Diet Modelling System to inform the revision of the Food-based Dietary Guidelines For Sri Lankans

Report

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Diet Modelling for Food Based Dietary Guidelines for Sri Lankans

1. Introduction

Diet (or food) modelling is a process used to provide important information for developing Food-based Dietary Guidelines (FBDG). This process is always planned to maintain the validity of FBDGs by delivering the nutrient requirements for people from different age/gender groups with varying physical activity levels at different life stages (Buttriss et al., 2014). Reflection of the dietary patterns of different cultures and socio-economic groups and consideration of the current food consumption patterns, food supply, food availability and accessibility in the country as well as sustainability are important features in food modelling. Food modelling also helps to improve the variety for food choices while promoting health and wellbeing (Cobiac et al., 2016).

The goal of the Modelling System is to translate the Recommended Dietary Allowances (RDA) into food consumption patterns that concurrently:

1. deliver the nutrient requirements for people of varying age/gender, activity levels and life-stages
2. culturally acceptable and reflect the diets of different socio-economic groups
3. consider the current food supply and food consumption patterns in the country
4. provide some flexibility in food choice
5. promote health and wellbeing

The guiding principles for developing the Modelling System were that it should:

1. address total diet and overall health
2. be evolutionary (incremental changes), flexible and practical
3. be based on current scientific evidence
4. address total diet and overall health
5. be evolutionary (incremental changes), flexible and practical
6. be based on current scientific evidence.

It should be noted that the dietary reference values (DRVs) are set for healthy people and, as such, dietary models based on the DRVs such as those described here, are not designed to meet the needs of those with specific medical conditions.

Modelling is conducted using an iterative process to ensure optimum combinations of foods to meet all selected nutrient requirements (Buttriss et al., 2014). The component of the models was achieved through the selection of nutrient-dense lower energy choices within each composite group in proportions reflecting the most recent consumption data for the Sri Lankan population, hence also optimizing their practicality. The resultant dietary models demonstrate that while nutritional needs are met through the whole diet and not by single foods, the combination of foods is critical. The models can meet all RDAs within energy requirements for all groups, including acceptable macronutrient distribution ranges and suggested dietary targets for selected nutrients (Cobiac and Baghurst, 2011). It is important to note that these models are for healthy people and are not designed to meet the specific nutritional requirements of individuals with various diseases or conditions, pre-term infants, or people with specific genetic or disease profiles.

Formulating FBDGs is a cumbersome, time-consuming and potentially biased consultation process (FAO/WHO, 1998). A Linear Programming (LP) approach can be used to develop optimized food-based recommendations (FBRs) using locally available foods commonly consumed by the target population to meet adequacy of nutrients within affordable cost (Furguson, 2004). LP allows researchers to identify nutrients that are likely to remain low in the best diets based on locally available foods (Furguson, 2004). Optifood, is a linear programming software developed by the London School of Hygiene and Tropical Medicine in collaboration with WHO and the Food and Nutrition Technical Assistant III project (FANTA III) (Daelmans et al. 2013).

Optifood can formulate and test FBRs to help inform decisions when planning a food-based intervention. By modelling the nutritionally best diet, it shows whether locally available foods together can provide all the nutrients needed by a target population; and when it is not feasible, it identifies the nutrient gaps. As such, it informs behaviour change strategies by identifying the food patterns (e.g. the number of servings per week of vegetables) or individual foods (e.g. liver) that will best ensure a nutritious diet. It identifies micronutrients whose requirements are unlikely to be met in the available diet, indicating when programmes need to address issues related to the availability, accessibility and/or affordability of nutritious foods.

In the Phase I of the study, Optifood was used to develop and compare food-based recommendations and identify problem nutrients in modelled diets based on 24-hour recall data of adult women of Sri Lanka. We assume these problem nutrients and the formulated FBRs can be extended to the general population.

In the Phase II of the present study, modelling was conducted using an iterative process to ensure optimum combinations of foods to meet all requirements. The aspirational component of the models was achieved through the selection of nutrient-dense lower energy choices within each composite group in proportions reflecting the most recent consumption data for the Sri Lankan women population.

Aim

To determine the amounts of various food groups needed to meet the estimated requirements of individuals of different ages, genders and lifestyle, body size and activity.

Objectives

1. To determine the current dietary patterns of the population.
2. To identify specific “problem nutrients” (inadequate nutrients in the population)
3. To develop realistic food-based recommendations based on habitual diets to optimize nutrient adequacy among different age/sex groups in Sri Lanka.
4. To determine the minimum number of servings required to meet the nutrient recommendations.

2. Methodology

Dietary data: The latest food consumption data is required for the food modelling process. Since national food consumption surveys have not been conducted in Sri Lanka, food consumption data collected in a large dietary survey conducted by the Wayamba University during 2015-2017 from a representative sample of rural, urban and estate populations were considered. Original survey had collected dietary data from 3000 adult women lived in urban (Gampaha and Negombo Divisional Secretariat Divisions), rural (Anuradhapura, Pannala, Batticaloa, Matale and Mahakumbukkadawala Divisional Secretariat Divisions) and estate communities in Agalawatta and Labukale areas. Dietary intake data were collected through single 24-hour recalls. Dietary data of one thousand (1000) women randomly selected from the above database weighted for rural (74%), urban (22%) and estate (4%) sectors were used for diet modelling. We assume that these intakes can be considered as a proxy for family food consumption for different age and gender groups assuming family members of the women eat the same food proportionately to their age and gender.

Ethical Clearance

The large study conducted in several districts was approved by the Ethics Review Committee of the Faculty of Livestock, Fisheries & Nutrition, Wayamba University of Sri Lanka. Written informed consent was obtained from the women after explaining about the study.

Phase I – Identification of dietary patterns and problem nutrients using Optifood linear programming

Twenty-four-hour recall data (as described above) was used to define model parameters for Optifood per target group, with the use of MS Excel. The defined parameters were: the list of foods consumed by the target group, the minimum and maximum of food servings per week (frequencies) for the food groups, food sub-groups and foods used in Sri Lanka (based on the food composition data compiled).

Food groups and food subgroups were defined prior to the importation of data into Optifood Software. Foods were categorized into food groups that include added fats, added sugars, bakery and breakfast cereals, beverages (non-dairy or blended dairy), composites (mixed food groups such as vegetable mixed noodles), dairy products, fruits, grains and grain products, legumes nuts and seeds, meat fish and eggs, miscellaneous, savory snacks, starchy roots and other starchy plant foods, sweetened snacks and desserts, and vegetables. Within these food groups, foods were also defined into subgroups. For example, in the bakery and breakfast cereal food group, it was further defined into subgroups such as pancakes, waffles, scones, crackers; fortified sweetened bakery products; and unfortified sweetened bakery products. Food was included in LP if it is consumed by at least 5% of the respondents or was nutrient-dense.

In defining modelling parameters for Optifood, the following assumptions were made:

• ***Food groups and food sub-groups:*** The number of servings per week (frequencies) of the food groups and food sub-groups were defined with the use of percentiles derived from the intake data. The chosen percentiles correspond with the minimum, average and maximum frequencies of the food groups and food sub-groups. The 5th, 50th and 95th percentiles were used for all target groups. the median (50th percentile) of food groups was identified to use as reference food pattern in Best Diet Food Pattern (FP).

• ***Food frequencies:*** Food frequency per food item for a specific target group was estimated using the following table:

Table 1: Equivalent maximum weekly frequency of intake

% subjects who consumed the food item	Equivalent maximum weekly frequency of intake
0-5	1
6-12	2
13-22	3
23-34	4
35-47	5
48-65	6
66-100	7

Source: SEAMEO-RECFON Optifood training manual

For example, if a food item was consumed by 15% of the subjects, maximum weekly frequency of 3 was assigned for that food item. Then the maximum (95th percentile) and the minimum (5th percentile) were determined for each food item.

- ***Food serving sizes:*** To determine serving sizes for foods per target group, the median serving size was taken. The serving sizes are expressed in g/day.

- ***Food Composition Table (FCT):*** Values from various global food composition data, primarily from Indian Food composition tables, United States Department of Agriculture (USDA, 2019) and the nutritional values calculated based on recipes (Thamilini et al, 2014) were used.
- ***Recommended nutrient intake (RNI) values:*** Recommended RNI values from FAO/WHO were used for all nutrients (FAO/WHO, 2002). Thirty per cent of the recommended intake of energy derived from fat. For energy the energy equation used was: 14.818 * [Body weight in kg] + 486.6) x [Physical Activity Level]. Average body weight of adult females was taken as 55 kg. Sedentary or light physical activity level value of 1.55 was used. Accordingly, the energy requirement is 2017 kcal. Recommended grams of proteins a day was calculated using the formula: 0.83 times bodyweight for women (FAO/WHO/UNU, 1985).

Optifood

Optifood is a linear programming tool with a multifactorial approach developed by the London School of Hygiene and Tropical Medicine in partnership with WHO, the Food and Nutrition Technical Assistance Project (FANTA) III and digital solutions provider blue-infinity (Ferguson et al., 2004). Optifood is used to analyse the nutrients people obtain from their local diets and identify "problem nutrients" (those expected to remain low in diets due to existing dietary patterns and availability of food). It then permits the formulation, testing and comparison of alternative food-based recommendations (FBRs) to optimize dietary adequacy. The tool helps to inform decisions when planning a food-based intervention. Optifood models with the following 13 nutrients: protein, fat, calcium, iron, zinc, vitamins A, B1, B2, B3, B6, B12, C, and folate.

Optifood uses the following three modules to analyse alternative FBRs:

- Module I checks if model parameters are generating realistic diets.

- Module II formulates two nutritionally-best diets for the target group, the food pattern and no food pattern diet, to show whether the local diet can reach nutrient adequacy. **The food pattern diet** is the best diet close to the average food patterns of the target populations. **The no food pattern diet** is the best diet that can deviate from average food patterns whilst remaining within the upper and lower food group pattern constraint levels.

- Module III tests FBRs. The FBR that reaches adequacy for the highest number of nutrients is selected as the best FBR. Before FBRs are tested, problem nutrients are identified with the estimated nutrient intake distribution, so **minimized (worst-case scenario) and maximized (best-case scenario)** nutrient content per diet is estimated. In the worst-case scenario the least nutrient-dense foods from the list of foods are chosen, while in the best-case scenario the most nutrient-dense foods are chosen (Buttriss et al., 2014).

Problem nutrients were identified in module III before FBRs are selected. A nutrient is identified as an **absolute problem nutrient (APN)** when the best-case scenario does not reaches 100 per cent of RNI. An APN will always remain a problem nutrient because it will never reach 100 per cent of RNI even when FBRs are introduced. A nutrient is identified as a **partial problem nutrient (PPN)** when 100 per cent of RNI is reached in the best-case scenario, but 70 per cent of RNI is not reached in the worst-case scenario. The reason for selecting 70 per cent of RNI as the cut-off point is due to the assumption that this value corresponds to the estimated average requirement. When 70 per cent is reached in the worst-case scenario, it is assumed that perhaps half of the people will reach an adequate intake for this nutrient. Therefore, when including FBRs in the diet we aimed to reach 70 per cent of RNI in the worst-case scenario for as many nutrients as possible.

The selected FBR per target group is that which achieves the highest number of nutrients reaching 70 per cent of RNI in the worst-case scenario.

Linear programming analysis using Optifood

Module I of the Optifood was run to determine whether model parameters generate realistic diets. Module I tested the constraints set in the foods, food groups, and food subgroups in order to ensure that there is sufficient flexibility in food choice for modeling the diets (i.e. so that at least some individuals from the target population could consume the diets generated by the Optifood). Module II (Draft recommendations) was used to identify the 2 best diets, the problem nutrient(s) and best food groups, food subgroup, and food sources of micronutrients in the existing diets which could be promoted to increase intakes of the "problem nutrient" in Module III. "Problem nutrient" was defined as nutrients that did not meet 100% RNI in Best-diet no FP (best diet which may deviate from median food pattern of food group).

Module III (Test recommendations) was first run without specifying any foods, food subgroup, or food group to identify minimized (worst case) and maximized (best case) scenarios for each nutrient to provide a baseline diet in order to be compared to different alternative FBRs. From Modules II and III, the types of problem nutrient were identified: "absolute problem nutrient," that is, nutrient that was less than 100% RNI in best case scenario and "partial problem nutrient," that is, nutrient that met or exceeded 100% RNI in the best-case scenario, but its level in the Module II best diets was below 70% RNI. While intake of partial problem nutrient can be optimized using the nutrient-dense foods, subgroups, or groups, intake of the absolute problem nutrient will likely remain inadequate using the local foods and local food patterns. Nutrients that were not identified as problem nutrients can be either meeting "dietary adequacy" (if its worst-case scenario >70% RNI) or else as "dietary inadequacy."

Phase II: Diet modelling using an iterative process

In the Phase II of the study, diet modelling was carried out using an iterative process to ensure optimum combinations of foods to meet all requirements. Each food item recorded in 1000*24 hr recalls were categorized under a food group or subgroup with the amount consumed (in grams) by the person and then the average per person consumption was calculated.

The summary of the process of Phase 1 diet modelling is illustrated as a summary in Figure 1.

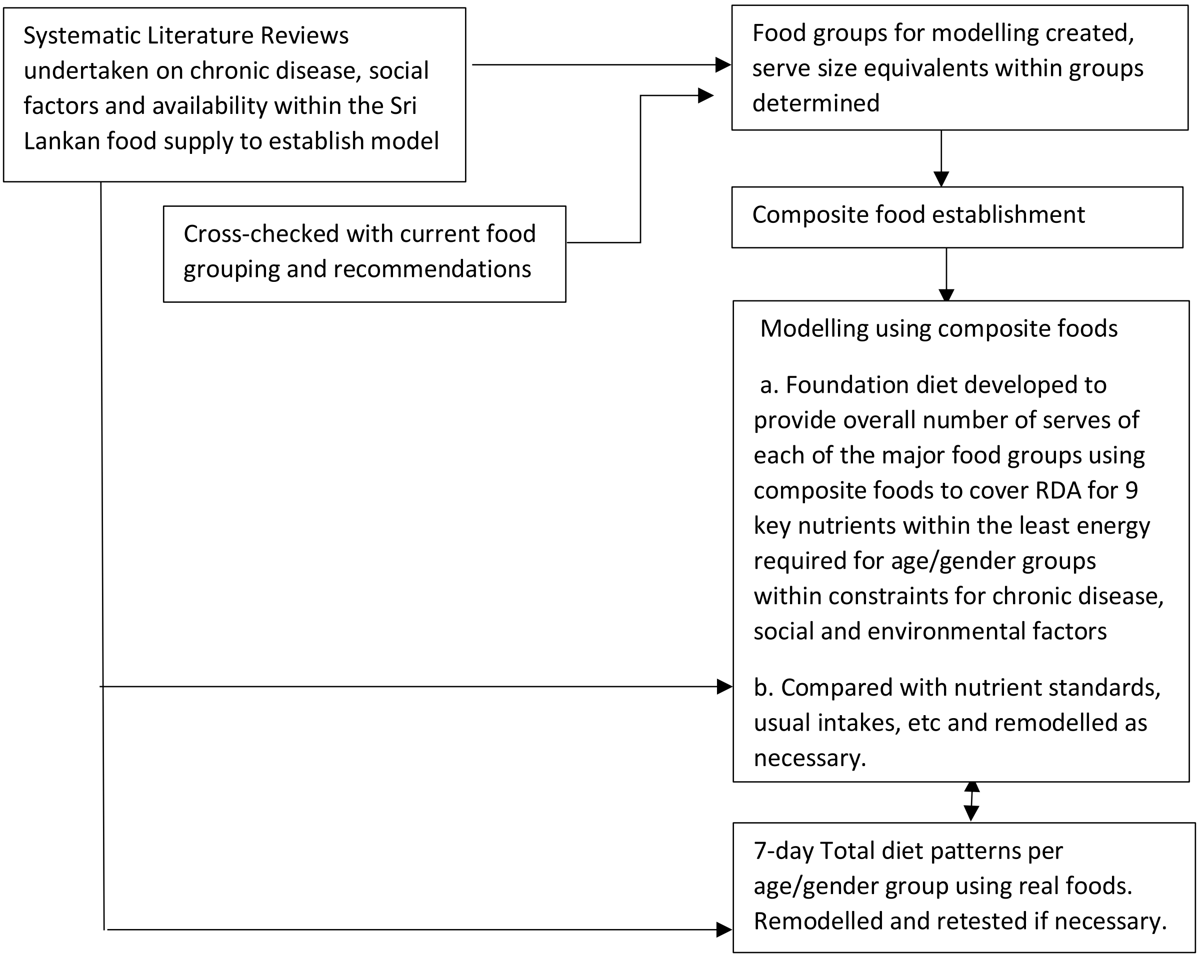

Figure 1: Outline of the methodology used to develop food intake patterns for the Foundation and Total Diet models in Phase 1

Stage 1: Development of Foundation Diet models comprised of composite food groups

The first stage used composite food groups to design culturally relevant Foundation Diets for each age/gender group that attained nutrient requirements for most people (i.e. met the Recommended Dietary Intakes, RDA). These Foundation Diets are the dietary patterns that meet the nutrient and energy requirements for the smallest and youngest, least active individuals in each age and gender group, and accounted for chronic disease, food supply, social and cultural constraints. The rationale for using RDAs (or Adequate Intake – AI) and not Estimated Average Requirements (EARs) for this initial composite food group analysis is because these models aspire to meet the nutrient requirements of most individuals within each age/gender group and it is recommended that the RDA, not EAR be used in planning diets for individuals.

Rationale for choice of nutrients to be modelled

Nutrients those for which an EAR and RDA had been established (FAO/WHO, 1995) were used for modelling. Some nutrients were excluded since intakes of these nutrients are not limiting in the Sri Lankan diet. RDA was used for planning diets for individuals ensuring that the needs of most people (97.5%) are covered by the modelled diets.

Foundation Diet

The *Foundation Diet* was informed by current scientific evidence derived from the literature, the available national food intake data and the WHO Recommended Daily Allowance (RDA). The diets were modelled to provide as close to 100% of the RDAs of 9 key nutrients as was feasible and to provide the estimated energy requirements of the smallest and very sedentary category (PAL 1.4) for each age and gender group. These *Foundation Diets* based on low energy requirements were then tested using several 7-day simulations with the aim that all of the simulations would meet the EARs of the 9 key nutrients.

Nine (9) nutrients and the Estimated Energy Requirements (EER) for the adults or children and most sedentary (Physical Activity Level (PAL) of 1.4) category in each age and gender group included as drivers in the model for the composite food group modelling.

As an initial step in the process of developing potential new food intake patterns, appropriate energy levels as recommended by WHO/FAO based on gender, age, height, weight, and physical activity level were used (FAO/WHO/UNU, 2001). It was targeted to contain median energy content of simulated diets at or below the median sedentary Estimated Energy Requirements (EERs). These EERs were calculated for each age and sex based on median height, weight derived from the median of normal BMI (WHO, 2007), and using a sedentary level of activity (PAL 1.4). A sedentary level of activity is considered most appropriate so that there was no overestimation of requirements.

Nutrients used in food modelling were:

Protein, Thiamine, Vitamin A as retinol equivalents, Vitamin C, Folate as Dietary Folate equivalents, Calcium, Iron, Magnesium and Zinc, along with Energy.

Four (4) main steps followed in developing foundation diets are described below.

Step 1: Identification of food groups, subgroups and additional subcategories.

The nature of the composite food groups (which foods comprised each group and the serve sizes for each of the individual foods) was determined after considering a wide range of potential food groups. The grouping of foods took into consideration botanical, culinary and nutrient composition of the individual foods with serve size for individual foods within a group determined on the basis of energy density and the nutrient density of key nutrients for that food group. The profiles of the composite food groups were based on the types and proportions of foods consumed by the adult women according to 1000 x 24-hour recalls considered. Because availability, accessibility, and affordability were implied by consideration of actual food consumption patterns, this dealt with issues of access for diverse groups in the construction of the models. Within each group, nutrient compositions for modelling purposes were calculated using 'healthier' nutrient dense options (i.e. lower fat and lower sodium options were selected for the modelling). Thus, items in the food database which were prepared in a high fat, high salt or high sugar fashion were included for their relative contribution in terms of weights consumed but items from the main food groups that were relatively high in energy density and high in fat, salt or added sugar or specially formulated foods (eg. Fried rice), were not included to develop nutrient compositions.

Major food groups considered were;

- cereals and starchy roots
- fruit
- vegetables
- legumes and pulses
- milk and dairy products
- meat, fish, poultry, eggs
- nuts and oil seeds

In addition, vegetable group was divided into sub groups as dark green leafy vegetables, orange vegetables and starchy vegetables and other vegetables. To ensure diet models are realistic and practical, an allowance of coconut oil, milk and scraped coconut, unsaturated spreads and oils were included in the modelling (with amount varied for age and gender) to reflect current culinary behaviour, and to ensure that the energy from these common foods provided is considered within the energy constraints of the Foundation Diets. 'Discretionary Choices' category comprised of those foods which were not included in any of the food groups described above. The foods in this category are generally higher in energy density, fat and/or added sugars or alcohol with limited additional nutrient value. This category includes foods and drinks such as cakes, biscuits, confectionery, sugary soft drinks, burgers and pizzas, cream and high saturated fat spreads, cordials and (for adults) alcoholic drinks. Modelling with composite food groups for Foundation Diets did not include the 'Discretionary Choices' category. Due to the very low consumption and lack of consumption data, fortified and processed foods were not included in modelling process. The food groups and sub-groups considered are given in Table 2.

Table 2: Food groups for which composites were derived for diet modelling and where components were subsequently weighted for levels of consumption

Composite food groups	Comments
Cereals	Included rice, breads, cereals, pasta, noodles, hoppers, those, string hoppers etc.
Fruits	Consideration at a preliminary stage was given to a citrus subgroup (i.e. high in vitamin C) but as vitamin C was more than adequate in all diets this did not proceed. Fruit juices and dried fruit were not included in the modelling of the fruit group but their nutrient equivalent was assessed for subsequent food guide purposes
Green leafy vegetables	As the energy and nutrient content per serve is highly variable across the 'vegetable/legumes' category, for modelling purposes, the 'vegetables and legumes" group was subdivided into 4 categories. The green and brassica group is a valuable low kilojoule source of a wide range of nutrients notably folic acid.
Yellow vegetables	The distinguishing nutrient for this group is pre-vitamin A (note: some vegetables such as sweet potato can be counted as either 'yellow' or 'starchy').

Starchy vegetables	These vegetables are higher in kilojoules per unit weight and lower in nutrient density than the other groups but are a valuable source of complex carbohydrate
Other vegetables	This category includes many of other vegetables – beans, brinjals, cabbage etc. are the most commonly consumed component of this nutrient dense, low energy subgroup.
Pulses	Legumes are a valuable, cost efficient, source of protein and iron but are currently eaten in relatively small amounts in Sri Lanka.
Nuts and seeds	The variety of commonly available nuts and seeds supply some protein, and are a valuable source of essential fatty acids, vitamin E, magnesium and a range of minerals. Cashew, pea nuts and sesame are the commonly but consumed in very lesser amounts by the Sri Lankans.
Dairy foods	The powdered milk and liquid milk, yoghurt, cheese category was subdivided for modelling on a fat/serve basis to explore messages related to choices within the group. Powdered milk was the most commonly consumed dairy product in Sri Lanka.
Fish, poultry and meat	For modelling purposes, poultry, fish, seafood and eggs were the animal food sources used. They are valuable sources of protein, iron and zinc. Some fish and seafood are good sources of fatty acids.
Unsaturated oils and spreads	Includes spreads, oils, seeds and nuts high in poly-unsaturated and mono-unsaturated fatty acid
Discretionary Choices	This category included saturated fats such as butter and cream but not unsaturated fats and oils which were modelled separately. As this food group is diverse in its nutrient composition the equivalents were based on energy (600 kJ). This group was included only in the Total Diet modelling.

Step 2: Development of composite foods and their compositions

Initial modelling to attain Foundation Diets was undertaken using composite foods representing the various food groups. To derive the composite food groups for modelling Foundation Diets, three steps were followed:

2.1. Estimation of the relative contribution by weight of individual foods to the food group;

2.2. Calculation of contribution percentage of each item cluster to total food group consumption;

2.3. Determination of the nutrient composition per 100g for the composite food group taking into account % contribution by weight and standard serve size;

Step 2.1: Estimation of the relative contribution by weight of individual foods to the food group

Disaggregation of mixed foods into component ingredients

Standard recipes used in preparing each mixed food in the dietary data were used to identify the ingredients in a mixed dish. The actual amount consumed from each individual food item were determined using the recipe. This disaggregation increases the specificity within a food group. **Item clusters** were created initially for all foods whose consumption was more than 1% of the total number of servings consumed from each group or subgroup. An example of disintegration of a mixed dish (dhal and spinach curry) is given in Figure 2.

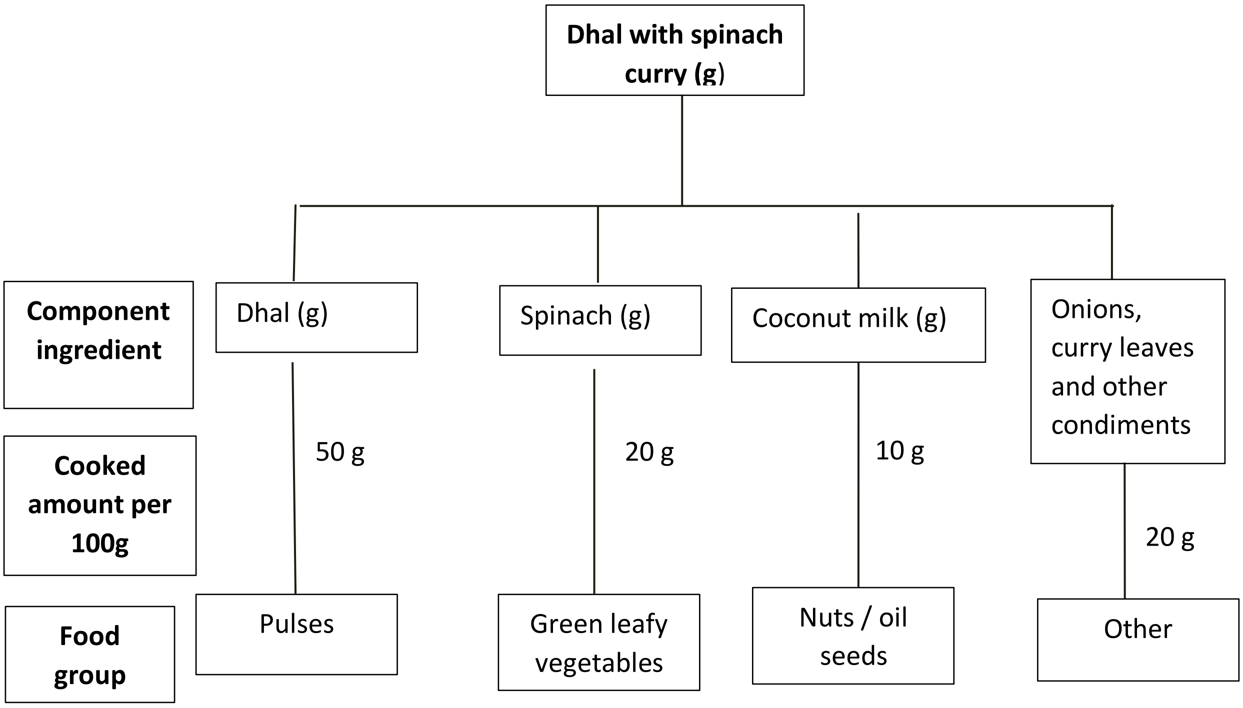

Figure 2. Example of disaggregation of a mixed dish in to food group/sub group (g: Dhal with spinach curry)

Aggregation of foods and ingredients in each 'item cluster'

After desegregating mixed foods into their component ingredients, those ingredients were then aggregated into **food item clusters** with the same ingredient from other foods, to identify the total consumption.

E.g.: Amounts of dhal can be eaten as part of spinach curry, "wade", dhal with drumstick curry, dhal curry "kirata", dhal curry tempered etc. (Figure 3).

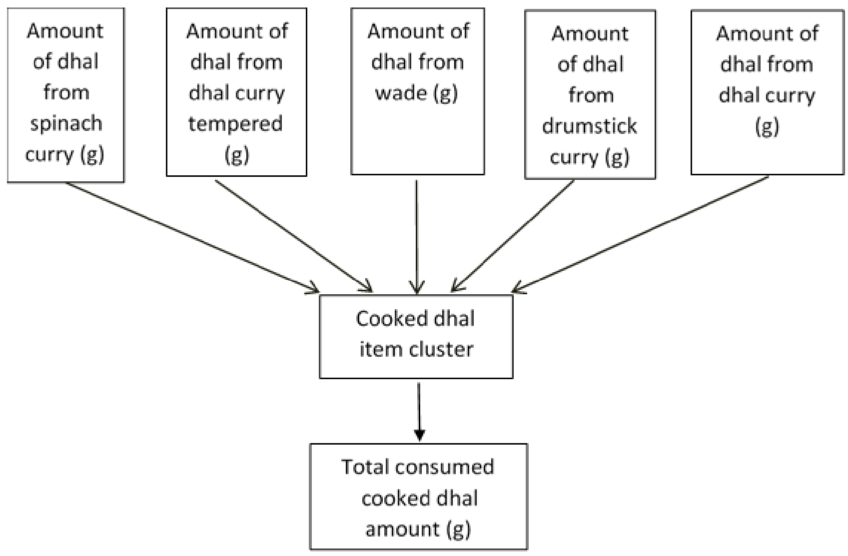

Figure 3. Example of aggregation of food ingredients into item clusters

Three hundred and sixty-five (365) individual food items were identified and they were categorized under 134 item clusters.

E.g: Pumpkin item cluster, Carrot item cluster etc. aggregated into orange vegetable sub group under the Vegetable group; Cashew nut item cluster and ground nut item cluster aggregate into Nuts and Oil seed group (Figure 4).

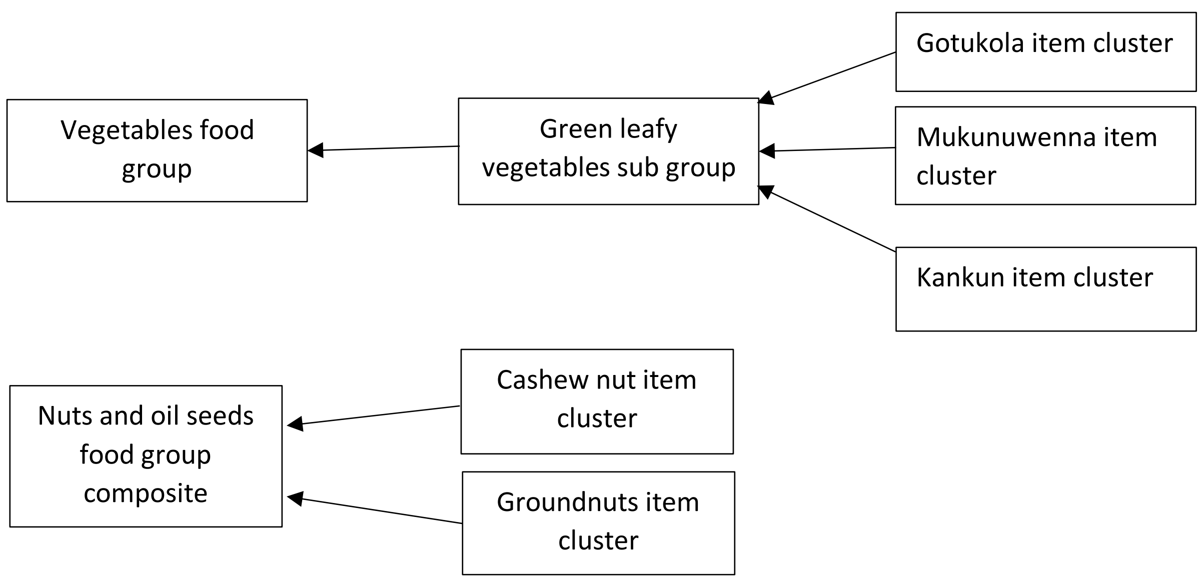

Figure 4: Aggregation of item clusters into nuts and oil seeds and vegetable groups

Step 2.2 Calculation of contribution percentage of each item cluster to total food group consumption

The sum of the total group intake from all item clusters within each group as a percentage of total consumption contributed by each item cluster was calculated [For instance, the amount of cooked dhal / total amount of pulses consumed]. The resulting percentages are the composite for the group and represent the probability of a food being eaten in comparison to other foods in the group.

$$\text{Contribution \% of cooked dhal item cluster to total pulse group} = \frac{\text{Total amount of cooked dhal consumed}}{\text{Total amount of cooked pulse}} * 100\%$$

As the calculation process continued, item clusters were retained for food items of which the intake represent more than 1% of the total intake of food group/sub group. Foods which had an intake less than 1% were combined to another item cluster already exist considering the similarity in nutrient composition of the food item and use in meals. Similarity in nutrient composition and use of a food item in meals were also considered in combining the foods.

E.g.: Chicken is the most commonly consumed meat item in Sri Lanka, hence other poultry such as turkey, quail etc. were grouped with chicken in a single item cluster.

Examples for composite green leafy vegetable and fruit are given in Table 2 and 3, respectively. Different food group composites include different number of item clusters. For example, composite green leafy vegetable group had 5 component item clusters (Table 3) and the fruit group composite had 8 component item clusters (Table 4).

Item clusters and composites help to examine typical food choices within a food group or subgroup among the Sri Lankan population. In the fruit group, for an example, bananas make up about 45%, mango and papaya each make up about 15% of total fruit consumption whereas intake of other fruits is about 25% of the total consumption.

Table 3: Percentage contribution of item clusters to composite green leafy vegetable

Item cluster	Percent of composite
Gotukola	43
Mukunuwenna	27
Kathurumurunga	10
Cabbage leaves	7
Kankun	6
Spinach	7

Table 4: Percentage contribution of item clusters to composite fruit

Item cluster	Percent of composite
Banana	45
Mango	16
Papaya	15
Guava	9
Orange	5
Water melon	5
Pineapple	4
Avocado	1

Step 2.3: Determination of the nutrient composition per 100g for the composite food group

Hypothetical composite foods were created for each food group/sub group using the consumption contribution percentage values. The nutrient profiles of composite foods were developed based on the percentage contribution of a specific food consumption.

After establishing the item clusters, one food item from food composition database was selected to serve as the representative food for the cluster. This representative food is a nutrient-dense food with low in fat and no added sugar. For all item clusters, a single food was selected to represent each cluster that is in its leanest or lowest fat form and that was prepared without addition of fat, oil, or sugar.

Eg: In cooked potato item cluster, boiled potato (the most nutrient-dense form with low added salt and fats) is the representative item over potato chips or French fries.

Nutrient composition for each food group and subgroup for energy and selected 9 key nutrients were weighted based on percent consumption of each representative food of its item cluster. Item clusters which have higher contribution percentage to the total food group consumption, contribute higher proportion to the nutrient composition of the food group composites.

Foodbase 2000 software (Institute of Brain Chemistry, UK) which consists of food composition data from various sources such as Indian food composition, USDA food compositions etc. was used to analyse the nutrient composition.

These **food group composite nutrient values** were used in further calculations in food modelling process.

Step 3: Determination of different age/gender groups and their energy and nutrient requirements

Following age, gender, life stage groups were used to model the diets:

1. Children 4–6 years, 7–9 years
2. Adolescents Females 10–18 years, Males 10–18 years
3. Adults Females 19–50 years
4. Adult Males 19–65 years, (19–50yrs) (50+yrs)
5. Elderly Females 65+years

For infants aged 0–6 months, exclusive breast feeding is the only food required so dietary modelling for this group was not undertaken in this work. Aged 6–36 months category also was not taken for the dietary modelling as they consume combination of breast milk and complementary foods.

Step 4: Development of Foundation Diets

The composite food groups were used to design culturally relevant **Foundation Diets** for each age/gender group that attained nutrient requirements for most people i.e RDA. These Foundation Diets provide the dietary patterns that meet the nutrient and energy requirements for the smallest and youngest, least active individuals in each age and gender group, and accounted for chronic disease, food supply, social and cultural constraints. Therefore, foundation diets were developed considering number of serves per week which provide to achieve RDA for selected 9 key nutrients within the least energy requirement for age/gender groups within the constraints for chronic disease, social and environmental factors.

Stage 2: Development of Foundation Diet models comprised of individual foods

The second stage was to cross-check the patterns obtained against outputs from several simulated 7-day diets for each age/gender group using individual foods to ensure that the dietary models for each group met the key nutrient requirements. For example, instead of using a composite 'fruit' group in the model, individual fruits e.g. papaya, bananas, pine apples, were used in the model. Patterns were generally deemed acceptable if all diets met the EARs for the nutrients included in the model. EARs were used in cross-checking the diets as EARs are the recommended standard to assess the adequacy of the planned diets for population groups.

Stage 3: Development of Total Diet Models

The third stage involved the development of a range of flexible options to add to these Foundation Diets to meet the higher energy requirements of people of varying body size and higher levels of physical activity. These latter diets were called 7-day **Total Diets**. As well as the final food groups an allowance for unsaturated oils and spreads was used in the development of the Foundation Diets 'Discretionary choices' (i.e. foods and beverages with higher fat/sugar and lower overall nutrient density) were also considered in modelling Total Diets. 'Discretionary choices' include foods and drinks such as cakes, biscuits, confectionary, sugary soft drinks, fast foods, other foods high in fats, particularly saturated fatty acids such as cream and some spreads, cordials etc.

Total diet

Progression from *Foundation Diets* to *Total Diets* can occur when total energy needs are greater than the energy provided by a *Foundation Diet* for a particular age and gender group. General principles were determined to ensure that diets remained within acceptable limits for percentage of energy from fat and the various fat components, protein and carbohydrate, the Upper Levels (ULs) and Suggested Dietary Targets (SDTs) for chronic disease prevention. The principles allow free addition of vegetables, fruits, nuts and seeds, and cereal foods and encourage a variety of choice of additional foods while defining the choices allowed in the modelling for the meat, dairy foods and unsaturated margarines and oils categories. 'Discretionary choices' can be included but it is important to note that they do not need to be included in the diet, and *Total Diets* without inclusion of any 'Discretionary choices' were also modelled for all age and gender groups.

Serve size determination

The basis for the serve or serving size used in dietary guidelines in different countries are widely varied and, in many cases, is not clearly stated. The clearest indications of the origins of serve size are given in the Australian Dietary Guidelines (Byron *et al*, 2011).

We used the basis of the serve size used in Australian Dietary Guidelines. Briefly;

- For food groups; fruits, vegetable groups and nuts and seeds, where the various item clusters (components) of the food group had similar energy and nutrient compositions, a single serve size was used for each food and this then became the composite serve size for that group.
- For food groups containing foods with highly variable energy and nutrient density such as the cereal group, the 'poultry/fish/seafood/eggs' group and the dairy food groups, an equivalent serve size for each item cluster was first determined and then a composite serve size for the group as a whole.
- For the within group serve equivalents, a food that is consumed in greatest quantity within the group (sentinel food) and its serve size was identified (e.g. a bread serve of 40g or rice 65g) and the other food serve sizes (e.g. for rice, pasta or for cheese and yoghurt) were determined based on equivalence for key nutrients.
- With increasing concern about obesity and the need to consider the concept of nutrient density, variations in energy per serve within food categories were also taken into consideration.
- After the serve size equivalents were determined within the group, the composite food serve size was determined based on the relative consumption of the various foods in the group and their individual serve sizes.

The serve size used in modelling process is given in Table 5.

Table 5. Standard serve sizes of different foods of food groups

Food group	Standard serve size
Vegetables	75 g (100-350 kJ)
	1/2 cup cooked green or orange vegetables (eg. Spinach, carrots, pumpkin)
	1 cup green leafy or raw salad leaves
	1 medium tomato
Roots and tubers	75 g (100-350 kJ)
	1/2 medium potato or starchy vegetables (sweet potato, cassava)
Fruit	150 g (350 kJ)
	1 medium banana, orange, apple
	1 small papaw, pine apple
	1 cup fruit salad (no added sugar)
	1/2 cup (125 ml) fruit juice (only occasionally)
	30 g dried fruits (1 ½ table spoons of sultanas / grapes, 4 dried dates)
Grain (cereal)	A standard serve is 500 kJ
	1 slice (40 g) of bread
	1/2 medium roti (90 g)
	1/2 cup (65-120 g) cooked rice, noodles, pasta,
	2/3 cup wheat cereal flakes
	5 medium size string hoppers (40g)
	2 Hoppers (120g)
	1 piece of Pittu, Itli or 1 Thosai (65 g)
Meat, poultry, fish, egg	500- 600 kJ
	65 g cooked lean red meat (beef, pork, lamb, goat)
	80 g cooked lean chicken
	100 g cooked fish
	2 large (120 g) eggs
Legumes and beans	500- 600 kJ
	1 cup (150 g) cooked legumes, beans (lentils, green gram, chick pea or peas)
Nuts and seeds	500- 600 kJ
	30 g peanuts, cashew or sesame
Milk and milk products or alternatives	500 – 600 kJ
	1 cup (250 ml) fresh milk, UHT, reconstituted powdered milk
	2 slices (40 g) of hard cheese (4 x 3 x 2 cm) such as cheddar
	200 g plain yoghurt (no added sugar)
	1 cup (250 ml) soy milk
	260g curd

Discretionary foods	600 kJ
The Dietary Guidelines recommend limiting the intake of discretionary choices, as they are not part an essential part of a nutritious diet. It is advised limiting the intake of discretionary choices to a maximum of one serve per day (approx. 600kJ).	2 scoops (75 g) regular ice cream 1/4 cup condensed milk 1 1/2 thick or 2 thin sausages 2-3 sweet biscuits 1 slice of plain cake (40 g) 40 g sugar confectionary (eg. toffees) 60 g jam / honey (about 2 table spoons) 1/2 small bar of chocolate (25 g) 1 table spoon of har margarine / fat spreads / butter 200 ml (1 glass) wine 60 ml spirits 400 ml regular beer 1 can soft drink (375 ml)

3. Results & Discussion

3.1 Intake of serves by adult women from different food groups

Table 6 shows the mean serves of food groups consumed by the sample of adult women (n = 1000). Consumption of foods from different food groups by adult women is widely varied compared with example recommended serves. Recommended serves considered were those given in Australian Dietary Guidelines (National Health & Medical Research Council, 2013). Number of serves from cereal group exceeds the recommended range and it should be due to the high consumption of rice. All other serves of food groups were below the recommendations.

Table 6: Current food group intake of the adult women

Food group	Per person/day consumption in standard serve size	Recommended serves/day*
Cereals	10.00	5
Milk /dairy products	0.14	2.5
Fruits	0.20	2
Vegetables	1.00	5
Fish/meat/egg/pulse/Nuts and oil seeds (except coconut)	1.24	2.5

*Since we used serve sizes recommended for Australians, recommended serves are also compared with Australian Dietary Guidelines (https://www.eatforhealth.gov.au/food-essentials/how-much-do-we-need-each-day/recommended-number-serves-adults)

3.2 Frequency of consumption of foods from different food groups

Table 7 shows the number of times a food group was consumed by women.

The consumption frequency of vegetables, fruits, dairy, legumes and meat, fish and eggs was relatively low. Grain products showed the highest consumption frequency.

Table 7: Number of times a food group was consumed by women

Food groups	Time consumed per week		
	Lower consumption[1]	Median Consumption[2]	Upper consumption[3]
Added fats	0	9	29
Added sugars	1	14	21
Bakery and breakfast cereals	0	0	3
Beverages (non-dairy or blended dairy)	0	6	18
Dairy products	0	6	12
Fruits	0	0	4
Grain and grain products	7	17	21
Legume, nuts and seeds	0	6	15
Meat, fish and eggs	0	6	13
Starchy roots and other starchy plant foods	0	0	8
Sweetened snacks and desserts	0	0	6
Vegetables (Including Green Leafy Vegetables)	0	6	12

Consumption of; [1]5th percentile; [2]50th percentile; [3]95th percentile

Altogether, 121 food items were consumed by the study group. Only 38 foods were consumed by more than 5% of the population. The major individual food items consumed in each food group are given in the Box given below.

Added fats

- Coconut Oil
- Coconut sambol
- Coconut milk (kiri-hodi)

Added sugar

- Sugar, white

Bakery & breakfast cereals

- White bread
- Buns

Beverages (non-dairy or blended dairy)

- Tea
- Malted drink

Dairy products

- Milk powder

Fruits

- Banana

Grains & grain products

- Rice
- String hoppers
- Roti

Legumes, nuts & seeds

- Dhal
- Texturized Vegetable Protein (Soy meat)

Starchy roots & other starchy plant foods

- Potato

3.3 Nutrient intakes of adult women

Table 8 shows the nutrient intakes of the adult women. Dietary intake of energy, protein, calcium, iron, zinc, folate, Vitamin A and Vitamin C are at relatively low levels compare to RDA values where the % energy from carbohydrates was higher than the recommended level.

Table 8: Nutrient intake of an adult women

Nutrient /Energy	Current intake	*RDA for 1.4 PAL
Energy (kcal)	1530	1650
Fat (g)	32	55
Protein (g)	47	62
Calcium (mg)	325	1000
Iron (mg)	10	13
Zinc (mg)	6	7
Folate (µg)	151	400
Thiamin	0.48	1.2
Vitamin C (mg)	27	90
Vitamin A (µg)	484	600
%Energy from protein	11	15
% Energy from fat	14	30
% Energy from carbohydrate	67	55

*WHO recommendations

3.4 Identification of problem nutrients

Figure 5 shows %RNI that can be achieved by the best diet close to the population's average food pattern (Food Pattern) and best diet that can deviate away from the average food pattern (No food pattern), respectively. Only energy, protein and vitamin B12 reached 100% of RNI in both diets.

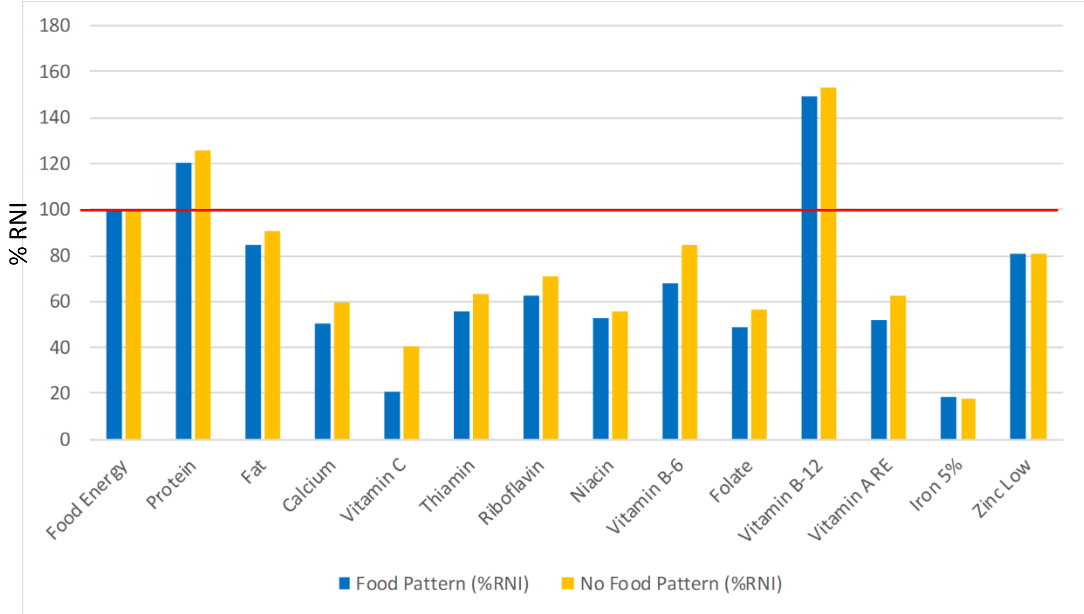

Figure 5: %RNI achieved by the best diet close to the population's average food pattern (Food Pattern) and best diet that can deviate away from the average food pattern (No food pattern)

Module III tested problem nutrients which were identified with the estimated nutrient intake distribution. Minimized (worst-case scenario) and maximized (best-case scenario) nutrient content per diet were estimated. In the worst-case scenario the least nutrient-dense foods from the list of foods are chosen, while in the best-case scenario the most nutrient-dense foods are chosen. Figure 6 shows the problem nutrients in the diet of the target women population.

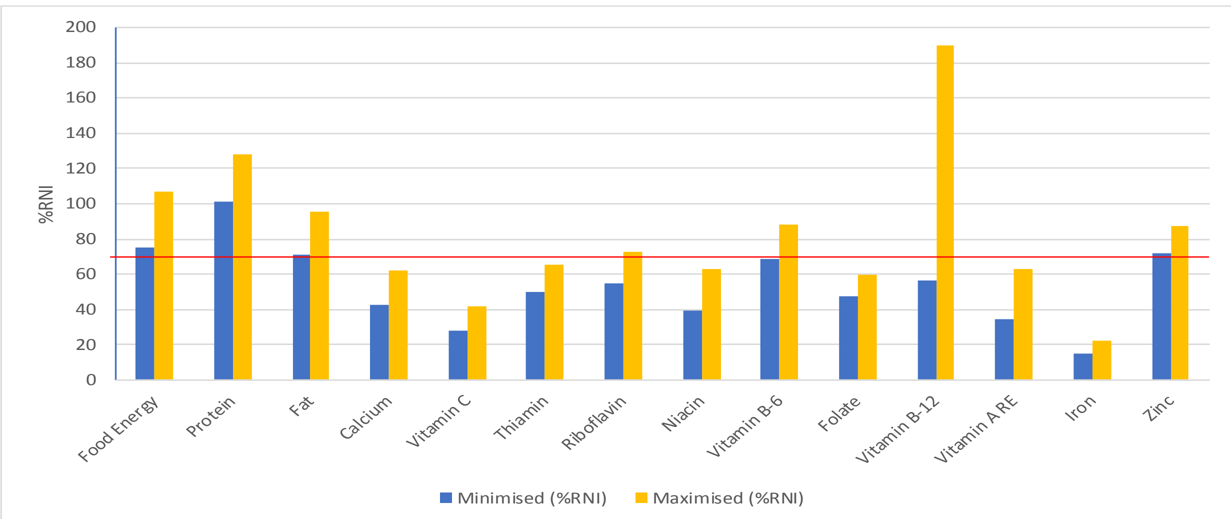

Figure 6: %RNI achieved in the worst-case scenario and best-case scenario

Absolute problem nutrients (best-case scenario does not reaches 100 per cent of RNI) identified in the model diet were Ca, Vitamin C, Folate, Vitamin A, Iron, Thiamine and Niacin. Partial problem nutrients (100% RNI is reached in the best-case scenario, but 70% RNI is not reached in the worst-case scenario) identified by the model diet were Riboflavin, B6 and B12.

3.5 Foundation diets developed based on composite foods

The resulting Foundation Diet patterns are summarized in Tables 9 and 10 showing serves per week for the various age/gender groups. Serves per week were chosen rather than per day to convey the message that it is not necessary to consume the same pattern of food intake everyday but that average weekly intake should be consistent with the patterns shown below.

Table 9: Omnivore Foundation Diets for females designed to attain RDA for the relevant age group within the energy needs of the youngest and very sedentary (PAL 1.4) in the group (serves per week)

Food group composite	Serve size	4-6 y 1300 kcal	7-9 y 1600 kcal	10-14 y 1850 kcal	15-18 y 2100 kcal	19-45 y 1650 kcal	70+ y 1700 kcal
Cereal	65g[1]	25	38	45	46	45	43
Pulses	150 g	2	3	4	5	4	4
Dairy	250 ml[2]	14	14	16	16	16	16
Fruit	150 g	7	7	7	10	7	7
Starchy vegetables	75 g	4	5	3	5	5	4
Yellow vegetables	75 g	1	1	1	2	2	2
Green leafy vegetables	75 g	2	2	2	2	2	2
Other vegetables	75 g	9	10	10	12	16	13
Starchy roots	75 g	5	5	4	5	4	4
Fish	100 g	2	2	3	3	3	3
Meat	80 g	2	2	2	3	2	2
Egg	60 g	4	4	4	5	5	4
Additional categories							
Nuts & oil seeds	30 g	-	1	2	4	2	4
Coconut oil	g	25	25	25	25	25	25
Unsaturated oil/spreads	g	20	20	20	20	20	20
Scraped Coconut	g	40	40	40	40	40	40
Coconut milk	g	150	150	280	280	280	280

[1]cooked rice equivalent = ½ cup (65 g)
[2]liquid milk equivalent= 1 glass (250 ml)

Table 10: Omnivore Foundation Diets for males designed to attain RDA for the relevant age group within the energy needs of the youngest and very sedentary (PAL 1.4) in the group (serves per week)

Food group composite	Serve size	4-6 yr 1300 kcal	7-9yr 1600 kcal	10-14yr 2000 kcal	15-18yr 2700 kcal	19-45yr 2000 kcal	70+yr 1700 kcal
Cereal	65g[1]	25	38	46	62	46	43
Pulses	150 g	2	3	5	6	5	4
Dairy	250 ml[2]	14	14	16	17	16	14
Fruit	150 g	7	7	10	18	10	7
Starchy vegetables	75 g	4	5	5	5	5	4
Yellow vegetables	75 g	1	1	2	4	2	2
Green leafy vegetables	75 g	2	2	2	3	2	2
Other vegetables	75 g	9	10	12	18	12	13
Starchy roots	75 g	5	5	5	8	5	4
Fish	100 g	2	2	3	4	3	3
Meat	80 g	2	2	3	4	3	2
Egg	60 g	4	4	5	5	5	4
Additional categories							
Nuts & oil seeds	30 g	-	1	2	4	2	4
Coconut oil	g	25	25	25	25	25	25
Unsaturated oil/spreads	g	20	20	25	25	25	25
Coconut fresh	g	40	40	40	40	40	40
Coconut milk	g	175	175	300	300	300	300

[1]cooked rice equivalent = ½ cup (65 g)
[2]liquid milk equivalent= 1 glass (250 ml)

3.6 From Foundation to Total Diets

Any Foundation Diet can be built upon to derive Total Diets for increasing energy needs (see Table 11). In this particular example, each diet builds on the previous diet with the addition of approximately 250 kcal/day building blocks, although it is not necessary, of course, to use this stepwise approach to design Total Diets.

Table 11: An example of how an Omnivore Foundation Diet could be built upon to derive Total Diets for varying daily energy needs (serves per week)

Composite food group	Omnivore foundation diet	Sample total diets – approximate energy/day					
	1650 kcal (PAL 1.4)	1850 kcal (PAL 1.6)	2000 kcal (PAL 1.75)	2250 kcal (PAL 2.0)	2500 kcal (PAL 2.2)	2750 kcal	3000 kcal
Cereal	45	46	46	54	60	62	70
Pulse	4	4	5	5	6	6	7
Dairy	14	16	16	16	16	17	17
Fruit	7	7	10	14	16	20	22
Starchy vegetables	5	4	5	5	4	5	5
Yellow vegetables	2	2	2	2	3	4	4
Green leafy vegetables	2	2	2	2	3	3	3
Other vegetables	16	11	12	13	15	18	21
Starchy roots	4	4	5	5	6	8	9
Fish	3	3	3	3	4	4	4
Meat	2	2	3	3	3	4	4
Egg	5	4	5	5	5	5	5
Nuts & oil seeds	2	2	2	2	4	5	5
Additional categories							
Coconut oil (g)	20	20	20	20	20	35	35
Unsaturated oil/spreads (g)	25	25	25	25	25	50	60
Coconut fresh (g)	140	140	140	140	140	140	140
Coconut milk (g)	300	300	300	300	300	400	450

There are many other possible combinations of food groups that would provide the nutrient and energy requirements for this group. They are shown in the table 10 for illustrative purpose only. However, as energy needs within a given group are limited, increases in one food group will affect the possibility of increasing others. The diets are based on the Foundation Diets patterns for this age/gender group with additional serves from various food groups to attain their particular energy requirements.

Table 10: Example for Possible combinations of food group composites would provide energy and nutrient requirements for different higher energy categories (serves per week)

Food group composite	Serve size	1850 kcal		2000 kcal		2250 kcal	
		Example 1	Example 2	Example 1	Example 2	Example 1	Example 2
Cereal	65g[1]	46	43	46	39	54	46
Pulse	150 g	5	5	5	5	5	6
Dairy	250 ml[2]	7	10	10	13	13	13
Fruits	150 g	3	5	5	5	5	5
Starchy vegetables	75 g	2	2	2	2	2	2
Yellow vegetables	75 g	2	2	2	2	2	2
Green leafy vegetables	75 g	12	13	12	14	14	20
Other vegetables	75 g	4	5	5	5	6	6
Starchy roots	75 g	16	16	16	16	16	16
Fish	100 g	3	3	3	3	3	3
Meat	80 g	2	2	3	3	3	4
Egg	60 g	4	5	5	5	5	5
Nuts	30 g	2	2	2	2	2	2
Additional categories (quantities in grams)							
Coconut oil		20	20	20	20	20	20
Sesame oil		25	25	25	25	25	25
Scraped Coconut		140	140	140	140	140	140
Coconut milk		300	300	300	300	300	300

[1]cooked rice equivalent = ½ cup (65 g)

[2]liquid milk equivalent = 1 glass (250 ml)

The food group parameters set by the WHO to address issues of chronic disease, health and wellbeing was a challenge in the modelling to attain some RDAs within the energy constraints of the Foundation Diets. However, both foundation diets and total diets developed, RDAs for the 9 nutrients modelled were attained within the kilojoule and food group limits for most nutrients for most age/genders. It was also possible in most instances to attain 90% - 110% of the RDAs for the nutrients, with the exception of iron for adolescents, adult females and elderly.

Total diets represent individual food items which gives more practicable idea for general public. Number of rice serves/day is 6-8 serves range. Adequate vegetables and fruits; three serves of vegetables and two serves of fruits; have included with increased variety. According to the amount allocated from composite milk, at least 2 glasses of milk and one yogurt or curd serve have to be included to reach nutrient requirements specially calcium and protein. Only two serves (60 g) of peanuts/sesame/cashew group have been reserved for a week. To promote pulse consumption in addition to Mysore dhal, chickpea, cowpea and green gram have been used in form of breakfast meals, curries and snacks. Starchy roots have been considered as a separate group and included in diets as a carbohydrate source rich in fiber.

A sample total diet for an adult female is given below.

Time	Description	Amount	Serves/day
6.30 am	Tea	1 cup	1
	- Milk powder	4 tsp (20 g)	
	- Sugar	1 tsp (5 g)	
7.30 am (Breakfast)	Boiled Mung bean	1 cup (150 g)	1
	Scraped coconut	1 tbsp (8 g)	
	Lunu miris	1 tbsp (10 g)	
	Banana	1 medium (40 g)	
10.30 am (Mid-morning snack)	Sandwich (vegetable)	1	
	- bread	1 slices (22 g)	1/2
	- boiled carrot and beetroot, potato	1tbsp (45 g)	1/2
	Plain tea	1 cup	
12.30 pm (Lunch)	Rice (red)	1 1/2 cups (195g)	3
	Beans curry (coconut milk added)	3 tbsp (45 g)	1/2
	Chicken curry (spicy)	1 medium piece (80g)	1
	Gotukola mallum	2 tbsp (30 g)	1/2
	Lotus stem curry (coconut milk added)	3 tbsp (45 g)	1/2
	Cabbage curry (coconut milk added)	3 tbsp (45 g)	1/2
	Papaya	1 large piece (150 g)	1
4.30 pm (Evening snack)	Tea	1 cup	1
	- Milk powder	4 tsp (20 g)	
	- Sugar	1 tsp (5 g)	
	Samaposha	1 Aggala	
7.30 pm (Dinner)	Noodles (vegetable mixed)	1 cup (130 g)	3
	Boiled egg	1	1
	Potato curry (coconut milk added)	2 tbsp (40 g)	1
	Yoghurt	1 cup (100 g)	1

A sample total diet for an adolescent girl is given below.

Time	Description	Amount	Serves/day
7.30 am (Breakfast)	Tea	1 cup	1
	- Milk powder	2 tbsp (30 g)	
	- Sugar	1 tsp (5 g)	
	Mung milk rice	2 pieces (60 g)	1
	Fish ambul thiyal	1 medium piece (50g)	1/2
	Lunu miris	1 tbsp (10 g)	
	Banana	1 medium (40 g)	1
10.30 am (Mid morning snack)	Tea	1 cup	1
	- Milk powder	2 tbsp (30 g)	
	- Sugar	1 tsp (5 g)	
12.30 pm (Lunch)	Rice (red)	1 1/2 cups (195g)	4
	Carrot salad (raw)	2 tbsp (30 g)	1/2
	Fish curry (spicy)	1 medium piece (50g)	1/2
	Ladies fingers curry (coconut milk added)	2 tbsp (30 g)	1/2
	Ambarella curry (coconut milk added)	2 tbsp (30 g)	1/2
	Curd	1/2 cup (75 g)	1/2
4.30 pm (Evening snack)	Boiled Chickpea	1/2 cup (75 g)	1/2
	-Scraped coconut	1 tbsp (8 g)	
	Plain tea	1 cup	
7.30 pm (Dinner)	Rice (red)	1 cups (130 g)	2
	Brinjal curry (coconut milk added)	2 tbsp (30 g)	1/2
	Mukunuwenna mallum	2 tbsp (20 g)	1/2
	sprat curry (spicy)	2 tbsp (20 g)	
	Beet root curry (coconut milk added)	2 tbsp (30 g)	1/2
	Boiled jack	2 tbsp (40 g)	1
	Custard apple (Anoda)	1 medium fruit (50 g)	1

Nutrient compositions of 7-day total diets for healthy adult males, adult females, adolescent boy, adolescent girl and children aged 7-9 y are present in Table 13-17, respectively. Mean provision of nutrient is comparable with the nutrient profile of foundation diet. The total diets formulated provide RNI for selected nutrients. However, achieving RNI for Iron in adult females is not possible even with the practically feasible food combinations in the diet. In such a situation, supplementation or fortification is warranted.

Table 13: Nutrient contents of diets developed for 7 days for an adult male aged 19-55 y / 1.4 PAL

Nutrient	Unit	Foundation diet	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean
Energy	kcal	2018	2035	1826	1974	1924	2108	1986	2094	1992
Protein	g	82	89	66	67	78	62	65	86	73
Fat	g	63	69	67	61	66	78	65	66	68
Carbohydrate	g	299	278	254	308	270	308	303	303	289
Ca	mg	1002	1407	1099	1286	1176	1141	957	1018	1155
Mg	mg	418	450	357	295	443	452	285	696	425
Fe	mg	12	26	13	12	18	20	13	23	18
Zn	mg	9	10	5	6	10	9	7	13	9
Thiamin	mg	1	2	1	1	1	1	1	1	1
Folate	µg	521	947	314	256	658	406	320	1075	568
Vitamin C	mg	134	148	66	131	199	120	131	97	128
Vitamin A	µg	928	1447	747	1201	748	895	626	533	885
% Energy from fat		28	31	33	28	31	33	30	29	31
% Energy from protein		16	18	15	14	16	12	13	16	15
% Energy from CHO		56	51	52	58	53	55	57	54	54

Table 14: Nutrient contents of diets developed for 7 days for an adult female aged 19-55 y / 1.4 PAL

Nutrient	Unit	Foundation diet	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean
Energy	kcal	1688	1637	1610	1770	1556	1728	1716	1595	1659
Protein	g	72	63	57	65	63	65	60	63	62
Fat	g	53	60	57	55	55	61	55	57	57
Carbohydrate	g	246	223	232	271	215	244	261	221	238
Ca	mg	945	1000	1007	1250	1147	1085	899	877	1038
Mg	mg	268	351	290	261	264	390	257	343	308
Fe	mg	10	21	11	11	12	17	11	13	14
Zn	mg	7.7	8.4	4.8	5.8	6.2	7.8	6.1	7.4	6.6
Thiamin	mg	1.1	1.2	0.7	1.0	0.8	1.1	0.7	0.8	0.9
Folate	µg	242	716	288	226	328	372	319	294	363
Vitamin C	mg	122	140	74	110	200	128	112	96	123
Vitamin A	µg	873	1185	1442	1178	705	939	456	618	932
% Energy from fat		28	33	32	28	32	32	29	32	31
% Energy from protein		17	15	14	15	16	15	14	16	15
% Energy from CHO		55	51	54	58	52	53	57	52	54

Table 15: Nutrient distribution within a week for adolescent boy aged 10-14 y / 1.4 PAL

Nutrient	Unit	Foundation diet	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean
Energy	kcal	2002	2319	2088	2072	2022	2108	2084	2192	2126
Protein	g	82	106	77	72	83	62	70	91	80
Fat	g	67	80	78	67	71	78	71	72	74
Carbohydrate	g	285	309	287	316	278	308	311	311	303
Ca	mg	1158	1848	1338	1490	1380	1141	1161	1222	1369
Mg	mg	283	532	411	312	460	452	302	713	454
Fe	mg	11	27	15	13	18	20	13	23	18
Zn	mg	9	12	7	7	11	9	7	14	9
Thiamin	mg	1	2	1	1	1	1	1	2	1
Folate	µg	255	1122	389	265	667	406	329	1084	609
Vitamin C	mg	136	153	69	133	201	120	133	99	130
Vitamin A	µg	980	1575	812	1264	812	895	689	596	949
% Energy from fat		30	31	34	29	32	33	31	29	31
% Energy from protein		16	18	15	14	16	12	14	17	15
% Energy from CHO		53	50	52	57	52	55	56	53	53

Table 16: Nutrient distribution within a week for adolescent girl aged 10-14y / 1.4 PAL

Nutrient	Unit	Foundation diet	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean
Energy	kcal	1733	1944	1942	1975	1948	2034	1907	1971	1960
Protein	g	77	87	73	71	78	67	67	85	75
Fat	g	58	71	72	64	69	76	68	68	70
Carbohydrate	g	242	253	266	298	268	289	272	275	275
Ca	mg	904	1270	1288	1476	1363	1336	1101	1184	1288
Mg	mg	272	377	389	299	407	447	285	573	397
Fe	mg	9.9	23.6	13.7	12.1	16.8	18.8	11.9	18.2	16
Zn	mg	8.4	9.1	6.4	6.7	9.6	8.8	7.0	11.2	8.0
Thiamin	mg	1.0	1.3	1.0	1.1	1.0	1.1	0.8	1.3	1.0
Folate	µg	231	716	341	257	578	402	314	826	491
Vitamin C	mg	92	147	67	124	201	116	124	98	125
Vitamin A	µg	755	1398	806	1263	822	949	683	596	931
% Energy from fat		30	33	34	29	32	33	32	31	32
% Energy from protein		18	18	15	14	16	13	14	16	15
% Energy from CHO		52	49	51	57	52	53	54	52	53

Table 17: Nutrient distribution within a week for children aged 7-9 y with moderate PAL

Nutrient	Unit	Foundation diet	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Energy	kcal	1454	1483	1718	1654	1559	1815	1556	1777	1652
Protein	g	58	64	52	59	62	54	56	60	58
Fat	g	50	53	60	61	54	60	56	61	58
Carbohydrate	g	208	198	260	231	221	283	220	264	239
Ca	mg	808	1274	728	673	821	735	741	807	826
Mg	mg	172	291	288	293	242	277	223	248	266
Fe	mg	8	19	9	12	12	13	10	11	12
Zn	mg	5	7	7	7	6	6	6	6	6
Thiamin	mg	1	1	1	1	1	1	1	1	1
Folate	µg	173	594	314	210	275	252	257	240	306
Vitamin C	mg	82	140	90	86	241	92	106	81	119
Vitamin A	µg	779	1194	779	2327	745	719	877	697	1048
% Energy from fat		31	32	31	33	31	30	33	31	31
% Energy from protein		16	17	12	14	16	12	14	13	14
% Energy from CHO		54	50	57	52	53	58	53	56	54

Table 18: Nutrient distribution within a week for elderly / 1.4 PAL

Nutrient	Unit	Foundation diet	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Energy	kcal	1723	1754	1846	1795	1730	1783	1858	1731	1785
Protein	g	74	75	73	71	71	72	71	69	72
Fat	g	59	65	82	70	58	83	77	69	72
Carbohydrate	g	239	231	243	261	247	226	235	271	245
Ca	mg	1025	1251	1322	1017	1368	1376	1233	1154	1246
Mg	mg	312	393	389	288	258	460	341	544	382
Fe	mg	11	18	14	15	13	13	14	17	15
Zn	mg	9	9	6	6	7	8	6	11	8
Thiamin	mg	1	1	1	1	1	1	1	1	1
Folate	µg	276	743	362	329	286	330	412	956	488
Vitamin C	mg	110	155	65	198	105	162	165	123	139
Vitamin A	µg	892	814	846	840	932	922	933	726	986
% Energy from fat		31	33	32	33	30	32	33	32	32
% Energy from protein		17	17	15	15	17	15	15	14	16
% Energy from CHO		52	50	53	52	54	53	52	53	52

When modelling, a small allowance of oils and spreads was included to reflect current culinary behavior and to ensure that the energy these foods provided was within the energy constraints of the Foundation Diets. Due to common habit of coconut consumption of Sri Lankans, saturate fat intake is generally higher than the recommendations. When planning the foundation diets, coconut was added separately to increase the practicability of diets. Margarine and plant-based oils (sesame oil) were used as a proxy for unsaturated oils and spreads. For Total Diets, additional amounts of unsaturated oils and spreads were included depending on the overall energy content of the diet. This mirrors the allowance of some amount of energy for discretionary or extra foods in the diets.

Number of serves from each food group and sub group suggest by modelled foundation diets were higher than current consumption of Sri Lankans for most vegetable categories, pulses, fruits, milk, fish, meat, egg, starchy vegetables, starchy roots except rice and percent of energy from carbohydrate, high fat/salt foods and discretionary foods. To provide guidance to the general public, these diets models should be translated into realistic and practical dietary guidelines. Other important issues such as food availability, accessibility, affordability, cultural barriers, socio-economic status also will be further considered during the process. If the food availability data indicate that there is no sufficient availability to provide the quantities include in the models to the whole population, overall production should be increased or additional supplies from other sources such as importing should be done.

The serve sizes and food groupings used in the modelling exercise will not necessarily be retained for subsequent food guides. Some food sub-groups may be merged within the larger group and serve sizes may be changed to better align with usual practices of people. Through the total diet, food models give more flexible possibilities for healthier dietary patterns. This range of options will also be necessary in revising of existing dietary guidelines. It is expected that future dietary guidelines will be culturally acceptable because it will be based on the most recent food consumption data and scientifically relevant. Moreover, it will be fully informed thorough a review of the scientific literature and will facilitate health and well-being once disseminated and adopted.

Discretionary or extras options are permittable but limited to 0-3 serves/day dependent on EER. In all diets, UL for sodium was not exceeded. %E from SFA exceeds the recommendation (10%) with low Polyunsaturate : saturate (P:S) ratio.

Diet models formulated do not apply to people with specific medical / physiological conditions (eg Diabetics, pregnant and lactating women) which require specialized dietary advice, nor the frail elderly who are at risk of malnutrition.

Our observations and modelling emphasize that the population groups require food with good nutritive value. A food-based approach is holistic, sustainable and hence, the best physiological approach to ensuring the nutritional well-being of population when it takes into consideration existing traditional dietary patterns and practices as well as cultural, political and religious factors. In addition, the consideration of culture, customs and tradition calls for a clear understanding of locally available foods and cooking practices and the nutritive value of these foods. Interventions in farming, dietary diversification and bio-fortification, not only the pharmaceutical approaches, will gain great importance to solve the nutrition-related problems.

Key findings:

- Dietary intake assessment of adult women comprised of rural, urban and estate populations show poor, unhealthy, unbalanced food and nutrient intakes. We assumed that similar dietary patterns are persistent in the households. Therefore, the findings of the study population are extrapolated to other age/sex groups.
- Dietary patterns of the women showed RNI of several nutrients cannot be achieved. Even of the model diet within the constraints of lowest and upper limits of current consumption of food groups does not permit to achieve several nutrients except for energy protein and vitamin B12.
- Optifood linear programming software found several nutrients as problem nutrients in women when the least (worst-case scenario) and most nutrient dense foods (best-case scenario) are used in the model diets. The Absolute Problem Nutrients are Ca, Vitamin C, Folate, Vitamin A, Iron, Thiamine and Niacin. These nutrients cannot reach even 70% of RNI (i.e at least 50% of the population achieve nutrient requirements) when the best-scenario is considered.
- Partial Problem Nutrients are Riboflavin, B6 and B12. These nutrients cannot reach 100% RNI but reach 70% RNI when the best-scenario is considered.
- The dietary patterns were developed in consideration of the inter-relationships between nutrients, foods, food groups and whole diets using an iterative process. The evidence in literature on diet and chronic disease, social factors and environmental sustainability were considered to establish model constraints of current food consumption (maximum and minimum).
- There is a need for alternative interventions to ensure dietary adequacy.
- Several sets of food groups were combined in developing Foundation Diets, which provide as close to 100% of the RNIs of key nutrients as was feasible and to provide the estimated energy requirements of the smallest and very sedentary category (PAL 1.4) for each age and gender group.
- Foundation Diets were used to develop a Total Diet for an individual, which reflects the additional energy requirements related to the individual's body size and activity levels, while allowing some flexibility for personal food preferences.
- Nutrient compositions of 7-day total diets for healthy adult males, adult females, adolescent boy, adolescent girl and children aged 7-9 y were planned.
- Serve sizes need to achieve RNIs are determined.
- The total diets formulated provide RNI for most of the selected nutrients. However, achieving RNI for Iron in adult females is not possible even with the practically feasible food combinations in the diet. In such a situation, supplementation or fortification is warranted.
- Discretionary or extras options are permittable but limited to 0-3 serves/day dependent on EER. In all diets, UL for sodium was not exceeded. %E from SFA exceeds the recommendation (10%) with low Polyunsaturate : saturate (P:S) ratio.
- Diet models do not apply to people with specific medical conditions which require specialised dietary advice (eg. Diabetics, Pregnant and lactating women), nor the frail elderly who are at risk of malnutrition.

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