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Healthy Menu Scheduling for High Blood Pressure Patient with Optimization Method through Integer Programming

Liew Su Hui, Suliadi Sufahani*

Department of Mathematics and Statistics, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Campus, 84600 Pagoh, Johor, Malaysia

* Corresponding Author

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Abstract: High blood pressure or hypertension is a global public health issue. It may cause other diseases appear such as cardiovascular disease, stroke, diabetes and others. The diet problem of high blood pressure patients has always been concerned by the field of operational research. Many previous and recent research have proposed that diet plays an important role in affecting the condition of high blood pressure. A balanced diet will provide essential nutrients for high blood pressure patients that help to control and lower blood pressure. The purpose of this study is to construct a diet menu that meet the nutritional requirements of high blood pressure patient as well as lower the food cost by developing a mathematical model. The model of this study involved 10 type of food groups with 100 variables based on the Malaysian recipes and developed by two programming techniques: linear and integer programming. The findings show that the solution produced by integer programming approach have achieved the constraints and the requirements of food group. The integer programming approach will provide the optimal and effective solutions for the diet problem of high blood pressure patients.

Keywords: High blood pressure, hypertension, menu planning, diet problem, optimization, mathematical model

1. Introduction

A balanced diet is a key to healthy lifestyle. It is a diet that contains the combination of foods in the right amounts of nutrient such as energy, fiber, proteins, fats, vitamins and minerals. It will provide benefits to our body, for example, provides energy, reduce the risk for health problems and make people feel better. When having an unbalanced diet, the body will not get nutrition. Besides, unbalanced diet may lead to health problems like coronary heart disease, high blood pressure, obesity and others.

Blood pressure is the force of blood against the walls of the blood vessels as blood flow through the arteries. When the blood pressure in the arteries increases as the blood vessels become narrow, it's called high blood pressure. In medical term, High blood pressure (HBP) also known as hypertension (National Heart, Lung, and Blood Institute, 2017). High blood pressure inside the arteries will make the heart work harder which reduce blood from heart flow to other organs. If not controlled, high blood pressure may lead to many health problems such as cardiovascular disease, stroke, diabetes and others. A normal blood pressure level is below 120/80 mmHg whereas the high blood pressure level is above 140/90 mmHg (National Heart, Lung, and Blood Institute, 2017). The blood pressure which excess 140/90 mmHg had categorized into stage 1 or stage 2 in terms of hypertension (Bacon et al., 2004). For those blood pressure ranging between 120/80 mmHg and 139/89 mmHg is known as prehypertension (U.S. Department of Health and Human Services, 2004).

Globally, the high blood pressure cases increase from year 1980 to 2008, there are approximately 40% of adults aged 25 and above suffered from high blood pressure (WHO, 2013). In Malaysia, the prevalence of hypertension has growing rapidly among the younger and adults. It is a non-communicable disease that rises among the adult in Malaysia, one in three adult Malaysians are suffering from this disease (New Straits Times, June 6, 2016). According to the Malaysian Society of Hypertension (MSH), this disease is affecting the younger people (The Star Online, January 25, 2014). Moreover, high blood pressure also affects the elderly in Malaysia (Eshkoor et al., 2016).

Diet plays an important role in treating high blood pressure. Diets containing vegetables, fruits, nuts, grains, fish, poultry, low-fat dairy, less sweet, unsaturated vegetable oils, less sugar-containing beverages and small amounts of

**Corresponding author: suliadi@uthm.edu.my*

red meat can reduce the blood pressure (Sacks & Campos, 2010). Besides, HBP patient should reduce sodium intake in their diet. Thus, high blood pressure patients should have a well-balanced diet that meet the nutritional needs to reduce the risk of having high blood pressure. However, most of the HBP patients are lack of knowledge about nutrition need. They do not clear on choosing food that meet their nutritional needs and the amount of food they should consume. Therefore, a proper and healthy planning diet menu for high blood pressure patient which developed by mathematical model can help to solve the doubt on food selection.

In medical term, a diet prepare for high blood pressure patient is known as Dietary Approaches to Stop Hypertension (DASH) diet. DASH diet was designed to help in creating a healthy way of eating that help treat high blood pressure. However, most Malaysian people refuse to follow the DASH diet. This is because they are lazy to keep up with the servings sizes of food that recommended in DASH diet. Previously high blood

pressure patient was referring to DASH diet, but in this case, the patient may refer to the diet menu which solved by using mathematical programming model like linear programming, integer programming and goal programming. Instead of following the serving sizes mentioned in DASH diet, people could just follow the developed diet menu plan. The aim of this study is to construct a diet menu by developing a mathematical model that meet the nutritional requirements of high blood pressure patient as well as lower the food cost thereby making it easier for HBP patient to consume. Besides, the lower bound and upper bound of nutrients that should be intake by HBP patient should be included in develop a diet menu.

2. Literature Review

Menu planning is a way to discover a person is eating a diet with a balanced nutrition. The general menu planning concepts is crucial for the target groups who need help. Razali *et al*. (2018) had proposed the concepts of menu planning. The researchers used self-adaptive hybrid genetic algorithm (SHGA) to develop a new menu planning model for Malaysian adolescents aged 13 to 18 years old, while considering the budget provided by the government, the RNI requirements of Malaysian adolescents and the capability and ability of caterer to cook. This research involved 409 types of Malaysian food items which listed in the book of Nutrient Composition of Malaysian Foods.

In addition, there are various types of mathematical programming techniques such as linear programming, integer programming and goal programming used to construct a diet menu. Each researcher used different techniques to solve their research problems. Darmon et al. (2002) had done an optimization study using linear programming to investigate the influence of cost constraint on the food choices of a person and the quality of nutritional. Okubo et al. (2015) developed a liner programming model to generate an optimal dietary pattern that the nutrient recommendation which know as Dietary Reference Intakes (DRIs) in the view of typical Japanese food choices. Kashima et al. (2009) generated a integer programming model to suggest a balanced menu planning framework to treat and prevent lifestyle-related diseases. Dhoruri *et al*. (2017) proposed a goal programming model which to identify the optimal balanced menu deviations by the deviation above or below the amount of recommendation for diabetes mellitus patients.

3. Methodology

3.1 Data Descriptions

The nutrients information for high blood pressure patients were obtained from some research and the book of Recommended Nutrient Intakes for Malaysia (RNI) 2017, then verified by a nutritionist. In this study, the diet menu is prepared based on the Malaysian style of recipes. The food data involved in the model are provided in the book of Nutrient Composition of Malaysia Food. (Tee *et al*., 2010) The amount of food intake and the nutritional requirements of high blood pressure patients are varied according to their age, gender, level of physical activity, stage of health and others. Hence, there are some considerations such as the price of the food items, the nutrient compositions of each food item and Recommended Nutrient Intake for Malaysia (RNI) should be taken in developing the model of menu planning.

The one-day diet menu designed for high blood pressure patients is presented in Table 1. Additionally, there were six nutrients: sodium, protein, potassium, calcium, Vitamin B2 and Vitamin C involved in this research which identified after seeking the advisory of nutritionist. The nutritionists emphasize that sodium is the most important nutrient for patients with hypertension.

Table 1: Food requirement per day

Type of Food	No. of requirement per day (n)
Beverage ($X_1 - X_{37}$)	6* including 2 plain water (X_9)
Cereal Flour Based ($X_{38} - X_{85}$)	1
Rice Flour Based ($X_{86} - X_{113}$)	1
Cereal Based Meal ($X_{114} - X_{126}$)	2* including 1 plain rice (X_{104})
Meat Dishes ($X_{127} - X_{158}$)	1
Vegetables ($X_{159} - X_{212}$)	1
Fruits ($X_{213} - X_{261}$)	2
Wheat Flour Based ($X_{262} - X_{286}$)	2
Seafood ($X_{287} - X_{324}$)	1
Miscellaneous ($X_{325} - X_{426}$)	1
Total Dished per Day	**18**

The foods are classified into six types of meals in one day as shown in Table 2.

Table 2: The menu planning of food item per day

Meal	Type of Food Group	Amount
Breakfast	Beverage	1
	Cereal Flour Based	1
Morning Tea	Beverages	1
	Rice Flour Based	1
Lunch	Beverages	1
	Cereal Based Meal	1
	Vegetables	1
	Fruits	1
	Meat / Seafood	1
Evening Tea	Beverages	1
	Wheat Flour Based	1
Dinner	Beverages	1
	Cereal Based Meal	1
	Vegetables	1
	Fruits	1
	Meat / Seafood	1
Supper	Beverages	1
	Miscellaneous	1
	Total	**18**

This study is prior to high blood pressure patients in middle and senior age. In this study, there are two high blood pressure patients have been considered. One of the patients is a female who aged 54 with 80kg. She is an inactive person but she does not have any other disease or allergy. While, the other patient is a male who aged 82 with 60kg. He is a current smoker, however, he does not have any other disease or allergy. Both patients have different requirements of nutrition according to their age, gender and health status. The requirements of nutrition for both patients are predetermined along with the Malaysian RNI through consultation with the nutritionist which shown as tables below.

Table 3: Lower and upper bound values of the 5 nutrients (female patient)

Nutrients	Lower Bound (LB)	Upper Bound (UB)
Sodium (mg)	-	1500
Protein (g)	52	-
Potassium (mg)	4700	-
Vitamin B2 (mg)	1.1	-
Calcium (mg)	1200	2000
Vitamin C (mg)	70	2000

Table 4: Lower and upper bound values of the 5 nutrients (male patient)

Nutrients	Lower Bound (LB)	Upper Bound (UB)
Sodium (mg)	-	1500
Protein (g)	58	-
Potassium (mg)	4700	-
Vitamin B2 (mg)	1.3	-
Calcium (mg)	1000	2000
Vitamin C (mg)	70	2000

3.2 Model Description and Development

There are two programming techniques: linear programming and integer programming are used in this study to construct a diet menu by developing a mathematical model with the 100 foods data.

3.1.1 Objective Function

This study is hoped to minimize the total food cost (Sufahani & Ismail, 2014),

$$\text{Minimize total cost} = \sum_{i=1}^{N}\sum_{j=1}^{P}\sum_{k=1}^{Q} c_i x_{ijk} \qquad (3.1)$$

where x_{ijk} is decision variable of food items, i for 10 food groups, j and 6 meals, k, c_i is the cost for each food items i, P is the number of meal per day and Q is the number of food groups.

3.1.2 Constraints

The 6 nutrient requirements based on Table 3 and 4 (Sufahani & Ismail, 2014),

$$LB_i \leq \sum_{i=1}^{N}\sum_{j=1}^{10}\sum_{k=1}^{6} w_i x_{ijk} \leq UB_i \qquad (3.2)$$

where LB_i and UB_i represent lower and upper bound for each nutrient content while w_i represent the weight of nutrient for the food. This study had six nutrients constraints with lower and upper bound values except for sodium, protein and Vitamin B2. The sodium only has upper bound values while the other two nutrients only have the lower bound values.

The food requirements based on Table 3.1,

$$\sum_{i=1}^{10} Type\ of\ food\ groups\ (x_i) = n \qquad (3.3)$$

Since the one-day menu consists of 18 dishes per day, the variables were all binary. If the food appears in the menu list, the decision variables (X_i) will 1 or 2, each food could only be served once or twice in a day, otherwise is zero. The coding will be programmed using the computer program, LPSolve IDE. When the user key in the data, an automated system will be built up to generate a list of menus for one day as an output.

Results and Discussion

The mathematical modelling is developed as the optimal solution for dietary problems in patients with high blood pressure. The results for linear and integer programming for menu planning per day as shown as table below:

Table 5: A one day menu for the 54 years old female patient using linear programming

Meals	Food items	Amount
Breakfast	Milk, UHT, full cream, recombined	0.1075
	Cookies, peanut	1
Morning tea	Plain water	1
	Kuih koci pulut putih	1
Lunch	Orange flavoured drink, powder	1.8925
	Rice, "dagang"	0.2497
	Chicken rice	0.7503
	Fern shoots	1
	Date, dried	1.1185
	Beef, fried (Daging	

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	lembu goreng)	1
Evening tea	Milk, UHT, low-fat, recombined Kuih ketayap	1 1
Dinner	Plain water Rice, cooked Fern shoots Banana, common varieties Hairtail scad, cooked in vinegar (Ikan cencaru masak cuka)	1 1 1 0.8815 1
Supper	Milk, UHT, low-fat, recombined Pengat keledek, gula merah	1 1
Total number of dishes per day		19
Total food cost		RM7.80

Table 6: A one day menu for the 54 years old female patient using integer programming

Meals	Food items	Amount
Breakfast	Milk, UHT, low-fat, recombined Cookies, peanut	1 1
Morning tea	Malted milk drink, packet Kuih koci pulut putih	1 1
Lunch	Plain water Chicken rice Fern shoots Banana, common varieties Lungs, fried (Paru lembu goreng)	1 1 1 1 1
Evening tea	Orange flavoured drink, powder Kuih kapit	1 1
Dinner	Plain water Rice, cooked Fern shoots Banana, common varieties Hairtail scad, cooked in vinegar (Ikan cencaru masak cuka)	1 1 1 1 1
Supper	Milk, UHT, low-fat, recombined Pengat keledek, gula merah	1 1
Total number of dishes per day		18
Total food cost		RM 8.30

Table 5 and Table 6 illustrate the result of a one-day menu for the 54 years old female patient generated by linear and integer programming approaches.

Table 7: A one day menu for the 82 years old male patient using linear programming

Meals	Food items	Amount
Breakfast	Milk, UHT, low-fat, recombined Cookies, peanut	1.5120 1
Morning tea	Orange flavoured drink, powder Kuih koci pulut putih	1 1
Lunch	Plain water Rice, “dagang” Chicken rice Fern shoots Date, dried Beef, fried (Daging lembu goreng)	1 0.0995 0.9005 1 1.0241 1
Evening tea	Orange flavoured drink, powder Kuih ketayap	1 1
Dinner	Syrup rose Rice, cooked Fern shoots Banana, common varieties Hairtail scad, cooked in vinegar (Ikan cencaru masak cuka)	0.4880 1 1 0.9759 1
Supper	Plain water Pengat keledek, gula merah	1 1
Total number of dishes per day		19
Total food cost		RM 7.50

Table 8: A one day menu for the 82 years old male patient using integer programming

Meals	Food items	Amount
Breakfast	Milk, UHT, full cream, recombined Cookies, peanut	1 1
Morning tea	Plain water Kuih koci pulut putih	1 1
Lunch	Syrup rose Chicken rice Fern shoots Banana, common varieties Lungs, fried (Paru lembu goreng)	1 1 1 1 1
Evening tea	Milk, UHT, full cream, recombined Kuih ketayap	1 1
Dinner	Syrup rose Rice, cooked Fern shoots Banana, common varieties Hairtail scad, cooked in vinegar (Ikan cencaru masak cuka)	1 1 1 1 1
Supper	Plain water Pengat keledek, gula merah	1 1
Total number of dishes per day		18

Total food cost	RM 7.80

Table 7 and Table 8 demonstrate the result of a one-day menu for the 80 years old male patient generated by linear and integer programming approaches. Based on the results, the cost of the one-day menu for the integer programming (IP) approach was higher than linear programming (LP) approach. The amount of food produced by the LP approach are expressed in real numbers with decimal place which impossible to be consumed. However, the IP approach produced the amount of food in whole unit which is possible to be consumed by the patients. Moreover, the total number of dishes are set to be 18 dishes per day, but the total number of dishes produced by LP approach are more than 18. This shown that the solution produced by LP approach does not achieve the constraints and the requirements of food group. Hence, the IP approach is preferred to be used to solve the diet problem for high blood pressure patients.

4. Conclusion

5.

The diet menu for high blood pressure patients can be developed by applying the mathematical programming approach as well as minimized the cost of the menu. The model will be developed using the computer program, LPSolve IDE. The cost increased slightly when using the integer programming instead of linear programming. In this study, the linear programming is used to test the validation of menu planning model. Since the amount of food produced by the linear programming approach is not possible to be consumed by the patients. Thus, integer programming is the better technique to generated the optimal solutions to solve the diet problem. This study could be a reference for researcher who are interested on scheduling balanced diet menu for high blood pressure patient and contribute towards the future study on offering balanced diet for patient with high blood pressure according to their age, gender and stage of health.

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