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AN INITIAL DEVELOPMENT OF AN INTEGER PROGRAMMING MODEL ON NUTRIENT RECOMMENDATION FOR HYPERTENSION PATIENT

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ABSTRACT

Hypertension is commonly called a silent killer that could affect people all over the world. Unbalanced diets are one of the risk factors for hypertension. Therefore, hypertension patients must put high concern on their health by taking the right quality and quantity of nutrient foods. This paper has presented the initial development of a mathematical model that will produce a menu for hypertension patients with an optimum amount of nutrients in a day focusing only on female hypertension patients aged 40-60 in Malaysia, non-pregnant and free from any other diseases or allergies. To identify the required nutrition, this study will analyze the nutrient recommendations that are needed for hypertension patients. To formulate the modified mathematical model, a cross-analysis of past studies that employed mathematical programming techniques in diet plans was comprehensively presented. This analysis investigates the elements that constitute a mathematical model, which is the model's objective functions, constraints, sets and parameters. This research is intended to modify an IP model that limits this daily calorie intake and considering taking two bananas every day to satisfy the requirement amount of nutrients is the anticipated novelty of this study. In this study, only ten types of food will be used in the model construction. They are drinks, cereal flour-based, rice flour-based, cereal-based meals, meat dishes, vegetables, fruits, wheat flour-based, seafood and miscellaneous. This study only selected ten nutrients which are carbohydrates, protein, fiber, fats, calcium, magnesium, potassium, sodium, vitamin B2 and vitamin C. Other nutrients are considered insignificant and not considered in this study. The solution to the mathematical programming model is expected to be referred to as a guideline for hypertension patients.

Keywords*: Mathematical Programming Model, Hypertension patients, balanced diets, nutrients*

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1. Introduction

Hypertension is often referred to as elevated high blood pressure in medical terms (Hui et al., 2021). Berthelot et al (2018) considered that pulmonary hypertension as an increase in resting pulmonary arterial pressure of 25 mmHg as measured by right cardiac catheterization. Hypertension is a significant risk factor for various cardiovascular diseases, including heart attacks, strokes, and kidney problems. Its insidious nature lies in the fact that it often goes unnoticed as the widespread and potentially silent health condition that affects millions of individuals worldwide, earning it the nickname "the silent killer".

A well-balanced diet plays a crucial role in managing hypertension, helping to lower blood pressure reduce the risk of complications and pursuit a healthier and longer life. Hypertension patients must be highly concerned about their health. The composition of nutrients and calorie intake for hypertension patients need to be identified. They should eat the right quality and quantity of nutritious foods. Practicing a healthy lifestyle with a good daily diet plan that contains the most optimum amount of nutrients will be a very good solution to their problem. Hypertension patients should take the right nutrient requirements on a diet plan. On the other hand, Stern et al. (2021) stated that reducing weight can reduce high blood pressure. Hypertension patients should have an ideal weight. They need to consume an optimum amount of calorie intake. They must know the calorie amount in food as they need to have a healthy lifestyle by consuming calories at a minimum amount.

Therefore, the objective of this paper is to present a comprehensive review of the factors and details needed to formulate the mathematical programming model that helps hypertension patients prepare a daily menu. Mathematical programming is one of the methods to produce the best list of the menu with the optimum nutrients. A mathematical programming model is a systematic tool of management science in which the operations are specified by mathematical equations. Having said that, many aspects need to be studied to guide the quantitative decision on the model development which include the objective functions, constraints, sets, parameters and other restrictions. The mathematical model is expected to be able to produce a daily menu recommendation for hypertension patients with an optimum amount of nutrients in a day. This paper develops a modified mathematical model so that it will consider including two servings of bananas every day and optimize the daily calorie intake for hypertension patients.

Hypertension becomes more common as people age. This is often due to changes in blood vessel elasticity and hormonal fluctuations. A diet that is high in sodium (salt) and low in potassium-rich foods (such as fruits and vegetables) can contribute to hypertension. This study only focuses on female hypertension patients who do not have any other illnesses or allergies and are non-pregnant. This is due to the prevalence of chronic diseases such as diabetes, hypertension, stroke and heart disease among Malaysians which commonly occur between the ages of 40 and 60 (Oo et al., 2020). Pregnant women have different nutrient intake. The low intake of minerals leads to a high risk of pregnancy (Aparicio et al., 2021). The data on food and nutrient requirements are the limitation of this study. There are varieties of food types being considered in research all over the world. However, in this study, only ten types of food will be used in the model construction. They are drinks, cereal flour-based, rice flour-based, cereal-based meals, meat dishes, vegetables, fruits, wheat flour-based, seafood and miscellaneous. This study only selected ten nutrients which are carbohydrates, protein, fiber, fats, calcium, magnesium, potassium, sodium, vitamin B2 and vitamin C. Other nutrients are considered insignificant and not considered in this study. As a result, it can serve as a reference for hypertension patients on the types of food to consume and the quantities to fulfill their nutritional requirements.

2. Diet Plan for Hypertension Patients

Patients with cardiovascular disease, stroke, metabolic syndrome, diabetes and hypertension need smooth blood flow. The healthier foods consumed will lower the cholesterol levels, thus, contributing to disease prevention. There are undoubtedly many health benefits from a balanced diet. A balanced diet is defined as a diet that will give necessary nutrients for hypertension patients, allowing them to better regulate and reduce their blood pressure (Hui et al., 2021). Incorporating healthy foods into a lifestyle immediately minimizes the chances of life-threatening diseases (Tian & Meng, 2019).

Overeating leads to overweight and obesity, which increases the risk of heart problems, diabetes, hypertension and cancer. Stern et al. (2021) stated weight loss treats high blood pressure by reducing calorie consumption. A calorie intake of 1500 kcal is related to the reduction in systolic blood pressure (SBP) and diastolic blood pressure (DBP). Eating a healthy diet prevents certain serious illnesses such as hypertension, heart disease, stroke and diabetes (Micha et al., 2017). It also helps reduce the risk of developing certain types of cancer. Menu planning is a method of determining whether a person has a balanced diet. A well-balanced diet rich in fruits and vegetables, at least 200 g per day for children and 400 g per day for adults, contributes to the prevention of illnesses (Nekitsing et al., 2018). This is because vegetables contain fewer naturally produced sugars than fruits.

Choosing a variety of food items from food groups means having a high food variation in diet meals. Food variety can have healthier eating habits. Food variety also increases the ability to get the nutrients needed from the different types of food groups. Alefan et al. (2009) stated the prevalence of hypertension in 15-year-old male and female participants was 27.8%. Males were more likely than females to have hypertension in participants aged 15-60 years in Malaysia. The nutrients required will be optimized per day with minimum calorie intake. There are some criteria to evaluate whether the menu can, fully or partially, satisfy the condition related to the required amount of nutrients.

3. Nutrition for Hypertension Patients

Hypertension is one of the most common chronic illnesses as well as one of the most critical health problems, causing death. In most cases, the primary cause of hypertension was not found. Hypertension is often known as a silent killer disease. If a hypertensive patient is not treated, it develops to major life-threatening issues in important organs such as the brain, eye, heart and kidney. Tobacco use, diabetes, poor nutrition and stress are established risk factors for hypertension (Buang et al., 2019).

The use of persistent SBP of above 140 mmHg and DBP of above 90 mmHg is classified as hypertension (Haldar, 2013). High SBP and DBP are associated with heart failure, renal disease, hardened arteries, visual discomfort and stroke. Hypertension must be treated as early as possible. Taking hypertension medications is not the best strategy for treating hypertension. Long-term drug use leads to other serious health problems hence it needs to find a healthy strategy for controlling blood pressure (BP). An improved diet helps control BP (Vats, 2019).

A healthy lifestyle starts with a balanced diet. A balanced diet is essential for the healthy growth of children and adolescents as well as for the prevention and treatment of chronic diseases. A well-balanced diet is also essential in the treatment of hypertension. Many hypertensive patients are generally uninformed of their dietary requirements, which now become one of the causes of hypertension (Hui et al., 2021). Juraschek et al. (2017) stated the most efficient strategy to lower BP is to eat a balanced diet. The benefit of potassium in meals helps decrease BP. Banana is one of the fruits that contain high potassium. A medium-sized banana has 350 mg of potassium. It leads to maintaining BP and cardiac disease. BP in hypertension patients was reduced by 10% by eating two bananas every day for a week (Kumar et al., 2012). Stern et al. (2021) stated that 1500 kcal caloric intake for hypertension patients is associated with a significant decrease in SBP and DBP levels. It helps by reducing the loss of weight and daily calorie consumption.

Stroke is the world’s biggest cause of death, after heart disease and cancer. High BP is a major contributor to stroke risk. Potassium, magnesium and fiber are identified as important stroke risk modulators. High consumption of these nutrients is linked to a healthier lifestyle. Macronutrients are essential for hypertension patients which are carbohydrates, protein, fiber and fats (Hsu & Tian, 2018). A diet high in fruits and vegetables is the best way to obtain enough of these nutrients (Solaiman et al., 2010). The nutrients for hypertension patients can be obtained from past studies. The amount of food consumed and dietary requirements of high BP patients vary depending on their age, gender, frequency of physical activity and health status.

Stern et al. (2021) stated weight loss treats high blood pressure by reducing calorie consumption. Calorie intake of 1500 kcal is related to a reduction in systolic blood pressure (SBP) and diastolic blood pressure (DBP). Dunkley (2019) stated that taking carbohydrates 130 g to 260 g daily helps regulate BP and lose weight. Protein intake at a minimum of 52 g is necessary for hypertension to lower BP (Hui et al., 2021). Waksmańska et al. (2020) stated fat intake of 115 g is essential for female hypertension patients.

Dietary fiber supplements are also used to improve metabolic syndrome and risk factors body weight and appetite. DASH has shown that a diet with high fiber and low in salt and fat can reduce arterial BP. The effect of fiber on various illnesses assists hypertension by controlling them. A consistent daily intake of 5.5 g of fiber for women will decrease the SBP and DBP decreased by 7.5 mmHg and 5.5 mmHg, respectively (Aleixandre & Miguel, 2016).

Nutrients of calcium, magnesium, potassium, sodium, vitamin B2 and vitamin C are the micronutrients needed for hypertension patients. Calcium consumption has shown many health benefits, including reduced hypertensive disorders of pregnancy, lower blood pressure, especially in young people, prevention of osteoporosis and colorectal adenomas and lower cholesterol levels. Intake of calcium between 1000 mg to 1500 mg per day, SBP was decreased by 1.05 mmHg (Cormick & Belizán, 2019)

Magnesium contributes to the regulation of hundreds of body systems, including hypertension, glucose levels and muscular function. Magnesium is necessary for blood vessel relaxation, energy production and bone development. Magnesium intake for women at 350 mg per day is necessary to normalize high BP in untreated hypertensive patients, whereas the same amount of magnesium per day could lower BP in patients using prescription medications (Houston, 2011).

Potassium intake helps reduce rising BP and it was claimed that hypertension is caused by a low-potassium diet and excessive salt chloride consumption. For patients with hypertension or other cardiovascular diseases, the DASH diet is advised as a routine lifestyle improvement. A daily potassium intake of 4700 mg for women is recommended by the DASH diet (Staruschenko, 2018).

Long-term excessive salt consumption in the diet is linked to an increased risk of hypertension, cardiovascular disease, chronic renal disease and death. Salt consumption between 1,000 mg and 2,300 mg per day is recommended for those with hypertension, diabetes or chronic kidney disease. Dietary salt can be reduced from a high to an intermediate level, which resulted in a 2.1 mmHg reduction in SBP (Aronow, 2017)

Ben et al. (2018) stated vitamin B helps in the reduction of BP. Vitamin B2 is also called riboflavin. Daily intake of vitamin B at a minimum of 1.1 mg for hypertension supplements assists in lowering BP. Vitamin C is essential to act as a diuretic, eliminating excess fluid from the body. This helps in lowering BP pressure. As the impact of the intake of 500 mg of vitamin C for hypertension patients, SBP and DBP can be reduced by 4.85 mmHg in hypertensive patients (Guan et al., 2020).

4. Mathematical Programming Model

A mathematical programming technique solves an optimization problem, with the objective function stated as performance criteria and the objective property that is satisfied which is presented as a constraint. Optimization technique extension to theory is a broad topic of applied mathematics (Lasiecka & Huyên, 2021). The process is used to solve linear, integer and mixed integer algorithms (Babi et al., 2017). There are several research applied mathematical programming models in various types of optimization and minimization in diet planning, costing and budgeting.

Eghbali (2020) used applications of the multi-objective linear programming (LP) model in optimizing nutrition intake in athletes. The study presented the nutrient type in the LP model and then solved it with MATLAB computing software. The goal of the LP model is to provide a diet that reduces fat consumption while increasing calorie intake for athletes. Alaini et al. (2019) used the LP model to develop a low-cost cancer-preventive diet plan for selected individuals to prepare balanced meals in Kuala Lumpur, Malaysia. The study focused on the specific nutrients required at a lower cost for cancer patients. Excel Solver was used to develop the LP model. Based on local market pricing, LP is a very effective technique for constructing a balanced diet. It developed the current cancer prevention recommendations at a minimal cost.

The cost of a four-day menu plan diet was optimized by adopting an integer programming (IP) approach done by Sheng and Sufahani (2018). IP model provides real-world solutions through which the product is provided as a whole. Ali et al. (2016) created a one-day food plan for the school's management. MATLAB and LPSolve tools were used to solve the model. It satisfies all of the constraints and provides a better solution using heuristic approaches. The goal of the study is to develop a menu plan model that minimizes the government's budget for boarding school caterers while increasing the food consumed. As a result, the study serves slightly expensive but high-quality foods for the children.

Sufahani et al. (2018) developed a binary programming (BP) model and delete-reshuffle-reoptimize algorithm menu scheduling for boarding school students, a menu planning technique that reduced the government's financial allocation for school chefs while increasing the variation and nutritional value of food. MATLAB with LPSolve was used to modify the coding and the study focused on lower cost and better nature of nourishments for the boarding school children.

Maximizing student meal options using Mixed Integer Linear Programming (MILP) was done by Cottrell (2018). The MILP model was developed to maximize the choice of meal options available to college students. It used social media to spread information about overweight and nutrition. The study helped to educate others on how to avoid the obesity epidemic among young college students. The MILP model successfully improved student lunch selections that provide a healthy meal recommendation. Cottrell et al. (2019) constructed a MILP model for personalized meal recommendations for African-American students. The OSMO model is a MILP model that includes food items in each meal to meet the student's dietary and daily nutritional needs. It has created a MILP model that optimized meal advice for individual students tailored to their nutrition needs.

Dhoruri et al. (2017) formulated a goal programming (GP) model for diabetes mellitus patients. The study identified the optimal balanced menu and number of recommendations for diabetes mellitus patients. Computational experiment using LINGO solve results of menu options with total calories needed at a minimum cost. Paidipati et al. (2021) produced effective approaches for determining the optimal menu plan using GP. The study essentially focused on generating pre-emptive and non-preemptive GP issues in the optimal menu planning for diabetes mellitus patients. GP focuses on maximizing energy or calorie levels by evaluating the maximum distribution of the amount of food in a recipe.

Preemptive GP for nutrition management optimization was formulated by Anugrah et al. (2019). The food combination produced is one of the types of food that meets the daily nutrition needs of teenagers. GP model was presented for finding a set of fulfill solutions to the problem of multi-objective decision-making. The purpose is to minimize the total cost and percentages of nutrient variations based on priority.

Table 1 illustrates the relevant works that applied LP, IP, MILP and GP models in menu planning. The purpose of many studies was to minimize calorie intake and meal costs to provide optimal nutrition. The mathematical models that were employed are shown in the rightmost column.

Table 1. List of Related Work using Linear, Integer, Mixed Integer Linear and Goal Programming

No	**Author (Year)**	**Purpose of Study**	**Mathematical Model**
1	Paidipati et al. (2021)	To optimize calories needed for diabetes mellitus patients at minimal cost	Goal Programming
2	Anugrah et al. (2019)	To minimize the total cost and percentages of nutrient variations for adolescents	Goal Programming
3	Eghbali (2020)	To minimize fat consumption and maximize calorie intake for athletes	Linear Programming
4	Alaini et al. (2019)	To maximize nutrients required at a minimal cost for cancer patients	Linear Programming

5	Hamid et al. (2019)	To optimize meal options for pregnant women at minimal cost	Linear Programming
6	Cottrell et al. (2019)	To minimize cost meal and maximize nutrient of meal for individual students	Mixed Integer Linear Programming
7	Sheng and Sufahani (2018)	To minimize the cost of a diabetic patient's diet by preparing a four-day meal	Integer Programming
8	Sufahani et al. (2018)	To minimize the government's financial budget for school meals and maximize the variety of food and nutrition	Binary Programming
9	Cottrell (2018)	To improve college students' access to a variety of meal options	Mixed Integer Linear Programming
10	Dhoruri et al. (2017)	To optimize calories needed for diabetes mellitus patients at minimal cost	Goal Programming
11	Ali et al. (2016)	To minimizes the government's budget for boarding school and maximize the food consumed	Integer Programming

5. The Gap Analysis for Model Development

This section provides a gap analysis on several diet planning model formulations that have been developed in previous studies, with emphasis on the models' features and attributes. By analyzing the components and qualities of these models, then the research gap can be determined. Ten mathematical models from previous research have been chosen to be studied in this section to evaluate the research gap. The selected literatures are the mathematical model for diet planning developed by Mohamed et al. (2021), Baharom and Isa (2021), Lee et al. (2020), Hui et al. (2020), Jalil et al. (2017), Hui and Sufahani (2019), Ping and Sufahani (2019), Sheng and Sufahani (2018), Sufahani and Ismail (2015) and Sufahani and Ismail (2014). New features to be included in the proposed mathematical model can be determined from the gap analysis.

5.1 Model Objective Function

An ILP model consists of an objective function, a set of constraints, decision variables and parameters. To solve an ILP, a minimization or maximization of the objective function is to be achieved and it must satisfy the set of constraints of the model. Mohamed et al. (2021) presented an ILP model to reduce the consumption of calories for McDonald's set menu while reducing the need for calorie requirements. Baharom and Isa (2021) formulated a mathematical model as an approach to the dietary problem of hypertensive patients. The goal of the research is to create a mathematical model of food planning for hypertension patients. The model attempted to satisfy the ideal nutritional requirements based on the required nutrient intakes. Hui et al. (2020) also used the IP approach to develop a diet menu by constructing a mathematical model using 413 food data. The goal of the study is to reduce the entire cost of food. As an output, the user entered the information, an automatic system was created to generate a list of menus for one day. Hui and Sufahani (2019) also utilized the IP approach to create a diet menu by developing a mathematical model using the data from 100 food items. The study aims to reduce the total food costs. IP technique was used to generate the amount of food in a unit that the hypertension patients.

Ping and Sufahani (2019) also utilized IP to determine the daily meals at the lowest possible cost. The study only focused on seven different categories of nutritional content for myopia patients. This can help patients with myopia to have a well-balanced diet at a minimal cost. Menu scheduling for breast cancer patients by Lee et al. (2020) was satisfied when the final results met all of the nutritional restrictions. A total of 426 food items were considered when developing a day's menu. In selecting the ideal food for the entire day's meal, the food items are selected from the most appropriate food group that contains all the nutrients required by the cancer patients. The cost for the total meals each day was minimized to allow patients to have a low-cost-of-day menu.

The mathematical model for a healthy diet menu plan by Jalil et al. (2017) is to limit the daily total fat consumption by teenagers aged 13 to 17 years old while satisfying Malaysian RNI standards within the budget allocated. There are 10 nutrients considered, which are carbohydrate, protein, fat, vitamin A, vitamin B1, vitamin B2, vitamin B3, iron and calcium. The data obtained is used to construct a BIP model. The goal of the study is to reduce the daily total fat consumption of teenagers.

Sheng and Sufahani (2018) presented a menu planning model developed using IP with 426 variables for eczema patients. The delete-reshuffle algorithm was applied to ensure food variety intake whereby, food items included for each day are different. The goal of this algorithm is to exclude the foods that were provided on the first day and consider the remaining foods for the next day's menu. The looping method is maintained so that foods are provided differently for the four-day menu plan. A mathematical model was created to serve as the ideal approach to the diet problem for eczema patients. The results for IP for menu planning and nutrients for four days. Sufahani and Ismail (2014) developed an IP approach to create a menu planning model that minimizes the meal cost which is RM9 per day for boarding school meals while offering a variety of food consumption. They later extended their work using the BIP model with a budgeted cost of RM15 per day (Sufahani and Ismail, 2015). The study focused on satisfying nutritional needs.

Table 2 presents the cross-analysis of the objective functions used in diet planning models. The majority of the models aim at minimizing the cost of a day's menu with an optimized amount of nutrients. Most of the models in the research have one objective function. This research has the same objective function as Mohamed et al. (2021) which is to minimize the consumption of calories for hypertension. This research only addresses one objective function which is to minimize the consumption of calories intakes.

Table 2. Cross Analysis of Objective Function Used in Models of Related Work

Objective Function	**Author(s)**										
	1	2	3	4	5	6	7	8	9	10	11
To minimize the consumption of calories	√										√
To minimize consumption of fat					√						
To minimize total cost for a day's menu	√	√	√	√	√	√	√	√	√	√	
To maximize the amount of nutrition				√			√		√	√	

Note: 1-Mohamed et al. (2021); 2-Baharom and Isa (2021); 3-Hui et al. (2021); 4-Lee et al. (2020); 5-Jalil et al. (2017); 6-Hui and Sufahani (2019); 7-Ping and Sufahani (2019); 8-Sheng and Sufahani (2018); 9-Sufahani and Ismail (2015); 10-Sufahani and Ismail (2014); 11-This research

5.2 Model Decision Variables

A decision variable is an unknown in an optimization problem. It has a domain, which is a compact representation of the set of all possible values for the variable Thus, the cross-analysis of decision variables used in the mathematical programming models in the selected literature is shown in Table 3

Table 3. Cross Analysis of Decision Variables Used in Models of Related Work

Decision Variables	**Author(s)**										
	1	2	3	4	5	6	7	8	9	10	11
Menus	√				√						
Food items		√	√	√		√	√	√	√	√	√
Food groups		√	√	√		√	√	√			√
Meals		√	√	√		√	√	√			√

Note: 1-Mohamed et al. (2021); 2-Baharom and Isa (2021); 3-Hui et al. (2021); 4-Lee et al. (2020); 5-Jalil et al. (2017); 6-Hui and Sufahani (2019); 7-Ping and Sufahani (2019); 8-Sheng and Sufahani (2018); 9-Sufahani and Ismail (2015); 10-Sufahani and Ismail (2014); 11-This research

5.3 Model Constraints

Any mathematical programming model must find the best feasible solution by satisfying and optimizing the constraints as stated in the problem. Constraints are restrictions imposed by the model programming language that the solution must not exceed. The feasible set is the set of possible solutions that fulfill all restrictions (Wang et al., 2019). The cost of meal constraint is applied to limit the entire expense of the diet cost.

The type of constraint that is vital in the optimum nutritional plan model is the nutritional requirement. The nutrient content of the mathematical programming diet was chosen to meet the measured daily nutrient intakes. It included constraints on both macronutrients and micronutrients to ensure that certain nutrients' safety limits were not exceeded. Food group requirement is also a type of constraint. To ensure that all model mathematical programming diets are within the range of diets, food quantities and food category patterns are employed in all models (Darmon et al., 2006). Table 4 presents the cross-analysis of the constraints used in models of related works. They are essential parts of mathematical models focusing on diet menu planning. A proper model must include a set of constraints to ensure the model's applicability.

Table 4. Types of Constraints Used in Models of Related Work

Common Types of Constraints	**Author(s)**										
	1	2	3	4	5	6	7	8	9	10	11
Total cost of daily meal	√	√	√	√	√	√	√	√	√	√	
Total calories intake	√										
Nutritional requirements	√	√	√	√	√	√	√	√	√	√	√
Food group requirements		√	√	√	√	√	√	√	√	√	√
Budget allocation					√						
Minimum calories intake											√
Banana intake											√

Note: 1-Mohamed et al. (2021); 2-Baharom and Isa (2021); 3-Hui et al. (2021); 4-Lee et al. (2020); 5-Jalil et al. (2017); 6-Hui and Sufahani (2019); 7-Ping and Sufahani (2019); 8-Sheng and Sufahani (2018); 9-Sufahani and Ismail (2015); 10-Sufahani and Ismail (2014); 11-This research

5.4 Model Sets and Parameter

Table 5 shows the cross-analysis of sets that are used in the mathematical models of the selected research works. Most of the models are based on meals, food groups, food items and nutrients. They are important sets of diet nutrition plan models to represent the actual diet plan. There are six types of meals which are breakfast, morning tea, lunch, evening tea, dinner and supper and there are ten types of food which are drinks, cereal flour-based, rice flour-based, cereal-based meal, meat dishes, vegetables, fruits, wheat flour-based, seafood and miscellaneous. Taking six meals per day ensures that blood glucose is available at all times (Peel et al., 2004). The total number of dishes needed is 18 per day. The set of meals, food groups, food items and nutrients dominate many of the models in the selected literature. Therefore, most of the models use similar sets. The sets to be included in this study are presented in the last column of the table.

Table 5. Analysis of Sets Used in Models of Related Work

SETS	Author(s)										
	1	2	3	4	5	6	7	8	9	10	11
Meals		√	√	√	√	√	√	√			√
Food groups		√	√	√	√	√	√	√	√	√	√
Food items	√	√	√	√	√	√	√	√	√	√	√
Nutrients	√	√	√	√	√	√	√	√	√	√	√

Note: 1-Mohamed et al. (2021); 2-Baharom and Isa (2021); 3-Hui et al. (2021); 4-Lee et al. (2020); 5-Jalil et al. (2017); 6-Hui and Sufahani (2019); 7-Ping and Sufahani (2019); 8-Sheng and Sufahani (2018); 9-Sufahani and Ismail (2015); 10-Sufahani and Ismail (2014); 11-This research

Due to the complexity of the IP and MIP models, the parameters used in model formulation need to be carefully chosen. When encouraging healthy diets, the calories of each food item are necessary. Hypertension patients should consume diets that are low in calories, fat and salt (Di Daniele et al., 2021).

Table 7 analyses the model parameters used in the chosen research works. Some of the models have almost identical parameters, whereas others add a set of parameters consequently enhancing an existing model. This study allocated some of the nutrient parameters that are needed by hypertension patients which is intended to bring benefits to them. Table 6 shows there are few research that considered different types and amounts of nutrients. Some of them took a certain type of nutrient to optimize the nutrient required per day.

Table 6. Analysis of Parameters Used in Models of Related Work

PARAMETERS	**Author(s)**										
	1	2	3	4	5	6	7	8	9	10	11
Cost of each food item	√	√	√	√	√	√	√	√	√	√	
Calories of each food item											√
Number of meals	√		√	√	√	√	√	√	√	√	√
Number of food groups			√	√	√	√	√	√	√	√	√
Number of food items			√	√	√	√	√		√	√	√
Amount of requirement of food group		√									√
Lower bound of nutrient		√	√	√	√	√	√		√	√	√
Upper bound of nutrient		√	√	√	√	√	√		√	√	√
Weight of nutrient for the food			√	√		√					√
Amount of energy in kilocalories for food item	√		√		√			√	√	√	
Amount of fat in gram for food item	√				√			√	√	√	√
Amount of protein in gram for food item	√		√	√	√	√		√	√	√	√
Amount of salt in gram for food item	√										
Amount of sugar in gram for food item	√										
Amount of carbohydrate in gram for food item	√		√		√		√	√	√	√	√
Amount of sodium in milligram for food item				√		√					√
Amount of potassium in milligram for food item				√		√					√
Amount of calcium in milligram for food item			√	√	√	√	√	√	√	√	√
Amount of iron in milligram for food item			√		√		√	√	√	√	
Amount of niacin in milligram for food item									√	√	
Amount of magnesium in milligram for food item											√
Amount of fiber in milligram for food item											√
Amount of Vitamin A in milligram for food item			√		√		√	√	√	√	
Amount of Vitamin B1 in microgram for food item			√		√		√	√	√	√	
Amount of Vitamin B2 in microgram for food item			√	√	√	√	√	√	√	√	√
Amount of Vitamin B3 in microgram for food item					√						
Amount of Vitamin C in milligram for food item			√	√	√	√	√	√	√	√	√

Note: 1-Mohamed et al. (2021); 2-Baharom and Isa (2021); 3-Hui et al. (2021); 4-Lee et al. (2020); 5-Jalil et al. (2017); 6-Hui and Sufahani (2019); 7-Ping and Sufahani (2019); 8-Sheng and Sufahani (2018); 9-Sufahani and Ismail (2015); 10-Sufahani and Ismail (2014); 11-This research

6. The Expected Result of the Model

The parameters for the model in this study are chosen by the applicability of the data to the diet planning problem. The IP model by Lee et al. (2020) contains many similarities with the parameters used for this research, based on the gap analysis of parameters utilized in the selected mathematical models shown in Table 7. Therefore, the model will be taken as the reference model for this study.

Menus can be classified in a variety of ways, and distinct types of menus are generally connected with specific types of food. In the reference model, the menu schedule deals with ten types of food groups which are drinks, cereal flour-based, rice flour-based, cereal-based meals, meat dishes, vegetables, fruits, wheat flour-based, seafood and miscellaneous. Each food group must be taken once per day while drinks must be taken six times and the cereal-based meal must be taken twice per day. There is a total of 426 food items chosen by Lee et al. (2020) to construct a diet menu.

The model by Lee et al. (2020) consists of nine constraints based on nine nutrient contents which are protein, carbohydrate, calcium, iron, vitamin B1, vitamin B2, vitamin C and vitamin A. There are seven constraints of nutrients that consist of LB and UB values except for vitamin B1 and vitamin B2. These two vitamins only have LB values. The proposed model of this research required ten constraints. There are some differences between hypertension patients and breast cancer patients. The proposed model of this research determined to minimize the calorie intake. IP is a good approach to constructing a diet plan that satisfies all the constraints with minimum calorie intake by developing a mathematical model.

In Lee et al. (2020) there are a total of 100 food items chosen to be used for the small data model. Then, all the food items were used for the formal study which was used to develop the big data model using IP. The objective function of Lee et al. (2020) is to minimize the total cost.

The reference model is a scheduling menu for breast cancer which is compatible with the proposed model of this research in terms of the concepts of food group types, total dishes per day, nutrient content and meal per day. Table 7 presents these similarities of the features between the two models. The food items adopted for this study are commonly consumed by Malaysians and suitable for hypertension patients. Only one type of dish will be selected from the 41 food items considered in this study.

Table 7. The Similarities Between the Reference Model and Proposed Model

No	Reference Model (Lee et al., 2020)	Proposed Model
1	Menu scheduling for breast cancer patients	Menu scheduling for hypertension patients
2	Minimize total cost per day	Minimize calories intake per day
3	10 of food group types - Drinks - Cereal Flour-Based - Rice Flour-Based - Cereal-Based Meal - Meat Dishes - Vegetables - Fruits - Wheat Flour-Based - Seafood Dishes - Miscellaneous	10 of food group types - Drinks - Cereal Flour-Based - Rice Flour-Based - Cereal-Based Meal - Meat Dishes - Vegetables - Fruits - Wheat Flour-Based - Seafood Dishes - Miscellaneous
4	Fruits group in general	Fruits group include banana
5	6 of meals per day - Breakfast - Morning Tea - Lunch - Evening Tea - Dinner - Supper	6 of meals per day - Breakfast - Morning Tea - Lunch - Evening Tea - Dinner - Supper
6	426 of food items	41 of food items

7	9 Nutrients content - Energy - Carbohydrate - Protein - Calcium - Vitamin B2 - Vitamin C - Iron - Vitamin A - Vitamin B1	10 Nutrients content - Carbohydrate - Protein - Calcium - Vitamin B2 - Vitamin C - Fiber - Fats - Magnesium - Potassium - Sodium

7. Conclusion

This paper has presented the initial development of a mathematical model that will produce a nutrient recommendation for hypertension patients. Therefore, a modified integer programming model is chosen to be the tool for finding the optimal solution for nutrient recommendations for hypertension patients. This study does not only produce a diet plan for hypertension patients but also presents the research novelties. The novelties are the inclusion of bananas as a source of potassium and the minimum calorie intake, which is strongly recommended for hypertension patients. The main elements supporting the model development are discussed in detail, with the novelty. The paper is expected to assist researchers in formulating structured models using a clear definition of model variables and parameters. The work is part of the study that will be conducted to find the optimum amount of nutrients for hypertension patients. The modified model and solution approaches will be presented in the next research paper of our study.

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10. Conflict of Interest

The authors have no conflicts of interest to declare.

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