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ORIGINAL RESEARCH

Construction of a Prediction Model for Sleep Quality in Embryo Repeated Implantation Failure Patients Undergoing Assisted Reproductive Technology Based on Machine Learning: A Single-Center Retrospective Study

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Objective: Constructing a predictive model for sleep quality in embryo Repeated Implantation Failure(RIF) patients using multiple machine learning algorithms, verifying its performance, and selecting the optimal model.

Methods: Retrospective collection of clinical data from RIF patients who underwent assisted reproductive technology at the Reproductive Medicine Center of Tongji University Affiliated Obstetrics and Gynecology Hospital from January 2022 to June 2022, divided into a training set and a validation set in an 8:2 ratio. Use Lasso regression to screen variables and construct a risk prediction model using six machine learning algorithms. Evaluate the validity of the model using the area under the curve (AUC), and comprehensively evaluate the performance of the model based on F1 score, accuracy, sensitivity, and specificity. Use SHAP method to explain the contribution of each variable in the optimal model to the occurrence of sleep disorders.

Results: A total of 404 RIF patients were included in the study. The incidence of sleep disturbances was 48.76%. After LASSO regression analysis, nine variables were selected for inclusion in the model. The RF model has an AUC of 0.941, Accuracy of 0.938, Specification of 0.950, and F1 score of 0.938 in the validation set, making it the optimal model for this study. According to the SHAP feature importance ranking of the RF model, the factors influencing sleep quality in RIF patients were E2, SDS, Fertiqol, FSH, daily exercise time, weekly shift work hours, coffee consumption, sunbathing, and SAS.

Conclusion: The RF model is the optimal model for predicting the sleep quality of RIF patients. Its sleep quality is not only affected by physiological factors, but also by psychological and lifestyle factors. Medical personnel should implement intervention strategies as early as possible based on relevant risk factors to improve the sleep quality of this population.

Keywords: recurrent implantation failure, assisted reproductive technology, sleep quality, predictive model, risk factors

Background

In recent years, the development of Assisted Reproductive Technology (ART) has brought hope to countless infertile families. However, some women still fail to achieve clinical pregnancy after multiple embryo transfers, a condition known as Recurrent Implantation Failure (RIF).[1] In the "Expert Consensus on Pre-implantation Genetic Diagnosis/Screening" released by the Chinese Medical Association's Reproductive Medicine Branch in 2018,[2] RIF is defined as the failure to achieve pregnancy after more than three embryo transfers or the transfer of 4–6 high-grade cleavage-stage embryos or three or more high-grade blastocysts, which accounts for about 12%-34% of ART-treated patients.[3] RIF

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patients, due to the high medical costs, repeated failures in assisted reproduction, and deteriorating marital relationships, become a vulnerable group within the assisted reproductive treatment population. They are prone to negative emotions and experiences such as anxiety, depression, and infertility stigma, which in turn affect their sleep quality and lead to the occurrence of sleep disorders,[4] severely impacting their quality of life. Sleep disorders are defined as abnormal sleep quality and quantity caused by organic or non-organic factors, resulting in sleep that cannot meet an individual's physiological needs and significantly affecting normal daytime activities.[5] These disorders can impact the number and quality of oocytes, fertilization potential, and clinical pregnancy rates of women undergoing ART, as well as interfere with the hormonal environment required for conception.[6] The "Healthy China Action (2019–2030)" initiative, launched by the National Health Commission of China,[7] emphasizes the importance of sleep health, making the improvement of sleep quality a key component of this action plan. However, sleep disorders in RIF patients are often overlooked by healthcare providers. It is essential for medical staff to identify early the factors influencing sleep in ART-treated patients, in order to improve their sleep health and, consequently, increase the success rate of embryo implantation. Machine learning, a core technology in artificial intelligence, is adept at handling complex nonlinear relationships between variables and can generate more robust risk prediction models. It has been widely applied in various areas of nursing.[8] Therefore, this study aims to use multiple machine learning algorithms to construct a predictive model for sleep disorders in RIF patients, evaluate and compare their performance, select the optimal model, and use the interpretable machine learning method SHAP (SHapley Additive ex Planations) to assess the main factors influencing sleep quality in RIF patients. The goal is to provide scientific evidence for the early detection and nursing intervention of sleep disorders in this population.

Materials and Methods

Study Subjects

The study subjects were selected from patients undergoing IVF/ICSI-ET assisted reproduction at the Reproductive Medicine Center of Tongji University Affiliated Obstetrics and Gynecology Hospital from January 2022 to June 2022. Inclusion criteria: 1) Patients who meet the diagnostic criteria for recurrent implantation failure (RIF) as defined in the "Chinese Expert Consensus on Clinical Diagnosis and Treatment of Recurrent Implantation Failure".[9] 2) There are no emotional disorders or serious mental illnesses present. 3) Willingness to voluntarily participate in the research study. Exclusion criteria: 1) Patients with immune system diseases. 2) Patients with a history of mental illness, alcohol or other psychoactive substances use (excluding tobacco, coffee, and tea), or those with chronic diseases such as hypertension, heart disease, uncontrolled or poorly controlled diabetes, autoimmune diseases, and severe systemic diseases. 3) Patients with chromosomal or genetic abnormalities in one or both partners. 4) Patients with reproductive system diseases affecting fertility, such as intrauterine adhesions, endometritis, or hydrosalpinx. Based on the four-step binary outcome prediction model,[10] previous studies have shown that 46% of infertile patients experience sleep disorders during embryo transfer.[11] With an absolute error of 0.05, the estimated sample size is at least 382 cases. This study strictly adhered to the indications and followed all relevant laws, regulations, and ethical principles, all subjects have informed consent and comply with the Helsinki Declaration. The study was approved by the Ethics Committee of Tongji University Affiliated Obstetrics and Gynecology Hospital (Ethics Approval Number: KS21296).

Methods

Research Tools

The research tools include: 1) General Information Survey: Designed by the researchers with reference to the "Chinese Guidelines for the Diagnosis and Treatment of Insomnia",[12] this survey includes 18 items such as age, body mass index (BMI), employment status, education level, monthly per capita income, duration of infertility, smoking history (>20 cigarettes/day), alcohol consumption history (40°–68° >100 mL/day), cola drinking habit (>500 mL/day), coffee drinking habit (>500 mL/day), strong tea drinking habit (>500 mL/day), sunbathing habit (outdoor activity >30 minutes/day), average daily exercise duration, weekly shift work hours, dinner time, sleep onset time, nap time, and whether the participant frequently changes sleep conditions. 2) Self-Rating Anxiety Scale (SAS):[13] The patients self-assess based on symptoms in the past week. The total raw score is calculated by summing the 20 items, with the standard score = raw score × 1.25. According to Chinese norms, a standard score of 50 indicates mild anxiety, 60–69 indicates moderate anxiety, and a score >70 indicates severe anxiety. 3) Self-Rating Depression Scale (SDS):[13] Patients self-assess based on symptoms in the past week. The total raw score is calculated by summing the 20 items, with the standard score = raw score × 1.25. According to Chinese norms, a standard score of 53 indicates mild depression, 63–72 indicates moderate depression, and a score >72 indicates severe depression. 4) Chinese Version of the Perceived Stress Scale (CPSS)[13:] Developed by Cohen et al in 1983 and revised by Chinese scholars such as Yang Tingzhong in 2003, with a Cronbach's alpha of 0.780, indicating good structural validity. The scale consists of two dimensions and 14 items. A total score of 11–26 indicates low perceived stress, 27–41 indicates moderate stress, and >42 indicates high stress. 5) Fertility Quality of Life Tool (FertiQoL):[14] Developed by the European Society of Human Reproduction and Embryology (ESHRE) and the American Society for Reproductive Medicine (ASRM), with a Cronbach's α of 0.92. The scale includes 34 items and consists of two main modules: the core fertility quality of life module (which includes emotional responses, body-mind relationship, marital relationship, and social relationships) and the treatment fertility quality of life module (which includes environmental and tolerance aspects). Certain items in both modules are reverse scored. The Likert 5-point scale (0–4 points) is used, and both the subscale and total scale scores can be converted to a 0–100 scale, with higher scores indicating better fertility quality of life. 6) Pittsburgh Sleep Quality Index (PSQI):[15] This scale evaluates subjective sleep quality in the past month across seven dimensions (subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction). Each dimension is scored from 0 to 3, with a total score range of 0–21, where higher scores indicate poorer sleep quality. A total score <8 is considered normal sleep quality, while a score ≥8 indicates sleep disorders. 7) Endometrial Thickness: Evaluated using Doppler ultrasound on the day of endometrial transformation to assess the thickness of the uterine endometrium. 8) Serum Hormone Levels: Blood samples (5 mL) are collected from the peripheral veins of the participants on the day of endometrial transformation. Electrochemiluminescence is used to measure the levels of follicle-stimulating hormone (FSH), luteinizing hormone (LH), prolactin (PRL), estradiol (E2), and progesterone (P).

Data Collection Method

The survey team consisted of two trained reproductive specialists, three reproductive nurses, and three nursing researchers. Prior to the investigation, experts from the reproductive medicine department and psychotherapists conducted training on the relevant knowledge for the participating medical staff. After obtaining consent from the study participants, the researchers distributed the questionnaires and asked patients to independently complete them on-site based on their actual conditions. The completed questionnaires were checked for completeness before being collected. Relevant laboratory data were obtained through electronic medical records. To ensure the accuracy and completeness of the data, all collected data were entered into Excel by two individuals for sorting and analysis.

Statistical Methods

Data were analyzed using SPSS 26.0 and Python 3.6.9 software. For normally distributed continuous data, the *t*-test was used, and the data were expressed as mean ± standard deviation Eqn. For non-normally distributed continuous data, the Mann–Whitney *U*-test was used, and the data were expressed as median (M) [interquartile range, IQR]. Categorical data were analyzed using chi-square or Fisher's exact test, and the results were presented as frequency (percentage) [n (%)]. LASSO (Least Absolute Shrinkage and Selection Operator) regression was used to select significant variables. Subsequently, 80% of the cases were randomly sampled without replacement to form the training cohort, and the remaining 20% were used as the validation cohort. Prediction models were built using six machine learning algorithms: Decision Tree (DT), Random Forest (RF), eXtreme Gradient Boosting (XGBoost), Support Vector Machine (SVM), MLP Neural Network (MLP), and Naive Bayes Classifier (NB). Ten-fold cross-validation was applied to enhance the models' generalizability. The models' performance was then assessed in both the training and validation cohorts using the area under the receiver operating characteristic curve (AUC), accuracy, sensitivity, specificity, and F1 score. SHAP values were used to explain the importance of the feature variables in the optimal model.

Results

Comparison of Clinical Data of RIF Patients

A total of 422 RIF patients who met the inclusion and exclusion criteria were surveyed in this study. After cleaning the data and removing outliers and patients with missing clinical data, 404 valid samples were obtained. Among these, 197 RIF patients had sleep disorders (PSQI ≥ 8), accounting for 48.76% of the total study population, while 207 RIF patients did not have sleep disorders (PSQI < 8), accounting for 51.24%. Comparison of the clinical data between the two groups showed statistically significant differences in 16 factors, including infertility duration and tea consumption ($P < 0.05$), as shown in Table 1.

Table 1 Comparison of Clinical Data Between the Two Groups of Patients

Item	Sleep Normally (n=207)	Sleep Disorders (n=197)	*t/x2/Z*	*P*
Age (year)	33(30,36)	33(31,36)	−0.744	0.457
BMI (kg/m2)	22.31(20.55,24.97)	22.48(20.44,24.94)	−0.273	0.785
Infertility duration	3(2,5)	4(2,5)	−3.279	0.001
Educational level			1.677	0.432
High school and below	53(25.60%)	57(28.93%)		
College/Undergraduate	110(53.14%)	92(46.70%)		
Master's degree or above	44(21.26%)	48(24.37%)		
Occupational status			0.744	0.389
Be on the job	50(24.15%)	55(27.92%)		
On the job	157(75.85%)	142(72.08%)		
Monthly income (Yuan)			2.565	0.464
0~5000	52(25.12%)	62(31.47%)		
5001~10000	68(32.85%)	60(30.46%)		
10,000~15000	46(22.22%)	44(22.33%)		
>15000	41(19.81%)	31(15.74)		
Cola			0.119	0.730
NO	179(86.47%)	168(85.28%)		
YES	28(13.53%)	29(14.72%)		
Tea			5.769	0.016
NO	113(54.59%)	84(42.64%)		
YES	9445.41%)	113(57.36%)		
Coffee			63.345	<0.001
NO	166(80.19%)	82(41.62%)		
YES	41(19.81%)	115(58.38%)		
Drinking			5.765	0.016
NO	195(94.20%)	172(87.31%)		
YES	12(5.80%)	25(12.69%)		
Smoking			1.001	0.317
NO	203(98.07%)	190(96.45%)		
YES	4(1.93%)	7(3.55%)		
Weekly shift work (h)			53.027	<0.001
None	161(77.78%)	93(47.21%)		
1~16	25(12.08%)	31(15.74%)		
17~32	13(6.28%)	47(23.86%)		
>32	8(3.86%)	26(13.19%)		
Daily dinner time			7.769	0.021
Before 18:00	25(12.08%)	33(16.75%)		
18:00~20:00	119(57.49%)	86(43.65%)		
After 20:00	63(30.43%)	78(39.59%)		

(*Continued*)

Table 1 (Continued).

Item	Sleep Normally (n=207)	Sleep Disorders (n=197)	t/x2/Z	P
Daily sleeping time			24.291	<0.001
Before 22:00	20(9.66%)	32(16.24%)		
22:00~24:00	121(58.45%)	67(34.01%)		
After 24:00	66(31.88%)	98(49.75%)		
Daily nap time (h)			1.222	0.748
None	32(15.46%)	38(19.29%)		
<0.5	93(44.93%)	88(44.67%)		
0.5~1	61(29.47%)	52(26.40%)		
>1	21(10.14%)	19(9.64%)		
Frequently changing sleep conditions			7.977	0.005
NO	158(76.33%)	125(63.45%)		
YES	49(23.67%)	72(36.55%)		
Sunbathe			18.819	<0.001
NO	162(78.26%)	184(93.40%)		
YES	45(21.74%)	13(6.60%)		
Daily exercise time (h)			116.091	<0.001
None	28(13.53%)	126(63.95%)		
≤0.5h	76(36.71%)	43(21.83%)		
0.5~1	68(32.85%)	23(11.68%)		
>1	35(16.91%)	5(2.54%)		
SAS			27.305	<0.001
None	104(50.24%)	71(36.04%)		
Mild	76(36.71%0	58(29.44%)		
Moderate	23(11.11%)	50(25.38%)		
Severe	4(1.93%)	18(9.14%)		
SDS			57.539	<0.001
None	116(56.04%)	56(28.43%)		
Mild	73(35.27%)	65(32.99%)		
Moderate	15(7.25%)	55(27.92%)		
Severe	3(1.44%)	21(10.66%)		
CPSS			14.362	0.001
Low pressure	27(13.04%)	18(9.14%)		
Moderate pressure	133(64.25%)	100(50.76%)		
High pressure	47(22.71%)	79(40.10%)		
Fertiqol	72.18±10.89	51.57±16.48	−14.895	<0.001
FSH (IU/L)	6.30(5.04,7.64)	11.21(9.12,13.67)	−16.012	<0.001
LH (IU/L)	3.97(2.72,5.76)	3.90(2.75,5.93)	−0.035	0.972
E2 (pg/mL)	86.54(74.72,97.95)	62.34(52.26,74.38)	11.885	<0.001
PRL (ng/mL)	11.03(8.32,15.65)	11.19(8.36,15.710	−0.118	0.906
P (ng/mL)	51.65(45.29,57.95)	51.75(43.04,60,54)	−1.204	0.228
T (ng/mL)	0.29(0.20,0.54)	0.27(0.19,0.47)	−1.122	0.262
Endometrial Thickness	8.52±1.44	8.34±1.47	1.236	0.217

Screening of Risk Factors Affecting Sleep Quality in RIF Patients

LASSO regression analysis was performed on the variables with statistically significant differences identified in the univariate analysis. A total of 9 risk factors were selected from the 16 variables, which were: Coffee, SDS, Weekly shift work hours, FSH, SAS, Fertiqol, E2, Sunbathe, and Daily exercise time. Using 10-fold cross-validation, models with different variable combinations were fitted. According to the lambda.1 se variable selection criterion, log(λ) = 0.0142, the model demonstrated excellent performance and was streamlined, as shown in Figures 1 and 2.

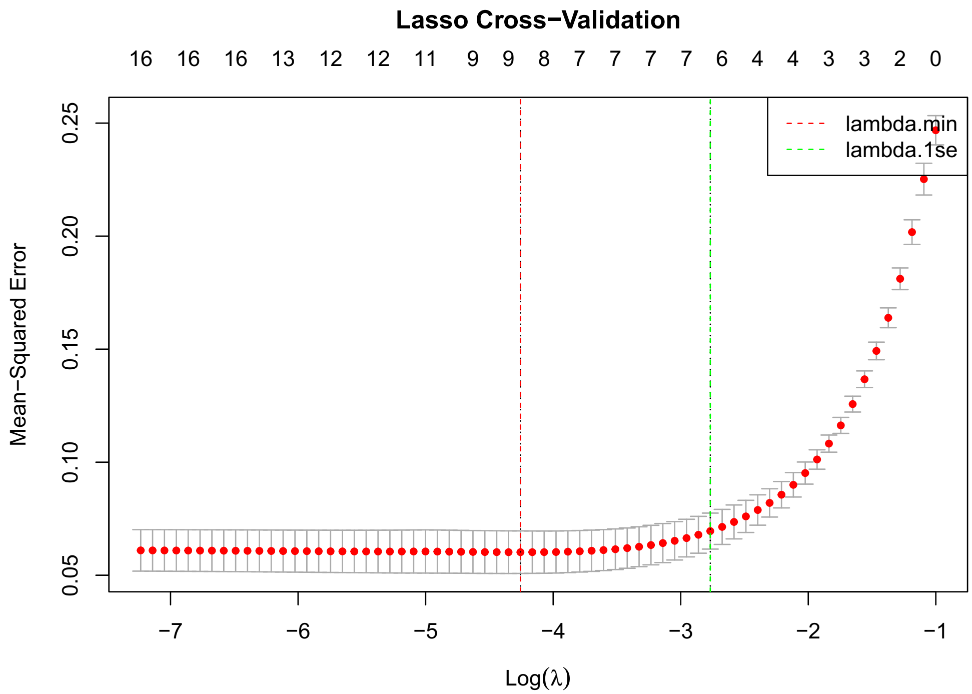

Figure 1 Risk Factor Selection Based on LASSO Regression.

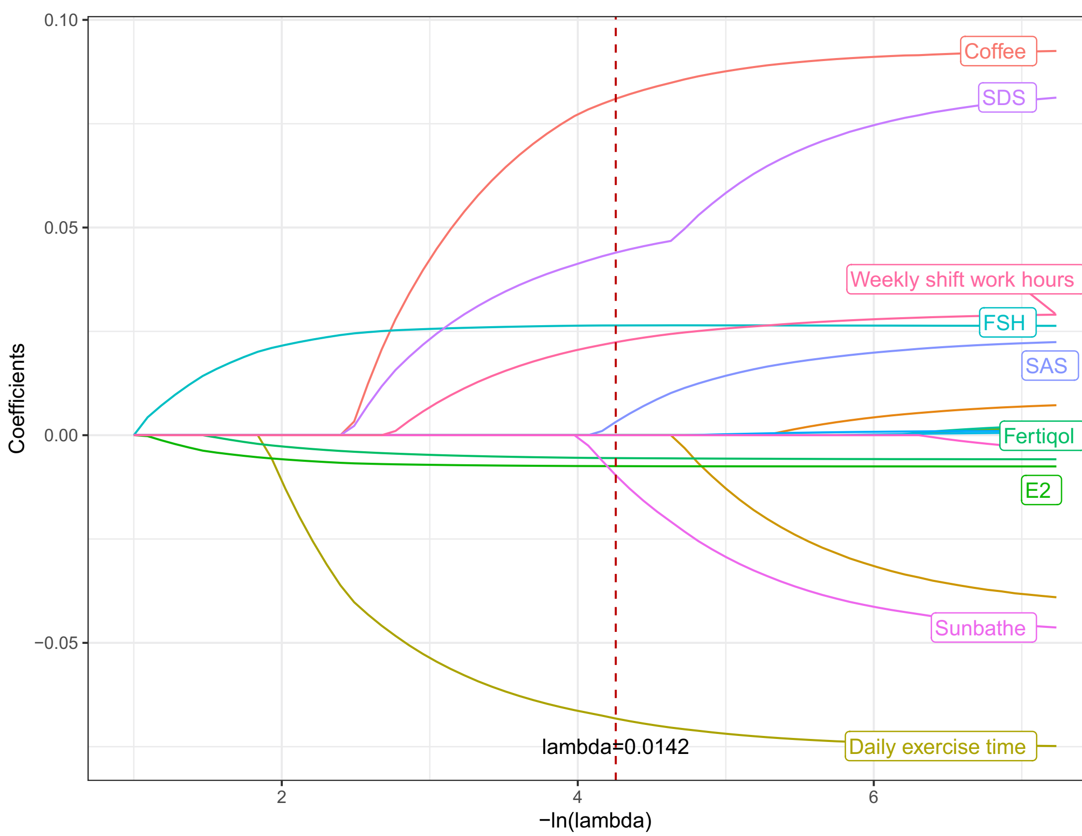

Figure 2 Coefficient Distribution Plot.

Table 2 Evaluation Comparison of Six Machine Learning Models

Model	AUC	Accuracy	Sensitivity	Specificity	F1
Training cohort					
DT	0.914	0.855	0.851	0.859	0.855
RF	0.992	0.955	0.942	0.967	0.954
XGBoost	0.993	0.963	0.950	0.975	0.924
SVM	0.943	0.905	0.876	0.934	0.941
MLP	0.953	0.917	0.917	0.917	0.935
NB	0.941	0.909	0.893	0.926	0.908
Validation cohort					
DT	0.842	0.765	0.756	0.775	0.765
RF	0.941	0.938	0.927	0.950	0.938
XGBoost	0.924	0.889	0.902	0.875	0.892
SVM	0.940	0.914	0.902	0.925	0.914
MLP	0.935	0.914	0.951	0.875	0.918
NB	0.938	0.926	0.927	0.925	0.927

Construction of Prediction Models

Using Python software, the NB, DT, RF, MLP, SVM, and XGBoost classifier modules from the sklearn library were imported. The 9 risk factors selected by LASSO regression were used as independent variables, and the occurrence of sleep disorders (yes/no) was used as the dependent variable. The data were randomly split into training and validation sets at an 80:20 ratio for model training and validation. Ten-fold cross-validation was employed to determine the optimal parameters, and the AUC, accuracy, sensitivity, specificity and F1 score were calculated for each model. The results showed that in the Training cohort, the XGBoost model performed the best, with the highest AUC, accuracy, sensitivity, and specificity values. The RF model performed second only to the XGBoost model, ranking second; however, in the Validation cohort, the RF model performed the best, although slightly inferior to the MLP model in Sensitivity, overall, RF is the optimal model for this study. The results are detailed in Table 2, Figures 3 and 4.

Feature Importance Ranking of the Optimal Model

To further visually explain the impact of selected variables on the RF model, SHAP was used to interpret feature contributions. The higher the positive or negative SHAP value, the more important the corresponding feature variable. In the SHAP summary plot, the length of each variable on the horizontal axis represents its contribution to the prediction result, and the color of the dots indicates the magnitude or category of the variable, as shown in Figure 5. The factors influencing sleep quality in RIF patients were ranked as follows: E2, SDS, Fertiqol, FSH, Daily exercise time, Weekly shift work hours, Coffee, Sunbathe, and SAS, as shown in Figure 6.

Discussion

Selection of the Optimal Model

In this study, the RF model exhibited the best overall predictive performance. Although the RF model's performance in the training set was not particularly outstanding, it achieved the highest AUC, Accuracy, Specificity, and F1 Score in the validation set. Despite having slightly lower Sensitivity compared to the MLP model, the RF model was still considered

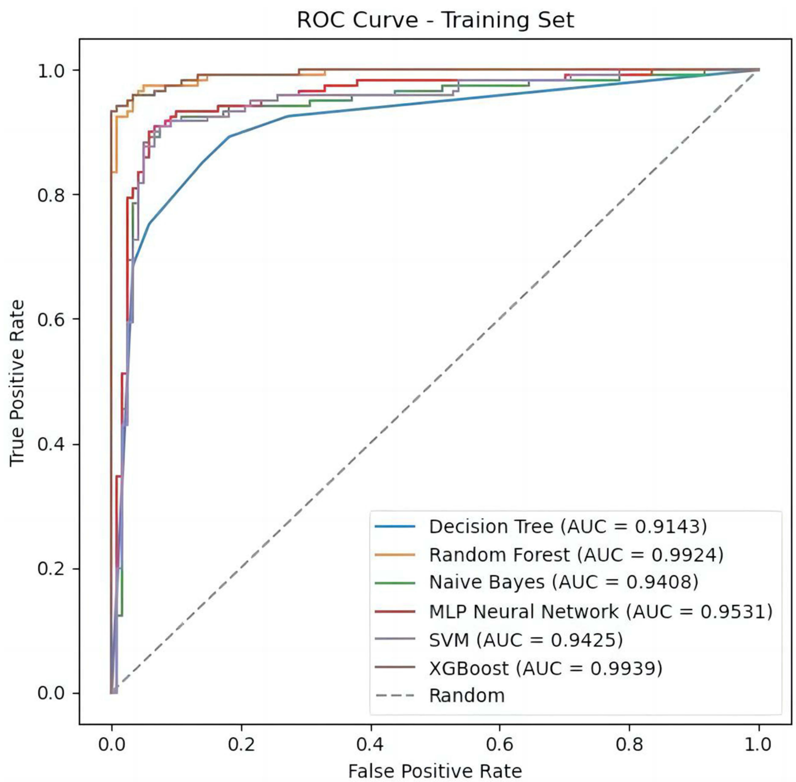

Figure 3 ROC of Six Machine Learning Models in the Training Cohort.

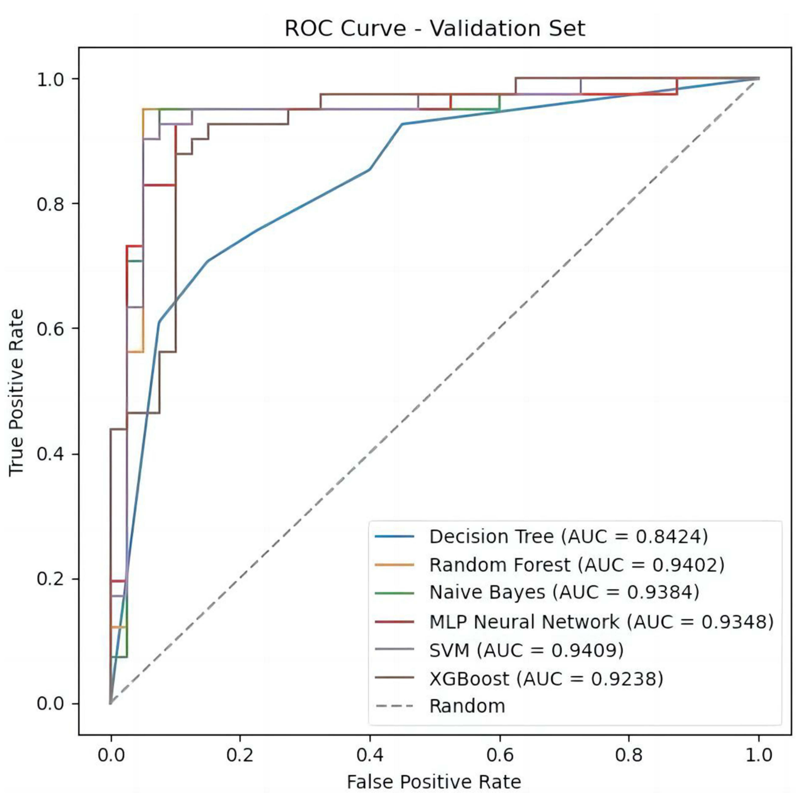

Figure 4 ROC of Six Machine Learning Models in the Validation Cohort.

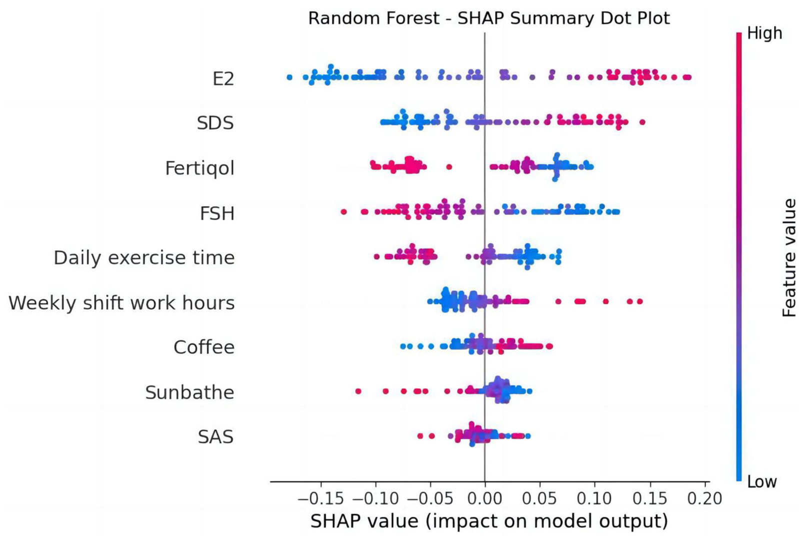

Figure 5 SHAP Summary Plot of the 9 Feature Variables in the RF Model.

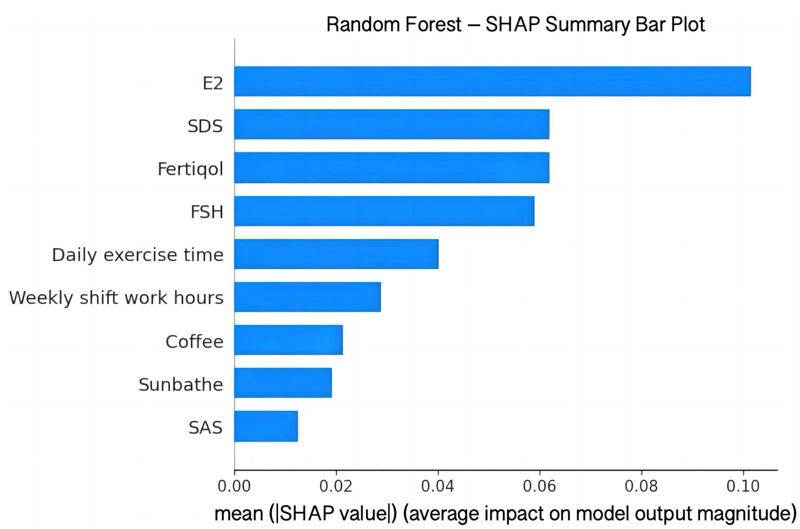

Figure 6 Feature Importance Ranking of the RF Model.

the best overall and was chosen as the optimal model for this study. Compared to traditional logistic regression models, machine learning algorithms handle complex nonlinear relationships between variables more effectively. Additionally, by using multiple machine learning algorithms, this study was able to identify the best-performing algorithm for the given dataset, facilitating the selection of a high-performance model. The RF model demonstrated strong adaptability to the dataset, utilizing all available data for both model construction and validation, effectively avoiding the tendency for overfitting. Therefore, the RF model is considered the optimal model in this research.

Moreover, feature selection through LASSO regression effectively eliminated multicollinearity among variables. However, while LASSO can reflect the overall impact of the variables, it does not capture the specific effects of variables within particular categories. To address this, the SHAP method was introduced to interpret the importance and contribution of variables in the RF model. This approach provided insights into the correlation between feature variables and prediction outcomes, allowing for a more intuitive understanding of how different risk factors influence sleep quality.

Factors Influencing Sleep Quality in RIF Patients

Physiological Factors Leading to Sleep Disorders

Fluctuations in reproductive hormones can significantly affect sleep quality. In this study, E2 and FSH were identified as major factors influencing the sleep quality of RIF patients. Some studies have pointed out that FSH is positively correlated with sleep duration, while E2 is negatively correlated with sleep quality.[16] The underlying reason might be that E2 is involved in regulating the body's temperature and daily routine. Low levels of E2 can affect normal thermoregulation, particularly after skin heat dissipation, leading to a decrease in core body temperature, which can interrupt sleep and contribute to sleep disorders.[17] On the other hand, FSH levels increase as E2 levels decline, and FSH may play a role in the feedback regulation process of E2, contributing to sleep disturbances.

Additionally, during ART treatment, gonadotropin-releasing hormone (GnRH) analogs, including GnRH agonists and GnRH antagonists, are used for controlled ovarian stimulation (COS) and luteal phase support (LPS) to induce follicle development and increase follicular numbers, thereby improving embryo implantation and pregnancy rates for better reproductive outcomes.[18] However, the use of hormonal drugs during treatment often leads to physical discomfort, including bloating, abdominal pain, dizziness, headaches, hot flashes, nausea, vomiting, breast tenderness, and mood swings, all of which can negatively affect sleep quality and contribute to sleep disturbances.[19]

Psychological Factors Leading to Sleep Disorders

In this study, anxiety, depression, and fertility-related quality of life were found to significantly influence the sleep quality of RIF patients. During ART treatment, women generally face greater reproductive pressure compared to men. In this study, RIF women, having failed to achieve clinical pregnancy despite multiple embryo transfers, experienced increasing pressure from family and society. This, combined with repeated medical visits, tests, and medication cycles, contributed to the accumulation of negative emotions, leading to a decline in fertility-related quality of life, ultimately resulting in the onset of anxiety and depression.

Studies have shown that poor sleep quality in infertility patients is often related to psychological factors.[20] Anxiety and depression are positively correlated with sleep quality, and they jointly affect poor subjective sleep quality, longer sleep onset latency, and lower sleep efficiency. Moreover, anxiety and depression influence sleep quality in an interactive way, creating a vicious cycle.[4] Prolonged negative emotions can disrupt the cortical function of the brain, increase sympathetic nerve excitability, and elevate catecholamine concentrations in the blood, triggering a stress response to counteract these negative emotions. When these emotions exceed the psychological coping capacity, pathological states can arise, leading to sleep disorders.[21] Additionally, anxiety and depression can cause an imbalance in brain neurotransmitters. Changes in dopamine and norepinephrine levels may affect the stability of the sleep-wake cycle, resulting in a decline in sleep quality.[22] Furthermore, as a special group among infertility patients, RIF patients often experience various difficulties in their marital relationships, sexual experiences, and psychosocial conditions.[23] These challenges contribute to a decline in fertility-related quality of life, with physical and mental health issues becoming more prominent, especially during COS and LPS phases, when frequent blood draws and ultrasound monitoring are required. This severely impacts the sleep quality of these patients.

The Impact of Poor Lifestyle on Sleep Quality

The results of this study indicate that factors such as lack of sunlight exposure, lack of exercise, shift work, coffee consumption, and fertility-related quality of life can all affect the sleep quality of RIF patients. From a physiological perspective, poor lifestyle habits primarily affect the endocrine regulation of the female body, leading to poor sleep quality in these patients. Light exposure impacts the suprachiasmatic nucleus in the hypothalamus, which controls the circadian rhythm, by regulating the secretion of melatonin from the pineal gland, thereby affecting sleep and alertness.[12] Light stimulation helps establish and consolidate regular sleep-wake cycles by modulating neural and endocrine system activity, including the secretion of hormones like melatonin.[24] Therefore, RIF patients who are not exposed to sunlight may experience sleep disorders. Regular physical exercise has been shown to help regulate the balance between pro-inflammatory and anti-inflammatory cytokines in chronic insomnia patients, stabilizing the sleep-wake cycle and improving the subjective experience of sleep.[25] Physical activity promotes the release of endorphins in the brain, inducing a sense of euphoria and distracting the patient from excessive concern about infertility, thus ensuring better quality of life and positively responding to stress, ultimately improving sleep quality. Frequent shift work can lead to

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insufficient sleep, lower sleep quality, and disruptions to the circadian rhythm. Studies have also shown that the total amount of sleep decreases as the shift work schedule intensifies.[26] Changes in sleep patterns may impair the hypothalamic-pituitary-gonadal axis, alter the secretion of gonadotropins and sex steroids, inhibit melatonin production, and disrupt the reproductive process. This not only further affects sleep quality but may also negatively impact ART outcomes.[27] Coffee has become an integral part of modern life, and its main component, caffeine, acts as an adenosine receptor antagonist. The primary mechanism by which caffeine causes insomnia is by binding to the A2A adenosine receptors, thereby inhibiting sleep and enhancing wakefulness.[28] Additionally, caffeine can stimulate the nervous system by modulating neurotransmitter systems, which can induce abnormal excitability and trigger insomnia or anxiety-like states.[29] It can also stimulate the adrenal glands to release excitatory neurotransmitters like adrenaline into the bloodstream, which in turn stimulates various body tissues and the central nervous system, enhancing muscle contraction and promoting arousal, leading to poor sleep quality.[30]

Limitations

Although this study constructed a predictive model for sleep quality in RIF patients, there are still many shortcomings in this research. First, this study is a single-center retrospective study, and the results may only represent the current situation of the hospital where the study was conducted. Firstly, this study is a single center retrospective study with limited sample size and no external validation conducted by external hospitals. The results may only represent the current situation of the research hospital, and extrapolation is worth further exploration. Secondly, the observation indicators of this study are limited, only based on the lifestyle and psychological status of RIF patients themselves, ignoring the role of family support (such as partners) and the possible impact of medication on sleep during assisted reproductive therapy. This may result in incomplete investigation results.

In future research, multiple centers can be contacted for collaboration to further validate the effectiveness of the prediction model; We look forward to the addition of a multidisciplinary team to incorporate more laboratory and drug action indicators that may be related to sleep quality, in order to improve the prediction model for sleep quality in RIF patients.

Conclusion

This study constructed predictive models for sleep quality in RIF patients using various machine learning algorithms. After evaluation and comparison, the Random Forest (RF) model emerged as the optimal model. The main risk factors identified include FSH, E2, Fertiqol, SDS, daily exercise time, weekly shift work hours, coffee consumption, SAS, and sunbathing. These factors encompass physiological indicators, psychological factors, and lifestyle habits. Clinical healthcare providers should develop and implement intervention strategies targeting these risk factors early to reduce the occurrence of sleep disorders during the ART process and improve the quality of life for RIF patients.

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Disclosure

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