A diet plan for Malaysian adolescent athletes using integer goal programming model

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ABSTRACT A good diet plan is one of the important aspects in developing healthy adolescent athlete because the main sources of energy and other nutrients come from the choices of food intake. This study aims to modify an integer goal programming model which can produce a nutritious diet menu plan that maximizes protein and minimizes fat while fulfilling the nutrient recommendation intake for Malaysian adolescent athletes aged between 13 to 18 years old. There are 50 food items with nutrition compositions and twelve nutrients are considered in the model formulation in this study. The data was mainly gathered mainly from websites of the Malaysian Food Composition Database (MyFCD) in addition to other food and diet websites. The computation experiment was run by Microsoft Excel Solver. The output results produce a solution containing 30 servings a day with optimum value of 115.8 grams of protein and 69.99 grams of fat. The diet planning solution can be referred to as the guidelines for sport schools to prepare nutritious diet meals for adolescent athletes.

KEYWORDS: Integer goal programming model; Adolescent athletes; Diet planning; Nutrient requirement; Meal plan.
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INTRODUCTION

Adolescent athletes basically undergo extensive physical training every day. Therefore, the daily meals taken must contain sufficient nutrients to support physical training and growth development of the adolescents. A good diet plan can fulfil their daily nutritional requirement and provide them with optimal nutrient levels through food intake. Having said this, a special designated menu for adolescent athletes is strongly needed. One of the methods to produce the best list of menus with the optimum nutrients is by using mathematical programming model approach.

Hui *et al.* (2021) developed a diet plan for hypertension patients using mathematical programming approach. The results revealed integer programming (IP) model produces a better diet plan with optimal dietary requirements and is less expensive than linear programming (LP) model. Dhoruri *et al.* (2017) developed diet plan for diabetic patients that low in cost, and yet, satisfy the nutrient requirement of patients. They solved the diet planning problem by minimizing deviations between each goal functions, constrained by the nutrition requirement for diabetic patients. Fauzi *et al.* (2019) developed a meal planning for undergraduate students. It was discovered that the goal programming (GP) technique produced a better meal plan than the LP method, in terms of cost. In addition, Nilu *et al.* (2020) presented a diet plan for three distinct groups of people, each of which was distinguished by age. The study aimed to reduce total costs while meeting the nutritional needs of the target groups. Ali *et al.* (2017) solved the menu planning challenge for secondary school students aged 13 to 18. Secondary school students require a well-balanced diet to promote and maintain their growth. The study was able to propose a diet plan that met the dietary requirements of secondary school students while also minimizing the cost and preparation time.

The objectives of the research are to modify an integer goal programming (IGP) model that represent the nutritional requirement for the diet plan of Malaysian adolescent athletes and to produce a one-day menu containing the combination of food items that best satisfy nutrient requirement for Malaysian adolescent athletes, with the optimum value for protein and fat within the range of nutritional requirement. This study plans to develop a diet plan that meets the nutritional needs of Malaysian adolescent athletes aged 13 to 18 years old with an average weight between 46.5 to 59.2 kilogram.

This paper is the continuation of the study done by Alwadood *et al.* (2022) which has presented the preliminary development of the IGP model. The paper has investigated the elements that constitutes the mathematical model, which are the model objective functions, constraints, sets and parameters. 12 nutrients were considered in the preliminary study which consist of macronutrients such as protein, carbohydrates, fat, fibre, as well as fluids. From the gap analysis done, a set of model objective functions which maximize protein intake while minimizing fat consumption has been developed. It has also been determined the decision variables of the diet plan model are food and nutrient intakes. The sets and parameters that have been identified to be included in the model namely the nutrient requirement, nutrients composition in food, food group and list of food items. This paper is intended to utilize the modified model obtained from the previous study and implement the experiment to achieve the desired research objectives.

METHODOLOGY

Data Collection

The menus utilised in this study were gathered from the Malaysian Food Composition Database (MyFCD, 2023) and the United States Department of Agriculture's Food Data Central (USDA). In this study, 50 food items with nutrition compositions were chosen. In addition, only 12 nutrients are included in this study, as per previous recommendations by Jalil *et al.* (2017) and Ali *et al.* (2017). Almost all nutrient requirements are extracted from Ministry of Health Malaysia (2017). This study has chosen the recommendation from Hannon *et al.* (2020) and Ministry of Health Malaysia (2017) for the daily nutrient requirements for very active adolescents. This recommendation is considered to help Malaysian adolescent athletes to get the optimum intake without being exposed to obesity. They also give other nutrients flexibility since other nutrients can also be transformed into energy such as carbohydrates and protein.

The Modified Integer Goal Programming Model

This paper is the continuation of the study done by Alwadood *et al.* (2022) which has presented the preliminary development of the IGP model. The elements that constitute the mathematical model were comprehensively presented in the work, including the model sets, parameters, constraints, and decision variables. Subsequently, in this paper, a pre-emptive linear programming model from Eghbali (2020) is modified to be a pre-emptive IGP model which can maximize protein and minimize fat. The modifications are made by introducing new objective function and an additional of new constraints, to make the diet planning menu satisfies the nutritional requirements for Malaysian adolescent athletes. There are two phases involved in this diet planning model for adolescent athletes and the modification is shown in this section.

First Phase of Pre-emptive IGP

The goal of this first phase is to maximize protein in the diet plan for Malaysian adolescent athletes while maintaining within the prescribed nutrient range.

$$Maximize\ T_1 = \sum_{k=1}^{50} C^1{}_n X_n \tag{1}$$

subject to

$$LL_m \leq \sum_{m=1}^{M} b_{mn} X_n \leq UL_m \quad , \quad \forall n, m \tag{2}$$

$$\sum_{n=1}^{32} X_n = A_f \quad , \quad f = 1,2,3,..,11. \tag{3}$$

$$LL_f \leq \sum_{n=33}^{50} X_n \leq UL_f \quad , \; f = 12,13,14,15. \tag{4}$$

$$X_{48} = 2 \tag{5}$$

$$X_1 = 8 \tag{6}$$

$$X_n \geq 0 \quad , \quad n = 1,2,..,50. \tag{7}$$

where T_1 - value of daily total protein intake, $C^1{}_n$ - amount of protein in n food item, X_n - the number of serving of food items n, n - index for food item *(n = 1,2,..,N)*, m - index for type of nutrient *(m = 1,2,..,M)*, f - index for food groups *(f = 1,2,..,F)*, N - total number of food items *(N = 50)*, M - total number of types of nutrients *(M = 12)*, F - total number of food groups *(F = 15)*, b_{mn} - amount of nutrient content in each m type of nutrient for each n food item, A_f - number of f food groups required in a day, LL_m - lower bound for each m type of nutrient, UL_m - upper bound for each m type of nutrient, LL_f - lower bound for certain f food group, UL_f - upper bound for certain f food group, X_{48} - variable represents milk, and X_1 - variable represents plain water.

Equation (1) is the first objective function of the model which is the function to maximize protein for the diet plan being represented by T_1 notation. The notation $C^1{}_nX_n$ represent the model decision variables which represent the total amount of protein contained in 50 food items. Constraint (2) represent the lower limit and upper limit of all considered nutrients in this study. Constraint (3) and Constraint (4) represent the restriction for number of serving of each food groups. Constraints (5) and Constraint (6) represent the requirement for milk and plain water, respectively. Finally, the non-negativity constraint is represented by Constraint (7) which also help the model to get integer solution.

Second Phase of Pre-emptive IGP

The second phase is different from first in terms of the additional constraint which is produced from the result obtained in the first phase.

$$Minimize\ T_2 = \sum_{n=1}^{50} C^2{}_n X_n \tag{8}$$

subject to

$$LL_{protein} \leq \sum_{m}^{M} b_{mn} X_n \leq T_1 \tag{9}$$

This is then followed by the constraint in Equation (2) to (7), and T_2 - value of daily total fat intake, $C^2{}_n$ - amount of fat in n food item, T_1 - maximum value of daily protein from first phase, and $LL_{protein}$ - lower bound of protein requirement.

Equation (8) represent the model's objective function to minimize fat intake in Malaysian adolescent athletes. The additional constraint in Equation (9) keeps the maximum value of protein obtained earlier, while minimizing fat in the diet planning.

RESULT AND DISCUSSION

The optimal solution for diet planning of Malaysian adolescent athletes is obtained by using Microsoft Excel Solver. Table 1 presents the output results in terms of the food group, food items, amount and weight of serving. The last two columns are total fat and protein intake for a day. The amount of serving represents the quantity of selected food item to be consumed daily. The weight of serving is the quantity used, in grams, for food and millilitre for beverages including plain water and milk. The unit used to represent total fat and total protein is also gram. Based on the results, the optimum list of menus for adolescent athletes can be produced with the minimum fat intake of 69.99 g and maximum protein intake of 115.88 g.

Table 1. The optimal result for Malaysia adolescent athlete diet plan

Food group	Food items	Serving number	Weight of serving (g/ml)	Total fat (g)	Total protein (g)
Beverages	Sugarcane juice	1	250 ml	0	1.03
	Orange juice	1	100 g	0.36	0.81
Fruits	Banana	1	77 g	0.23	1.08
	Honeydew	1	165.75 g	0.58	0.54
	Watermelon	1	311 g	0.62	1.87
Vegetables	Fried swamp cabbage	2	285.4 g	22.64	10.24
Rice		2	317.6 g	0.32	7.3
Bread	Whole meal bread	1	25 g	0.15	2.13
Pasta/noodles	Soup noodle	1	563 g	14.64	20.27
Cereal	Corn flakes cereal	1	30 g	0.6	2.04
Other cereal	Corn biscuits	1	14.4 g	2.71	1.13
Tubers	Potato	1	81.7 g	0	1.39
Fish dishes	Cuttlefish fried in chili	1	37.4 g	2.88	4.97
Poultry/meat	Beef curry	1	90 g	5.13	13.14
Eggs	Lower cholesterol eggs	1	48.71	0.66	0.99
Legumes	Chickpeas	1	14.6 g	7.12	3.07
Nuts	Cashew	1	100 g	0.2	19.3
Plain water		8	2000ml	0	0
Low-fat Milk		2	514.2g	8.74	10.54
Total		**30**	**-**	**69.99 g**	**115.88 g**

Table 2. Recommended food item arrangement for each meal session

Session	Food Item	Food Group	Detail on Serving
Breakfast	Cornflakes cereal	Wholegrain cereal	1 bowl, 30 g
	Low-fat UHT milk	Milk	1 glass, 257.1 g
	Plain water	Plain water	1 glass, 250 ml
	Cashew	Nuts	10 pieces, 100 g
	Low cholesterol egg	Eggs	1 whole egg, 48.71 g
Morning Tea	Soup Noodle	Noodles/pasta	1 bowl, 563 g
	Plain water	Plain water	1 glass, 250 ml
	Honeydew		1 slice, 165.75 g
Lunch	Beef curry	Poultry/meat	1 serving, 90 g
	Plain rice	Rice	1 bowl, 158.8 g
	Plain water	Plain water	1 glass, 250 ml
	Sugarcane juice	Beverages	1 cup, 250 ml
	Swamp cabbage fried	Vegetables	2 cup, 285.4 g
	Potato	Tubers	1 whole medium, 81.7 g
	Chickpea	Legumes	1 cup, 14.6 g
Evening Snack	Banana	Fruit	1 serving, 77 g
	Whole meal bread	Bread	1 slice, 25 g
	Plain water	Plain water	1 glass, 250 ml
Dinner	Cuttlefish fried in chili	Fish/seafood	1 serving, 37.4 g
	Plain rice	Rice	1 bowl, 158.8 g
	Orange juice	Beverages	1 serving, 100 g
	Plain water	Plain water	1 glass, 250 ml
	Watermelon	Fruits	1 big slice with skin, 311 g
	Soupy spinach	Vegetables	1 serving, 100 g
Supper	Low-fat UHT milk	Milk	1 glass, 257.1 g
	Corn biscuits	Other cereal	2 pieces, 14.4 g
	Plain water	Plain water	glass, 250 ml

Meal session plans is vital particularly for continuous energy supply in adolescent athlete body. It is a common practice for boarding schools to provide students six meals every day. Table 2 shows the suggested food arrangement in each meal session for the optimal diet plan for Malaysian adolescent athletes, based on the solution obtained from the modified mathematical model.

Breakfast, morning tea, lunch, evening snack, dinner, and supper are the mealtimes. Starting with breakfast, the meal in the session should be the heaviest after lunch and dinner. This is done to ensure that they have enough energy to begin their day. Morning tea and evening snack sharing the same ideal as pre-lunch and pre-dinner, respectively. The purposes of morning tea are to continue supplying nutrients and energy, as well as to prevent them from hunger before lunch. Heavy meal should not be served during this session. Protein and fats should be avoided as they take more time to be processed in the body. Lunch and dinner are the heaviest meal and usually comprises of rice and protein dishes, vegetables, fruit and beverages. It is important for adolescent athlete to have the intake of milk during supper because it can promote bone development while they are sleeping. This can be achieved when positive nitrogen balance is fulfilled.

These results were compared to the study by Ali *et al.* (2017) as they formulated a diet plan model for Malaysian normal adolescents. In contrast, the optimum value for macronutrients (energy, protein, fat, and carbohydrate) in the diet plan in this study is greater. This suggests that adolescent athletes require higher number of macronutrients as compared to the normal adolescents. Beside this, the amount of calcium, iron and vitamin B2 follow the same trend with their findings. In addition to this, they obtained a higher optimum value for some nutrients such as vitamin C, vitamin B1, niacin and vitamin A. However, as these nutrients are categorized as micronutrients, thus, the optimum value obtained in this study is considered acceptable as it can offer sufficient nutrients for adolescent athletes.

CONCLUSION

This paper has presented a modified integer goal programming model that able to produce a daily meal menu for Malaysian adolescent athletes. The menu contains a combination of food items that best satisfy the nutritional requirement for the athletes. The computational experiment has produced a solution containing 30 servings a day with optimum value of 115.8 grams of protein and 69.99 grams of fat. The optimum diet plan can be regarded as guidelines for sport schools to prepare nutritious diet meals for adolescent athletes. Further research could focus on a study on minimizing the cost of adolescent athlete diet plan. This is believed to be a good guidance for sport school or even secondary boarding school in planning the best cost-efficient diet plan. Future research may also utilize more powerful optimization approach to solve the mathematical model, such as metaheuristics method.

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