DEVELOPMENT OF FOOD-BASED RECOMMENDATIONS FOR FILIPINO SCHOOLCHILDREN USING LINEAR PROGRAMMING

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Abstract. The study aimed to identify problem nutrients and formulate food-based recommendations (FBRs) for Filipino schoolchildren 6-9 years of age attending an elementary school in Labuin, Pila, Laguna, Philippines. A cross-sectional study design was conducted among 100 randomly selected children. A 24-hour food recall, food weighing and food record were used to collect data on their food and nutrient intake. The problem nutrients were identified using a linear programming software and FBRs were formulated based on their current dietary patterns and habits. The findings showed that calcium was an absolute problem nutrient among schoolchildren, while vitamin C was a partial problem nutrient. Moreover, <65% of the recommended nutrient intakes for folate, riboflavin, and vitamins A and B12 could only be achieved in the worst-case scenario. The set of FBRs that could best achieve this consisted of seven servings of egg, five servings of fortified milk, and three servings of dark green leafy vegetables per week. However, while this set of FBRs could prevent possible dietary inadequacy, calcium and vitamin C remained problem nutrients among schoolchildren. Thus, implementation the formulated FBRs for this age group should be supplemented with other health and nutrition interventions that address these concerns.

Keywords: food-based recommendations, linear programming, nutrient gaps, Optifood, school-and-home garden project, school-based feeding program, schoolchildren

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INTRODUCTION

Schoolchildren need proper nutrition to attain optimal health, cognitive development, and educational achievement (Best *et al*, 2010). In the Philippines, there are various measures such as school-based programs, which aim to improve the health and nutrition of school-aged children (DepEd, 2011). However, the prevalence of stunting and underweight among schoolchildren remains a public health importance while the cases of obesity are steadily increasing despite the country's efforts to prevent this (DOST-FNRI, 2020). The need for innovative strategies is apparent to complement the existing programs addressing malnutrition in schoolchildren.

The London School of Hygiene and Tropical Medicine, the World Health Organization (WHO), and United States Agency for International Development (USAID) Food and Nutrition Technical Assistance Project (FANTA)/FHI 360 recently developed a linear programming tool, known as Optifood, to allows users to find the nutrient gaps in a given population. The tool can be used to develop food-based recommendations (FBRs) that takes into account the target population's dietary pattern and locally available nutrient-dense food to increase the intake of nutrients lacking in the existing diet. It also offers an option to include cost of the diet for more feasible food-based recommendations (FBRs) (Ferguson *et al*, 2006). This method has already been used in identifying problem nutrients and in the formulation of complementary feeding recommendations for Filipino children 6-23 months of age (Mejos *et al*, 2021). Other studies have also used the tool to improve cognitive function in Myanmar (Soe *et al*, 2020) and overall nutrient adequacy among schoolchildren in Kenya (Talsma *et al*, 2018).

Hence, in this study, Optifood was used to identify problem nutrients and formulate FBRs for Filipino schoolchildren 6-9 years of age in Labuin Elementary School, Pila, Laguna Philippines. The results of the study can be used as a pilot model of FBRs for schoolchildren and provide insights and recommendations to strengthen existing school-based health and nutrition programs helping to address malnutrition of children in this age group in the country.

MATERIALS AND METHODS

Study design

A cross-sectional survey was employed to determine the nutrient gaps in the diet of 6-9 years old children attending Labuin Elementary School in Pila, Laguna, Philippines during 2018.

Study setting

The school was selected as it is one of the recipients of the School-Plus-Home Gardens Project (S+HGP), a collaborative project among the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), the University of the Philippines Los Baños (UPLB) and the Department of Education (DepEd) of Laguna district, Philippines. The school was also implementing the School-Based Feeding Program (SBFP), the country's national school feeding program that aims to address undernutrition among public schoolchildren as per DepEd Order 039, series of 2017 (DepEd, 2017).

Study participants

A total of 100 randomly selected from 350 schoolchildren 6-9 years of age attending Labuin Elementary School were included in the study.

The study was conducted following the ethical standards in the Helsinki Declaration of 1975. Prior to data collection, the school administration, teachers, students, and their parents were informed about the objectives of the study. Participation was voluntary and the participants were free to withdraw at any time without any consequences. Prior signed informed consent by the parent/guardian was obtained for each child participant. Verbal assent was obtained from children ages 7-9 years old while no formal assent was required for children under 7 years old, provided there is no indication of dissention, in accordance with the National Ethical Guidelines for Health and Health-Related Research (PHREB, 2017).

Data collection

A three-day data collection was conducted by the trained personnel (*ie*, Barangay Nutrition Scholars and Barangay Health Workers) to gather quantitative dietary data of the schoolchildren. On the first day, a food recall was carried out by an interviewer to determine food intake of the pupil during the previous 24 hours; on the second day a 12-hour food weighing was conducted; and on the third day a non-consecutive food intake was record. The interviewer used tools, such as a food recall form, food weighing form and food record form, to facilitate the collection of data. An estimated food cost was based on the actual purchase cost of the food items.

Data analysis

The children dietary intake data were analyzed using a linear programming software Optifood (version 4.0.14.0) (WHO, Geneva, Switzerland). The collected dietary data were encoded using Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA) to prepare the model parameters, namely, i) a list of food items obtained from the food recall, food weighing, and food record; ii) the average amount in grams consumed by the pupils based on the median intake per day; iii) food groups and sub-groups based on the food grouping used in Optifood; iv) weekly food intake frequencies defined as a minimum (5th percentile), 50th percentile and maximum (95th percentile); and v) food cost.

Optifood Modules I, II, and III were used for the linear programming analysis. Module I checks the model parameters and examines the diet to ensure that the generated modeled diet can be realistically consumed by the target population. Module II generates the two best diets that were close to meeting the recommended nutrient intakes (RNIs) of the target population with and without taking into account the dietary patterns (FANTA, 2013). This module was also used to identify problem nutrients and food sources of problem nutrients to help identify strategies for improve dietary intake. Problem nutrients are nutrients that are difficult to meet the requirements owing to local food supply and existing dietary patterns. Module III tests the draft of FBRs and compares among alternative FBRs drafts by taking into consideration the current practices and nutrient needs. Prior to testing the FBRs draft, a base diet was generated for the target group, producing a list of "absolute" and "partial" problem nutrients. A set of analyses produced a best-case scenario of nutrients levels, the nutrient's highest achievable level (≥100% RNI) in any diet. These were also used to define the absolute and partial problem nutrients (FANTA, 2013). An absolute problem nutrient is defined as a nutrient whose best-case scenario level is <100% RNI, thus unable be meet the required RNI using local foods and local food patterns. Partial problem nutrient is defined when the best-case scenario level is ≥100% RNI but whose level in Module II best diet is below the RNI. The remaining set of analyses generated the worst-case scenario nutrient levels of each nutrient at the lowest possible level (≤65% RNI) in any diet (Gusnedi *et al*, 2019).

The dietary intake of pupils was converted into weight (gram) using the Food Exchange List (DOST-FNRI, 1994). The Philippine Food Composition Table was used to translate food portions into nutrient intake (DOST-FNRI, 1997). For commercial or processed food products, data on nutrient composition was obtained from the packaging and encoded in the database. Folate, zinc and vitamins B6 and B12 nutrient values were adopted from the USDA food and nutrient database (USDA, 2019). These values were determined by adjusting for the water content based on the Philippine data. Using 6-9 years old female children as nutritional constraints, the Philippine Dietary Reference Intakes recommended energy intake (REI) and RNIs as follows: 29 g protein, 700 mg calcium, 45 mg vitamin C, 0.7 mg thiamin, 0.7 mg riboflavin, 9 mg niacin or niacin equivalents (NE), 0.8 mg vitamin B6, 300 µg folate or dietary folate equivalents (DFE), 1.5 µg vitamin B12, 400 µg vitamin A or retinol equivalents (RE), 9 mg iron, and 5 mg zinc. Fat intake was set at 20% of energy intake based on computed energy levels, keeping within the range of 15-30 % of energy from fat based on the acceptable macronutrient distribution range for children of 3-18 years of age (DOST-FNRI, 2015b). Iron bioavailability was assumed at 5% and a low bioavailability was specified for zinc.

RESULTS

Given the data on the dietary intake of the schoolchildren and their RNIs, Optifood analysis confirmed that the model can generate realistic diets in Module I. No further changes were made to model parameters in making the diet realistic. In Module II, the best diet was identified by running two sets of optimized diets: one that took into account the dietary or food patterns based on dietary habits and practices of the schoolchildren, while the other deviated from their average food patterns but remained to be within the normal range. Higher servings per week were generated for no food pattern in almost all the food groups except for savory snacks, meat, fish, egg, and snack, which remained the same, and lower servings were observed for grain and grain products and added fats in the no-food pattern. Table 1 shows the comparison of these two diets based on the number of servings of each food group per week.

The nutrient adequacy of the modeled diets was also assessed in Modules II of the Optifood analysis. The analysis showed that the diet that takes into account existing dietary pattern of the schoolchildren had <100% RNI for calcium and vitamin C, whereas only calcium had not achieved ≥100% RNI in the diet that did not take into account their dietary pattern (Table 2). Hence, the best diet for schoolchildren was the one that does not take into account their existing dietary patterns. The high percent RNI of certain nutrients in an optimized diet with no food pattern might be attributed to higher servings of food groups since this diet was not restricted to the average food patterns as shown above.

The best diet identified in Module II was then tested in the best and worst-case scenarios in Module III of the Optifood analysis. The best-case scenario were diets generated with maximized nutrient contents or diets that exceed their RNI (≥100% RNI). The worst-case scenarios were a diet with minimal nutrient contents or a diet at the lowest possible level (≤65% RNI). Based on the generated best and worst-case scenario diets, calcium was identified as a nutrient with absolute problem among the schoolchildren, with a best-case scenario level <100% RNI, while vitamin C was identified as a nutrient with a partial problem, with ≥100% RNI but levels in Module II best diets were <RNI. Moreover, results also revealed that <65% of the RNIs for folate, riboflavin, and vitamins A and B12 were found in the worst-case scenarios, indicating a possible dietary inadequacy among the schoolchildren for these nutrients.

Table 1

Comparison of the food patterns (serving/week) in the two optimized diets of 6 to 9 years old children with food pattern and with no food pattern goal

Food group	Food pattern (serving/week)	No food pattern (serving/week)
Vegetable	10.0	25.0
Miscellaneous	24.0	38.0
Dairy product	2.0	9.0
Added sugar	1.0	5.0
Beverage (non-dairy or blended dairy)	5.0	9.0
Sweetened snack and dessert	1.0	4.1
Staple	21.0	22.7
Starchy root and other starchy plant food	1.0	2.4
Composite (mixed food group)	0.1	1.3
Legume, nut and seed	0.1	1.3
Bakery and breakfast cereal	7.0	7.7
Fruit	0.1	0.3
Savory snack	0.1	0.1
Meat, fish and egg	27.0	27.0
Snack	21.0	21.0
Grain and grain product	21.0	20.1
Added fat	16.0	14.7

Table 2

Optifood analysis of the dietary intake of the schoolchildren in Labuin Elementary School, Pila, Laguna, Philippines

Analysis (Module)	Percent recommended nutrient intake (RNI) per day based on the recommended nutrient intake of female children 6-9 years of age												
	Protein g/day	Fat %/day	Vitamin A μg RE/day	Vitamin C mg/day	Thiamin mg/day	Riboflavin mg/day	Niacin mg NE/day	Vitamin B6 mg/day	Folate μg DFE/day	Vitamin B12 μg/day	Calcium mg/day	Iron mg/day	Zinc mg/day
Module II													
Optimized diet with food pattern	233.7	145.8	102.3	33.8	212.4	144.7	205.6	143.8	100	201.5	37	145.1	217.9
Optimized diet with no food pattern	241.4	104.2	219.1	100	214.2	273.4	525.2	196.9	104.6	251.4	83.6	141.3	164.6
Module III													
Best case	308.7	175.6	269.5	115.7	274.6	308.9	589.4	251.9	126.3	446	87.6	216.2	266.2
Worst case	128.5	72.8	4.7	0.2	109.7	63.4	114.9	76.2	64.4	27.8	10.2	83.9	93.2
Egg*	129.1	72.8	24.4	0.2	109.7	88.8	114.9	78.3	72	56.5	13.7	88.4	94.8
Fortified milk†	134.5	72.8	40.6	3.6	114.4	105.8	114.9	76.4	66.2	91.6	49.9	83.9	98.8
Egg*, fortified milk†	139.1	72.8	61.2	3.6	114.4	131.7	114.9	79.1	73.6	121.8	53.4	88.4	101

Table 2 (cont)

Analysis (Module)	Percent recommended nutrient intake (RNI) per day based on the recommended nutrient intake of female children 6-9 years of age												
	Protein g/day	Fat %/day	Vitamin A µg RE/day	Vitamin C mg/day	Thiamin mg/day	Riboflavin mg/day	Niacin mg NE/day	Vitamin B6 mg/day	Folate µg DFE/day	Vitamin B12 µg/day	Calcium mg/day	Iron mg/day	Zinc mg/day
SFWB[‡]	130.3	72.8	4.7	0.2	109.7	63.4	118.2	76.2	64.4	40.3	10.2	83.9	93.2
DGLV[§]	128.7	72.8	28.9	3.4	110.1	64	115.2	77.1	65.2	27.8	10.7	84.6	93.2
Egg*, fortified milk[†], SFWB[‡]	143.6	72.8	61.2	3.6	114.4	131.7	118.2	79.2	73.7	134.8	53.5	88.4	101
Egg*, fortified milk[†], DGLV[§]	139.3	72.8	85.5	6.8	114.9	132.4	115.2	80	74.5	121.8	54	89	101
SFWB[‡], DGLV[§]	130.5	72.8	28.9	3.4	110.1	64	118.5	77.1	65.3	40.3	10.8	84.6	93.2
Egg*, fortified milk[†], SFWB[‡], DGLV[§]	143.9	72.8	85.5	6.8	114.9	132.4	118.5	80.1	74.6	134.8	54.1	89	101

*Seven servings of eggs per week; [†]Five servings of fortified milk per week; [‡]SFWB: Small fish with bones at three servings per week; [§]DGLV: Dark green leafy vegetables at three servings per week

In order to formulate FBRs, food items, namely, eggs, fortified milk, small fish with bones, and dark green leafy vegetables, with the greatest possible contribution to the nutrient intake of the schoolchildren, especially those contributing to the identified problem nutrients, were selected and modeled individually or in combination to produce different sets of FBRs. A total of nine alternative sets of FBRs were tested. The set of FBRs that could best achieve the RNIs for the identified problem nutrients among schoolchildren was selected as the final set of FBRs. The final FBR set identified consisted of seven servings of eggs, five servings of fortified milk and three servings of dark green leafy vegetables per week. Compared to the worst-case scenario nutrient levels, the final set of FBRs was able to improve the percent RNIs of all modeled nutrients, except for fat that remained at 72.8%. Nevertheless, this set of FBRs was able to achieve ≥65% of the RNIs of the schoolchildren for all modeled nutrients, except for calcium (54.0%) and vitamin C (6.8%). Vitamin C was still low because the FBRs were based on what the children were consuming in the previous seven days. Even after several trials and errors with different food groups, vitamin C intake remained the same. The nutrient adequacy of the modeled best and worst-case scenario diets and the nine alternative sets of FBRs in Modules III of the Optifood analysis are summarized in Table 2.

DISCUSSION

The findings showed that the best diet for schoolchildren was a diet that did not conform to any existing dietary patterns. A similar study also showed that the best diet that meets the higher nutrient requirements in pregnant and lactating women has no similarity with existing dietary pattern (Wessels *et al*, 2019). In the case of the dietary pattern of schoolchildren, the reason was that their food consumption data were based only on locally available food. The best diet offered more food sources of essential nutrients, thus providing higher nutrient adequacy. Using the Optifood analysis protocol, results showed that optimizing the diet of the schoolchildren based on the best set of FBRs identified by the Optifood analysis would prevent, in the worst-case scenario, possible dietary inadequacy for folate, riboflavin, and vitamins A and B12.

However, it also revealed that even with consumption of this diet, schoolchildren would still have problems with inadequate intake of calcium and vitamin C. In general, there is a high prevalence of inadequate calcium and vitamin C intake among Filipino schoolchildren, particularly the poor and those living in rural areas, which may be attributed to changes in the trends of food consumption habits (Angeles-Agdeppa *et al*, 2019). Children who started consuming more fats and sweetened beverages, with fewer intake of fruits and vegetables, can result in nutrient inadequacy (DOST-FNRI, 2015a; Pedro *et al*, 2006). Furthermore, inadequate access to nutrient-rich food, limited availability of food variety and low income are also contributing factors to children in the 6-9 years of age group not meeting their nutrient needs, particularly in rural areas (James *et al*, 1997; Briones *et al*, 2017; Global Panel, 2017).

Inadequate calcium intake during the age group could compromise optimal bone mass development and increase their risk of osteoporotic fracture in later life (Zhu and Prince, 2012). Vitamin C plays a complementary role in growth and development and promotes a healthy immune system among children (Maggini *et al*, 2010). It is also needed in a myriad of other body functions, and thus a deficiency in its intake could present a range of consequences such as depressed mood, clinical symptom of scurvy and even death if left untreated (Carr and Rowe, 2020).

Due to the importance of these nutrients, several strategies have been developed and proven to be able to bridge the gaps in calcium and vitamin C intakes of schoolchildren. One of those is the supplementation of multiple micronutrient-fortified drinks, which are efficacious in improving micronutrient status in schoolchildren, including that of vitamin C (Thankachan *et al*, 2013). There was also an effort to increase the vitamin C content of plant-based foods that are major sources of nutrients for a specific population to maximize dietary intake (Gallie, 2013). In addition, studies have shown that behavioral modification and nutritional education intervention involving family members can successfully increase the calcium intake of children (Hovell *et al*, 2009; Weber *et al*, 2017). Furthermore, in the review of Nguyen (2021) on school-based nutrition interventions, it was concluded that school milk programs significantly increase calcium intake and thus can be effective in promoting and improving bone health in schoolchildren.

The use of Optifood has also been used to develop FBRs for schoolchildren. Similar to the findings of the present study, Soe *et al* (2020) showed that ≥65% of RNIs for schoolchildren for various micronutrients still may not be achieved even with an optimized diet based on the best set of FBRs. Hence, it is suggested that the optimized FBRs be supplemented alongside other various nutrition promotion programs. Thus, the formulated FBRs in this study should be recommended in conjunction with other nutrition and health interventions that aim to increase calcium and vitamin C intake of schoolchildren.

To the best of our knowledge, this study is the first to use linear programming techniques in formulating FBRs in optimizing the diet of schoolchildren in the country by identifying and addressing the problem nutrients in the current diet by taking into consideration locally available nutrient-dense food in the locality and dietary patterns. The results of this study can be used by policy and decision-makers in streamlining the existing health and nutrition interventions for schoolchildren, such as school-based gardening and feeding programs, and the overall food systems to be more nutrition-sensitive by making the food supply chain and food environment sensitive to the nutritional needs of the consumers, particularly the needs of those in the age groups with high nutritional risks. Moreover, food science researchers can also build upon the findings of this study to develop food products to be used to complement the optimized FBRs for schoolchildren

In conclusion, our findings showed that calcium was an absolute and vitamin C a partial problem nutrient among schoolchildren 6-9 years of age in Labuin Elementary School, Pila, Laguna, Philippines. Using Optifood, a set of FBRs that could best achieve the schoolchildren's RNIs for these nutrients was identified as consisting of seven servings of eggs, five servings of fortified milk, and three servings of dark green leafy vegetables per week. Nevertheless, the study showed that calcium and vitamin C remained problem nutrients even with the consumption of an optimized diet. Hence, upon implementation of the formulated FBRs recommended for schoolchildren in this age group, it should be complemented with other strategies and interventions to address these concerns.

ACKNOWLEDGEMENTS

The authors would like to thank the school administrators, teachers, and students for their kind cooperation. The study was funded by SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA).

CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

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