Gender | | | 20.0 | | | | | |
| Night shift physician-to-had ratio | | | 19.0 | | | | | |
| Total number of ICII bade | | 1 | 8.0 | | | | | |
| Weekly working hours | | 14.0 | | | | | | |
| Whether receiving further education | | 11.0 | | | | | | |
| Education level | | 11.0 | | | | | | |
| Whether married | 5.0 | | | | | | | |
| Whether baying children | 4 0 | | | | | | | |
| mitcher having children | | | | | | | | |
| 0 | | 0 | no i | | | | | i. |

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.

Acknowledgment

We thank for the help from Critical Care E Institute (CCEI) and the Chinese Neurocritical Care Study Group(CNCSG).

Disclosure

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

References

- 1. Chuang CH, Tseng PC, Lin CY, et al. Burnout in the intensive care unit professionals: a systematic review. *Medicine*. 2016;95(50):e5629. doi:10.1097/MD.00000000005629
- Stocchetti N, Segre G, Zanier ER, et al. Burnout in intensive care unit workers during the second wave of the COVID-19 pandemic: a single center cross-sectional Italian study. Int J Environ Res Public Health. 2021;18(11):6102. doi:10.3390/ijerph18116102
- 3. LeClaire M, Poplau S, Linzer M, et al. Compromised integrity, burnout, and intent to leave the job in critical care nurses and physicians. *Crit Care Explorations*. 2022;4(2):e0629. doi:10.1097/CCE.00000000000629
- 4. Hayes LJ, O'Brien-Pallas L, Duffield C, et al. Nurse turnover: a literature review-an update. Int J Nurs Stud. 2012;49(7):887-905. doi:10.1016/j. ijnurstu.2011.10.001
- 5. Poeira A, Mamede RP, Martins M. Predictors for changing to a non-Nursing profession. Predict Chang Non Nurs Prof. 2019;22:73-84.
- 6. Sousa-Poza A, Henneberger F. Analyzing job mobility with job turnover intentions: an international comparative study. *J Econ Issues*. 2004;38 (1):113–137. doi:10.1080/00213624.2004.11506667
- 7. Daouda OS, Hocine MN, Temime L. Determinants of healthcare worker turnover in intensive care units: a micro-macro multilevel analysis. *PLoS One*. 2021;16(5):e0251779. doi:10.1371/journal.pone.0251779
- 8. Albougami AS, Almazan JU, Cruz JP, et al. Factors affecting nurses' intention to leave their current jobs in Saudi Arabia. Int J Health Sci. 2020;14(3):33.
- 9. Jang SJ, Son YJ, Lee H. Prevalence, associated factors and adverse outcomes of workplace violence towards nurses in psychiatric settings: a systematic review. *Int J Ment Health Nurs*. 2022;31(3):450–468. doi:10.1111/inm.12951
- 10. Oh S, Kim H. Turnover intention and its related factors of employed doctors in Korea. Int J Environ Res Public Health. 2019;16(14):2509. doi:10.3390/ijerph16142509
- 11. Jarrar MT, Binti Ali N, Shahruddin R, et al. The impact of the working hours among Malaysian nurses on their Ill-being, intention to leave, and the perceived quality of care: a cross-sectional study during the COVID-19 pandemic. J Multidiscip Healthc. 2023;Volume 16:119–131. doi:10.2147/JMDH.S394583
- 12. Chen ML, Su ZY, Lo CL, et al. An empirical study on the factors influencing the turnover intention of dentists in hospitals in Taiwan. J Dent Sci. 2014;9(4):332–344. doi:10.1016/j.jds.2013.01.003
- Al-Surimi K, Almuhayshir A, Ghailan KY, et al. Impact of patient safety culture on job satisfaction and intention to leave among healthcare workers: evidence from middle east context. *Risk Manag Healthc Policy*. 2022;Volume 15:2435–2451. doi:10.2147/RMHP.S390021
- 14. Khan N, Jackson D, Stayt L, et al. Factors influencing nurses' intentions to leave adult critical care settings. Nurs Crit Care. 2019;24(1):24-32. doi:10.1111/nicc.12348
- 15. Islam MM, Haque MR, Iqbal H, et al. Breast cancer prediction: a comparative study using machine learning techniques. SN Comput Sci. 2020;1:1–14. doi:10.1007/s42979-020-00305-w
- 16. Ley C, Martin RK, Pareek A, et al. Machine learning and conventional statistics: making sense of the differences. *Knee Surg Sports Traumatol Arthrosc.* 2022;30(3):753–757. doi:10.1007/s00167-022-06896-6
- 17. Qiu Y, Zhou J, Khandelwal M, et al. Performance evaluation of hybrid WOA-XGBoost, GWO-XGBoost and BO-XGBoost models to predict blast-induced ground vibration. *Eng Comput.* 2021;2021:1–18.
- 18. Li W, Yin Y, Quan X, et al. Gene expression value prediction based on XGBoost algorithm. Front Genet. 2019;10:1077. doi:10.3389/fgene.2019.01077
- 19. Chen J, Liang D, Zhu Z, et al. Social media popularity prediction based on visual-textual features with xgboost. Paper presented at the Proceedings of the 27th ACM International Conference on Multimedia; 2019.
- 20. Holi M, Sammallahti P, Aalberg V. A Finnish validation study of the SCL-90. Acta Psychiatr Scand. 1998;97(1):42-46. doi:10.1111/j.1600-0447.1998.tb09961.x
- 21. Wang T, Abrantes ACM, Liu Y. Intensive care units nurses' burnout, organizational commitment, turnover intention and hospital workplace violence: a cross-sectional study. *Nurs Open*. 2023;10(2):1102–1115. doi:10.1002/nop2.1378
- 22. Tsai YH, Huang N, Chien LY, et al. Work hours and turnover intention among hospital physicians in Taiwan: does income matter? *BMC Health* Serv Res. 2016;16:1–8. doi:10.1186/s12913-016-1916-2
- 23. Jang HJ, Baek ML. Influencing factors of the turnover intention in hospital paramedics. Korean J Emerg Med Serv. 2013;17(3):39-51. doi:10.14408/KJEMS.2013.17.3.039
- 24. Hatamizadeh M, Hosseini M, Bernstein C, et al. Health care reform in Iran: implications for nurses' moral distress, patient rights, satisfaction and turnover intention. J Nurs Manag. 2019;27(2):396–403. doi:10.1111/jonm.12699
- 25. Ki J, Choi-Kwon S. Health problems, turnover intention, and actual turnover among shift work female nurses: analyzing data from a prospective longitudinal study. *PLoS One*. 2022;17(7):e0270958. doi:10.1371/journal.pone.0270958
- 26. Willis-Shattuck M, Bidwell P, Thomas S, et al. Motivation and retention of health workers in developing countries: a systematic review. *BMC Health Serv Res.* 2008;8:1–8. doi:10.1186/1472-6963-8-247
- 27. Jarrar MT, Al-Bsheish M, Aldhmadi BK, et al. Effect of practice environment on nurse reported quality and patient safety: the mediation role of person-centeredness. Paper presented at the Healthcare; 2021.

Risk Management and Healthcare Policy

Dovepress

f 🏏 in 🕨 DovePress 2553

Publish your work in this journal

Risk Management and Healthcare Policy is an international, peer-reviewed, open access journal focusing on all aspects of public health, policy, and preventative measures to promote good health and improve morbidity and mortality in the population. The journal welcomes submitted papers covering original research, basic science, clinical & epidemiological studies, reviews and evaluations, guidelines, expert opinion and commentary, case reports and extended reports. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit http://www.dovepress.com/testimonials.php to read real quotes from published authors.

Submit your manuscript here: https://www.dovepress.com/risk-management-and-healthcare-policy-journal