Research on the relationship between mother's physical and mental health and infant sleep status based on regression analysis

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Abstract. This study explores the influence of maternal physical and mental indicators on infant sleep. A mathematical model is established by examining the data of 390 infants aged between 3 and 12 months, along with relevant information about their mothers. The data undergoes quality checks, including the identification of missing values and outliers using tools such as the "find" function in MATLAB. Categorical variables are encoded, and the time-based variable of sleep duration is transformed into a numerical format. Spearman's correlation coefficient is then employed to analyze the relationships between different variables, specifically focusing on the patterns between maternal physical and mental indicators and infant sleep duration. The reliability of the questionnaire is ensured through KMO testing, and a linear regression model is established to examine the relationship between mothers and infants. Finally, the linear regression equation is used to predict the behavioral characteristics of the last 20 infants. The findings of this study are of significant importance in understanding the impact of maternal factors on infant sleep and provide valuable insights for further research in related fields.

Keywords: Numerical Processing, Quality Inspection, Regression Analysis, Partial Least Squares (PLS) Model.

1. Introduction

In a baby's life, the mother is one of the most important people. Whether it is the baby's material provision and protection, or the baby's emotional support, it is inseparable from the mother. Thus, a mother's negative mental health status may have a negative impact on the baby. The HuaShu Cup national Mathematical Modeling Competition provided data on 390 infants aged 3 to 12 months and their mothers. Data includes physical and mental indicators for mothers as well as sleep quality indicators for babies.

Wright et. al. investigate infant development and mental health along with maternal characteristics and the mother-infant relationship in 45 dyads (60% New Zealand European, 20% Māori, 11% Pacific) admitted to a new MBU [1]. In the study conducted by Fochesatto et. al., frequencies, means, standard deviations, and generalized linear models were used for the data analysis. Additionally, a 95% confidence interval was employed for the analyses [2]. Norholt presented brief theoretical framework for mother-infant contact, drawing on animal studies as well as human studies of preterm infants and neonates [3]. Panza et. al. analyze the relationship between maternal psychological status during pregnancy and postpartum and the main infantile functional gastrointestinal disorders [4]. Saraswat et. al. give the information that if there is untreated maternal depression then it can lead to anxiety, fear, negative effect on child development, disruption of the mother-infant relationship, and the occurrence of depressive symptoms in the early life of infants [5]. Malinit makes an effort towards bridging the "10/90 gap in infant mental health research," wherein 90% of the world's infants are born in low-middle-income countries Population Reference Bureau, and only 10% of the worldwide spending on health research is directed towards the problems that primarily affect the poorest 90% of the world's population Tomlinson et al. [6-7]. Roubinov et. al. propose a conceptual model whereby mothers' ACEs impact maternal-infant dyadic functioning and later biobehavioral health outcomes through heightened perinatal psychosocial risk. Correia et. al. investigate whether infants' chronotype, sleep and development were associated with their respective mothers' chronotype, sleep, mental health and socioeconomic status [8]. Wang et. al. explore the relationship between physical activity and individual psychology, physiology, subjective quality of life and well-being after traumatic events, so as to provide some valuable clues or enlightenment for individual psychological intervention after traumatic events [9]. While existing research suggests that perceived stress in caregivers is associated with poorer sleep outcomes in children, research on the relationship is often limited to infant and early childhood populations; therefore, Mansolf et. al. investigated the association in school-age children and adolescents. Mansolf et. al. apply item response theory (IRT) followed by meta-analysis to assess the relationship between caregiver perceived stress and child sleep disturbance, and moderation of this relationship by child age and the presence of a child mental or physical health condition [10].

First of all, it is necessary to determine whether there is a pattern, that is, to determine whether there is a correlation between the mother's physical and psychological indicators and the baby's behavioral characteristics and sleep quality. Since the data of the HuaShu Cup National Mathematical Modeling Competition includes quantitative variables and categorical variables, and the data does not necessarily completely satisfy the normal distribution, we can solve the Spearman coefficient between each variable and calculate the Spearman coefficient according to the calculated Spearman coefficient. The correlation coefficient and significant P value respectively analyzed that the mother's physical and mental indicators have a significant impact on the infant's behavioral characteristics and sleep quality.

Then it is necessary to first establish a relationship model between the mother's physical and mental indicators and the infant's behavioral characteristics, and then use the data to determine the behavioral characteristic information of the last 20 groups of infants in the table. For this problem, you can first test the reliability and validity of the questionnaire, and use the previous label coding of the infant's behavioral characteristics, and establish a multiple linear regression model with the mother's physical indicators and psychological indicators, and finally use the multiple linear regression model Realize the judgment of the last 20 groups of infant behavioral characteristics.

2. The basic content of the research

2.1. Data preprocessing

The data set was first examined for missing values, and the "find" function in MATLAB was used to identify any missing values. It was found that there were no missing values in the provided data set. Subsequently, an outlier detection procedure was conducted to identify any abnormal values in the data. Upon inspection, it was observed that participant 181 had a sleep duration value of 99.99, which was clearly an erroneous entry and was therefore removed from the data set. Additionally, in relation to the marital status of the mothers, responses of 3 and 6 were recorded. Typically, a value of 1 indicates unmarried, while a value of 2 indicates married. The presence of values 3 and 6 was considered anomalous and were consequently excluded from further analysis.

2.2. Data analysis

First, the variable of infant behavior characteristics needs to be encoded. Use the pandas library in Python along with the sklearn. preprocessing library to encode all the data in the attachment. (introverted type 1, moderate type is 2, contradictory type is 3). Text narrative to digital table is shown in table 1.

Table 1. Text narrative to digital table

Infant behavior characteristics	conversion figures
Introverted type	1
Moderate type	2
Contradictory type	3

Then, through the table 1, the infant's overnight sleep duration needs to be processed by using the SUBSTITUTE function to convert the time type into a numerical type.

2.3. Spearman correlation analysis

To visually observe the impact of maternal physical and psychological indicators on infant behavioral characteristics and sleep quality, importing the data into SPSS for correlation analysis. The correlation coefficient table obtained through Spearman correlation analysis is presented in table 2:

Table 2. Spearman correlation coefficient table

	mother's age	marital status	education level	Pregnancy time (weeks)	mode of delivery	CBTS	EPDS	HADS	Infant behavior characteristics	wake up times	Way to sleep	sleep time throughout the night
mother's age	1(0.000***)	0.011(0.833)	0.183(0.000***)	0.124(0.016**)	0.039(0.453)	0.033(0.522)	0.087(0.090*)	0.069(0.178)	0.087(0.089*)	0.051(0.323)	0.088(0.085*)	0.016(0.749)
marital status	0.011(0.833)	1(0.000***)	0.11(0.032**)	0.004(0.946)	0.023(0.661)	0.008(0.882)	0.023(0.662)	0.066(0.203)	0.005(0.919)	0.036(0.488)	0.052(0.313)	0.019(0.705)
education level	0.183(0.000***)	0.11(0.032**)	1(0.000***)	0.026(0.615)	0.016(0.760)	0.072(0.163)	0.114(0.026**)	0.1(0.051*)	0.041(0.426)	0.07(0.172)	0.036(0.487)	0.059(0.255)
Pregnancy time (weeks)	0.124(0.016**)	0.004(0.946)	0.026(0.615)	1(0.000***)	0.18(0.000***)	0.077(0.133)	0.05(0.336)	0.106(0.039**)	0.002(0.972)	0.087(0.089*)	0.04(0.441)	0.07(0.176)
mode of delivery	0.039 (0.453)	0.023 (0.661)	0.016(0.760)	0.18(0.000***)	1(0.000***)	0.021(0.683)	0.02(0.700)	0.066(0.201)	0.003(0.956)	0.063(0.221)	0.063(0.218)	0.015(0.766)
CBTS	0.033(0.522)	0.008(0.882)	0.072(0.163)	0.077(0.133)	0.021(0.683)	1(0.000***)	0.781(0.000***)	0.71(0.000***)	0.114(0.027**)	0.074(0.150)	0.054(0.295)	0.128(0.013**)
EPDS	0.087(0.090*)	0.023(0.662)	0.114(0.026**)	0.05(0.336)	0.02(0.700)	0.781(0.000***)	1(0.000***)	0.784(0.000***)	0.132(0.010***)	0.112(0.029**)	0.009(0.863)	0.173(0.001***)
HADS	0.069(0.178)	0.066(0.203)	0.1(0.051*)	0.106(0.039**)	0.066(0.201)	0.71(0.000***)	0.784(0.000***)	1(0.000***)	0.123(0.017**)	0.07(0.172)	0.059(0.248)	0.122(0.017**)
Infant behavior characteristics	0.087(0.089*)	0.005(0.919)	0.041(0.426)	0.002(0.972)	0.003(0.956)	0.114(0.027**)	0.132(0.010***)	0.123(0.017**)	1(0.000***)	0.245(0.000***)	0.002(0.971)	0.118(0.022**)
wake up times	0.051(0.323)	0.036(0.488)	0.07(0.172)	0.087(0.089*)	0.063(0.221)	0.074(0.150)	0.112(0.029**)	0.07(0.172)	0.245(0.000***)	1(0.000***)	0.255(0.000***)	0.318(0.000***)
Way to sleep	0.088(0.085*)	0.052(0.313)	0.036(0.487)	0.04(0.441)	0.063(0.218)	0.054(0.295)	0.009(0.863)	0.059(0.248)	0.002(0.971)	0.255(0.000***)	1(0.000***)	0.232(0.000***)
sleep time through out the night	0.016 (0.749)	0.019(0.705)	0.059(0.255)	0.07(0.176)	0.015(0.766)	0.128(0.013**)	0.173(0.001***)	0.122(0.017**)	0.118(0.022**)	0.318(0.000***)	0.232(0.000***)	1(0.000***)

Note: ***, **, *Representing the significance level of 1%, 5%, 10%

Chart description:

The table 2 above shows the parameter results table of the model test, including the correlation coefficient and explicit P value.

1. First test whether there is a statistically significant relationship between XY and determine whether the P value is significant ($P<0.05$).

2. If it is significant, it means there is a correlation between the two variables; otherwise, there is no correlation between the two variables.

3. Analyze the positive and negative directions of the correlation coefficient and the degree of correlation.

Through the table, it can be found that the mother's physical indicators have little correlation with the baby's sleep quality, and their correlation coefficients are all lower than 0.1. In order to more clearly display the correlation between each variable, a heat map is drawn through SPSS as shown in figure 1:

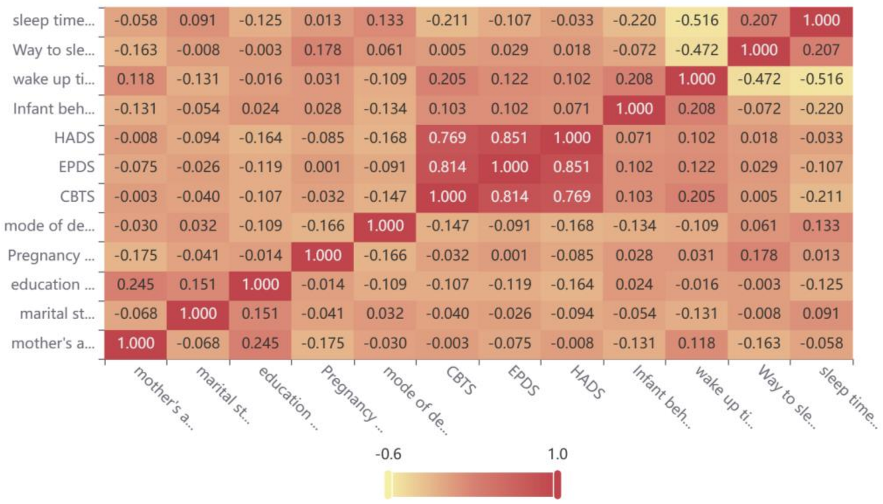

Figure 1. Heat map

Through the figure 1, it can be found that the mother's physical indicators do not have much impact on the baby's sleep time and infant behavioral characteristics. At the same time, it can be found that the mother's psychological indicators have a greater correlation with the infant's behavioral characteristics.

From this, concluding that there is a certain correlation between the baby's behavioral characteristics and the mother's age, CBTS, EPDS, and HADS, while the relationship with other indicators is not significant.

2.3.1 Quality inspection

Firstly, testing the reliability of the questionnaire. Using the Cronbach α $(Alpha)$ reliability coefficient method to test the reliability of the questionnaire.

First, using SPSS to conduct KMO test on the questionnaire to determine the relevant relationship.

$$\alpha = \frac{N}{N-1}\left[1-\frac{\sum S_i^2}{S_T^2}\right] = \frac{N}{N-1}\left[1-\frac{N}{N+2r}\right] \tag{1}$$

$$KMO = \frac{\sum\sum_{i\neq j} r_{ij}}{\sum\sum_{i\neq j} r_{ij}^2 + \sum\sum_{i\neq j} a_{ij}^2} \tag{2}$$

Table 3. Cronbach α Coefficient Table

Cronbach α coefficient	Standardized Cronbach α coefficient
0.885	0.902

From the results in Table 3 get that the Cronbach α coefficient is 0.885, When the Cronbach α coefficient is between 0.8-0.9, it means that the reliability is good, so the reliability of our questionnaire is acceptable.

2.3.2 Establishment of multiple linear regression models

Setting the infant behavioral habit index as y to establish a multiple linear regression model. Through dual analysis of the graph influence and test results, finally obtaining the relationship between variables, and using this to establish a multiple linear regression model as shown below:

Then substitute the data into MATLAB and use the regress function to calculate the results as table 4:

$$\begin{cases} y = \alpha_0 + \alpha_1 x_{age} + \alpha_2 x_{CBTS} + \alpha_3 x_{EPDS} + \alpha_4 x_{HADS} \\ \xi \sim N(0, \sigma^2) \end{cases} \tag{3}$$

Table 4. Linear regression analysis results table

Linear regression analysis results n=390									
	unstandardized coefficient B		Standardized coefficient	t	P	VIF	R²	AdjustedR²	F
	B	standard error	Beta						
constant	1.121	0.231	-	4.853	0.000***	-	0.028	0.018	F=2.745 P=0.028**
mother's age	-0.014	0.007	-0.1	-1.968	0.050**	1.02			
CBTS	-0.002	0.01	-0.016	-0.199	0.843	2.697			
EPDS	0.01	0.009	0.106	1.085	0.279	3.777			
HADS	0.005	0.012	0.034	0.406	0.685	2.772			
dependent variable: baby behavior traits									
Note: ***, **, * represent the significance levels of 1%, 5%, and 10% respectively									

Table 4 shows a significant P value of 0.028**, which is statistically significant. By assuming that the regression coefficient is rejected as 0, knowing that the model basically meets the requirements.All VIFs are less than 10. It can be known that the model does not have multicollinearity problems and the model is well constructed. The final multiple linear regression equation is as follows:

$$y = 2.136\text{-}0.014x_{year}\text{-}0.002x_{CBTS} + 0.008x_{EPDS} + 0.006x_{HADS} \tag{4}$$

The results of predicting the last 20 groups using the multiple linear regression model are as table 5:

Table 5. forecast result

serial number	391	392	393	394	395
forecast result_Y	2.431893213	2.631487387	2.841917093	1.577866742	0.442166792
actual value	Contradictory type	Contradictory type	Contradictory type	Moderate type	Introverted type
serial number	396	397	398	399	400
forecast result_Y	1.420738751	2.275755679	0.578075475	2.077662778	0.928795142
actual value	Moderate type	Contradictory type	Introverted type	Contradictory type	Introverted type
serial number	401	402	403	404	405
forecast result_Y	4.680009764	1.545633469	0.840296285	1.038211961	1.909591373
actual value	Contradictory type	Moderate type	Introverted type	Moderate type	Moderate type
serial number	406	407	408	409	410
forecast result_Y	0.336661733	1.804363817	0.827510132	0.508259563	0.848669312
actual value	Introverted type	Moderate type	Introverted type	Introverted type	Introverted type

3. Conclusions

In order to prove whether the mother's physical indicators and physical and mental indicators are related to the baby's sleep, this article attempts to conduct quality inspection and establish a mathematical model based on the relevant data of 390 infants aged 3 to 12 months and their mothers.

First, preprocess the data and use tools such as the find function in MATLAB to find missing values and outliers. Secondly, use coding tools to code some categorical variables, and use the function sleep time to convert the time type into a numerical type. Finally, the Spearman coefficient was used to conduct correlation analysis between each data to determine the pattern between the mother's physical and mental indicators and the baby's sleep time.

The reliability of the questionnaire is ensured through KMO testing to ensure that the reliability of the questionnaire is acceptable. Secondly, by establishing a linear regression model between mother and baby, and then re-importing the data, the linear regression equation is obtained. Finally, linear regression equations are used to predict the behavioral characteristics of the last 20 groups of infants.

In conclusion, this study provides valuable insights into the influence of maternal physical and mental indicators on infant sleep. By establishing a mathematical model and analyzing a large dataset of 390 infants aged between 3 and 12 months, we were able to examine the relationships between various variables and identify patterns between maternal factors and infant sleep duration. The findings highlight the significance of maternal well-being in promoting healthy sleep patterns in infants.

Through rigorous data quality checks and statistical analyses, we ensured the reliability of the questionnaire and established a linear regression model to explore the relationship between mothers and infants. The predictive power of the regression equation further enhances our understanding of the behavioral characteristics of infants based on their mothers' indicators.

These findings contributeto the existing body of research on infant sleep by emphasizing the importance of considering mat ernal factors when studying sleep patterns and disturbances in infants. They also provide a foundation for further investigations in related fields, such as interventions and support programs aimed at improving maternal well-being and, consequently, optimizing infant sleep quality.

Overall, this study underscores the significance of maternal physical and mental indicators in shaping infant sleep behavior, highlighting the need for comprehensive approaches that address both maternal and infant factors to promote healthy sleep habits during early development.

The findings of this study suggest the feasibility of applying maternal physical and mental indicators to understand and influence infant sleep patterns. By utilizing a mathematical model and analyzing a substantial dataset, we have demonstrated the potential for using these indicators as predictors of infant sleep duration.

Based on the promising results obtained in this study, future research could explore interventions and strategies to improve maternal well-being, with the goal of positively impacting infant sleep outcomes. Additionally, investigating the long-term effects of maternal factors on sleep patterns throughout childhood and adolescence could provide a more comprehensive understanding of the developmental trajectory of sleep.

Furthermore, considering the potential interplay between maternal and environmental factors might offer insights into how external influences can moderate the relationship between maternal indicators and infant sleep. Exploring the impact of cultural and societal factors on maternal well-being and infant sleep would enhance our knowledge of the complex dynamics involved.

In summary, this study paves the way for further research aimed at developing practical interventions and guidelines that promote healthy sleep habits in infants by addressing maternal physical and mental well-being. By expanding upon this work, researchers can contribute to improved sleep outcomes for infants and their families, ultimately supporting their overall health and well-being.

Shortcoming:

Assumption dependence: The reliability and validity of a model depends on the validity of its assumptions, such as the authenticity and accuracy of the data and the assumptions in the questionnaire. If the assumptions do not hold true, the results of the model may be affected.

Data quality: The accuracy and reliability of the model depend on the quality of the questionnaire data. Any issues in the data collection process, such as sampling bias, respondent subjectivity, or inaccurate responses, may affect the results of the model.

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