

Research on the Impact of Mother's Physical and Mental Health on Infant Behavioral Characteristics and Sleep Quality

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Abstract: This study focuses on the close connection between mother's physical and mental health and infant growth, and comprehensively employs various mathematical models and analytical methods to conduct in-depth analysis of the relevant data of 390 infants aged 3 to 12 months and their mothers. The aim is to reveal the intrinsic relationship between mother's physical indicators, psychological indicators, and infant behavioral characteristics and sleep quality, and accordingly propose scientific and reasonable intervention strategies to provide strong theoretical support and practical guidance for promoting infant growth and development. The research results show that mother's psychological indicators have a significant impact on infant's behavioral characteristics and sleep quality, while the impact of physical indicators is relatively weak. The relationship model constructed based on methods such as random forest model can describe and predict infant's growth status more accurately, providing quantitative basis for optimizing intervention measures.

Keywords: Mother's Physical and Mental Health; Infant Growth; Random Forest Model; Spearman Correlation Coefficient; K-means Clustering.

1. Introduction

Mothers play an irreplaceable role in infants' growth, providing both material support and emotional security. Maternal adverse psychological conditions like depression, anxiety, and stress can negatively impact infants' cognitive, emotional, and social development. Despite prior research in this area, there are gaps in indicator correlation depth, model accuracy, and quantitative intervention strategies.

Neuroscientifically, infants' brain development in early stages is shaped by mothers' emotional states through interactions. Sociologically, the mother - infant relationship, the start of infants' socialization, is affected by maternal mental health. Previous studies mainly offer qualitative descriptions, lacking in - depth exploration of multi - factor interactions in indicator analysis, simplifying model construction, and basing intervention strategies on experience without a quantitative basis.

This study will use multidisciplinary theories and advanced data analysis. It aims to deeply analyze the links between maternal mental health and infant growth indicators, construct more accurate models, and quantify intervention strategies. By doing so, it hopes to provide practical scientific evidence for improving maternal - infant health and advancing research in this field.

2. Research Methods

2.1. Data Sources

This study's data covers rich information of 390 infants aged 3 to 12 months and their mothers. The mother's information includes physical indicators such as age, marital status, education level, gestation period, and delivery method, as well as psychological indicators such as CBTS (Postpartum Trauma-Related Stress Disorder Questionnaire), EPDS (Edinburgh Postnatal Depression Scale), and HADS

(Hospital Anxiety and Depression Scale). The infant's information includes sleep duration throughout the night, number of awakenings, and sleep patterns. These data provide a solid foundation for in-depth exploration of the relationship between maternal and infant health.

2.2. Data Analysis Methods

To effectively analyze the relevant data on maternal and infant health, this study comprehensively employs various data analysis methods.

In the data preprocessing and dimension reduction stage, this study uses the CRITIC weighting method to assign weights and perform dimension reduction on the data. This method uses standard deviation to measure the fluctuation of data and correlation coefficient to represent the conflict degree between indicators, thereby determining the weights of each indicator. Through this process, the initial 12-dimensional data is reduced to 4-dimensional data of physical indicators, psychological indicators, behavioral characteristics, and sleep quality, effectively highlighting key information and laying the foundation for subsequent analysis, which is shown in Table 1.

When exploring the correlation between variables, given that the data do not satisfy the characteristics of normal distribution, this study selects the Spearman correlation coefficient for analysis. This coefficient calculates the linear correlation between the ranks of two variables and can accurately measure the degree of association between quantitative or ordinal variables. It does not have specific requirements for the distribution shape of the original variables, thus providing an appropriate analytical tool for precisely revealing the correlation between maternal physical and mental indicators and infant growth indicators.

Table 1. CRITIC Weight Table

Indicator	Details	Weight	Direction
Physical Indicators	Mother's Age	56.519	Positive
	Marital Status	2.432	Negative
	Educational Attainment	12.132	Negative
	Gestation Time	12.132	Negative
	Delivery Method	1.605	Positive
Psychological Indicators	CBTS	34.119	Positive
	EPDS	34.119	Positive
	HADS	34.119	Positive
Behavioral Characteristics Sleep Quality	Infant Behavioral Characteristics	1	Positive
	Total Nighttime Sleep Duration	29.678	Negative
	Number of Awakenings	41.949	Positive
	Sleep Onset Method	28.372	Negative

In terms of constructing the relationship model, this study selects the Random Forest model and XGBoost model. The Random Forest model belongs to an ensemble learning algorithm, consisting of numerous decision trees. It constructs multiple different decision tree models through bootstrap sampling and integrates their decision results. It performs exceptionally well in handling high-dimensional data and classification prediction tasks. The XGBoost model is an ensemble algorithm based on gradient boosting, with advantages such as regularization and parallel computing. It can effectively avoid overfitting and improve the accuracy and efficiency of the model. By comparing the performance of these two models in terms of accuracy, recall rate, precision, and F1 index, the more superior model is selected to depict the relationship between infant behavioral characteristics and maternal physical and mental indicators.

Regarding the research on infant sleep quality, this study adopts the K-means clustering method. This method iteratively calculates the distance between data points and cluster centers, divides the data into different clusters, and realizes the classification of infant sleep quality. At the same time, it combines the Principal Component Analysis method to draw scatter plots, visually presenting the clustering effect, and further deeply analyzing the distribution characteristics of infant sleep quality and its potential connection with maternal physical and mental indicators.

3. Model Construction and Result Analysis

3.1. Correlation Analysis of Maternal Physical and Mental Indicators and Infant Growth Indicators

After preprocessing the data, including handling missing values and outliers, and quantifying "infant behavioral characteristics" (quiet type is recorded as 1, moderate type as 2, and contradictory type as 3), the Spearman correlation coefficients of 12 detailed items and 4 indicators were calculated respectively. The results show that there is a significant correlation between maternal psychological indicators and infant behavioral characteristics and sleep quality, while the correlation between maternal physical indicators is not significant. Further analysis reveals that possible influencing mechanisms include care style, emotional transmission, sleep patterns, mother-infant interaction, and biological factors, among others. For example, the emotional stability of the mother will affect her care style for the infant, thereby influencing the establishment of the infant's sense of security and trust; the mother's emotional state can be transmitted to the infant through facial

expressions and body movements, affecting the infant's emotional and social behavior development; the sleep patterns of the mother during pregnancy or lactation may also affect the infant's sleep quality.

3.2. Construction and Validation of the Model for the Relationship between Infant Behavioral Characteristics and Mother's Physical and Mental Indicators

Two models, namely Random Forest classification model and XGBoost model, were respectively constructed to describe the relationship between infant behavioral characteristics and mother's physical and mental indicators. During the construction of the Random Forest model, 50 trees were selected for testing. The mother's physical indicators (age, mode of delivery, educational level, marital status, and gestation period) and psychological indicators (CBTS, EPDS, HADS) were taken as input variables, and infant behavioral characteristics as the output variable. Through multiple training sessions, the accuracy rate, recall rate, precision rate, and F1 index of different training models were compared in Table 2, and the model with the best performance was selected.

For the XGBoost model, binary:logistic is selected as the loss function, gbtrees as the booster, and 5-fold cross-validation method is adopted to optimize the model parameters. Through the analysis of the data, the proportion of importance of each indicator for the behavioral characteristics of infants is determined.

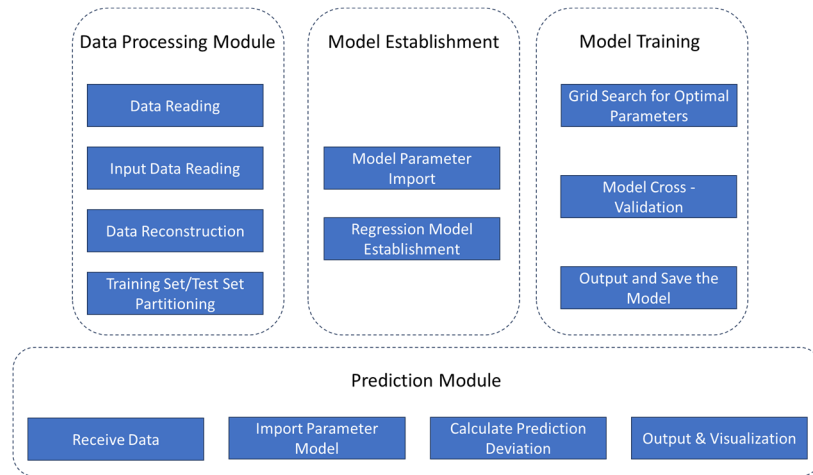
By comparing the evaluation indicators of the two models, it was found that the random forest classification model performed better in terms of accuracy, recall rate, precision rate and F1 index. Therefore, this model was selected as the model to describe the relationship between the behavioral characteristics of infants and the physical and mental indicators of their mothers. Using this model to predict the behavioral characteristics of the last 20 groups of infants in the dataset provided an important basis for subsequent research.

3.3. Optimization of Treatment Plan Based on Behavioral Feature Transformation

Treat the relationship between the illness score and the treatment cost as a linear one. Based on the given data of illness score and treatment cost, calculate the treatment cost per point. Here, i represents the order of the psychological indicator scale, and CBTS is recorded as 1, EPDS as 2, and HADS as 3. After calculation, $k_1 \approx 870.667$, $k_2 = 695$, $k_3 = 2440$ (Unit: Yuan/minute).

Table 2. Prediction results of the Random Forest model

Mother Age	Marital Status	Education Level	Gestation Time	Delivery Mode	CBTS	EPDS	HADS	Predict Infant Behavioral Characteristics
29	2	4	40	1	7	15	12	2
29	2	3	42	1	9	14	12	2
23	2	2	38.5	1	7	12	7	2
27	2	3	36.3	1	8	4	5	2
36	2	4	39	1	6	6	8	2
30	2	5	41.2	1	5	8	5	1
28	2	2	40.6	1	8	11	9	1
32	2	5	37	1	3	6	7	2
28	2	5	38	1	7	11	5	2
31	2	4	42	1	4	5	8	2
25	2	2	40.5	1	16	22	15	2
27	2	5	40.4	1	4	6	10	2
33	2	5	39	1	6	6	4	2
25	2	3	39	1	0	4	5	1
28	2	2	41	1	9	6	5	2
31	2	3	39.5	1	1	4	4	1

**Figure 1.** The Establishment Process of the XGBoost Algorithm**Table 3.** Prediction results of the XGBoost model

Mother Age	Marital Status	Education Level	Gestation Time	Delivery Mode	CBTS	EPDS	HADS	Predict Infant Behavioral Characteristics
29	2	4	40	1	7	15	12	1
29	2	3	42	1	9	14	12	0
23	2	2	38.5	1	7	12	7	1
27	2	3	36.3	1	8	4	5	1
36	2	4	39	1	6	6	8	1
30	2	5	41.2	1	5	8	5	1
28	2	2	40.6	1	8	11	9	2
32	2	5	37	1	3	6	7	0
28	2	5	38	1	7	11	5	1
31	2	4	42	1	4	5	8	1
25	2	2	40.5	1	16	22	15	1
27	2	5	40.4	1	4	6	10	1
33	2	5	39	1	6	6	4	1
25	2	3	39	1	0	4	5	0
28	2	2	41	1	9	6	5	1
31	2	3	39.5	1	1	4	4	0
26	2	2	37	1	4	9	14	0
26	2	5	39	1	0	3	3	0
27	2	5	41.2	1	0	0	4	1
31	2	5	38	1	3	7	7	1

Table 4. Comparison of the two models

		Accuracy	Recall	Precision	F1-Score
Random Forest	Training Set	0.906	0.906	0.919	0.902
	Test Set	0.588	0.588	0.517	0.506
XGoost	Training Set	1	1	1	1
	Test Set	0.535	0.535	0.513	0.52

Meanwhile, in this paper, the treated score will be denoted as x_i , where $x_1 \in [1,16]$, $x_2 \in [0,23]$, $x_3 \in [0,19]$, $x_1, x_2, x_3 \in M$. The treatment scores of the three psychological indicators, namely CBTS, EPDS and HADS, were arranged and combined in all possible ways, resulting in a total of 6,992 treatment plans. A treatment cost equation was then established:

$$P = k_1 \times (16 - x_1) + k_2 \times (23 - x_2) + k_3 \times (19 - x_3) + C$$

Herein, P represents the treatment cost and C is a constant, with $C = 1000$.

Taking infant No. 238 with contradictory behavioral characteristics as an example, when the characteristic values of physical indicators remain unchanged, the characteristic values of psychological indicators are changed to predict the behavioral characteristic results. After calculation, the boundary point between contradictory and moderate psychological indicators is determined to be 72.62, and the

boundary point between moderate and quiet is 59.95. By screening out the treatment plans that meet the conditions, the plan with the lowest cost is found, providing an economically effective intervention strategy for improving the behavioral characteristics of infants.

3.4. Construction of the Infant Sleep Quality Assessment and Prediction Model

The K - means clustering method is used to classify the sleep quality of infants. Based on the three elements of the infant's total sleep time, number of awakenings during sleep, and sleep onset method, through multiple iterations of calculation, the infant's sleep quality is divided into four categories. The scatter plot is drawn using the principal component analysis method to visually display the clustering effect. It is found that category 1, category 2, category 3, and category 4 correspond to the poor, medium, good, and excellent sleep quality of infants respectively.

Table 5. K - means Clustering Results

Cluster Category	Frequency	Percentage
Cluster Category_1	95	25.0%
Cluster Category_2	169	44.47%
Cluster Category_3	37	9.74%
Cluster Category_4	79	20.79%
Total	380	100.0%

Maintaining the settings unchanged, using MATLAB to predict the 20 sets of samples with solved problems through

the K-Means model, the clustering prediction scatter plot and the K-Means prediction results are as follows:

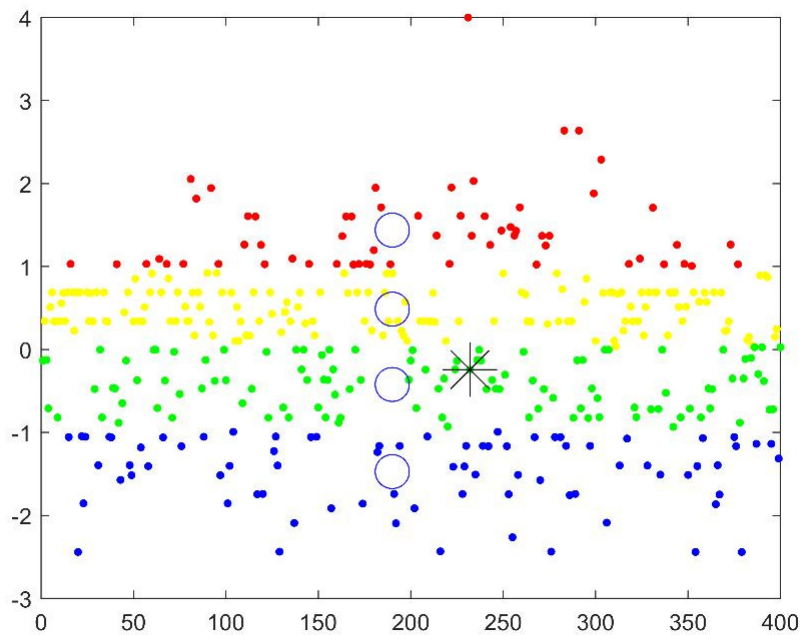
**Figure 2.** Scatter Plot of Clustering Prediction

Table 6. K - Means Clustering Summary and Prediction Results Table

Age	Marital	Educational	Gestation	Method	CBTS	EPDS	HADS	Sleep Quality
29	2	4	40	1	7	15	12	Medium
29	2	3	42	1	9	14	12	Good
23	2	2	38.5	1	7	12	7	Good
27	2	3	36.3	1	8	4	5	Medium
36	2	4	39	1	6	6	8	Good
30	2	5	41.2	1	5	8	5	Medium
28	2	2	40.6	1	8	11	9	Poor
32	2	5	37	1	3	6	7	Medium
28	2	5	38	1	7	11	5	Good
31	2	4	42	1	4	5	8	Medium
25	2	2	40.5	1	16	22	15	Medium
27	2	5	40.4	1	4	6	10	Good
33	2	5	39	1	6	6	4	Good
25	2	3	39	1	0	4	5	Medium
28	2	2	41	1	9	6	5	Poor
31	2	3	39.5	1	1	4	4	Medium
26	2	2	37	1	4	9	14	Good
26	2	5	39	1	0	3	3	Good
27	2	5	41.2	1	0	0	4	Poor

Based on this, a random forest classification model was established, with the physical and psychological indicators of the mother as input features and the comprehensive sleep quality rating of the infant as the target variable. Through the division and training of the training set and the test set, the model parameters were continuously optimized to improve the prediction accuracy of the model. Using this model, the comprehensive sleep quality of the last 20 groups of infants in the dataset was predicted, providing a scientific and reliable method for evaluating the sleep quality of infants.

3.5. Adjustment of Treatment Plans Based on Comprehensive Consideration of Behavioral Characteristics and Sleep Quality

Based on the above research, sleep quality indicators are further considered to optimize the treatment plans. By conducting permutations and combinations, various possible treatment plans are obtained. Combined with K - means clustering analysis, treatment plans that meet both the requirements of infant behavioral characteristics and sleep quality are selected. Among all the qualified plans, the one with the lowest cost is retrieved to provide comprehensive intervention strategies for the overall improvement of infant growth quality.

4. Model Verification and Reliability Analysis

To ensure the accuracy and reliability of the research results, the established model was comprehensively verified. In the correlation analysis, not only the degree of correlation between variables was calculated, but also significance tests were conducted. By calculating the statistical t-value and querying the corresponding probability P-value, the significance of the influence of maternal physical indicators and psychological indicators on infant behavioral characteristics and sleep quality was verified.

During the model selection process, by comparing the evaluation indicators of the random forest model and XGBoost model, the performance differences of different models were analyzed, and the optimal model was selected to ensure that the model could accurately describe the relationship between variables. In the process of optimizing

treatment plans and evaluating sleep quality, various possible situations were comprehensively considered. Through permutation combinations and clustering analysis and other methods, the reliability and validity of the results were ensured.

5. Conclusion

This study explored the impact of maternal physical and mental health on infant behavior and sleep via data analysis and model building. It found maternal psychological indicators crucial, established relationship and prediction models, and proposed intervention strategies. However, it has limitations. Future research should expand the sample size, cover different regions and socioeconomic backgrounds. Also, factors like family environment and social support should be included to improve the model. This will deepen understanding, offer more effective strategies, and support infant healthy growth.

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