

Comprehensive Evaluation of Dietary Nutrition Based on Normalization and Linear Weighted Model

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Abstract. Dietary recipes play a pivotal role in maintaining nutritional health. A balanced and scientific diet can enhance nutrient absorption and preserve physical well-being. Nevertheless, many dietary nutritional assessment methods suffer from the limitation of being partial or one-sided. To address this issue and better facilitate the search and design of dietary plans, we have employed a normalized and refined linear weighted method to construct a novel comprehensive evaluation model. This approach eliminates the influence of different dimensions, allowing various types of indicators to be compared and analyzed simultaneously. Therefore, it enables a holistic evaluation of multiple nutritional indicators, yielding a comprehensive result. Furthermore, we illustrate the application of this model with a daily dietary plan for a male college student as an example. Based on the fundamental principles of balanced diets and food information, a comprehensive nutritional evaluation of the diet is conducted. This model not only facilitates the design of scientific dietary plans but also aids individuals in cultivating healthy eating habits, thereby safeguarding their overall health.

Keywords: Linear Weighted; Normalization; Comprehensive Evaluation Method; Dietary Nutrition.

1. Introduction

Health serves as a fundamental prerequisite for promoting holistic human development, and dietary habits represent a significant factor influencing health status. However, quite a considerable number of people suffer from malnutrition due to improper dietary habits such as irregular meal times and unbalanced diets. This issue urgently needs to be solved [1].

Analyzing and evaluating people's daily recipes is a major strategy to find scientific dietary combinations. By evaluating the intake for three meals a day is helpful to design scientific recipes and cultivate healthy eating habits. According to The Dietary Guidelines and the nutritional evaluation process of dietary recipes, six dietary nutrition evaluation indicators should be analyzed to assess a diet: food structure, total energy intake, meal ratio of energy intake per meal, energy supply ratio of energy capacity, non-energy intake of nutrients, and essential amino acid score (AAS) [2]. Given the variety of criteria, many previous dietary nutrition evaluation methods like Index of Nutritional Quality, Food Frequency Questionnaire and Single Nutrient Evaluation could only assess a subset of indicators, which result in incomplete consequence [3].

To overcome these challenges and achieve a comprehensive evaluation of recipes, we constructed a linear weighted method with normalized improvement. Initially, each of the six dietary nutrition evaluation metrics undergoes normalization. After converting the different dimensions to a common scale, the linear weighted method is then applied for evaluation [4]. This process transforms the previously incomparable and intricate metric scoring into a format that is readily comparable. Ultimately, the end result is a comprehensive and unbiased evaluation.

2. The basic fundamental of normalization and linear weighted comprehensive evaluation

2.1. The normalization processing of evaluation indicators

The calculation of the score needs to be reasonable and the first step involves preprocessing all the indicators. The pretreatment of evaluation indicators usually includes two treatment methods: consistency and dimensionless processing [5]. When dealing with different types of indicators, it is necessary to employ distinct methods. For food structure, normalization to the [0, 1] interval is adopted. For total energy intake, meal ratio of energy intake per meal, energy supply ratio of energy capacity and non-energy intake of nutrients, it requires min-max normalization. For AAS, decimal scaling normalization is employed. The preprocessing methods for evaluation indicators are shown in Figure 1.

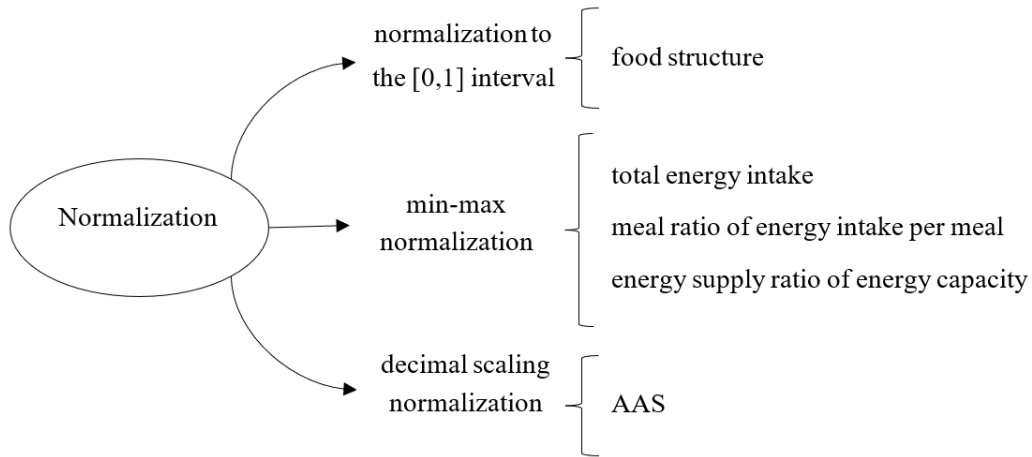


Figure 1. The preprocessing methods for evaluation indicators

The criterion for judging the food structure is whether the average daily intake of food types exceeds 12 varieties, and whether the daily food consumption encompasses the five major food categories [6]. If the daily intake food types and food categories meets the criteria, a full score will be given. Otherwise, the maximum normalization will be applied. The formula is as follows:

$$b_{11} = \begin{cases} 1, & n_i \geq 12 \\ \frac{n_i-0}{12-0}, & 0 \leq n_i < 12 \end{cases} \quad (1)$$

$$b_{12} = \frac{N_i-0}{5-0} \quad (2)$$

Where b_{11} and b_{12} are scored for the normalized food type and food category respectively.

Interval indicators such as total energy intake need to be normalized.

Suppose the optimal range for a certain interval-type indicator is $[a_j^o, a_j^*]$, and the lower and upper limits of its intolerance are respectively a_j' and a_j'' . Then the normalized score can be calculated by the following formula:

$$b_{ij} = \begin{cases} 1 - \frac{a_j^o - a_j}{a_j^o - a_j'}, & a_j' \leq a_j \leq a_j^o \\ 1, & a_j' \leq a_j \leq a_j^* \\ 1 - \frac{a_j - a_j^*}{a_j'' - a_j^*}, & a_j^* \leq a_j \leq a_j'' \\ 0, & a_j \leq a_j' \text{ or } a_j \geq a_j'' \end{cases} \quad (3)$$

Where b_2 is the total energy intake score, b_{3j} is the energy intake meal ratio score for meal j , b_{4j} is the energy supply ratio score for meal j and b_{5j} is the non-energy nutrient intake score for meal j . The decimal scaling normalization formula for AAS is as follows [7]:

$$\overline{AAS} = \frac{1}{n} \sum_{j=1}^n AAS_j \quad (4)$$

$$b_6 = \frac{\overline{AAS}}{10^2} \quad (5)$$

Where AAS_j represents the essential amino acid score for meal j and b_6 is the normalized score.

In this way, the six indicators of dietary recipes have all been normalized. Differences in units and orders of magnitude are eliminated, allowing the various indicators to participate fairly in the calculation of the overall evaluation.

2.2. The construction of the linear weighted method

In order to get a comprehensive score, we need to use linear weighted method to unify those six indicators. Since the six indicators have roughly the same influence on the evaluation of dietary balance, their weights can be set equal to $\frac{1}{6}$ [2, 8]. The food structure includes food type and food category, the meal ratio includes multiple meals a day, the energy supply ratio includes protein, fat and carbohydrates, and the non-energy nutrients includes calcium, iron, zinc, vitamin A, vitamin B_1 , vitamin B_2 , and vitamin C [2, 6]. Therefore, the average score of each of these indicators is calculated first, and then carry out linear weighted. The formula is as follows:

$$S'_j = \frac{1}{6} \cdot \frac{\sum_{j=1}^2 b_{1j}}{2} + \frac{1}{6} + b_2 + \frac{1}{6} \cdot \frac{\sum_{j=1}^n b_{3j}}{n} + \frac{1}{6} \cdot \frac{\sum_{j=1}^3 b_{4j}}{3} + \frac{1}{6} \cdot \frac{\sum_{j=1}^7 b_{5j}}{7} + \frac{1}{6} \cdot b_6 \quad (6)$$

Where S'_j is the evaluation score.

The linear weighted method assigns weights to different indicators, reflecting their importance in dietary nutrition evaluation. Through this method, the results of the comprehensive evaluation are more accurate and can more truly reflect the overall situation of dietary nutrition.

2.3. Comprehensive Evaluation of Dietary Nutrition

After normalization and linear weighted, we have obtained a composite score with a range score of 0 to 1. For the sake of convenience and observational analysis, it can be converted to a 100-point scale to obtain the final score S_j :

$$S_j = 100 \cdot S'_j \quad (7)$$

Thus, the score range becomes 0 to 100. Higher scores represent a better overall level of dietary nutrition. This score can be used for comparison and evaluation, which not only improves the efficiency but also enhances the accuracy.

3. Results

3.1. Utilization of the comprehensive evaluation model

Adolescence is a critical period for physical growth. Meanwhile, it is also an important stage for the learning of nutrition knowledge and the formation of dietary behavior [9]. Considering that college students are usually in adolescence, there is a representative age group of physical growth. At the same time, their lives are relatively concentrated on campus or in the surrounding area, which makes them have a certain similarity in their dietary choices. Therefore, we can use the recipe data of a male college student and a female college student as examples (<http://shumo.neepu.edu.cn/>). By evaluating their diets, the application of the evaluation model in the age group of young people is reflected. According to the China Food Composition Tables [10, 11], we can calculate a number of indicators such as total energy intake and nutrient intake. The calculation of the comprehensive score also requires the optimal interval of some nutritional indicators and the intolerable upper and lower limits [12, 13]. The specific data for the male college student is shown in Table.1 and the specific data for the female college student is shown in Table.2.

Combined with the above data and the comprehensive evaluation model, we can calculate that the recipe score of this male college student on that day is $S_j = 76.84$, while the female college student's recipe score is $S_j = 86.48$. This approach facilitates both a granular examination of their nutritional intake in every facet and an evaluation of their holistic wellbeing.

Table 1. Intake of dietary nutrition evaluation indicators for the male college student

Indicator	Numerical value	Optimal interval	Intolerable lower limit	Intolerable upper limit
Food type	19	≥ 12		
Food category	5	5		
Total energy	2633.71kcal	2400kcal	1400kcal	3400kcal
Breakfast energy percentage	30.17%	30%	20%	40%
Lunch energy percentage	37.23%	30%~40%	20%	50%
Dinner energy percentage	32.60%	30%~40%	20%	50%
Protein	13.53%	10%~15%	5%	22.5%
Fat	41.93%	20%~30%	10%	50%
Carbohydrates	43.93%	50%~65%	30%	80%
Calcium	755.46mg	800mg	500mg	1100mg
Iron	22.90mg	12mg	8mg	16mg
Zinc	10.31mg	12.5mg	8mg	18mg
Vitamin A	213.55 μ g	800 μ g	400 μ g	1200 μ g
Vitamin B_1	1.00mg	1.4mg	0.7mg	2mg
Vitamin B_2	0.78mg	1.4mg	0.7mg	2mg
Vitamin C	29.60mg	100mg	50mg	150mg
AAS_1	69.31	≥ 80		
AAS_2	87.03	≥ 80		
AAS_3	40.77	≥ 80		

Table 2. Intake of dietary nutrition evaluation indicators for the female college student

Indicator	Numerical value	Optimal interval	Intolerable lower limit	Intolerable upper limit
Food type	15	≥ 12		
Food category	5	5		
Total energy	1312.39kcal	1900kcal	1000kcal	3000kcal
Breakfast energy percentage	24.29%	30%	20%	40%
Lunch energy percentage	43.48%	30%~40%	20%	50%
Dinner energy percentage	32.23%	30%~40%	20%	50%
Protein	16.80%	10%~15%	5%	22.5%
Fat	30.01%	20%~30%	10%	50%
Carbohydrates	52.10%	50%~65%	30%	80%
Calcium	209.15mg	800mg	500mg	1100mg
Iron	8.06mg	20mg	10mg	30mg
Zinc	4.94mg	7.5mg	5mg	15mg
Vitamin A	174.35 μ g	700 μ g	300 μ g	1100 μ g
Vitamin B_1	0.79mg	1.2mg	0.5mg	2mg
Vitamin B_2	0.51mg	1.2mg	0.5mg	2mg
Vitamin C	39.60mg	100mg	50mg	150mg
AAS_1	92.94	≥ 80		
AAS_2	88.01	≥ 80		
AAS_3	93.58	≥ 80		

3.2. Analysis of experimental results

Given the differences between males and females in terms of physiological structure, basal metabolic rate, etc., there are differences in their energy and nutrient requirements. And they have different eating habits and health needs, so their evaluation criteria will also be different, and they need to be evaluated separately.

By comparing the nutritional indicators with the standard indicators, we can analysis their dietary structure. The total energy intake and meal ratio of the male college student meet the health standards. The daily energy intake and the energy intake of breakfast of the girl is low. The energy intake of lunch is high. The boy's fat intake is too high and carbohydrate intake is low, while the girl consumes too much protein. Moreover, the male student's intake of other non-energy nutrients except iron is low, with vitamin A and vitamin C deficiencies being the most obvious. The AAS of his breakfast, lunch and dinner protein are respectively insufficiently reasonable, relatively reasonable and unreasonable. Non-productive nutrients were generally low in the female student's table, with calcium, vitamin A and vitamin C deficiencies being the most obvious. The AAS of her breakfast, lunch and dinner was reasonable, relatively reasonable and reasonable, respectively.

For the overall score, referring to the scoring design of the China Healthy Diet Index (CHDI), we set the final score S_j less than 60 as unreasonable, 60~80 as insufficiently reasonable, 80~90 as relatively reasonable and greater than 90 as reasonable [14]. While male college student's score is 76.84 and the female college student's score is 86.48, therefore, the dietary nutrition of them on that day belonged to the insufficiently reasonable and relatively reasonable evaluation levels respectively.

4. Conclusion

In this paper, we construct a comprehensive evaluation model and use it to assess and analyze the daily diet of a male college student. The results show that this model can evaluate multiple aspects while measure overall comprehensive score. A scientific and reasonable diet can provide us with sufficient energy and maintain a good physical condition. Besides, it can improve learning efficiency and body immunity [15]. Making full use of this model can better aid in the study of dietary recipes. It also has the following advantages:

- (1) The Normalization and Linear weighted method improve the accuracy and the unification of evaluation indicators for a variety of diets has been realized.
- (2) The comparability of the data is enhanced, providing a way to eliminate the different dimensions of the indicator.
- (3) This method also has strong adaptability, which can adapt to various evaluation needs and can be combined with other methods to form a more comprehensive dietary nutrition evaluation system.

There are some limitations and shortcomings in this model. If food is ingested in large quantities, it may cause nonlinear changes, which in turn can have an impact on the linear programming model. It also has a dependency on data. Evaluation and optimization are based on the input data. So incomplete or non-standard data will affect the accuracy of the model.

All in all, the comprehensive evaluation model has a wide range of practical applications to improve people's meal distribution and their quality of life.

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