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T4 ________		F4 ________

2019 Mathematical Contest in Modeling (MCM) Summary Sheet
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Sleep Tight

Summary

With the rapid pace of life, sleep quality has gradually become a concern issue. High sleep quality ensures people to be energetic and efficiency. Therefore, the study of sleep quality has great significance for improving people's health, both physically and mentally. In this study, we look into the indicators that effect sleep quality and the correlation between diagnosis results with sleep status. On the basis, we give several scientific sleep advice to keep us healthy.

In first stage, we use likelihood ratio test to study the correlation between various indicators and sleep quality, and excluded the irrelevant indicator. Since the data given for sleep quality are classified variables and the effect of simple linear regression is not ideal, we establish a multivariate Logistic regression model. At the same time, we give the expression of the probability when the score of sleep quality is 0,1,2,3. On the basis, we establish the probability relationship between sleep quality and each index.

In second stage, we establish a composite score model of indicators based on factor analysis. Furthermore, we study the relationship between diagnosis results and sleep indicators. Subjectively, we divide the diagnosis results into two categories according to the cumulative contribution rate of the number of species - common disease types and uncommon disease types. For uncommon diseases, we establish a database to implement the one - to - one matching system. For common disease types, we use the expression of comprehensive score in factor analysis to give the relationship between diagnosis results and each sleep index. In addition, we consider gender factors based on model I. For common disease types, different genders have different composite score expressions.

In third stage, we diagnose 10 patients based on the established index composite score model. We first put 10 patient data into the uncommon disease database for matching but all fail. Then we calculate the corresponding common disease type scores according to gender difference. Diagnostic results show patients No.1, 2, 4, 8, 9 has sleep disorder, patient No.3 has non-organic insomnia, patient No.5 has anxiety disorder, and patient No.6, 7, 10 has bipolar affective disorder.

Whats more, we provide two targeted suggestions on sleep based on the correlation between sleep status and diagnostic results. At last, we use the Analytic Hierarchy Process to give the weight of each index, and we also evaluate the strengths and weaknesses of the suggestions according to the indicator weight.

Contents

1 Introduction

1.1 Problem Background

According to statistics[1], more and more people, especially teenagers, are troubled by insomnia. They suffer from various physical and mental problems, such as difficulty falling asleep, short sleep time, easy to wake up, and drowsiness during the day. Long-term insomnia can make people feel tired and unable to concentrate[2]. Severe insomnia can even lead to neurological disorders and imbalances in various systems in the body.

There are many factors affecting insomnia, which can be generally divided into objective factors and subjective factors. Objective factors are environmental changes, tea or coffee before going to sleep, and so on. Subjective factors are generally mental factors such as life stress, emotional loss, and spiritual excitement.

Therefore, determining the factors that affect sleep is of great significance for doctors to diagnose patients with insomnia. At the same time, we can also establish a reasonable rest time plan by analyzing the factors affecting sleep, so as to maintain a healthy body.

1.2 Previous Research

So far, people have conducted in-depth research on the problem of insomnia. By using a variety of medical measuring instruments, research experts have tried to find influencing factors related to sleep quality.

Marialite and Saarinen use actigraphy to collect information about people's sleep and wake-up periods to analyze factors affecting sleep quality [3]. [4] studied the current sleep management services on the market, where home monitoring of sleep devices allows people to reduce the cost of sleep management and quality assessment. The device does not use sleep time to assess sleep quality, but proposes an evaluation mechanism. Also used for family diagnosis, the literature [5] used the slow-wave sleep period to evaluate the sleep quality, avoiding the situation of maladjustment caused by sleep examination in the sleep center.

Cardiac activity during sleep has also been extensively studied. Marina Nano and Pedro Fonseca studied polysomnograms and electrocardiograms of multiple healthy subjects at night to explore the effects of the autonomic nervous system on falling asleep [6]. [7] and [8] focused on wearable devices to facilitate data analysis of sleep quality.

Each of the above studies has advantages, but no in-depth study has been conducted on the indicators affecting sleep quality. Therefore, we will focus on the research of the relationship between various indicators and sleep quality

1.3 Our Work

- We analyze the relationship between the given indicators and the quality of sleep according to the given data. Among the given indicators, we determine one indicator that is no correlation with sleep quality.
- We investigate the relationship between the diagnosis results and sleep.
- Based on the results of the previous step, we give the diagnosis results for the patients in Annex III.
- We develop a scientific sleep program and evaluate its effectiveness.

2 Analysis and Key Points

2.1 Overall Analysis

The study starts with various indexes that affect sleep quality. Research on indicators that affect sleep quality can help prevent a variety of sleep disorders, such as common insomnia symptoms. However, due to the objective factors and subjective factors affecting sleep quality, we have to extract the most representative factors from the variety of factors for further research. At the same time, in the case of known indicators of patients, how to analyze the relationship with various diseases and make diagnosis is of great significance.

The selection of accurate and reliable influencing factors needs to consider the elimination of indexes that have less influence on sleep quality, so we consider from the aspect of influence degree. For the judgment of the disease, the corresponding relationship should be established to diagnose the disease according to the sleep index.

2.2 Key Points Analysis

2.2.1 Relationship between Indicators and Sleep Quality

In order to improve the accuracy of the model, we first carried out regression calculation for each indicator, and eliminated the indicators that were not related to sleep quality through a kind of test method.

2.2.2 Relationship between the Diagnosis results and Sleep

There are many types of diseases related to mental state, including mental illnesses with a small number of samples, and a combination of multiple mental illnesses.

Considering that the sample size is small, we cannot give sufficient data support. So, we reduce the dimensionality of the sleep score index to obtain a comprehensive score expression to qualitatively give the relationship between the sleep score index and the diagnosis result.

2.2.3 Run Diagnosis

Based on the diagnosis plan established by Question 2, we can get the condition of each patient according to each sleep condition index (i.e., sleep status score) of the patient.

2.2.4 Sleep Program and Evaluation

Based on the above considerations, we can start from the various factors affecting sleep, targeted sleep plan. In terms of evaluation, we try to establish an evaluation system to judge the quality of our sleep plan.

3 Generall Assumption

- Assumption 1: In the whole testing, we assume that the level of test is 0.05, which means the probability of error is less than 5
- Assumption 2: The cumulative contribution of 80% in factor analysis is sufficient.
- Assumption 3: The larger the composite factor score, the more significant the relationship between the original variable and the dependent variable.
- Assumption 4: There is a linear positive correlation between the Pittsburgh sleep quality index and various impact factors.

4 Symbols and Definitions

In the section,we use some symbols for constructing the model as follows:

P.s.Other symbols instructions will be given in the text.

Table 1: Symbols and Definitions

Symbols	Meanings
f	Syndrome composite score
$PSQI$	Pittsburgh sleep quality index
A	Pairwise comparison matrix
CI	Coincident index
RI	Average random consistency index
U^*	Normalized eigenvectors
U_i^*	The i-th component of U^*

5 The Model

Before delving into the specific modeling steps, briefly explain the whole idea and analyze the mind map shown in **Figure.1** :

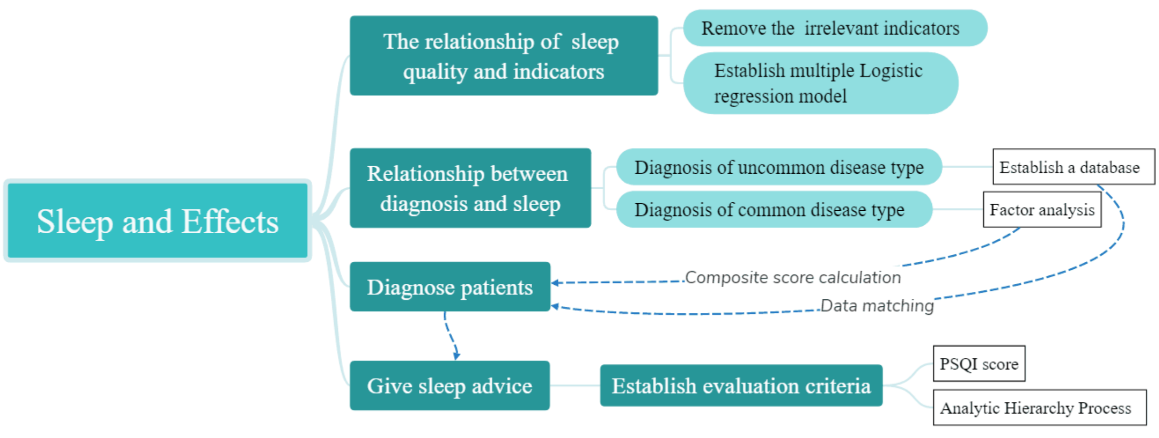

Figure 1: Mind Mapping

5.1 Model I:Multiple Logistic Regression Model

5.1.1 Modeling Ideas

Since sleep quality is a classification dependent variable, we first perform logistic regression on each indicator. Then we confirm the indicators that are not related to sleep quality with **LRT**(the Likelihood Ratio Test). Finally, we establish the multivariate logistic regression model between the strongly correlated indexes and sleep quality.[9]

5.1.2 Supplementary Assumptions and Justification

In order to facilitate the study of the relationship between the indicators and sleep quality, we classify the indicators in annex. According to the latest regulations of WHO (World Health Organization) on age stratification, we set the age below 18 as a minor, 18 to 40 as a young person, 41 to 65 as a middle-aged person, and 66 and above as elderly, which are respectively named as Age1-Age4.For the indicators Reliability, Psychoticism, Nervousness, and Character, we assume that the values 0-30 are low, 31-50 are medium, and greater than 50 are high, respectively correspond to 1, 2, and 3.

5.1.3 Calculation of Multiple Logistic Regression Model

Since the dependent variable, namely sleep quality, is a categorical variable, and its influencing factors are multiple, we can establish a multivariate logistic regression model as follows:

$$Log\frac{P}{1-P} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_6 x_6 \tag{1}$$

where $P(y=0|x)$ is the probability of good sleep quality, $P(y=1|x)$ is the probability of normal sleep quality, $P(y=2|x)$ is the probability of poor sleep quality, and $P(y=3|x)$ is the probability of very poor sleep quality, β_0 is constant and $\beta_1 \dots \beta_6$ are the coefficients of the six independent variables.

We add a goodness-of-fit test method that uses a simple model to replace the original complex model to eliminate indicators that are not related to sleep, while improving model accuracy. In this regard, we choose **LRT** to assess the applicability of model.

5.1.4 Likelihood Ratio Test and Correlation Analysis

We import the data in Annex I into SPSS software for regression model calculation, and the results are shown in **Table 2**.

Table 2: Results of likelihood ratio test

Index	Chi-Square	*df*
Age	115.27	9
Sex	10.881	3
Reliability	7.434	6
Psychoticism	22.243	6
Nervousness	54.537	6
Character	17.315	6

As indicated in **Table 2**, in the likelihood ratio test the Reliability chi-square value $\chi^2(Rl)$<$\chi^2_{0.05}(6)$=12.69, which indicates that fitting a logistic regression model without Reliability is sufficient. Hence, we can conclude that Reliability index has no influence on sleep quality, while other indexes are correlated with sleep quality.

Therefore, the modified multivariate logistic regression model can be written in the following form:

$$Log\frac{P}{1-P} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_5 x_5 \tag{2}$$

where $x_1 \ldots x_5$ represent indexes Age, Sex, Psychoticism, Nervousness, and Character respectively.

5.1.5 Modeling Results

To obtain the regression model of different sleep quality, we use SPSS software to find the result as follows:

$$\begin{cases} Log\frac{P(sq=0)}{1-P(sq=0)} = -2.56 + 1.63Age_{i=1} + 0.41Age_{i=2} - 0.202Age_{i=3} - 0.41Sex_{i=0} + \\ 0.22Psy_{i=1} + 0.001Psy_{i=2} + 1.95Ner_{i=1} + 1.04Ner_{i=2} - 1.10Cha_{i=1} - 0.52Cha_{i=2} \\ \\ Log\frac{P(sq=1)}{1-P(sq=1)} = -1.03 + 1.60Age_{i=1} + 0.44Age_{i=2} - 0.12Age_{i=3} - 0.14Sex_{i=0} + \\ 0.42Psy_{i=1} + 0.14Psy_{i=2} + 0.21Ner_{i=1} + 0.24Ner_{i=2} - 0.26Cha_{i=1} + 0.003Cha_{i=2} \\ \\ Log\frac{P(sq=2)}{1-P(sq=2)} = -0.26 + 1.04Age_{i=1} + 0.39Age_{i=2} - 0.15Age_{i=3} - 0.18Sex_{i=0} + \\ 0.28Psy_{i=1} + 0.24Psy_{i=2} - 0.35Ner_{i=1} + 0.28Ner_{i=2} - 0.32Cha_{i=1} - 0.07Cha_{i=2} \end{cases} \tag{3}$$

and we have:

$$P(sq=0) + P(sq=1) + P(sq=2) + P(sq=3) = 1 \tag{4}$$

From equations (3) and (4), we can determine the relation between sleep quality and the five indicators:

- Sleep quality gets better with age.
- Women's sleep quality is better than men.
- With the increase in degree of Psychoticism, Nervousness and Character, sleep quality gets worse.

5.2 Model II: Relationship between Diagnosis and Sleep

5.2.1 Modeling Ideas

Due to the variety of diagnostic results, we first consider the classification of diagnostic results. We set the diagnostic results according to the assumed criteria as common and uncommon.

For the common diseases, we consider using factor analysis to reduce the dimension of the correlation index. We develop the relationship between the diagnosis result and sleep by giving the factor score expression. The higher the factor score of a diagnosis result, the stronger the correlation between the factor and the diagnosis.

For uncommon disease types, we consider establishing a database to develop a one-to-one or many-to-one relationship between each data and diagnosis results, and reflect the correlation by calculating the difference vector.

5.2.2 Preprocessing of Data

1. Processing of abnormal data

Based on the data in Annex II Translation, we performed outlier detection on given data in Excel and find out some abnormal and null values such as Unknown, To be determined, To be identified, ?etc. Since the small amount of abnormal data, we get rid of the samples containing abnormal data and the data like Schizophrenia? is corrected.

2. Classification standard

We assume that the diagnosis results with a data volume of more than 100 and a cumulative contribution rate of nearly 80% are common diseases.

Therefore, we select Sleep Disorder, Depression, Anxiety Disorder, Anxiety, Mix Anxiety and Depression, Bipolar Affective Disorder, and Non-Organic Insomnia as common diseases, and other diseases are classified as uncommon. We can visually distinguish the contribution rate of each disease from **Figure 2**.

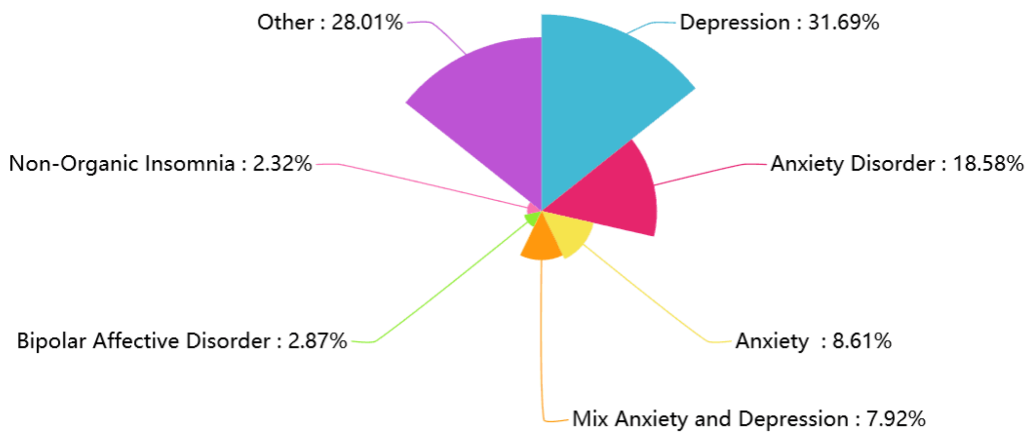

Figure 2: Cumulative contribution rate of each disease

5.2.3 Correlation Analysis

1.Principle of factor analysis

Since the common disease type is a character variable, we consider to give the comprehensive score of each common disease type through factor analysis. Then we use score size to measure the degree to which each sleep factor correlated with the diagnosis. The concrete steps of factor analysis are as follows:

Step 1: Adaptive testing

We use KMO test and Bartlett test to determine whether the data meet factor analysis condition. the criteria are as follows:

- KMO test value >0.5
- Bartlett test p-value<0.5

Step 2: Factor extraction

Based on principal component analysis (PCA) ,extract the factor and assume $F_1 \ldots F_p$ are p factors, where the total amount of data information contained in the first m factors (i.e., their cumulative contribution rate) is not less than 80%, the first m factors can be used to represent the original evaluation index, and the component matrix can be calculated.

Step 3: Rotate and name

By rotating the component matrix, each variable has a large load on a factor, so that it is named according to the variable information reflected by the factor.

Step 4: Calculate factor score

From the factor score coefficient matrix, the expressions of each factor on the variable can be taken into the original observed variable. The factor score f is calculated as follows:

$$f_i = \begin{pmatrix} X_1 & X_2 & \ldots & X_P \end{pmatrix} \begin{pmatrix} a_{11} \\ a_{22} \\ \vdots \\ a_{ip} \end{pmatrix} \tag{5}$$

where $\begin{pmatrix} a_{i1} \\ a_{i2} \\ \vdots \\ a_{ip} \end{pmatrix}$ is each column of the component score coefficient matrix.

Step 5: Composite scores

Taking the variance contribution rate of each factor as the weight, the composite score index function can be obtained by the linear combination of each factor as follows:

$$f = \frac{\sum_{i=1}^{m} \gamma_i f_i}{\sum_{i=1}^{m} \gamma_i} \tag{6}$$

where γ_i is the variance contribution rate of each factor.

2. Correlation analysis based on factor analysis

According to Model I, age and gender have an impact on sleep quality. Therefore, when considering the influencing factors of diagnosis results, in order to highlight the influence of gender, we divide the data into two categories according to gender. Then select age, sleep quality, sleep latency, sleep time, time efficiency, sleep disorder, hypnotic, daytime dysfunction as the influencing factors of the diagnosis results.

The score expression between each common disease type and other factors could be calculated through factor analysis:

$$f = \sum_{i=1}^{8} c_i X_i \tag{7}$$

where: $c_i = \gamma_i / \sum_{i=1}^{8} \gamma_i$, and $X_1 ... X_8$ correspond to age, sleep quality, sleep latency, sleep time, sleep efficiency, sleep disorder, hypnotic and daytime dysfunction, respectively. With this formula, we can describe the relationship between the indicators and the diagnosis results.

5.2.4 Diagnosis of Uncommon Disease

We construct a database of uncommon disease samples (male and female separately) by screening the Annex II samples that have been removed from common cases. And on that basis, we establish one-to-one or many-to-one relationship between each sleep indicator vector $(X_1, X_2, \ldots, X_8)$ and the diagnosis result.

Therefore, when analyzing an uncommon disease type, we only need to find the disease type with the same sleep indicator vector as its corresponding diagnosis result.

5.2.5 Modeling Calculation and Result Analysis

(1) Applicable test

We use SPSS software to analyze the data of seven common disease types. After the computing, the results are shown in **Table 3**.

As can be seen in Table 1, KMO test values are all greater than 0.5, and Bartlett test p-values are all less than 0.05. Therefore, the model is applicable.

(2) Score results

Based on the component score coefficient matrix, we calculate the composite score expression of each sleep index.

The expression corresponding to sleep disorder are as follows: (the remaining diagnostic results are given in the appendix)

$$female: \begin{array}{l} f = 0.1781X_1 + 0.1518X_2 + 0.0676X_3 + 0.1039X_4 + 0.0904X_5 + \\ 0.1366X_6 + 0.0701X_7 + 0.0904X_8 \end{array} \tag{8}$$

$$male: \begin{array}{l} f = 0.1472X_1 + 0.1227X_2 + 0.1054X_3 + 0.0927X_4 + 0.0956X_5 + \\ 0.1077X_6 + 0.1069X_7 + 0.125X_8 \end{array} \tag{9}$$

Table 3: Factor analysis test results

Category \ Test statistic	KMO test value		Bartlett test p-value	
	male	female	male	female
Sleep disorder	0.746	0.776	0	0
Depression	0.826	0.822	0	0
Anxiety disorder	0.757	0.769	0	0
Anxiety	0.785	0.789	0	0
Mix anxiety and Depression	0.7	0.741	0	0
Bipolar affective disorder	0.73	0.763	0	0
Non-Organic insomnia	0.501	0.711	0.011	0

According to the expressions, the component scoring system are presented in **Figure 3** and **Figure 4**.

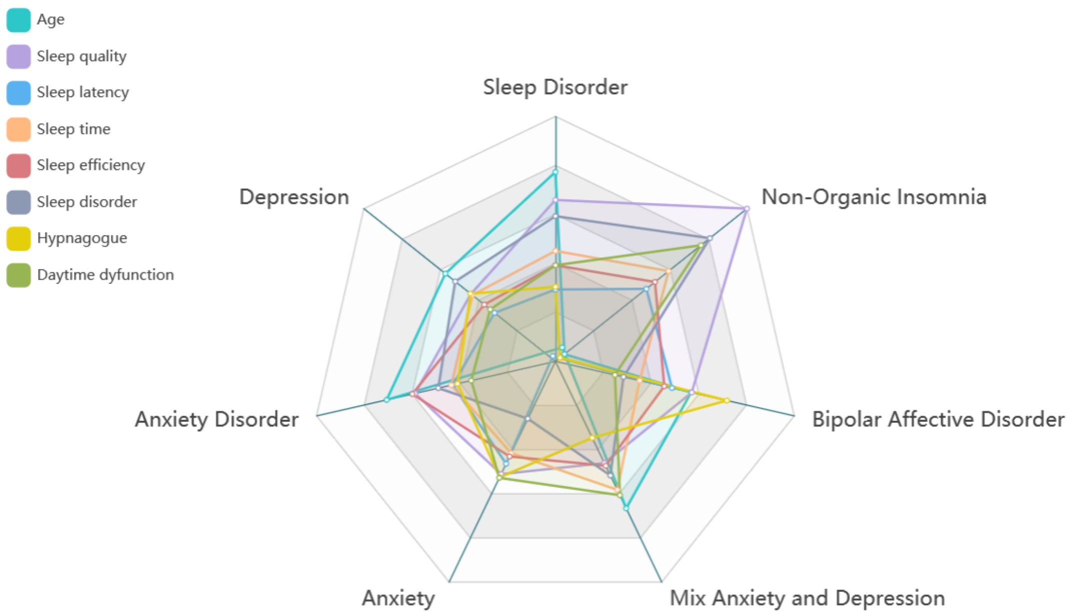

Figure 3: Male component score coefficient

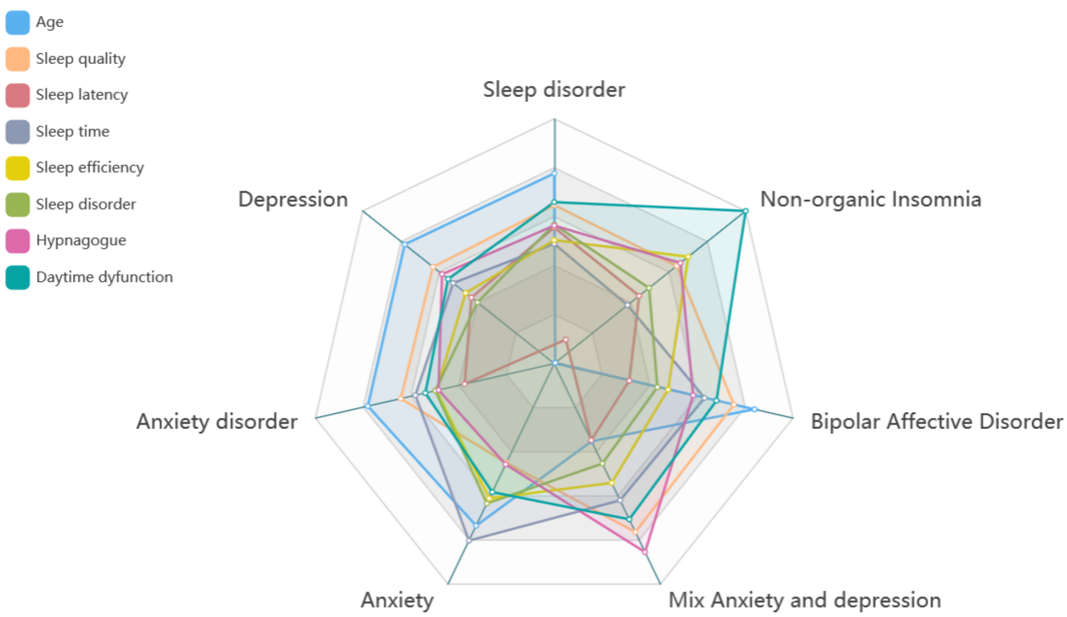

Figure 4: Female component score coefficient

From the result expressions, we can draw the following conclusions:

- For male, the older they get, the more likely they are to develop Sleep disorder. At the same time, Non-Organic Insomnia is closely related to Sleep disorder, Daytime dysfunction, Sleep quality.
- For Female, Sleep disorder, Depression and Anxiety disorder are common causes of insomnia as the increased of age. Besides, poor sleep quality can easily lead to the onset of these seven common diseases. For Anxiety, it also associates with Sleep time evidently.
- In general, Bipolar Affective Disorder in male and Mix Anxiety and depression in female are more likely to take hypnotics. Moreover, the Sleep latency index has a small effect on the common disease types.

5.3 Diagnosis Results for the Patients

On the basis of Model II, we can diagnose patients in Annex III.

5.3.1 Diagnosis Methods

As indicated in **Figure 5**, for the sleep status indicators of a given patient, we first use the uncommon diseases to make a one-to-one comparison. Otherwise, the diagnosis will be transferred to the common types of disease. According to the correlation between diagnosis results and each sleep condition index in Model II, we can give the confirmed diagnosis results of each patient.

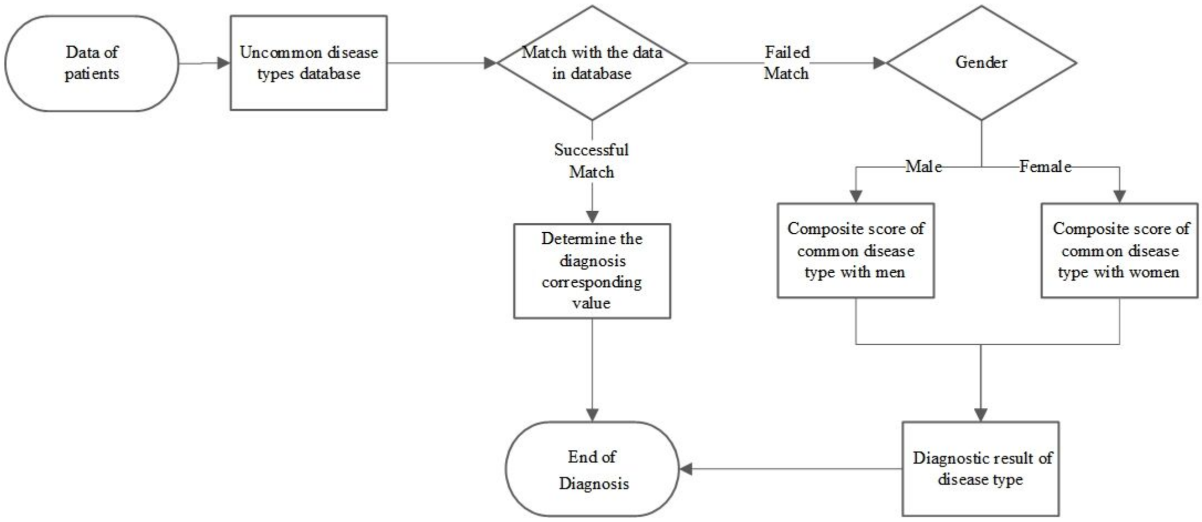

Figure 5: Diagnosis methods

5.3.2 Diagnosis Process

Step1: Match the data in the uncommon diseases database

We compare each actual indicator of the 10 patients with database, and find that there is no identical situation. Therefore, we can classify the given patients diagnosis into common disease type and move on to the next step.

Step2: Calculate composite scores

According to the gender difference, we put the data of patient into the score expressions in Model II, and determine diagnosis result with the highest composite score to patient.

5.3.3 Diagnosis Results

After calculation, the scores of each patient on each disease can be obtained, as shown in **Table 4** and **Table 5**.

Therefore, we can conclude the diagnosis results of each patient, shown in **Table 6**.

5.4 Sleep Program and Evaluation

Based on the above research results and in combination with the sleep duration required by different age groups, we give several rational sleep recommendations.

Table 4: Composite scores of male patients

Diagnosis \ Number	1	2	3	5
Sleep disorder	0.909	1.3689	2.0272	1.6624
Depression	0.7676	1.1702	1.6814	1.5104
Anxiety disorder	0.8502	1.3548	2.0089	1.8555
Anxiety	0.487	0.845	1.1891	1.2584
Mix anxiety and Depression	0.8857	1.2087	1.745	1.4957
Bipolar affective disorder	0.7633	1.2018	1.6633	1.8546
Non-Organic insomnia	0.7549	1.3614	2.1483	1.3609

Table 5: Composite scores of female patients

Diagnosis \ Number	4	6	7	8	9	10
Sleep disorder	1.936	1.6121	1.3218	1.5422	2.1768	1.5437
Depression	1.786	1.534	1.2657	1.4294	2.0291	1.4584
Anxiety disorder	1.7821	1.4959	1.2286	1.4372	2.0672	1.4579
Anxiety	1.5634	1.2879	1.1446	1.3074	1.9576	1.4146
Mix anxiety and Depression	1.8811	1.64	1.2223	1.415	1.9569	1.5111
Bipolar affective disorder	1.9245	1.6452	1.3671	1.4991	2.1591	1.5498
Non-Organic insomnia	1.6529	1.3377	1.0426	1.2672	1.6112	1.308

Table 6: Diagnosis results

Patient Number	1	2	3	4	5
Diagnostic category	sleep disorder	sleep disorder	non-organic insomnia	sleep disorder	anxiety disorder
Patient Number	6	7	8	9	10
Diagnostic category	bipolar affective disorder	bipolar affective disorder	sleep disorder	sleep disorder	bipolar affective disorder

5.4.1 A Scientific Sleep Program

Having a high quality, well-timed sleep is significant to ensure good health. However, the optimal amount of sleep varies by age. People can know how much sleep they need every day according to their age and actively adjust to achieve the best sleep time. The sleep time required for different age groups is shown in **Table 7**[10].

Table 7: Sleep time required for different age groups

Age/year	$0\sim 3$	$4\sim 12$	$13\sim 29$	$30\sim 60$	≥ 60
Time/hour	≥ 15	$10\sim 12$	8	7	$5.5\sim 7$

With reference to **Table 7**, and combined with the results of previous study, we offer the following sleep suggestions:

Suggestion A: Improve sleep quality. By reducing sleep latency to improve efficiency, so that the actual sleep time close to the best sleep time.

Suggestion B: Get rid of drug dependence, and reduce the effects of sleep disorder and daytime dysfunction.

5.4.2 Evaluation Model Based on AHP

According to the PSQI scale, we set the score value of the seven sleep indicators as 0, 1, 2, 3, where the higher the score, the worse the sleep quality.[11]

For each index, the score value can directly reflect the quality of sleep. Therefore, we determine the weight $\omega_i (i = 1, 2, ..., 7)$ of each index by using the analytic hierarchy process (AHP), and then evaluate the rationality of given sleep programs.

(1)Construct pairwise comparison matrix

When comparing the importance of the element i and j to a factor in the upper layer, we use quantitative relative weight a_{ij} to describe it. The comparison matrix is as follows:

$$A = \begin{bmatrix} 1 & 5 & \frac{1}{3} & 1 & 5 & 3 & 3 \\ \frac{1}{5} & 1 & \frac{1}{3} & \frac{1}{3} & 1 & 1 & 3 \\ 3 & 3 & 1 & 1 & 5 & 7 & 3 \\ 1 & 3 & 1 & 1 & 5 & 5 & 3 \\ \frac{1}{5} & 1 & \frac{1}{5} & \frac{1}{5} & 1 & 3 & 1 \\ \frac{1}{3} & 1 & \frac{1}{7} & \frac{1}{5} & \frac{1}{3} & 1 & \frac{1}{3} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & 1 & 3 & 1 \end{bmatrix}$$

the meanings of each value in the pairwise comparison matrix is shown in **Table 8**.

(2)Consistency test

Based on the pairwise comparison matrix, calculate the eigenvalues and eigenvec-

Table 8: Meanings of value in pairwise comparison matrix

a_{ij}	Meanings
1	C_i has the same effect as C_j
3	C_i affects a bit stronger than C_j
5	C_i affects stronger than C_j
7	C_i affects much stronger than C_j
9	C_i affects absolutely stronger than C_j
2,4,6,8	The ratio of the effects of C_i and C_j is between 7 and 9
1,1/2,...,1/9	The ratio of the effects of C_i and C_j is opposite number of the adjacent a_j

tors:

$$\lambda_{max} = 7.60, U = (-0.472, -0.181, -0.657, -0.508, -0.145, -0.096, -0.157)$$

Standardize the eigenvector so that each component is greater than 0, and the sum of each component is 1. Standardized eigenvector U^* can be written as:

$$U^* = (0.213, 0.082, 0.297, 0.229, 0.065, 0.043, 0.071)$$

Calculate the degree of inconsistency CI of pairwise comparison matrix A(n=7):

$$CI = \frac{\lambda_{max}(A) - n}{n - 1} = 0.1 \tag{10}$$

Calculate the random consistency ratio of the pairwise comparison matrix:

$$CR = \frac{CI}{RI} \tag{11}$$

The standard of the average random consistency indicator is shown in **Table 9**.

Table 9: Consistency indicator

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Thus, we have $CR = 0.076 < 0.1$, which indicates that the pairwise comparison matrix has satisfactory consistency. So, the i^{th} component of U^* can be used as the weight of the i^{th} sleep indicator.

5.4.3 Evaluation Result

For **Suggestion A** mentioned in 5.4.1, the weight of sleep indicators involved can be expressed as:

$$U_1^* + U_2^* + U_3^* + U_4^* = 0.821 \tag{12}$$

As for **Suggestion B**:

$$U_5^* + U_6^* + U_7^* = 0.179 \tag{13}$$

From the equations, we know that **Suggestion A** has a larger contribution to PSQI score, indicating that it can effectively help people improve their sleep quality. In comparison, **Suggestion B** contributes less to PQSI score, which indicates a less influence on sleep improvement.

6 Future Improvements

- In order to more accurately study the relationship between sleep quality and various indicators, we can conduct further stepwise regression analysis on the basis of eliminating the credibility index.This can make the regression effect of the model better.
- When dealing with uncommon samples, we should analyze them in depth and classify them further.The correlation between the index and the diagnosis result cannot be reflected by the single one-to-one pairings on the data.
- In the process of establishing evaluation criteria, we only consider the weight of the first layer of criteria, without giving specific scheme layer content.Therefore, in order to enhance the credibility of the evaluation, detailed quantitative classification can be made for each sleep arrangement.

7 Strengths and Weaknesses

7.1 Strengths

- Our multiple Logistic regression model can effectively reflect the impact of various levels of indicators on sleep quality.
- The hypothesis in the process of simplification is very reasonable, and the analytical method used is very effective and applicable.
- In the correlation analysis of diagnosis results, we fully consider each category and exclude invalid diagnosis results.
- The proposed Suggestions are based on the previous research results and combined with relevant literature, which is very scientific.

7.2 Weaknesses

- The classification method is too subjective when classifying the diagnosis results.

- In the correlation study between uncommon disease types and diagnosis results, specific relationship isnt given, so the influence of various indicators on diagnosis results cant be analyzed.
- In the evaluation system, only the weight of each index is considered without further discussion.

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