A study on recipes based on the Diet Quality Index method

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Abstract. In recent years, there has been increasing attention to the health of college students, and in order to better maintain their health, it is necessary to plan and improve the current nutritional meal plans. So far, no relevant research has been conducted to analyze this issue. This paper collected the daily food intake records of one male and one female college student for three meals a day, using the Diet Quality Index (DQI) model to standardize the scores. By assigning weights to each food or nutrient, the overall score was calculated to assess the diet quality. Subsequently, the meal plans for both students were modified, and the results showed that the improved scores were higher. The meal plans revised using the DQI model were more reasonable, potentially addressing the current issues of low nutritional levels and unbalanced diets among college students, thus better maintaining their health.

Keywords: Diet Quality Index Model, Standardized Score, Eergy Intake.

1. Introduction

In recent years, the optimization and evaluation of balanced diets for college students have become a key focus for researchers. Various methods have been employed to explore the effects of dietary optimization on students' health, academic performance, and economic benefits. By designing and optimizing balanced meal plans through comprehensive evaluation models, researchers aim to provide dietary solutions that strike the best balance between nutrition and cost. Wei et al, using a five-dimensional comprehensive evaluation model, analyzed the diets of college students and found significant improvements in both nutritional balance and economic efficiency after optimization, particularly in protein balance and energy supply [1]. Whatnall et al. conducted a randomized controlled trial to evaluate the impact of the online intervention tool EATS on students' dietary behaviors and found that although the intervention group reduced their intake of unhealthy foods, overall improvements in dietary quality were limited [2]. Van Woerden et al. used self-reported data and school meal plan records, employing logistic generalized estimating equations to analyze the relationship between meal plan usage and food insecurity. Their research revealed a close connection between insufficient meal plan usage and food insecurity, particularly among low-income students [3]. To further optimize the dietary structure of college students, Cai et al. and Doe & Smith proposed using mathematical models and machine learning techniques to design personalized meal plans. These methods allow for precise analysis of students' nutritional needs and food intake, significantly improving the rationality and healthfulness of their diets, which in turn contributes to improving students' overall health [4-5]. Additionally, Lesani et al., in a cross-sectional study, examined the relationship between diet, stress, and lifestyle factors, demonstrating that a healthy diet not only improves students' physical health but also effectively alleviates stress [6]. It has been observed that previous studies have not utilized the Diet Quality Index (DQI) model to develop meal plans. for the first time, this paper introduces the DQI model, comparing actual food intake with recommended dietary guidelines and standardizing it into scores. The standardized scores for each nutrient or food group are weighted and summed to calculate the total DQI score. To provide a clear understanding of the DQI model presented in this paper, the introduction in Chapter 1 outlines the background and current research status. Chapter 2 explains the theoretical foundation of the DQI model. Chapter 3 details the experimental design, methodology, and process. Chapter 4 presents the experimental results, and Chapter 5 concludes by verifying the reliability of the DQI model.

2. Related Theories

2.1. Standardized scoring

The actual intake is compared with the recommended intake from dietary guidelines and standardized into a score. The score typically ranges from 0 to 100, where 0 indicates complete non-compliance with the recommendation, and 100 indicates full compliance.

For a given nutrient or food group i, its standardized score Si can be expressed as

$$S_i = \max\left(0, \frac{X_i - L_i}{U_i - L_i}\right) \times 100 \quad (1)$$

Where Xi represents the actual intake, Li is the lower limit of the recommended intake, and Ui is the upper limit of the recommended intake.

2.2. Calculate overall rating

The standardized scores for each nutrient or food group are weighted and summed to calculate the total score of the Diet Quality Index. The weights can be assigned based on the importance of each nutrient or food group, with the total weight usually equal to 1.

The formula can be expressed as

$$DQI = \sum_{i=1}^{n} W_i \times S_i \quad (2)$$

Where Wi is the weight of the i-th nutrient or food group, Si is the standardized score of the i-th nutrient or food group, and n is the total number of nutrients or food groups.

2.3. Interpretation of Results

The final Diet Quality Index (DQI) score ranges from 0 to 100, with higher values indicating better dietary quality. Typically, the scores can be classified into different levels, such as 80-100 Excellent；60-79 Good; 40-59 Average; 20-39 Poor.

3. Experiment

Based on the theoretical framework, practical data collection and analysis further validated the application of the Dietary Quality Index (DQI) model in assessing university students' diet quality. A systematic review by Burrows et al. demonstrated a significant association between a healthy dietary structure and improved academic performance, indicating that a balanced diet supports enhanced academic outcomes in university students[7]. Additionally, Rodrigues et al. highlighted the widespread issue of insufficient vegetable intake among university students, advocating for nutrition education to increase vegetable consumption and thus improve overall nutritional balance[8]. Further studies suggested that meal timing has a potential impact on obesity risk among students. Baquerizo-Sedano et al., using an observational study design and dietary records, found that irregular meal timing may increase obesity risk, recommending regular meal scheduling as a weight control strategy[9]. Simultaneously, Soldavini et al., through surveys, evaluated the prevalence and impact of food insecurity, revealing that food insecurity exacerbates nutritional imbalance among university students, preventing many from accessing sufficient healthy foods. They recommended that universities implement supportive policies to mitigate the negative effects of food insecurity on student diet quality[10]. To more accurately understand and optimize university students' dietary patterns, this section presents an experiment that recorded the daily food intake of two university students across three meals, scored against recommended dietary intake guidelines. By comparing actual intake to recommended levels, the total DQI score was calculated, providing a scientific basis for subsequent dietary optimization. The following sections will detail the experimental design and implementation process.

The actual intake is compared with the recommended dietary intake, as shown in Table 1 and Table 2.

Table 1. Recommended Intake (grams)

	cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil
Male student	300	300	400	150	50	300	20-30
Female student	250	200-300	300-400	120	30	250-300	20-25

Table 2. Actual intake (grams)

	cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil
Male student	320	0	430	215	60	0	69
Female student	220	150	280	90	40	200	20

Use the following standardized formula to calculate the standardized score for each food group

$$S_i = \max\left(0, \frac{X_i - L_i}{U_i - L_i}\right) \times 100 \tag{3}$$

Among them, Xi is the actual intake, Li is the lower limit of recommended intake (80% recommended intake), Ui is the upper limit of recommended intake (120% recommended intake), Si is the standardized score, and the lowest score is 0. Calculate the formula based on the upper and lower limits of recommended intake for boys. As shown in Table 3.

Table 3. Upper and lower limits for boys (grams)

	cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil
upper limit	360	360	480	180	60	360	30
lower limit	240	240	320	120	40	240	20

Grain standardization score

$$S_{grains} = \max\left(0, \frac{320-240}{360-240} \times 100\right) = 66.67 \tag{4}$$

Standardized rating for fruits

Due to the absence of fruits in the recipe, the standardized rating is

$$S_{fruit} = \max\left(0, \frac{0-240}{360-240} \times 100\right) = 0 \tag{5}$$

Standardized scoring for vegetables

$$S_{vegetables} = \max\left(0, \frac{430-320}{480-320} \times 100\right) = 68.75 \tag{6}$$

Standardized rating of animal-based foods

$$S_{animal} = \max\left(0, \frac{215-120}{180-120} \times 100\right) = 100 \tag{7}$$

Standardized scoring for soybeans and nuts

$$S_{legurnes} = \left(0, \frac{60-40}{60-40} \times 100\right) = 100 \tag{8}$$

Standardized rating for milk and dairy products

Due to the absence of milk and dairy products in the recipe, the standardized rating is

$$S_{dairy} = \max\left(0, \frac{0-240}{360-240} \times 100\right) = 0 \tag{9}$$

Oil Standardization Rating

$$S_{oil} = \max\left(0, \frac{69-20}{30-20} \times 100\right) = 100 \quad (10)$$

Weighted average calculation of dietary quality index (DQI)

Assuming that the weights of each food group are equal, the total score is the average score of each food group

$$DQI = \frac{66.67+0+68.75+100+100+0+100}{7} = 62.92 \quad (11)$$

According to the recommended upper and lower limits for girls, carry out public calculation. As shown in Table 4.

Table 4. Upper and lower limits for girls (grams)

	cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil
upper limit	300	240	360	144	36	300	24
lower limit	200	160	240	96	24	200	16

Grain standardization score

$$S_{grains} = \max\left(0, \frac{220-200}{300-200} \times 100\right) = 20 \quad (12)$$

Standardized rating for fruits

$$S_{fruit} = \max\left(0, \frac{150-160}{240-160} \times 100\right) = 0 \quad (13)$$

Standardized scoring for vegetables

$$S_{vegetables} = \max\left(0, \frac{280-240}{360-240} \times 100\right) = 33.33 \quad (14)$$

Standardized rating of animal-based foods

$$S_{animal} = \max\left(0, \frac{90-96}{144-96} \times 100\right) = 0 \quad (15)$$

Standardized scoring for soybeans and nuts

$$S_{legurnes}\left(0, \frac{40-24}{36-24} \times 100\right) = 100 \quad (16)$$

Standardized rating for milk and dairy products

Due to the absence of milk and dairy products in the recipe, the standardized rating is

$$S_{dairy} = \max\left(0, \frac{200-200}{300-200} \times 100\right) = 0 \quad (17)$$

Oil Standardization Rating

$$S_{oil} = \max\left(0, \frac{20-16}{24-16} \times 100\right) = 50 \quad (18)$$

Weighted average calculation of dietary quality index (DQI)

Assuming that the weights of each food group are equal, the total score is the average score of each food group

$$DQI = \frac{20+0+33.33+0+100+0+50}{7} = 29.05 \quad (19)$$

4. Results

By calculating the dietary quality index, the health level of the recipe can be evaluated. As shown in Table 5.

Table 5. DQI Score

	cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil	Total score
Male student	9.52	0	9.82	14.28	14.28	0	14.28	62.92

Continued Table 5.DQI Score

	cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil	Total score
Female student	2.85	0	4.76	0	14.28	0	7.14	29.04

The total scores of the dietary quality index for a male college student and a female college student were calculated using a formula to be 62.92 and 29.04, respectively**.**

4.1. Analyzing Food Structure

According to the food category classification table, analyze the number of types of recipes for male and female students. As shown in Table 6.

Table 6. Food Categories

	Grains & Tubers	Vegetables, Fungi, Fruits	Meat, Poultry, Fish, Eggs & Products	Dairy, Legumes, Nuts, Seeds & Products	Plant Oils
Male student	Rice, Noodle Soup, Steamed Buns	Stir-fried Black Fungus, Stir-fried Vegetables, Noodle Soup, Steamed Buns	Braised Pork, Steamed Buns, Fried Chicken	Noodle Soup	Stir-fried Black Fungus, Stir-fried Vegetables, Braised Pork, Noodle Soup, Steamed Buns
Female student	Chicken Noodles, Egg Pancakes, Dumplings, Rice	Dumplings, Stir-fried Mushrooms with Vegetables, Grapes, Apples	Egg Pancakes, Dumplings, Stir-fried Mushrooms with Vegetables, Stir-fried Meat with Garlic, Sardines in Tomato Sauce	Soy Milk	Chicken Noodles, Egg Pancakes, Dumplings, Stir-fried Mushrooms with Vegetables, Stir-fried Meat with Garlic

There are 15 kinds of food in boys' recipes: rice, agaric, sesame oil, eggplant, potato, green pepper, soybean oil, pork, tofu, corn flour, cabbage, rape, wheat flour, pickled Chinese cabbage, chicken nuggets.

There are 15 kinds of food in girls' recipes: soybeans, wheat flour, soybean oil, chicken, eggs, ham sausage, pork, cabbage, rice, grapes, rape, mushrooms, garlic, sardine in tomato sauce, and apples.

In summary, the five major categories of food that these two college students eat in a day are complete, and the types of food they eat are more than 12**.**

Calculate the main nutrient content of the recipe, and the results are shown in Table 7.

Table 7. Main Nutrient Content of Male and Female Students' Diets

	Protein (g)	Fat (g)	Carbohydrates (g)
Male student	118	124.27	414.16
Female student	54.825	48.99	175.805

4.2. Evaluate the energy, meal to meal ratio, and non productive main nutrient content provided by the recipe

Calculate the energy, meal to meal ratio, and nonproductive major nutrient content provided by the recipe, as shown in Table 8.

Table 8. Energy Provided by the Diet, Meal Ratios, and Non-Caloric Main Nutrient Content

	Energy Intake (kcal)	Meal Ratio (Breakfast/Lunch/Dinner)	Calcium (mg)	Iron (mg)	Vitamin A (μg)	Vitamin B1 (mg)	Vitamin B2 (mg)	Vitamin C (mg)
Male student	4348.93	30% / 40% / 30%	3081.2	355.82	313.4	1.856	0.748	44.6
Female student	2037.93	20% / 40% / 40%	214.15	20.46	336	0.932	0.6676	76.2

According to the table, the male student's total energy intake is excessive, but the proportion of meal times is consistent with the reference value. The intake of calcium and iron has seriously exceeded the standard, and the intake of vitamin A, vitamin B2, and vitamin C is relatively low, while the intake of vitamin B1 is relatively high. The female student's total energy intake is slightly higher than the reference value, the proportion of breakfast meals does not match the reference value, the proportion of lunch and dinner meals matches the reference value, the intake of calcium is lower, the intake of iron is normal, and the intake of vitamin A, vitamin B1, vitamin B2, and vitamin C is lower.

4.3. Evaluating the Energy Sources of Recipes

Male (percentage of protein, fat, and carbohydrates in total energy): 2% protein; Fat 3%; Carbohydrates 10%.

Overall, the male student's diet contains less energy in protein, fat, and carbohydrates.

Female students (percentage of protein, fat, and carbohydrates in total energy): protein 3%; Fat 2%; Carbohydrates 10%.

Overall, the female student's diet contains less energy in protein, fat, and carbohydrates.

4.4. Evaluate the protein and amino acid score of each meal

Calculate the score of protein amino acids, as shown in Table 9.

Table 9. Protein Amino Acid Score

	Breakfast	Lunch	Dinner
Male student	98	214	283
Female student	290	397	216

4.5. Overall evaluation and suggestions

Through the analysis of the dietary quality index model and the "Chinese Dietary Guidelines for Residents", it was found that male students scored higher in their diet, with balanced nutrition, but lacked fruits, milk, and dairy products, and had higher oil content in their food. Girls' diet scores are too low, with imbalanced nutrition and a lack of intake of grains, vegetables, soybeans, milk, and dairy products.

Adjust diet based on nutritional evaluation results: If certain nutrients are not adequately or excessively consumed, make corresponding adjustments.

Boys should increase their intake of 20g grains, 280g fruits, 20g vegetables, 280g milk and dairy products. Girls should increase their intake of 60g grains, 70g fruits, 40g vegetables, 30g animal food, 50g milk and dairy products, and reduce their intake of 4g soybeans and nuts. The comparison of DQI scores before and after improvement is shown in Table 10.

Table 10. Comparison of DQI Scores Before and After Improvement

		cereal crop	Fruit category	Vegetables	Animal-based foods	Legumes and nuts	Dairy and dairy products	Oil	Total score
Male student	Before Improvement	9.52	0	9.82	14.28	14.28	0	14.28	62.92
	After Improvement	11.9↑	9.52↑	11.6↑	14.28	14.28	9.52↑	14.28	85.27↑
Female student	Before Improvement	2.85	0	4.76	0	14.28	0	7.14	29.04
	After Improvement	11.42↑	10.71↑	9.52↑	7.14↑	14.28	7.14↑	7.14	80↑

After improvement, the total score for male students was 85.27, with a more reasonable diet and higher scores; The total score for girls is 80, with a significant improvement in their recipe score and a more comprehensive and balanced nutritional intake.

5. Conclusion

This article addresses the issue of imbalanced dietary structure among college students and establishes a dietary quality index model. By analyzing the daily three meal dietary data of a male college student and a female college student, the dietary quality index is calculated. Through model evaluation, it is found that the dietary structure of male students is relatively reasonable, but there is a problem of insufficient intake of fruits and dairy products, while the dietary quality of female students is poor and there are multiple types of nutrient deficiencies. We significantly improved the dietary quality index of two students by adjusting their recipes. The score of boys increased from 62.92 to 85.27, and the score of girls increased from 29.04 to 80, verifying the reliability of our proposed dietary quality index model in evaluating and optimizing dietary structure. In the future, this model can be extended to more college students to help improve their nutritional intake and health status.

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