Sleep Quality Assessment of the Elderly Based on Intelligent Mattress Monitoring Data

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Abstract: Due to the special nature of the elderly in nursing homes, their sleep problems are difficult to evaluate conveniently and in a timely manner. Based on the guardian data of smart mattresses in nursing homes, according to the sleep characteristics of the elderly, combined with the opinions of medical experts, the Analytic Hierarchy Process (AHP) was used to construct the sleep evaluation model for the elderly in nursing homes. The results of sleep evaluation model is compared with the results of the professional sleep evaluation scale. The correlation coefficient between Pearson Correlation Coefficient and Spearman Correlation Coefficient is 0.930 and 0.956, respectively. The experimental results show that there is a strong correlation between the two. And consistency, proved the reliability of this model.

1. Introduction

Sleep not only relaxes the mind and body, but also allows brain to repair, refreshes vital physical functions, and helps maintain physical and mental health [1]. Long-term sleep deprivation can contribute to a wide range of physiological and psychological ailments [2]. Especially for the elderly, sleep problems are more frequent.

This article is aimed at the evaluation of sleep in the elderly in nursing homes. Based on the elderly guardian data of smart mattresses in nursing homes, the Analytic Hierarchy Process (AHP) was used to construct a comprehensive evaluation model for the elderly in nursing homes. Firstly, a hierarchical evaluation index system for the elderly is defined. The comparison matrix is constructed and the weights of each indicator are obtained through the consistency test[5]. The accurate evaluation of the sleep quality of the elderly in the nursing home is realized, and it is successfully applied to the nursing home with smart mattress.

2. Evaluation model of sleep quality for the elderly in nursing homes

2.1 Selection of evaluation indicators

The evaluation system established in this paper is for the elderly in the nursing home, based on the data obtained from the smart mattress of the nursing home. According to the characteristics of the sleep of the elderly in the nursing home, and referring to the opinions of medical experts, the following index system is obtained. There are 3 first-level indicators \((B₁-B₃)\), 9 second-level indicators \((C₁-C₉)\).
2.2 Constructing a multi-factor judgment matrix for sleep evaluation of the elderly
A indicates the quality of sleep for the elderly, and B indicates all the primary indicators that affect A: B1 is sleep state, B2 is sleep disorder index, B3 is sleep regularity, we compare the three first-level indicators in pairs, and use the 7-digit ratio to rank the relative merits and demerits of each indicator. We find the judgment matrix of A relative to the primary indicator:

\[
A - B = \begin{bmatrix}
1 & 2 & 6 \\
1/2 & 1 & 2 \\
1/6 & 1/2 & 1
\end{bmatrix}
\]  
(1)

C represents 9 secondary indicators. Similarly, B1 represents sleep state. B2 represents the sleep disorder index. B3 represents the sleep regularity. It can be obtained as a formula (2)-(4)

\[
B1 - C = \begin{bmatrix}
1 & 5 & 3 & 2 \\
1/5 & 1 & 1/3 & 1/4 \\
1/5 & 3 & 1 & 1/2 \\
1/2 & 4 & 2 & 1
\end{bmatrix}
\]  
(2)

\[
B2 - C = \begin{bmatrix}
1 & 3 & 1 \\
1/3 & 1 & 1/3 \\
1 & 3 & 1 \\
1 & 1 & 1
\end{bmatrix}
\]  
(3)

\[
B3 - C = \begin{bmatrix}
1 & 1 \\
1 & 1
\end{bmatrix}
\]  
(4)

2.3 Calculation of index weight vector
We calculate the weight vector. It is necessary to calculate each comparison matrix to obtain the largest eigenvalue and corresponding eigenvector of each matrix. We use the consistency indicator to test the consistency of the results. If the consistency test has passed, we normalize the feature vector and calculate the weight vector of the group of factors [10]. The index weight table is obtained, as shown in equations (5)-(8).

2.4 Calculation of the combination weight vector of the evaluation index
After calculation, the quality of sleep and the three primary indicators of the elderly are as follows;
A = 0.117 \times B_1 + 0.615 \times B_2 + 0.268 \times B_3 \tag{5}

The three primary indicators and their corresponding secondary indicator models are as shown in equations (9)-(11).

\begin{align*}
B_1 &= 0.473 \times C_1 + 0.073 \times C_2 + 0.170 \times C_3 + 0.284 \times C_4. \tag{6} \\
B_2 &= 0.8468 \times C_5 + 0.2565 \times C_6 + 0.466 \times C_7. \tag{7} \\
B_3 &= 0.5 \times C_8 + 0.5 \times C_9. \tag{8}
\end{align*}

Tab.1 Summary of correspondence judgment matrix and calculation results for indexes at all levels

| Judgment matrix | Calculation results |
|-----------------|---------------------|
| A — B           | \( W = [0.615, 0.268, 0.117] \), \( \lambda_{\text{max}} = 3.0184 \), \( CI = 0.0092 \), \( RI = 0.58 \), \( CR = CI/RI = 0.0159 < 0.1 \) |
| B1—C            | \( \bar{W} = [0.473, 0.073, 0.170, 0.284] \), \( \lambda_{\text{max}} = 4.0507 \), \( CI = 0.017 \), \( RI = 0.90 \), \( CR = 0.019 < 0.10 \) |
| B2—C            | \( \bar{W} = [0.54, 0.16, 0.3] \), \( \lambda_{\text{max}} = 3.0092 \), \( CI = 0.0046 \), \( RI = 0.52 \), \( CR = 0.009 < 0.10 \) |
| B3—C            | \( \bar{W} = [0.5, 0.5] \), \( \lambda_{\text{max}} = 2 \), \( CI = 0 \), \( RI = 0 \), \( CR = 0.019 < 0.10 \) |

As can be seen from the table, Each judgment matrix has strong consistency and passed the consistency check.

3. Experiment and analysis

3.1 experiment procedure

This article obtains the monitoring data of the elderly for nearly two months from the nursing home using smart mattresses[11], and selects the representative 100 times, and the monitoring data of 100 days per person. And we sort out the various indicator data of the evaluated personnel with the formula quantification. In this paper, the evaluation model proposed in this paper is used to calculate the second-level evaluation indicators, and the first-level indicators and the final evaluation total scores are calculated by weighting. Then we use the Pearson correlation coefficient and the Pierceman rank correlation coefficient to reflect the validity of the model.

3.2 Experimental results and analysis

Through the relevant calculations, the first-level indicators of sleep of the elderly, the sleep state, the sleep disorder, and the scores of the sleep patterns, as well as the scores of the model evaluation scores and the author's field sleep evaluation table are shown in Table 3.

Tab. 2 Data examples for the evaluation model

| index       | Sleep state index | Sleep disorder index | Sleep regularity | Model rating | Score of Sleep table |
|-------------|-------------------|----------------------|------------------|--------------|----------------------|
| user1       | 4.27              | 4.16                 | 4.55             | 4.28         | 4.15                 |
| user2       | 3.98              | 3.88                 | 4.26             | 3.99         | 4.06                 |
| user100     | 4.13              | 4.10                 | 4.03             | 4.11         | 4.15                 |

It can be seen from Table 2 that using the evaluation model of this paper to evaluate the sleep of the elderly can not only calculate the overall score of the sleep quality of the elderly, but also calculate the scores of the first-level indicators of the model such as sleep state and sleep disorder. While showing the sleep quality of the elderly, the quality of sleep of the elderly can be more comprehensively evaluated through the first-level indicators, and the management staff of the nursing
home can also have a more accurate understanding of the elderly's sleep shortcomings based on the scores of the primary indicators.

Calculate the preprocessed data and use Matlab to derive the Pearson Correlation Coefficient ($r(PCC)$) and the Spearman Correlation Coefficient ($\rho(SCC)$) based on the dispersion of the selected sample data. The above experimental results were uniformly placed in Table 3 for analysis.

| Model                  | $r(PCC)$ | $\rho(SCC)$ | $p$       |
|------------------------|----------|-------------|-----------|
| Sleep evaluation model | 0.930    | 0.956       | 1.68E-8   |

As we can see in Table 3. The significance test result of this result is less than 0.05, indicating that the data is significant. The Pearson correlation coefficient of the extinction $r(PCC)$ verifies that the evaluation results of the sleep evaluation model proposed in this paper are more correlated with the Pittsburgh sleep evaluation values. The Spearman correlation coefficient $\rho(SCC)$ proves that the original model can predict the ordering monotony of the scores in the original dataset more accurately. The overall experimental results show that the analytic evaluation model of the elderly sleep evaluation is more effective.

It can be seen from the above experimental results that the evaluation of the sleep of the elderly in nursing homes by the model proposed in this paper is very similar to the results of the authoritative sleep evaluation form in most cases. Although the Pittsburgh sleep evaluation form is used for questionnaire surveys, the old people's responses are also subjective. However, for users who participate in the test, even if there is a large error in a single evaluation, the probability of positive and negative errors is equal. In the case of a large number of evaluations, the positive and negative errors are offset, and the overall error value is extremely small. The quality of life has an excellent evaluation reference, so as to achieve an effective evaluation of the quality of sleep for the elderly.

4. Summary

Based on the monitoring data of smart old-age mattresses, this paper constructs a sleep-level analysis and evaluation model for the elderly in nursing homes by using the analytic hierarchy process and the characteristics of sleep in the elderly in nursing homes. The characteristics of this model are: 1) Combine the actual situation of the elderly in the nursing home with the authoritative literature and the experience of authoritative experts, making the evaluation results more scientific and objective. 2) We use the analytic hierarchy process to build a model. The analysis indicators are comprehensive and the model is highly applicable. 3) Based on the actual data analysis of a large number of elderly nursing homes and the results of several field investigations, the practicality of this evaluation model is proved. The analytic evaluation model of sleep quality of the elderly in the nursing home can accurately evaluate the sleep quality of the elderly in the nursing home. It can help to understand the sleep status of the elderly in real time, and adopt specific measures to improve the sleep quality of the elderly and improve the quality of life of the elderly.

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