Research on Comprehensive Evaluation and Optimization Design Methods for the Elderly Home Exercise Bikes

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Abstract: In order to optimize the user experience of home exercise bikes for the elderly and improve user satisfaction, this study explores the users' needs for exercise bikes through multi-channel research on target users and uses the Delphi method to hierarchically divide the demand indicators, thus establishing a design evaluation model for home exercise bikes for the elderly. This study uses the combination of the analytic hierarchy process method (AHP) and the objective entropy weight method (EWM) to calculate the comprehensive weights of each evaluation index and combines the fuzzy comprehensive evaluation method (FCE) to conduct a comprehensive evaluation of the elderly home exercise bike product cases. Finally, this study comprehensively analyzes the results of demand index importance ranking and example evaluation and comes up with several significant factors affecting the user experience satisfaction of home exercise bikes for the elderly, as well as strategies for design optimization. The purpose of this paper is to help the subsequent designers better grasp the optimization design direction through the study of fuzzy comprehensive evaluation methods and optimization design strategies for home exercise bikes for the elderly, and also to provide help for solving the health problems of the elderly in an aging society.

Keywords: elderly home exercise bike; analytic hierarchy process; entropy weight method; fuzzy comprehensive evaluation method; design optimization

1. Introduction

In recent years, the trend of population aging has become increasingly serious in all countries around the world. According to the latest data from China's National Bureau of Statistics, by the end of 2019, China's aging population had reached 254 million, accounting for 18.1% of the total population, and the proportion of the elderly population is expected to reach 1/3 in 2050. The most worrying issue brought by a deeply aging society is the health of the elderly, and improving the health status of the elderly is the basis for actively coping with population aging, which is also the focus of aging research[1]. In 2016, China proposed in the "Health China 2030 Plan" that "people should actively respond to population aging and realize "healthy aging" starting with fitness. The development of a fitness service industry for the elderly can effectively improve the science of physical exercise and health management for

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the elderly and reduce the negative effects of population aging in various countries[2]. According to the survey, aging at home is the most popular new model of aging, and the exercise bike is a typical simulation of outdoor exercise aerobic fitness equipment, which can strengthen the muscles and cardiorespiratory function of the elderly through the appropriate intensity of exercise, and effectively improve the health of the elderly[3]. Therefore, the development of a home exercise bike for the elderly suitable for home retirement has become one of the hot issues in the current design community and also has far-reaching social significance.

2. Comprehensive Evaluation Process of Elderly Home Exercise Bike

The analytic hierarchy process (AHP) is an analytical decision-making method to hierarchize multi-objective complex problems[4-5], which was proposed by Professor Saaty[6] in 1971. The analytic hierarchy process method relies to a certain extent on the subjective experience of experts, while the entropy weighting method is an objective weighting method. Combining the two can retain the qualitative opinions of experts and scholars as well as effectively correct the subjective arbitrariness of the hierarchical analysis method so as to determine the comprehensive weights of evaluation indexes more objectively and reasonably. The fuzzy comprehensive evaluation method is a comprehensive evaluation method combining qualitative and quantitative based on fuzzy mathematics, which can effectively solve the problems of multi-level and complexity of evaluation elements and unquantifiable indexes in design evaluation.

In the design evaluation process of home fitness bicycle for the elderly, in order to reduce the subjective influence of the design evaluator and improve the scientific and objective evaluation results, this paper firstly uses the combination of hierarchical analysis and entropy weight method to determine the comprehensive subjective and objective weight values of each index in the evaluation model, based on which, then conducts fuzzy comprehensive evaluation of the product example of home fitness bicycle for the elderly, and the overall process is shown in Figure 1.

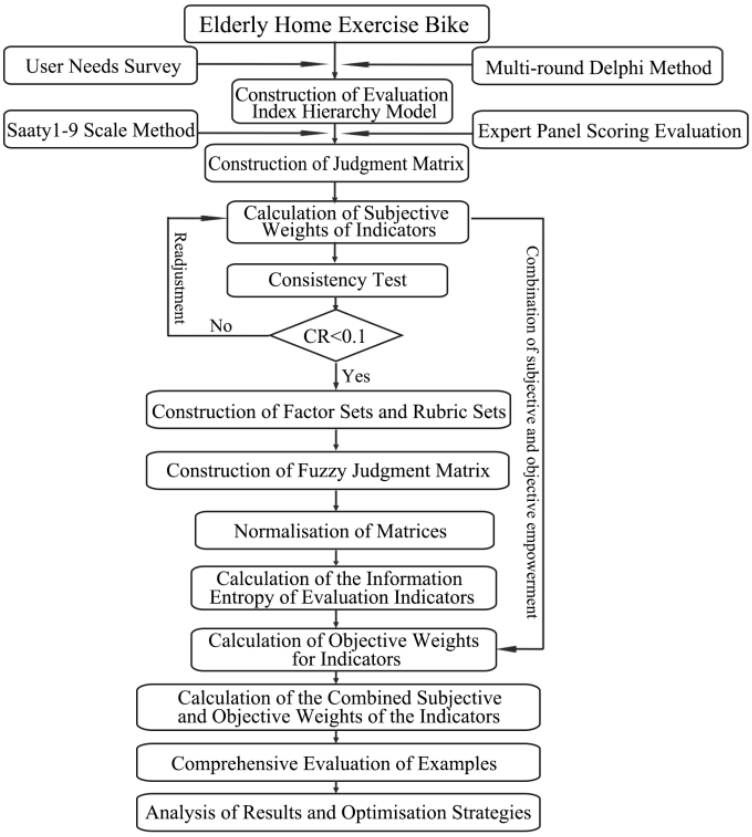

Fig.1 Comprehensive evaluation flowchart of home exercise bike for the elderly

3. Construction of a Fuzzy Comprehensive Evaluation Method of Home Exercise Bike for the Elderly

3.1 Construction of Hierarchical Model of Evaluation Index of Home Exercise Bike for the Elderly

This study was took the elderly group of home aging as the research object, 15 home exercise bike users aged 60-70 were selected for field observation and semi-structured interviews, and the original demand information obtained from the research was summarized and analyzed. Combined with the multi-round Delphi method [7], an expert group consisting of 2 experts in the direction of aging-appropriate research, 3 product designers, 3 professors in industrial design, 2 senior workers in health care for the elderly, and 10 elderly users conducted multiple rounds of discussion and adjustment, organized and clustered the collected original needs of users, and finally determined a ladder hierarchy model with five criterion-level indicators of comfort factors, safety factors, economic factors, functional factors, and aesthetic factors and 16 subdivided sub-criterion-level evaluation indicators, as shown in Figure 2.

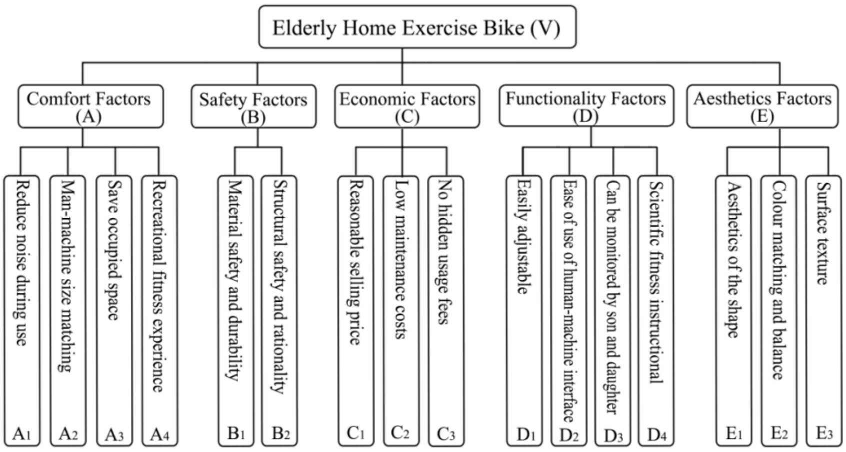

Fig.2 The hierarchical analysis model of evaluation index of elderly home exercise bike

3.2 Calculation of evaluation index weights

3.2.1 Calculation of subjective weights based on analytic hierarchy process

The judgment matrix is a two-by-two comparison of the relative importance between the indicators[8]. The scaling method from 1 to 9 was used to assign values (scales and meanings are shown in Table 1), and the values were used to express the different importance degrees between two index elements. Each member of the expert group was invited to quantify the scores of each evaluation index and construct the index judgment matrix by combining years of practical experience and relevant knowledge in their respective fields.

Table 1. Judgment matrix index importance level numerical scale table

Scale value	Importance Level	The meaning of importance level
1	Equally important	Indicator X is of equal importance compared to indicator Y
3	Slightly important	Indicator X is marginally important compared to Indicator Y
5	Outstandingly important	Indicator X is significantly more important than Indicator Y
7	Extremely important	Indicator X is extremely important compared to indicator Y
9	Completely important	Indicator X is completely important compared to Indicator Y
2，4，6,8	Eclectic use	The importance level is between two adjacent importance levels
1/2,1/3...1/9	Anti-comparison	If the importance scale value of indicator X over indicator Y is n, and vice versa is 1/n

In this paper, the geometric mean method is used to calculate the weight, and the specific calculation steps are as follows:

(1) Multiply the indicators of the judgment matrix row by row to obtain a new vector M_j, see formula (1):

$$M_j = \prod_{i=1}^{n} a_{ij} \, (j = 1,2,\cdots,n) \tag{1}$$

In the formula: *n* represents the order of the matrix, and a_{ij} represents the elements in the judgment matrix;

(2) Solving for the geometric mean of the metrics for each row a_j, see formula (2):

$$a_j = \sqrt[n]{M_j} \tag{2}$$

(3) Normalize the results and calculate the relative weights ω_j, see formula (3):

$$\omega_j = \frac{a_j}{\sum_{j=1}^{n} a_j} \tag{3}$$

In order to ensure the reasonableness and compatibility of the weight values in the judgment matrix, after determining the judgment matrix and weight values of each evaluation index, a consistency test is required. The test steps are as follows.

(1) Calculate the maximum characteristic root, see formula (4):

$$\lambda_{\max} = \frac{1}{n} \sum_{j=1}^{n} \frac{(A\omega)_j}{\omega_j} \tag{4}$$

In the formula: n is the number of orders of the judgment matrix; $(A\omega)_i$ is the i-th component of the vector.

(2) Calculate the consistency index CI, see formula (5):

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{5}$$

In the formula: λ_{max} indicates the maximum characteristic root of the judgment matrix; n indicates the order of the judgment matrix.

(3) Consistency ratio calculation, see formula (6):

$$CR = \frac{CI}{RI} \tag{6}$$

In the formula: RI indicates the random consistency index, and the RI values of different order matrices are shown in Table 2.

When $CR<0.1$, it means the consistency test is passed, otherwise, the matrix should be adjusted and tested again.

Table 2. RI value of matrix order 1-9

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

3.2.2 Calculation of objective weights based on the entropy weight method

The entropy weight method is a typical objective weighting method, and its objectivity lies in the fact that it utilizes the variability among information, and it is based only on the dispersion degree of the data itself [9]. In the evaluation system, the greater the entropy value of the indexes, the smaller the amount of information contained, the higher the degree of dispersion, and the smaller the weight of the indexes and their influence on the comprehensive evaluation results[10-11]. The introduction of entropy method and hierarchical analysis for combined assignment can correct the influence of single subjective assignment on the results and make the results more reasonable.

(1) Establish the original matrix

Assuming that there are n evaluation indicators and m evaluation levels, the original evaluation matrix T is established by the expert group's evaluation opinions on each evaluation indicator in the evaluation model, see formula (7):

$$T = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1n} \\ t_{21} & t_{22} & \cdots & t_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{m1} & t_{m2} & \cdots & t_{mn} \end{bmatrix} \tag{7}$$

(2) Normalize the matrix T to get the standardized matrix C, see formula (8):

$$C_{ij} = \frac{t_{ij} - \min(t_{ij})}{\max(t_{ij}) - \min(t_{ij})} \tag{8}$$

Calculate the information entropy value of each evaluation index, see formula (9):

$$e_j = \frac{1}{\ln m} \sum_{i=1}^{m} f_{ij} \ln f_{ij} \tag{9}$$

In the formula: $0 \le e_j \le 1$, $f_{ij} = \frac{C_{ij}}{\sum_{i=1}^{m} C_{ij}}$

Calculate the objective weight of each indicator, see formula (10):

$$\upsilon_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{10}$$

3.2.3 Calculation of the combined weight of indicators

The weight vector of evaluation indexes obtained by the hierarchical analysis method will be recorded as: $\omega_e = (\omega_1^{(e)}, \omega_2^{(e)}, \cdots, \omega_n^{(e)})$, and the weight vector of evaluation indexes obtained by the entropy weight method will be recorded as: $\upsilon_a = (\upsilon_1^{(a)}, \upsilon_2^{(a)}, \cdots, \upsilon_n^{(a)})$. According to the combination weighting method[12-13], the comprehensive weight of each index can be calculated by the following formula (11).

$$W_j = \frac{\omega_j^{(e)} \upsilon_j^{(a)}}{\sum_{j=1}^{n} \omega_j^{(e)} \upsilon_j^{(a)}} \tag{11}$$

3.3 Fuzzy integrated evaluation method

The specific process of fuzzy comprehensive evaluation is:

(1) Establish the set of index factors $V=\{V_1, V_2, \cdots, V_n\}$;

(2) Determine the set of rubrics and their corresponding criteria. Establishing the set of comments $X = \{X_1, X_2, \cdots X_m\}$= {very satisfied, satisfied, generally satisfied, unsatisfied, very unsatisfied} ;

(3) The expert group is invited to evaluate the factors of the index layer in the model. The affiliation degree of evaluation indicators relative to each grade in the rubric set is obtained by calculating the number of expert scores, and the affiliation degree is the ratio of the number of experts evaluating an indicator belonging to the evaluation level X to the total number of experts, so as to construct a fuzzy comprehensive evaluation matrix P of the indicators at each level of the elderly exercise bike is constructed, see formula (12):

$$P=\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix} \quad (0 \leq p_{ij} \leq 1) \tag{12}$$

(4) After determining the comprehensive weight W of each evaluation index, the evaluation results of the product solution is obtained by synthesizing the operation with the corresponding evaluation matrix P, see formula (13):

$$S = W \circ P = (W_1, W_2, \cdots, W_n) \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix} \tag{13}$$

4. A case study of home exercise bikes for the elderly based on fuzzy comprehensive evaluation

Through market research and comprehensive analysis of the sales of major e-commerce platforms, selected a more popular elderly home exercise bike on the market (see Figure 3).

Fig.3. Case of home exercise bike for the elderly

4.1 Analytic hierarchy process to determine the subjective weights of evaluation indexes of home exercise bike case for the elderly

The judgment matrix was established by the expert group according to the importance of each indicator, and the subjective weight vectors of the indicator layer and the criterion layer were calculated by formulas (1) to (3), and the consistency test was conducted by formulas (4) to (6), as shown in Table 3:

Table 3. Indicator weight and consistency test

Evaluation Metrics	Weight vector	CR	Consistency check passed or not
V	(0.1583,0.3841,0.0569,0.3516,0.0491)	0.039	Yes
A	(0.1403,0.4194,0.0713,0.3691)	0.037	Yes
B	(0.2000,0.8000)	0.000	Yes
C	(0.4000,0.4000,0.2000)	0.000	Yes
D	(0.1673,0.3813,0.1069,0.3446)	0.017	Yes
E	(0.5714,0.2857,0.1429)	0.000	Yes

4.2 Entropy weighting method to determine the objective weights of evaluation indexes of home exercise bike case for the elderly

The 20 expert panelists in the evaluation model construction phase were invited to score the evaluation indicators for this product, and the fuzzy integrated evaluation matrix is as follows:

$$P_A = \begin{bmatrix} 0.9 & 0.1 & 0 & 0 & 0 \\ 0.3 & 0.6 & 0.1 & 0 & 0 \\ 0.4 & 0.5 & 0.1 & 0 & 0 \\ 0.3 & 0.4 & 0.3 & 0 & 0 \end{bmatrix}$$

$$P_B = \begin{bmatrix} 0.8 & 0.2 & 0 & 0 & 0 \\ 0.3 & 0.5 & 0.2 & 0 & 0 \end{bmatrix}$$

$$P_C = \begin{bmatrix} 0.5 & 0.4 & 0.1 & 0 & 0 \\ 0.7 & 0.3 & 0 & 0 & 0 \\ 0.9 & 0.1 & 0 & 0 & 0 \end{bmatrix}$$

$$P_D = \begin{bmatrix} 0.3 & 0.6 & 0.1 & 0 & 0 \\ 0.2 & 0.6 & 0.2 & 0 & 0 \\ 0.1 & 0.4 & 0.5 & 0 & 0 \\ 0.2 & 0.7 & 0.1 & 0 & 0 \end{bmatrix}$$

$$P_E = \begin{bmatrix} 0.6 & 0.3 & 0.1 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 & 0 \\ 0.8 & 0.2 & 0 & 0 & 0 \end{bmatrix}$$

The objective weight vector $\upsilon_A,\upsilon_B,\upsilon_C,\upsilon_D,\upsilon_E$ of the indicator layer and the objective weight vector υ_V of the criterion layer can be obtained by calculating formulas (8) ~ (10)

$$\upsilon_A = (0.3952 \quad 0.2249 \quad 0.2129 \quad 0.1671)$$
$$\upsilon_B = (0.6505 \quad 0.3495)$$
$$\upsilon_C = (0.2318 \quad 0.3380 \quad 0.4303)$$
$$\upsilon_D = (0.2501 \quad 0.2310 \quad 0.2368 \quad 0.2821)$$
$$\upsilon_E = (0.2617 \quad 0.3396 \quad 0.3987)$$

4.3 Determine the subjective and objective comprehensive weights of the evaluation indexes of the elderly home exercise bike case

The subjective and objective combined weight vectors of each indicator in the indicator layer can be calculated by formula (11) as follows.:

$$W_A = (0.2445 \quad 0.4162 \quad 0.0671 \quad 0.2723)$$
$$W_B = (0.3175 \quad 0.6825)$$
$$W_C = (0.2952 \quad 0.4306 \quad 0.2739)$$
$$W_D = (0.1656 \quad 0.3490 \quad 0.1002 \quad 0.3851)$$
$$W_E = (0.4926 \quad 0.3196 \quad 0.1878)$$

The comprehensive weight values and importance ranking of each indicator for the decision objectives were further solved, as shown in Table 4, to provide a reference standard for the comprehensive evaluation analysis and optimization of the final elderly home exercise bike product solution.

Table 4. The comprehensive weight value and importance ranking of indicator factors

Guideline level indicators	Weights	Indicators of the indicator layer	Weights	Combined weights for the target layer	sequence
A	0.1584	A1	0.2445	0.0387	8
		A2	0.4162	0.0659	5
		A3	0.0671	0.0106	15
		A4	0.2723	0.0431	7
B	0.3841	B1	0.3175	0.1220	4
		B2	0.6825	0.2621	1
C	0.0569	C1	0.2925	0.0166	12
		C2	0.4306	0.0245	10
		C3	0.2739	0.0156	14
D	0.3516	D1	0.1656	0.0582	6
		D2	0.3490	0.1227	3
		D3	0.1002	0.0352	9
		D4	0.3851	0.1354	2
E	0.0491	E1	0.4926	0.0242	11
		E2	0.3196	0.0157	13
		E3	0.1878	0.0092	16

In order to better integrate the information of the indicator weight vector and matrix, the evaluation weight vector of each indicator in the indicator layer is further calculated using a weighted average type fuzzy operator as follows:

$$P_A = (0.453 \quad 0.417 \quad 0.130 \quad 0 \quad 0)$$
$$P_B = (0.459 \quad 0.405 \quad 0.137 \quad 0 \quad 0)$$
$$P_C = (0.696 \quad 0.275 \quad 0.030 \quad 0 \quad 0)$$
$$P_D = (0.207 \quad 0.618 \quad 0.175 \quad 0 \quad 0)$$
$$P_E = (0.606 \quad 0.345 \quad 0.049 \quad 0 \quad 0)$$

On this basis, the second-level fuzzy comprehensive evaluation matrix can be constructed:

$$P_V = \begin{bmatrix} P_A \\ P_B \\ P_C \\ P_D \\ P_E \end{bmatrix} = \begin{bmatrix} 0.453 & 0.417 & 0.130 & 0 & 0 \\ 0.459 & 0.405 & 0.137 & 0 & 0 \\ 0.696 & 0.275 & 0.030 & 0 & 0 \\ 0.207 & 0.618 & 0.175 & 0 & 0 \\ 0.606 & 0.345 & 0.049 & 0 & 0 \end{bmatrix}$$

The combined weight vector of the overall indicators of this elderly home exercise bike is as follows:

$$W_V = (0.1583 \quad 0.3841 \quad 0.0569 \quad 0.3516 \quad 0.0491)$$

The comprehensive evaluation vector of this elderly home exercise bike is as follows:

$$S = W_V \circ P_V = (0.390 \quad 0.471 \quad 0.139 \quad 0 \quad 0)$$

According to the fuzzy evaluation results, 39.0% of people are "very satisfied" with the product, 47.1% are "satisfied" with the product, and 13.9% are "generally satisfied" with the product. Following the principle of maximum affiliation, the product user satisfaction belongs to the "satisfied" level. The evaluation results show that this exercise bike as a whole meets the basic needs of elderly users, but there are still shortcomings in some aspects. Comprehensive analysis of the results of the calculation of the weight of each demand indicator, the priority ranking results and the scoring of each indicator of the fuzzy comprehensive evaluation in Table 4 shows that among the more important indicators in the design of the elderly home exercise bike, the satisfaction of structural safety and reasonableness, entertaining fitness experience, ease of use and convenience, cientific guidance of fitness, and the function of remote monitoring by sons and daughters are relatively low. These indicators with high importance and low satisfaction ratings provide a clear direction for subsequent product optimization. This is also the important basis for the authors to propose the following optimization design strategies.

5. Optimized design strategies for home exercise bikes for the elderly

(1) strengthen the safety of the elderly exercise bike

Considering the special physiological condition of elderly users, the shape design of the exercise bike should avoid sharp angles and right angles on the basis of following the function, and adopt a rounded and smooth structure to prevent accidental bruises and scratches when the elderly exercise; the overall body shape should be solid and stable to prevent the danger of overturning due to improper force and other operations; in addition, due to the gradual decline of the elderly's perception and reaction ability, the handrail, pull ring and other structural changes should be easy to perceive the color or force feedback structure to remind users.

(2) To ensure that the operation is simple and convenient

With the decline of physical functions, the elderly user's eyesight, memory and learning ability also decreased significantly, easy to learn and easy to use is an important factor in the design of elderly products, the simple and convenient operation of the elderly exercise bike mainly includes two aspects:

a) Ease of use of the human-machine interface

The design of the functional interface of the exercise bike should enhance intuitiveness and visibility, consider the reasonable layout of the keys while enhancing the readability and accuracy of the target information, and for the more frequently used function keys can improve the accuracy of recognition through layout position, material contrast, color distinction, and increased font description. The overall design of the function interface of the exercise bike for the elderly should grasp the principle of large display screen, eye-catching and few buttons, and simplify the operation steps as much as possible, and the voice instruction function can also be appropriately added.

b) The convenience of free adjustment operation

The convenience of the elderly home exercise bike operation is reflected in two aspects: ① users can quickly find the need to adjust the adjustment of the parts of the way, that is, the product has a good comprehensibility, can be simplified through the structure and indicative signs or patterns to increase comprehensibility; ② adjustment operation is easy and effortless, elderly users can easily complete the adjustment of resistance size, hand and foot straps tightening, angle and torque, seat and other functions alone.

(3) Strengthen the scientific fitness guidance function

The design of the elderly home exercise bikes needs to strengthen the user exercise data recording and reminding function, which can regularly monitor the changes in the physical function of the elderly, establish the user physical function data file, and provide more scientific and effective guidance for the next exercise according to the physical needs.

(4) Improve the comfort and entertainment experience of home fitness for the elderly

The comfort of fitness exercise includes both physiological and psychological feelings. Physiological mainly lies in the fitness bike man-machine size and human body match, the design should make the product form and size to fit the needs of the elderly. On the other hand, the fitness process can enhance the entertainment to enhance the user's psychological feelings. Home fitness car for the elderly can be realized through the Internet technology remote online interactive game mode, so that elderly fitness users through the game mode together with the cloud fitness to enhance the sense of home fitness entertainment experience.

(5) Add the function of remote monitoring by sons and daughters

Design fitness products for elderly users from an emotional perspective and analyze the emotional needs of users. Many children are separated from their parents due to work, school and other reasons, but they are very concerned about their parents' health, so the elderly home fitness car can increase the function of remote monitoring by sons and daughters. Children can monitor the fitness cloud data of the elderly through the cell phone APP conduction, real-time understanding of the physical condition of parents.

6. Conclusion

(1) Based on the survey of elderly users and the analysis of related literature, this paper constructs a bottom-up evaluation hierarchy model of home exercise bike design for the elderly in terms of comfort, functionality, safety, aesthetics and economic factors, and quantifies the evaluation indexes.

(2) In this study, the entropy weighting method is introduced to correct the subjectivity in determining the index weights by the hierarchical analysis method, which improves the scientificity and reliability of the evaluation of the design of home fitness bikes for the elderly.

(3) This study summarizes the design optimization strategy of home fitness bikes for the elderly, which provides some reference for subsequent designers to optimize the design of home fitness bikes for the elderly and develop products with higher user satisfaction in a more targeted way, and also contributes to weakening the negative impact brought by the social problem of population aging.

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References

[1] Tian W., Jiang L., Li M.Y., et al. The status quo and difference analysis of the development of the concept of "active aging" in urban and rural areas in my country[J]. Human Resources Development. 2020,(19):33-35.

[2] Chen L. The Research on the Policy Support to Health Services to Elderly Population in China[J]. Journal of Xi’an Physical Education University, 2011, 28(5): 565-568.

[3] Wu G., Zhang M.H., YANG Z H. The design of multifunctional exercise bike [J]. Mechanical Engineer, 2011 (6): 42-43.

[4] Gouareh A, Settou B, Settou N. A new geographical information system approach based on best worst method and analytic hierarchy process for site suitability and technical potential evaluation for large-scale CSP on-grid plant: An application for Algeria territory[J]. Energy Conversion and Management, 2021, 235: 113963.

[5] Janković A, Popović M. Methods for assigning weights to decision makers in group AHP decision-making[J]. Decision making: applications in management and engineering, 2019, 2(1): 147-165.

[6] Saaty T. L. How to make a decision: the analytic hierarchy process[J]. European Journal of Operational research, 1994, 24(6): 19-43.

[7] Lee S, Kim J, Park S A, et al. Study for revision of Hwa-Byung Scale: The Delphi Method[J]. European Psychiatry, 2022, 65(S1): S548-S549.

[8] Gao X.Y., Wang H., Song Q., et al. Evaluation and optimization of the comfort of orchard operating platform based on AHP-TOPSIS[J].Journal of Graphics. 2020, 41 (05):788-795.

[9] Zhong J., Liu M.J., Luo C., et al. Ship-bridge collision risk assessment based on combined weight fuzzy matter-element model[J]. Journal of Safety and Environment. 2018,18(02): 423-427.

[10] Qi T.L., Hu H.J. Evaluation of Equipment Maintenance Quality Impact Factor Based on AHP-Entropy Comprehensive Theory[J]. Value Engineering,2019,(2):66-69.

[11] Jia L.G., Yang J. Running Energy Efficiency Assessment in Electric Vehicle Charging Station Based on AHP-Entropy Method[J]. Electric Power Construction, 2015, 36 (7):209-215.
[12] Hu S., Liu J. Application of fuzzy fomprehensive evaluation method in product design scheme decision[J]. Machinery Design 2020,37(01),135-139.
[13] Wang Y.B., Yang T.H., Wang S.D., Evaluation of Urban Public Security Sense Based on Combination Empowerment and Grey Relation[J]. Statistics and Decision. 2019,35 (18),45-49.