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Research article

Building a personalized diet proposal algorithm for covid 19 patients' treatment at home with linear programming planning method

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ABSTRACT

Building a personalized menu for disease prevention and treatment is a complicated problem due to several reasons such as constraints on nutritional balance that vary for each specific user; the combination of type and amount of ingredients for each dish diverges greatly depending on personal preferences, the number of ingredients and dishes is excessively substantial, and so on. This article aims to build an algorithm providing an adequate diet for seven days based on personal nutritional information entered by the user. To achieve that goal, the algorithm needs to ensure three parts: the first is to determine the energy and volume of each nutritional ingredient suitable for the subject, the second is to determine the number of meals and the selection of dishes to eat pertinent to health requirements and the third is to determine the composition and volume of each dish so that the total nutritional value is close to the values calculated before. In part one, the "set of target nutritional indicators" is determined using nutritional calculation methods combined with the table of recommendations of the Ministry of Health and the Institute of Nutrition. The selected number of meals and dishes in part two and part three based on information from users and nutritional advice of nutritionists. 42 meals equivalent to about 70 dishes are randomly selected from a database to satisfy taste and nutrition requirements. Finally, the linear programming method is applied to solve the problem of determining the volume of ingredients in the dish so that the recommended menu and nutritional needs in 7 days are the lowest. In the linear programming, assuming that the amount of each course is a variable and the diet total nutrient content is the objective function that depends on those variables, the constraint from the difference of those with the "set of target nutritional indicators" to find the solution to optimize the objective function (i.e., minimize the difference). Compare that final result with the nutritional requirements from part one, repeat the selection step if the difference exceeds the allowable threshold mean that the selected dish is not suitable until the menu is appropriate. It is feasible to build a software or website recommending personalized diets for Covid-19 patients recovering at home based on this algorithm.

Key words: COVID-19 patients, personalized diet, linear programming, nutrition recommendation system

INTRODUCTION

Recent studies all agree that an adequate diet is imperative in improving morbidity during the treatment of patients with COVID-19 (F_0) [1–3]. In addition, a growing body of evidence shows that malnutrition negatively affects immune system function, impairing the body's ability to protect against infection. [4]

Statistics show that only a small portion of patients infected with COVID-19 have severe changes that require monitoring in medical facilities. For instance, in the US, only about 12% of patients are hospitalized, while the rest can self-treat and recover at home [5]. Hence, it is particularly significant to make patients and their relatives aware and ensure their nutrition.

Self-isolation, home treatment, and nutrition guidelines for patients infected with COVID-19 have developed in diverse forms presently. Current guidelines for F_0 are just at the most general level. Nutritionally, each subject with distinctive characteristics in body figure, age, pathology, and physical activity has very different needs. However, in general, there are no nutritional consulting products and menus designed for each specific COVID-19 patient. Therefore, it is fundamental to provide specific suggestions for dishes of different meals.

The goal of the algorithm proposed by the project team is: to build an algorithm that allows creating menus from a database of dishes that meet the nutritional needs of each user.

RESEARCH METHODS

Factors To Consider When Building A Menu

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Calculating "Recommended Nutritional Value Set"

"Recommended Nutritional Value Set" is a set of recommended nutritional values made up by calculations according to nutritional formulas and combined with looking up the recommendation table from information provided by the user.

The "Recommended Nutritional Value Set" includes the energy needs and nutrient composition in a day recommended by the Ministry of Health [Decision No. 2615/QD-BYT dated June 16, 2016]. The menu requires to ensure the least deviation from the Recommended Nutritional Value Set.

Consumers will provide parameters about gender, height, weight, age, level of labor, and the number of meals in a day. The basal metabolic energy requirement of a particular subject was determined by the Harris-Benedict formula [6]. Based on the parameters provided by the user, retrieval in the tables of "Recommended nutritional value for Vietnamese people" [7] will identify the components of the "recommended nutritional value set" including Recommended Daily Allowances (RDA) of nutrients such as protein, lipid, carbohydrate, cholesterol, calcium, phosphorus, iron, sodium, potassium, beta carotene, vitamin A, vitamin C... as well as animal/vegetable protein ratio and animal/vegetable lipids.

Modified the recommended values to suit each specific user

As 4.0 technology develops, nutrition is aiming to build menus for each specific user depending on the health situation. Specific recommendations on energy levels, nutrient requirements, should/shouldn't use ingredients, etc. will be modified by consultants differently from the average person. In addition, the personal preferences of users also need to pay attention to removing dishes containing such ingredients from the menu. Therefore, it is necessary to adjust the "recommended nutritional value" to suit individual recommendations of the COVID19 patient (proposed by the Ministry of Health and the Institute of Nutrition for COVID19 patients) [8] before using it as a target for the algorithm. This set of nutritional needs is called the "target nutrient set".

Incompatible food ingredients combinations

In meals, there are generally copious dishes, composed of multifarious ingredients. Therefore, when building a database for the diet, special attention needs to be paid to food combining, averting food combinations detrimental to the absorption of nutrients and even harmful to health.

Algorithms construction

Database construction

To have data for the algorithm, it is necessary to build a suitable and scientific database. The database is built with 5 parts as follows

- Ingredients: Information about the type of ingredient (ingredient code and name) and its nutritional information (rejection rate, energy, total protein, vegetable protein, total lipid, vegetable lipids), cellulose, cholesterol, calcium, phosphorus, iron, sodium, potassium, beta-carotene and vitamin A, vitamin B, vitamin C), especially the content of bioactive and immune-boosting compounds that recommended in COVID treatment.
- Dish ingredients: Ingredients of each dish and the amount of each ingredient per 100g of that dish
- Dishes information: dish code, dish name, unit of measure, smallest division, minimum quantity, maximum quantity, dish attributes. The dishes are divided into small groups including savory dishes, soups, stir-fries, water dishes…
- Nutritional recommendations: subject-specific nutritional recommendations proposed by the Ministry of Health and the Institute of Nutrition for COVID19 patients.

For each user, after the user provides complete information, the algorithm will create a copy of this database which excludes the materials that the user does not want (due to preference, due to preference, or allergies…) and run the algorithm on that database.

Calculating "target nutrient set" according to user data

The user enters information: Full name, Age (year), Gender (Male/female), Height (m), Weight (kg), Time of rest/light/moderate/heavy activity /very heavy in the day, Target group, Ingredients not eaten.

Select "Total Energy" per day

Compare the calculated BMI value with the recommended BMI range of Asia-Pacific guidelines [9]. If the calculated BMI is higher than 23, the nearest smaller energy datum will be selected. If the calculated BMI is between 18.5 and 23, the nearest energy datum will be selected. If the calculated BMI is lower than 18.5, the nearest higher energy datum will be selected.

There are 11 standard energy levels (kcal) to choose from 900, 1200 1500; 1800; 2100; 2400; 2700; 3000, 3300, 3600, 3900) – This option ensures that the energy provided by the menu does not exceed 10% of the energy needs in the "target nutrient set".

Energy distribution per meal

The energy distribution per meal in the menu is necessary to ensure that users have enough energy for activities between meals. In the first stage, for simplicity, the total energy for meals is divided according to the following percentages: breakfast 20%; 20% lunch; dinner 30% and 10% for each snack.
At the same time, the amount of food at each meal must also be limited to not be too full or too hungry.

Dishes selection for each meal:

After having the energy level for each meal, the algorithm will choose the dish for each meal according to the following steps:
Step 1: Determine the meal code to choose the dish. Starting from the Monday breakfast, turn in all the meals of the day and then move on to the next day.
Step 2: Determine the number of dishes needed in the meal.
Step 3: Randomly choose the first dish that matches the meal. (For example, the meal under consideration is lunch, the first dish must be identified as the dish with the attribute ”Main” in the column ”Lunch”
Step 4: Randomly select the next dishes that match the previously selected dish and match the meal until there are enough dishes in the meal.

Linear programming to find the optimal quantity

Linear programming is a method used to optimize an objective function (minimum or maximum value) in mathematical modeling problems where constraints are represented by linear relations. More specifically, the linear programming problem can be expressed as:
Find a vector x
that maximizes $c^T x$
subject to $Ax \leq b$
and $x \geq 0$
Let n be the number of variables to find. In which, x is the column vector of size n the non-negative real values need to be determined, c and b are the column vectors of size n representing the coefficients of the objective function and the righthand side of the constraints, respectively. A is the m*n matrix corresponding to m number of constraints in the given condition.
This topic uses linear programming in the field of integers (i.e., all the variables to be searched are integers), only considering an integer with computational units (i.e., the result is the number of units ”Divisions”). “best” of each dish instead of calculating the amount of each dish in grams). Contrary to the conventional linear programming problem on real numbers which can be solved efficiently in the worst case, the linear programming problem on integer field in real situations is classified as an NP-hard problem (the class of problems without any algorithms with time complexity is a solvable polynomial function). Some difficult and famous algorithms are used to solve this problem such as the Cutting-plane method, Branch and bound, or Branch and cut, ...

Building a food dosing system

After the dishes have been selected, the quantity of the dishes will be determined using the linear programming method in the integer field. The problem requires to satisfy the constraint condition and at the same time optimize the loss function.
Let A, B, C, D be the main dish, side dish, vegetable, and dessert, respectively. (Depending on the meal, there may be only one or all four dishes.)
Let the number of nutritional indicators to be considered by j.
Let’s call the quantity to be searched a, b, c, d corresponding to the number of dishes of each dish A, B, C, D.
Let X_i with $X \in \{A,B,C,D\}$, i=1,...,j be the i-th nutritional index in dish X.
Let Y_i be the target index for the i-th nutrient index.
Let p_i, q_i be the upper and lower bound rates for the i-th nutrient index, respectively.
Let w_i be the weight (importance) of the i-th nutrient index.
Call the constrain function for the i-th nutrient index:
$R_i(a, b, c, d) = A_i*a + B_i*b + C_i*c + D_i*d$ (eq.1) with i = 1, .., j
Let the loss function for the i-th nutrient index be:
$L_i(a, b, c, d)=w_i*(R_i - Y_i)$ (eq.2) with i = 1, .., j
The set of pattern constraints is:
$R = \{p_i * Y_i \leq R_i \leq q_i * Y_i | i = 1, \ldots j\}$ (eq. 3)
Let the loss function of the system be:
$\mathrm{Loss}(a,b,c,d) = \sum_{i=1}^{j} |L_i(a,b,c,d)|$ (eq.4)
Since the loss function needs to be optimized containing absolute values, it is necessary to destroy them by considering 2^j cases corresponding to 2^j 1-indexed arrays $arr_n = [\pm1, \pm1, \pm1, ..., \pm1]$ with j values and receiving 2 values of -1 and 1.
Let’s call the n-th complement set of constraints:
$RR_n = \{arr_n[i] * R_i \leq Y_i | i = 1, \ldots j\}$ (eq. 5)
From here, it is possible to create 2^j different constraints and objective functions:

$$\begin{cases} R \cap RR_n & \text{(eq. 6)} \\ \mathrm{Loss}(a,b,c,d) = \sum_{i=1}^{j} L_i(a,b,c,d) * arr_n[i] \end{cases}$$

with $n = 1, \ldots, 2^j$

For the above system, use the method of Linear Programming in the integer field to solve for (a_n, b_n, c_n, d_n) satisfying the condition function and minimize the objective function in the n-th system. In the case of a system with a solution, a set of (a_n, b_n, c_n, d_n) numbers will be obtained, and the minimum loss corresponding to the nth system is

$\mathrm{MinLoss_n} = \mathrm{Loss_n}(a_n, b_n, c_n, d_n)$ (eq.7)

On the contrary, if the system has no solution, it will obtain a set of roots (INF,INF,INF,INF) along with the minimum loss corresponding to the n-th system $\mathrm{MinLoss}_n$ = INF (with INF being an extremely large number). Next, the order of the system with the smallest minimum loss in the systems will be determined by the formula.

$i = \arg\min_{i=1,\ldots,2^j} \mathrm{MinLoss_i}$ (eq.8)

If $(a_i, b_i, c_i, d_i) \neq$ (INF, INF, INF, INF) then the output for this meal is the items A, B, C, D along with the amount of the dish (a_i, b_i, c_i, d_i). On the contrary, in the worst case, if all 2^j cases are unsuccessful, it is necessary to go back to the previous step so that the system can choose another suitable dish set.

Method evaluation

The research team analyzed and deployed a quantitative system for dishes to become a Linear Programming problem in an integer field containing absolute values. The appearance of absolute values is a fairly new idea and has not been exploited deeply in mathematical modeling problems.

Along with that, breaking the absolute value brings breadth in the search journey, making the probability of the existence of solutions higher, more diverse, and selecting the most optimal solution. However, this method suffers from time complexity problems because the linear programming problem in the integer field is an **NP-hard** problem (which cannot be solved in polynomial time complexity), and more, they have to repeat this process 2^j **times**. This is one of the major disadvantages of this method.

In this method, the technique used to estimate the loss function is the Mean Absolute Error **(MAE)**. In practice, to estimate the loss of a model relative to the test value, another more common method such as Mean Squared Error **(MSE)** can be used.

$\mathrm{Loss}(a,b,c,d) = \sum_{i=1}^{j} \mathrm{L_i}(a,b,c,d)^2$ (eq.9)

However, with this approach, the problem will become a Quadratic programming problem. The difficulty and time complexity to solve this problem depend very much on the coefficients of the objective function. If they are positive definite matrices, the problem can be solved using the Ellipsoid method to solve in polynomial time. But if the coefficient of the objective function is not a deterministic matrix, the problem becomes an NP-hard problem and becomes even more difficult if the matrix contains at least one negative eigenvalue. More specifically, the food quantification system will be the Mixed-integer quadratic programming problem – a problem that currently does not have many effective solutions in terms of time and efficiency. Because of these inconveniences, estimation of the loss function as the mean absolute error MAE combined with the Linear Programming method was used.

Compare and decide to accept the results

After the optimal number of dishes for each meal is given, compare the results with the following requirements: calculated total energy of each meal adapt 80% to 120% of recommendation and total energy of each day adapt 90 to 110%; total protein and lipid adapt 70 to 130% recommendation each meal and 80 to 120% daily; other indicators using continuously narrow down day-to-day with acceptable limit.

For the meal guarantee requirement, if the nutritional value of the meal is out of the acceptable range, go back from the order selection step, change the last selected dish, and then continue to find the optimal number of dishes and compare and make a decision.

For day-to-day guarantees, the above steps are taken with the last meal of the day.

RESULT AND DISCUSSION

Built an initial database of the nutritional information of ingredients and dishes.

Build a menu ordering algorithm for each individual user from only simple nutritional information at first.

Shorten menu calculation time compared to manual work.

The result from the algorithm is shown in this source: https://drive.google.com/file/d/15cw7XWtpRFrpswGZvNSUNkmZykSpqMGn/view

CONCLUSION

Linear programming is a very promising method for the problem of optimizing the eating amount of each dish with multiple nutritional targets in menu building. The sequential random dish selection method combined with post-test results gives good efficiency in the problem of choosing dishes as well as quite a well optimization of the algorithm's solving time. The "target nutrient set" can be modified to suit not only the COVID19 patients but also other special user conditions.

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ABBREVIATION

RDA: Recommended Daily Allowances
BMI: Body mass Index
MAE: Mean Absolute Error
MSE: Mean Squared Error
COMPETING INTERESTS
The authors declare that they have no competing interests

AUTHORS' CONTRIBUTION

Nguyen Gia Khiem is in charge of main ideas to sketch and build up the nutritional part of the algorithm and the database. He also writes "Factors to consider when building a menu", "Database construction", "Calculating "target nutrient set" according to user data", "Dishes selection for each meal", "Compare and decide to accept the results".
Quach Minh Tuan is responsible for coding, evaluate and correct the technical issues. He suggests to use Linear Programming as a solution.
Luu Ngoc Thuy An is in charge of writing the first part and correcting English and format of this manuscript.
Tran Thi Thu Tra instructs all the members, gives advises and corrects all of the rest issues that this research come up with.

REFERENCES

1. Laviano A, Koverech A, Zanetti M. Nutrition support in the time of SARS-CoV-2 (COVID-19). Nutrition. 2020;74:110834;Available from: https://doi.org/10.1016/j.nut.2020.110834.
2. Moscatelli F, Sessa F, Valenzano A, Polito R, Monda V, Cibelli G et al. COVID-19: role of nutrition and supplementation. Nutrients. Mar 2021;13(3):1-12;PMID: 33803015. Available from: https://doi.org/10.3390/nu13030976.
3. Fernández-Quintela A, Milton-Laskibar I, Trepiana J, Gómez-Zorita S, Kajarabille N, Léniz A et al. Key aspects in nutritional management of COVID-19 patients. J Clin Med. 2020;9(8):2589;PMID: 32785121. Available from: https://doi.org/10.3390/jcm9082589.
4. Mentella MC, Scaldaferri F, Gasbarrini A, Miggiano GAD. The role of nutrition in the COVID-19 pandemic. Nutrients. Apr 2021;13(4):1093;PMID: 33801645. Available from: https://doi.org/10.3390/nu13041093.
5. CDC. COVID-19 response team. Severe Outcomes Among Patients Coronavirus Dis. 2019 (COVID-19) - United States, Feb 12-March 16, 2020," Morb. Mortal. Wkly. Rep.;69(12):343, Mar. 2020;PMID: 32214079. Available from: https://doi.org/10.15585/mmwr.mm6912e2.
6. Harris JA, Benedict FG. A biometric study of human basal metabolism. Proc Natl Acad Sci U S A. 1918;4(12):370-3;PMID: 16576330. Available from: https://doi.org/10.1073/pnas.4.12.370.
7. Bảng Nhu cầu dinh dưỡng khuyến nghị cho người Việt Nam được ban hành theo Quyết định số 2615/QĐ-BYT ngày 16 tháng 6 năm 2016 của Bộ Y tế;.
8. Bộ Y Tế. Hướng dẫn chế độ dinh dưỡng trong điều trị người bệnh COVID-19 2020;.
9. Nishida C et al. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. Jan 2004;363(9403):157-63;Available from: https://doi.org/10.1016/S0140-6736(03)15268-3.