

Research Application Summary

Development of food based dietary guidelines for rural Kenyan women using linear programming

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Abstract

Developing countries women (of child bearing age) are vulnerable to micronutrient deficiencies which can have major adverse health consequences. The aim of this study was to improve dietary quality of women of childbearing age in rural Kenya using linear programming (Optifood) LP. The study was conducted in 2008 (March/ April) at Mbooni division, Makueni district, Kenya. A total of 210 women of child bearing age (15-49 years), with children 2-5 years old were recruited for the study. Data were collected to formulate FBR was generated, composed and evaluated using a four based approach of LP. Mbooni women do not have sufficient fat, calcium, folate and iron in their local diets to achieve nutrient requirements. Sukuma wiki and cowpea leaves (vitamin A dark green leafy vegetables), maize flour cooked (starchy staple), milk cow (dairy products), avocado (and other fruits) and added fat would improve the diets nutrient levels (worst-case scenario nutrient levels) in existing food pattern. The LP was successfully used to generate and formulate food based recommendation for rural women of Kenya, who have limited food choices. Limited nutrient, were identified needing food based approaches for diets to reach required nutrient levels.

Key words: Child bearing women, dietary quality, Kenya, micro nutrient deficiency, optifood, women

Résumé

Les femmes en âge de procréation des pays en voie de développement sont vulnérables aux carences en micronutriments qui peuvent avoir des conséquences néfastes majeures sur la santé. La présente étude vise à se servir de la programmation linéaire (Optifood) LP pour améliorer l'état nutritionnel des femmes en âge de procréation dans les zones rurales du Kenya. L'étude a été conduite en Mars-Avril 2008, à Mbooni dans le district de Makueni au Kenya. Au total 210 femmes en âge de procréation (15 à 49 ans), avec des enfants âgés de 2 à 5 ans, ont été recrutées pour l'étude. Des données ont été collectées pour générer, composer et évaluer des recommandations alimentaires (FBR) en utilisant une approche à quatre bases de LP. Les femmes de Mbooni n'ont pas suffisamment de matières grasses, de calcium, de folate et de fer dans leur alimentation locale pour répondre aux besoins en nutriments. Les feuilles de sukuma wiki et de niébé (légumes à feuilles vert foncé riche en Vitamine A), la pâte de maïs (féculents de base), le lait de vache (produits laitiers), l'avocat (et autres fruits) et autres matières grasses serviraient à améliorer les contenus nutritionnels de l'alimentation (pire niveaux nutritionnels) dans le modèle alimentaire existant. Le LP a été utilisé avec succès pour générer et formuler des recommandations alimentaires à l'endroit des femmes rurales du Kenya qui

ont des choix alimentaires limités. Peu de nutriments se sont révélés nécessitant la mise en oeuvre d'approches basées sur l'alimentation pour que les régimes alimentaires fournissent les niveaux de nutriments requis.

Mots clés: Femmes enceintes, qualité de l'alimentation, Kenya, carence en micronutriments, optifood, femmes

Introduction

Studies show that women of child bearing age are especially vulnerable to micronutrient deficiencies (Bartley *et al.*, 2005; Arimond *et al.*, 2007; Acham *et al.*, 2011). In developing countries women's diets are nutrient poor with low dietary diversity (Black, 2000). Womens' diets consist of: starchy staples, devoid of flesh foods hence not meeting women's dietary requirements (Briend *et al.*, 2003). Public health strategies have improved quality of womens' diet in developing countries. The World Health Organization (WHO) and Food and Agriculture Organization (FAO) recommend that successful approach should be sustainable and focus on the diet as a whole. Emphasis should be on local foods complemented by alternative intervention strategies such as fortification, dietary diversification and modification (Bartley *et al.*, 2005). Improvement of dietary quality in developing countries would benefit from Linear Programming (LP) analysis. Linear Programming uses mathematical optimization to produce optimal set of food-based recommendations (FBR) for a specific target population. Linear Programming makes use of the most of local foods: their nutrient density, availability and price to produce a combination of nutrient-dense foods closely achieving the desired nutrient levels. Linear Programming has successfully been used to identify best combination of local foods making diets adequate.

Inadequate diets lead to major adverse health consequence: impaired immune systems and poor reproductive outcomes (Bartley *et al.*, 2005; Arimond *et al.*, 2007; Acham *et al.*, 2011). In developing countries women's diets are nutrient poor and low in dietary diversity (Black, 2000). Womens' diets consist of: starchy staples, devoid of flesh foods hence not meeting women's dietary requirements (Briend *et al.*, 2003). Public health strategies have aimed at improving quality of womens' diet in developing countries. The WHO and FAO recommend that successful approach should be sustainable and focus on the diet as a whole. Emphasis should be on local foods complemented by alternative intervention strategies such as fortification, dietary diversification and modification (Bartley *et al.*, 2005). Improvement of dietary quality in developing countries, would benefit from linear programming analysis. Linear Programming uses mathematical optimization to produce optimal set of food-based recommendations (FBR) for a specific target population. Linear Programming makes the most of local foods: their nutrient density, availability and price to produce a combination of nutrient-dense foods producing desired nutrient levels. Linear Programming has successfully been used to identify best combination of local foods making diets adequate for breastfeeding children in Malawi, Indonesia and France. This study focuses on improvement of poor dietary quality of the women of childbearing age in rural Kenya. Linear Programming (namely software Optifood) was used to formulate context specific food based recommendations (FBR).

Methodology

Study population and setting. The study was conducted in 2008 (March/ April) at Mbooni division, Makueni district in Kenya. A total of 210 women of child bearing age (15-49 years), with children 2-5

years old were recruited. The study site, sample size and sampling procedures of the survey calculation, and inclusion criteria has been described in details elsewhere (Daniels, 2009). Anthropometric data were obtained by taking the weight and height measurements using standard procedures (Darmon *et al.*, 2006). Weight measurements were taken twice using a digital bathroom scale (Seca scale, gmbh & co. Kg) to the nearest 0.1 kg. Height was measured twice using a stadiometer (Seca 206CM Bodymeter, 0-220 centimeters) to the nearest 0.1 cm.

Dietary data and Linear Programing (LP). Food based recommendations (FBR) were generated, composed and evaluated using a four based approach of LP (Darton-Hill *et al.*, 2005). The computer program: i) dietary data from three non-consecutive 24 hour recall (24 hr), ii) a list 63 food items where 30 of the foods were consumed by 10% of the women, iii) average portion size, and vi) frequency of food consumption per week. The consumption pattern of the women was classified in three categories: low, average and high level. The Linear Programing categoried food consumed as staple or snack. Anthropometric data estimated included average body weight and average energy requirements of women using LP, Optifood (FAO/WHO nutrient requirements). Physical activity level [PAL] of the women was 1.55 (Rambeloson *et al.*, 2005). Most women were house-wives (24%) and subsistence farmers with 1 ha land (58.3%) (Nishida *et al.*, 2004).

The food groups categories were: all starchy staples, legumes and nuts, milk and milk products, dark green leafy vegetables, vitamin A-rich fruits, vitamin A-rich vegetables and tubers, flesh meat, eggs, organ meat, small fish eaten whole with bones, white root and tubers, other vegetables and other fruits being key nutrient suppliers for women's health (Mwadime *et al.*, 1995). Nutrient intake calculations were based on food composition table developed for the study (Nishida *et al.*, 2004). Microsoft Excel form VBS software version was used to calculate energy of nutrients 4 (Briend *et al.*, 2003). Vitamin C was included as it enhances absorption of non-heam iron. Ms Access program calculated daily portion sizes, % of women consuming various foods and estimated weekly serving of food group and sub-food group.

This study was implemented in phases. Phase I, determined whether womens' dietary pattern reached desired nutrient levels, based on 30 foods consumed. In Phase II the draft sets of FBR were evaluated for nutritionally adequate diet comparing the nutrient intakes to dietary reference values using a series of LP models (except model constraints 9) (FAO/WHO, 2002). It involved minimizing (worst case scenario) and maximizing (best case scenario) for selected nutrient levels (Ferguson *et al.*, 2008). Key problem nutrients were identified for two achievements: i) nutrients in the best case scenario analysis did not achieve 100% of the Recommended Nutrient Intakes (RNI) levels, and ii) potential problem nutrients in the worst-case scenario analysis not achieving 70% of the desired nutrient level (RNI). Phase III model was a modification of the original model described in phase I (Darton-Hill *et al.*, 2005): It aimed at identifying a combination of foods when combined into dietary pattern provides the amounts of selected nutrients meeting RNI levels. Food-based approach in phase III wre not designed to meet average daily energy need, rather to show the set of foods and the frequency of consumption of local foods reaching RNI levels (disregarding availability and cost). In Phase IV, a set of FBR developed in phase II were analyzed to develop alternative sets of FBR. Alternative sets of FBR enables comparison on the basis of nutrient levels (meeting RNI), palatability, acceptability, balance of food groups and affordability in order to select a final set of FBR (Darton-Hill *et al.*, 2005).

Food groups categories used for Linear Programing wre standard and documented (Daniels, 2009). Microsoft Excel form VBS software version 4 (Briend *et al.*, 2003) was used to provide energy values

for all nutrients key for women's health (Ferguson *et al.*, 2006). Ms Acces program was used to calculate daily portion size of each food, number and percentage of women consuming the foods and estimate weekly serving of food group and sub-food group.

Results

Background characteristics. Average age of the women was 35.9 ± 9.0 years old (range 20-49). About 82% were married and 63% had primary education. Women subsistence farmers were 58%. Womens' mean weight and height were 56.6 ± 8.4 kg and 157.4 ± 6.2 cm respectively. Mean Body Mass Index (BMI) was 22.90 ± 3.70 kg/m² with 9.70% of the women at <18.5 kg/m² and 12.90% were >25 kg/m². The mean daily energy intake of the women was 1571 (CI 1558-1585) kcal.

Foods groups consumed by more than 10% of women of child bearing age in Mbooni district Kenya. Food groups, consumed by $>10\%$ of the women: six were grains and grain products, 3 legumes, 2 fruits, 3 starchy roots and other plant foods, 8 vegetables, 3 added fats (cooking fats), 2 added sugars, only one person consumed dairy product and miscellaneous foods. The most common foods consumed (70% of women) were maize flour, maize grains, cow's milk, sugars, dry red beans, sukuma wiki and cow pea leaves. Less consumed foods ($<10\%$ of women), were: food-sub-groups unfortified vegetable oils ('added fats'), eggs (0.5%), poultry (chicken 2.4%), red meat (beef 9.3%), ('meat, fish and eggs'); vitamin A and C rich fruits and condiments (herbs, spices and other miscellaneous foods). No fish or fortified foods were consumed in the study area.

For the 30 foods consumed, the serving size (daily, not per meal) of 18 (60%) foods were <100 grams per day and the serving size of 7 (23%) foods were between 100-200 g/day and 5 (17%) foods were consumed in portion sizes >200 g/day. Maize flour, maize grains, sukuma wiki, cabbage and sweet potatoes were consumed in large amounts, i.e., >200 grams per day. The serving sizes for protein rich foods (legumes, seeds and nuts) were 50 to 62 g/day.

Draft food-based recommendations. The nutrient content and food groups of the optimized diet was expressed as a percentage of the desired levels (Ferguson *et al.*, 2008). Four nutrients: fat (47.8%), calcium (52.5%), folate (48.7%) and iron (33.2%) were low in the womens' diet, below 70% of desired levels. The frequency of consumption of food groups were: staples 3 times/day (23 times/week), vegetable (18 times/week) and grains and grains product (16 times/week) 2 times/week while added sugar and snacks everyday of the week. Dairy products, added fat, miscellaneous 4 foods and legumes, nuts and seeds were consumed, five days/week. Fruits and Starchy roots (other starchy plant foods) were consumed twice a week.

Foods eaten everyday of the week. Sukuma wiki (kale), cow pea leaves, maize flour white, maize grains dry white and brown sugar were eaten daily. Three foods were eaten five times/week namely cows milk, beans dry red and tea leaves (milk and tea leaves to make tea). Foods consumed twice/week were cassava, rice white, onion, avocado fruit, pumpkin leaves and Fat (kimbo brand). Fat (mallo variety) was used on average 3.3 times/week. Cabbage was consumed less than ones a week.

Evaluating the women's diet with food-based approaches. Draft food-based recommendations (FBRs) were based on worst and best case scenario of the nutrients of interest in the womens diet. In phase III, identification of nutrient-dense local foods that provide key and potential problem nutrients were undertaken. Women of Mbooni did not have sufficient fat, calcium, folate and iron in their local foods (the worst case scenario levels for less than 70%). Results indicated best-case scenario levels were below 70% of recommendation (Table 1).

Sukuma wiki and cowpea leaves (vitamin A dark green leafy vegetables), maize flour cooked (starchy staple), milk cow (dairy products), avocado (and other fruits) and added fat would improve the worst-case scenario nutrient levels of FBR if foods are added to existing food pattern. Absolute problem nutrients remain below 70% RNI, improvement means promoting FBR by serving the following food groups: 2 fruits/week, 3 servings of vegetables/day or 18 servings/week, 5 servings of dairy, legumes and added fat/week, 2 – 3 servings of grains/day or 16 servings/week, a snack each day of the week (7 snacks per week). For specific foods items: consumption of FBR in addition to maize flour (ugali or porridge), beans red dry, sukuma wiki (kale), milk (fresh or in tea) and fat mallo everyday of the week but beans red dry five time/week (Table 2) would be required.

Recommendation for improving the worst-case scenario %RNI. Food energy from 70.9% to 84.1%, fat from 37.8% to 42.6%, calcium from 37.2% to 54.5%, , vitamin A (RE) from 35.4% to 170.5%, vitamin A (RAE) from 12.3% to 79.1% and iron from 28.7 to 31.3% are needed. Folate levels fell from 43.5% to 40.2% (Table 1).

Table 1. The worst and the best case scenario for the draft food based recommendations (FBRs), percentage of desired amounts (%RNI)¹

	Worst-case scenario % RNI	Best-case scenario % RNI
Food Energy	70.9	105
Protein	95.8	107.7
Fat	37.8	55.6
Carbohydrate	0	0
Calcium	37.2	63.7
Vitamin C	137.3	334.6
Thiamin	385.5	571.7
Riboflavin	99.5	125.5
Niacin	97.3	112.9
Vitamin B-6	138.4	179.8
Folate	43.5	59.5
Vitamin B-12	3246.4	5081.8
<i>Vitamin A RE</i>	<i>35.4</i>	<i>223.4</i>
<i>Vitamin A RAE</i>	<i>12.3</i>	<i>105.5</i>
Iron	28.7	34.3
Zinc	79.9	96.9

¹%RNI: % desired requirement of nutrient intake is defined by the Optifood authority for the target population.

Discussion

Linear programming successfully generated food based recommendation for the women of Mbooni, Kenya using locally available foods. The partial problem nutrient was Vitamin A, its requirement met by implementation of FBR. The absolute problem nutrients, i.e., fat, calcium, iron and folate requirements could not be met by consuming the local diets. Studies found diets lacking in similar nutrients on applying Linear Programming to formulate FBR (FAO/WHO, 2002 ; Briend *et al.*, 2003; Darton-Hill *et al.*, 2005)

Table 2. Final food based recommendations of fomulated diets

Food Groups	Serves/week	Food Groups	Serves/week
Fruits	2		
Vegetables	18	Sukuma wiki	7
Dairy products	5	Cow milk	7
Added fats	5	Fat mallo	7
Grains & grain products	16	Maize flour	7
Legumes,nuts & seeds	5	Beans dry red	5
Snacks	7		

Linear Programing optimised complementary foods for breastfeeding children 6 to 11 months old and non-breastfed children 6 to 24 months old whose diets were not nutrient dense, iron being the limiting nutrient (Hunger, 2011). A study found out that fruits, vegetables, fish, refined grains, potatoes, milk and vegetable fats improved nutritional quality relative to price. Animal source foods were intermediate nutrient quality relative to price (Maillot *et al.*, 2008). In relation to Metzgar *et al.* (2011), our study did not achieve FBR from local foods simulating nutrient density of F100. The formulation needed vitamin E, riboflavin, thiamine, niacin, zinc, calcium and copper additional supplement. It should be noted that Paleolithic diets for low-income women was unaffordable (Mwadime *et al.*, 1995). Four nutrients in Mbooni division i.e., vitamin A, calcium, fats and iron are of public health concern. Lack of access to vegetables (vitamin A sources) especially sukuma wiki (kale) in the market implies vulnerability to diseases. Calcium source in womens' diet is needed from milk, vegetables (kale and cow pea leaves), beans, legumes and nuts. The diets lacked citrus fruits for enhancing calcium absorption. Legumes and nuts need specific cooking methods to lower antinutrients. Intakes of calcium below recommended levels as observed in this study leads to osteopenia, risks of osteoporosis and bone fractures (Ferguson *et al.*, 2010). Women use very little cooking fat as it is an expensive food commodity. No FBR would meet folate requirements for Mbooni women. Even Western European countries (with diverse dietary patterns), meeting iron requirement among women of reproductive age and folate in pre-conceptional period is difficult (Torheim *et al.*, 2010). Most women ate 3 times in a day, without snacking. Eating fruits would improve the vitamin and mineral components of womens' diet. In Mbooni district, FBR would be useful if combined with behaviour change communication for dietary patterns.

Consumption of animal protein was minimal. A study in Kenya showed that consumption of ugali and sugar was 90.3% and 83.3%, respectively while fish and meat consumption was only 4.2% and 6.4%, respectively (Torheim *et al.*, 2010). Yet animal source foods are usually good sources for most of the nutrient that have been found as absolute problem nutrients in our study. The final set of FBRs included 'added sugars' 7 servings/week (5.90% of total energy requirements), while high intake of sugar increases risk of chronic diseases (27,28). A South African study recommended less sugar consumption in their food-based dietary guidelines (Steyn *et al.*, 2013). In our study, 75% of the respondants consumed white and brown sugar (ranged from 20-30 g/day) and no commercial beverages containing sugar were consumed. In terms of frequency and quantity, the FBR on sugar consumption was adequate and complied with South African dietary guidelines (Steyn *et al.*, 2013). Similarly in Kenya women have very limited oral health awareness. Guideline on sugar consumption should be promoted along side oral health care. The FBR in this study are only generalizable to areas with comparable dietary habits, not all rural Kenyan women of child bearing age

Conclusion

Linear Programming was successfully used to generate and formulate food based recommendation for rural women in Kenya who have a limited range of available food choice. The Linear Programming should incorporate African based foods in their data-base to improve sensitivity for identification of nutrients needed for food based approaches in developing countries setting.

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