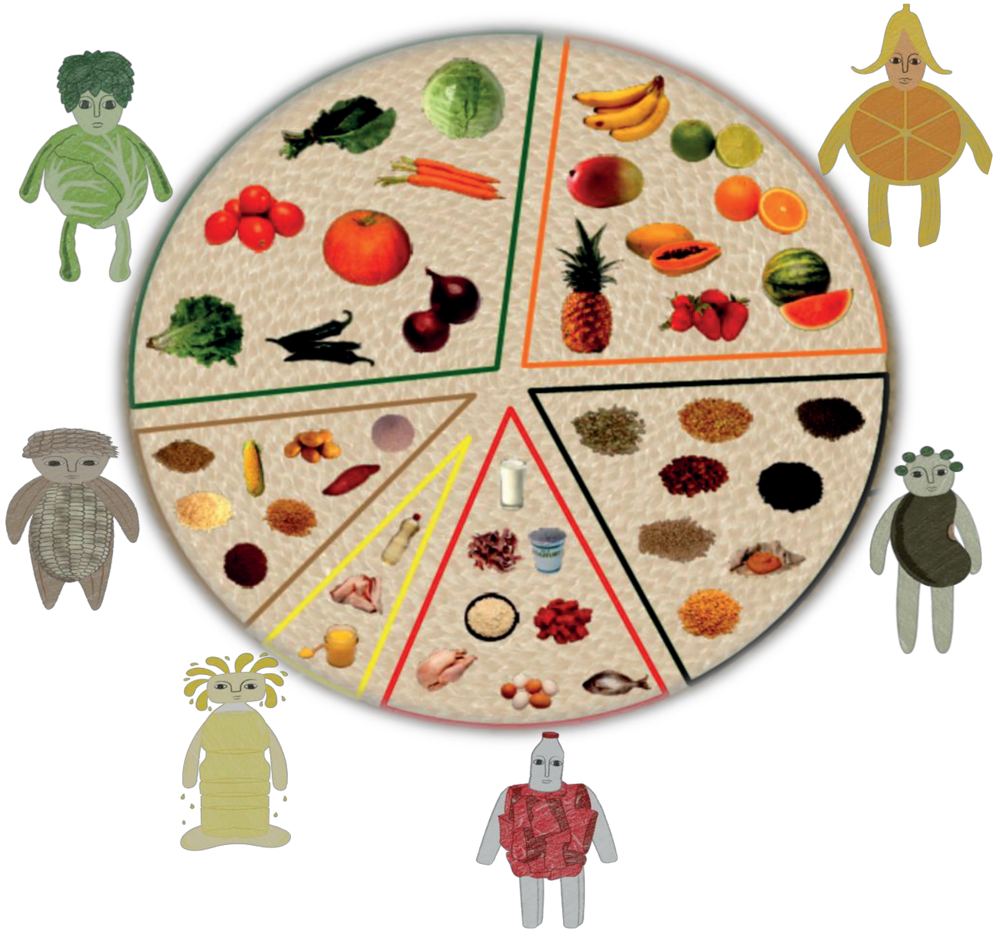
Ethiopian Food-Based Dietary Guidelines: Development, Evaluation, and Adherence Monitoring



Tesfaye Hailu Bekele

Propositions

1. National dietary guidelines are only useful when developed within the context of the target country.

   (this thesis)

2. A healthy diet requires extra effort and cost from all food system actors, including consumers.

   (this thesis)

3. Healthcare services are improved more by countries' investments in telemedicine than in traditional health care facilities.

4. High publication costs introduce bias by limiting the publication in open access journals from researchers in low- and middle-income countries.

5. Involving immigrant parents in their children's learning process will improve the Dutch education system.

6. The way a person looks reflects his current living conditions. (based on Ethiopian proverb)

Propositions belonging to the thesis entitled:

Ethiopian Food-Based Dietary Guidelines: Development, Evaluation, and Adherence Monitoring

Tesfaye Hailu Bekele

Wageningen, 30 August 2022

Ethiopian Food-Based Dietary Guidelines: Development, Evaluation, and Adherence Monitoring

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Ethiopian Food-Based Dietary Guidelines: Development, Evaluation, and Adherence Monitoring

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In loving memory of my mother, ***W/ro Wageye Teka Shibeshi***

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Chapter 1

General Introduction

1.1.Ethiopia's current nutrition and socioeconomic status

Ethiopia, Africa's second-most populous country and one of the continent's oldest nations, has a large diversity in ethnic groups, cultural and religious heritages, ways of living, and eating habits(1; 2). The long history of poverty and food insecurity marks the country with one of the highest prevalence of undernutrition on the African continent. More than half (67%) of the adult population is affected by undernutrition during childhood(3; 4; 5). At present, the prevalence of stunting among children under the age of 5 years (36.8%) and underweight among women of reproductive age (22%) is one of the highest in sub-Saharan Africa(6; 7). According to the 2011 national food consumption survey, inadequate intakes of zinc (prevalence 50%), vitamin A (81%), and iron (13%) among women of reproductive age are a public health concern(8). In 2016, the prevalence of deficiencies of serum zinc (34%), vitamin A (11%), iron (6%), and anaemia (18%) in the national micronutrient survey confirmed the deficiencies observed in the 2011 food consumption survey(9). On the other hand, over the past 15 years, overweight and obesity have emerged among adult men and women and school-age children in urban areas(10; 11). According to the 2015 STEPS survey, the prevalence of cardiovascular diseases (CVD) among women aged 40-69 years was 5%, and more than 30% of women 40-54 years had an elevated 10-years CVD risk as defined according to age, sex, blood pressure, smoking status, total cholesterol, and diabetes(12). The same survey indicated the percentage of raised fasting blood glucose and increased cholesterol concentration was 5.8% and 8.3%, respectively. The country's triple burden of malnutrition (undernutrition, micronutrient deficiencies, and the rise of overnutrition) has resulted in the increase of non-communicable diseases and their health consequences. According to research on the cost of hunger, Ethiopia is losing 16% of its GDP due to malnutrition, affecting productivity, education capacity, and medical expenses. Thus, in terms of finding the right solution, a healthy diet is critical(5).

Evidence shows a fast shift in unhealthy dietary patterns over the last couple of decades due to urbanization, economic changes, population growth, and food supply(13; 14; 15). Over time, cultural and religious diversity and dynamic changes in living impact consumers' eating habits, daily lives, and attitudes about food (16; 17). Indications for dietary transitions are observed in several overall Ethiopian eating habits (13; 18), such as increased energy intake, a declining but still a dominant share of cereals in diets, and the use of more processed foods. It is unclear whether diets change towards healthier or unhealthier patterns and how this differs between and within regions and population subgroups. The increase in consumption of unhealthier components might be faster than that of healthy components, as in many other countries [19]. In addition, Ethiopia's food production and food supply are very vulnerable to climate change[20] and variability (droughts in 2015-2016), which leads to high temporal levels of severe food insecurity and malnutrition, which can easily affect the dietary pattern of the population[21].

For most Ethiopians, consuming a healthy and nutritious diet is out of reach due to this economic situation and related factors[22; 23]. Despite a very low initial economic level, the GDP grows at 9.5% annually, making it one of the fastest-growing economies in Sub-Saharan Africa (5.2%) over the past ten years[24]. Since the start of the COVID-19 pandemic and the recent political instability, the country's economic development has slowed (6.1%) since 2020, but the economy is still growing[25]. However, the food inflation rate is extremely high (26%). In 2020, the government debt was above 55% of GDP, and the export-import imbalance remains enormous. The country imports more than five times its exports, less than $3 billion per year[26]. Unless the government, in partnership with private sectors and other nutrition stakeholders, transforms the whole food system, the current nutrition programs may struggle to reduce the triple malnutrition burden[13] and impact dietary habits[27; 28]. For Ethiopians, as a developing nation, a healthy diet is an issue of sustainable development[29]. The country's socio-economic, health, and nutrition situation needs to be considered in developing a healthy diet [15].

Food-based dietary guidelines (FBDG) may play a vital role in informing consumers to make healthy dietary choices and set proper targets for food system actors to ensure a healthy diet's availability, accessibility, affordability, and sustainability [31; 32]. FBDG serve as the foundation for government food and nutrition policies, health and agriculture policies, and nutrition education programs to promote healthy eating habits and lifestyles. FBDG give recommendations on the intake of foods, food groups, and dietary patterns to the general public to ensure that they get the food and nutrients they need to be healthy and avoid chronic illnesses[33; 34].

1.2.Rationale

A lack of a healthy diet is one of the major challenges in preventing and managing the burden of undernutrition, micronutrient deficiencies, overnutrition, and diet-related non-communicable diseases in Ethiopia[35; 36]. Successful dietary interventions typically implement a feasible healthy diet for different demographic groups. We focus on women of reproductive age for two main reasons. First, this target group is the generation in charge of grocery shopping and cooking the family's diet, even though the man handles most homes' financial matters. Secondly, the current infant and young child feeding programs in Ethiopia focus mainly on the first 1000 days of life. Therefore, our study will complement the ongoing infant and young child feeding (IYCF) strategy by contributing to filling dietary intervention gaps primarily among women of reproductive age (15-49 years), as targeting women's dietary intake will benefit both the women's and their children's health and nutrition [37].

Ethiopia's food and nutrition policy and strategy and national food system road map include developing and implementing Ethiopian food-based dietary guidelines as key[38; 39]. Country-specific FBDGs are relevant because foods that make up a diet are more than just a collection of nutrients. The nutrients in food interact differently when present as food or combined in a meal or diet, and the food preparation, processing, and cooking (i.e., food culture) influence the nutritional values of foods. FBDGs should target the total diet, including all foods in daily meals and snacks, be based on food commonly consumed, and include all types of foods. The list of food groups used in FBDGs should be recognizable by consumers, permit the maximum flexibility in food choice to accommodate different eating traditions in a country, and the description of food serving size should be in terms of commonly used household measures[40]. Furthermore, the country's future economic growth and literacy levels (48% of women and 28% of men aged 15-49 years have no formal education)[6] need careful consideration[30].

A healthy eating index is considered an important dietary assessment tool for monitoring and evaluating adherence to a FBDG(42). Therefore, developing an index specifically for Ethiopian FBDG (Et-HEI) is relevant. The FBDG will be implemented as part of Ethiopia's current food system roadmap. Monitoring intake, dietary assessment, and research will all be part of the Ethiopian food system initiative's implementation. Further research on the trend and relationship between diet and disease in different agro-ecological zones is required to adapt the FBDG for various regions and subpopulation groupings.

Through the food system for a healthier diet flagship initiative Agriculture for Nutrition and Health (A4NH)[41], and with the support of the United Nations Food and Agriculture Organization, the government of Ethiopia was able to develop the FBDG and Et-HEI. This thesis presents the primary evidence for developing and evaluating the Ethiopian food-based dietary guidelines and a healthy eating index, suitable for measuring adherence to these FBDG, targeting women of reproductive age, representing an important subpopulation of the general population above 2 years of age.

1.3.Outline of the thesis

The full methodological framework used is presented in **Chapter 2**. In **Chapter 3** reviews the current knowledge on the relationship of food, food groups, diet, and dietary patterns with Ethiopia's major diet-related diseases and causes of death in a healthy population above two years of age. This review is based on a literature search of systematic reviews and meta-analyses conducted on health outcomes of interest for Ethiopia. The findings from this review, combined with evidence from other low and middle-income countries and global dietary recommendations, informed the development of key dietary recommendations for Ethiopia. **Chapter 4** presents the findings from evaluating the acceptability, cultural appropriateness, consumers' understanding, and practicality of the Ethiopian food-based dietary guideline's food guide and graphics developed based on the dietary recommendations. Consumers (women of reproductive age), health extension workers, agriculture extension workers, nutrition program coordinators, policy advisors, and academics were interviewed for this study. The study findings from this chapter helped finalize the food guide and food graphics and were used as input to develop assumptions for diet optimization. **Chapter 5** presents this development of a feasible healthy diet for Ethiopian women of reproductive age based on linear goal programming. The aim was a diet that closely resembles their current eating habits while meeting predetermined nutrient recommendations and cost constraints using mathematical modelling. The work was based on dietary intake data collected among 500 women of reproductive age from five regions in Ethiopia, using 24-hour dietary recall interviews on two non-consecutive days. This information sets the recommended daily intake of foods in the FBDG. **Chapter 6** presents the development of the Ethiopian healthy eating index (Et-HEI) based on the dietary recommendations and the recommended food and food group amounts resulting from the diet optimization. We evaluated the developed Et-HEI score against the self-reported energy intake and probability of nutrient adequacy, the minimum diet diversity score for women (MDD-W), and the socio-demographic characteristics of the women collected earlier. In the general discussion (**Chapter 7**), the key findings from these studies are summarized and discussed further.

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Chapter 2

A proposed methodology for developing and evaluating food-based dietary guidelines and a healthy eating index for Ethiopia

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ABSTRACT

Food-based dietary guidelines (FBDG) promote and maintain healthy eating in a population by providing country-specific guidance. However, many African countries like Ethiopia do not have FBDG. This paper describes the methodology for developing Ethiopian FBDG and for creating and evaluating a healthy eating index and a scoring tool that can be used to monitor the population's Adherence to FBDG. A multidisciplinary technical working group will be tasked to develop FBDG for the general population above 2 years based on identifying priority diet-related public health problems and risk factors and a systematic review of dietary patterns related to the identified priority health outcomes following a multi-step process. The FBDG will be translated into daily food choices for specific subpopulations by applying linear programming using the national food consumption survey (NFCS) of 2011. The FBDG will be evaluated for cultural appropriateness, acceptability, consumer understanding, and practicality. A dietary gap assessment will be conducted by comparing the national food supply with the country's food demand. In addition, an Ethiopian healthy eating index (Et-HEI) will be developed based on the FBDG using the NFCS data. Evaluation of the Et-HEI will be conducted by comparing the Et-HEI score based on 24-hour recall with that of the Et-HEI score based on a food frequency questionnaire (FFQ) by analysing the association of Et-HEI score with population characteristics and micronutrient intake with or without additional adjustment for energy intake. Finally, a brief Food Quality Screening (FQS) tool scoring for the important Et-HEI components will be developed to enable Evaluation for counselling. Ethical approval is received from the scientific and ethical review office of the Ethiopian Public Health Institute. This protocol was registered on https://register.clinicaltrials.gov/ in 2018 with registration number NCT03394963. The findings will be disseminated through peer-reviewed publications.

Introduction

Ethiopia's economy has experienced rapid growth over the past 10 years [1]; this has been accompanied by a changing food environment, characterised by declining total shares of household income spent on food [2] and increased access to non-staples, processed foods, edible fat and sugary beverages [3]. A national food consumption survey conducted by the Ethiopian Public Health Institute (EPHI) in 2011 indicated major dietary gaps, including inadequate intakes of vitamin A, calcium, and folate. Similarly, the national micronutrient survey conducted by EPHI in 2016 showed zinc, vitamin A, iodine, folate, and vitamin B12 deficiencies are public health problems among all population groups in Ethiopia[4; 5]. Stunting among young children has reduced impressively from 57% in 2000 to 38% in 2016 [6]. Nevertheless, the prevalence of stunting is still among the highest globally due to being underweight among mothers, low birth weight, inadequate dietary intake, and diet-related health outcomes as possible determinants[7; 8]. The national nutrition survey conducted by EPHI in 2015 indicated that 20% of women of reproductive age were underweight (BMI<18.5 kg/m^2) and 13% overweight (BMI > 25 kg/m^2). Overweight among women increased by 10% between 2009 and 2015 from 3% to 13% [9; 10; 11]. Similar to other low-and middle-income countries (LMICs), Ethiopia is suffering from the triple burden of malnutrition (i.e., undernutrition, micronutrient deficiencies, and overnutrition) [9; 12; 13; 14; 15; 16].

An unhealthy diet is one of the most important risk factors that need to be addressed to tackle the triple burden of malnutrition [17; 18; 19] and diet-related diseases [20; 21] in LMICs like Ethiopia. Dietary factors were responsible for 60,402 deaths (95% Uncertainty Interval [UI]: 44,943-74,898) in 2013 among all Ethiopians—almost a quarter (23.0%) of those deaths due to non-communicable diseases (NCDs; like diabetes, cardiovascular diseases, cancer, and others)[22]. Diets low in fruits and vegetables and high in sodium are the leading dietary risk factors and contribute 14.3, 6.1, and 6.3%, respectively, to the NCD deaths in Ethiopia [22]. In Sub-Saharan African (SSA) countries like Ethiopia, micronutrient intake has declined over the past 50 years, as shown by a reduced dietary micronutrient density index (average micronutrient density of the food supply based on 14 micronutrients, calcium, copper, iron, folate, magnesium, niacin, phosphorus, riboflavin, thiamine, vitamin A, vitamin B12, vitamin B6, vitamin C, and zinc). Reasons for this include increased availability of grains (rice, maize, and wheat) and vegetable oils, which have low micronutrient density, and decreased proportional availability of pulses, dairy products, meat, nuts and seeds, fruit, and vegetables [23]. Recent changes in dietary patterns in LMICs [24; 25] and Ethiopia (rise in both unhealthy and healthy components of diet) in particular [26; 27] indicate that a critical gap needs to be addressed towards improving dietary quality for better health, prevention of diet-related diseases, and reduction of the triple burden of malnutrition [28; 29].

A healthy diet means eating a variety of foods that provide adequate intakes of energy and different nutrients needed to maintain or improve health and feel good [30] and limits components such as salt, sugar, and some types of fat (e.g. trans fat) proven to increase health risk. A critical area of focus is that people eat foods and not individual nutrients. FBDG therefore be translated into a culturally appropriate diet. Ethiopia's important considerations are the variation in food availability across regions, by season, and rural/urban settings. The nutrients needed for a healthy diet include protein, carbohydrates, the right type of fat, dietary fiber, water, vitamins, and minerals. Moderate intake of salt and sugar, as well as avoiding unwanted foods such as alcohol, trans fatty acids, and ultra-processed foods, are part of a healthy diet [31; 32]. Promoting healthy eating in LMIC can also reduce the social inequality in diet among the poor and rich, mainly targeting disadvantaged population groups and short- and long-term economic benefits to households due to better health and educational outcomes [33].

Food-based dietary guidelines (FBDG) are a set of simple advisory statements that give direction to consumers on healthy eating patterns and the type of food or food groups or sometimes nutrients (sodium) that need attention to promote better nutrition and well-being and to address diet-related health conditions in a country [34; 35]. FBDG should be specific to a given country or setting and appropriate in sociodemographic profile, nutritional status, health status, and dietary patterns. The FBDG can support improving health [22; 36; 37], work and learning capacity, growth for different populations, and facilitate national food supply planning [38; 39], reduce health care costs [40], and assist food industries in food product reformulation. Country-specific FBDG are important because they are tailored to national food habits, including commonly consumed and available foods, and are developed to recognize their prevailing health and nutrition problems. The nutrients in different foods may interact differently, and the food preparation, processing, and cooking (i.e., food culture) influence the nutritional values of food. FBDG should target the total diet, including all daily meals and snacks. The list of food groups used in FBDG should be recognizable by the targeted consumers/population, permit the maximum flexibility in food choice to accommodate different eating traditions in a country. The description of food serving size should be in terms of commonly used household measures that the given population can relate to as widely as possible [35].

Out of 58 African countries, only seven (Benin, Kenya, Namibia, Nigeria, Seychelles, Sierra Leone, and South Africa) have FBDG [41]. To maintain healthy eating in Ethiopia, it is crucial to develop and implement country-specific FBDG [42; 43]. Furthermore, developing a Healthy Eating Index derived from the FBDG will enable tracking the Adherence of the population to the FBDG so that positive trends can be maintained and the negative trends mitigated through appropriate interventions [44]. In collaboration with FAO and other key local partners, Wageningen University (WU), the Agriculture for Nutrition and Health (A4NH) program led by International Food Policy Research Institute (IFPRI), and EPHI have initiated the development of FBDG and Et-HEI for the Ethiopian population above 2 years in the forthcoming four years (2017-2021). This paper describes the methodological approach to generate knowledge, data, and tools to support the development and Evaluation of FBDG and Et-HEI for Ethiopia.

Aim and Objectives

Overall, the methodological approach aims to develop and evaluate FBDG and an Ethiopian Healthy Eating Index (Et-HEI) for the Ethiopian population above 2 years and generate lessons to inform similar processes in other parts of the African continent with the following objectives:

1. To develop FBDG for Ethiopia informed by systematic reviews and data analysis from global and national datasets;
2. To translate the general guideline messages into daily practical food choices using linear mathematical programming and to evaluate the FBDG developed for cultural appropriateness, consumer understanding, acceptability, and practicality;
3. To develop an Et-HEI for the general population based on the developed FBDG, and to evaluate this index among women of reproductive age in urban and rural settings;
4. To develop and evaluate a brief food quality screener to assess Adherence to the Ethiopian FBDG;

5. To assess whether the national food supply can support adherence to the FBDG for Ethiopia

METHODS AND ANALYSES

The methodology to develop Ethiopian FBDG and Et-HEI has been adapted from the 1998 FAO/WHO preparation and use of FBDG [45] and the process used to develop the 2015 Dutch FBDG and Dutch healthy diet index [46; 47; 48]. The methodology is adapted to the Ethiopian context and will consider existing (or prevailing) diet-related public health problems, cultural and dietary habits, and socioeconomic status.

A multidisciplinary national technical working group (NTW) composed of senior experts from the ministries of Health, Agriculture, and Education, universities, research institutes, UN organizations, and NGOs will be established to provide oversight over developing the FBDG. The NTW will prepare a working document (terms of reference) that will define the role and responsibilities of the working group in the development of Ethiopian FBDG. Next, the NTW will identify key evidence-based dietary recommendations [49] for addressing diet-related public health problems in Ethiopia based on the relationship between diet and priority diseases generated by WUR and EPHI. The NTW will also evaluate the quality and strength of research used to develop evidence-based dietary recommendations [49].

The FBDG development process described below and in Figure 2.1 comprises two major parts. The first part is developing evidence-based dietary guidelines for the general population above 2 years of age. These general guidelines will be translated into everyday healthy dietary choices for specific population subgroups, such as women of reproductive age, school-age children, adolescent girls, adults, and elderly, based on their dietary reference values using linear mathematical programming. A food guide (a visual representation of the FBDG) will be designed using the most commonly consumed foods in different regions of the country for the general population. In addition, a dietary gap assessment will assess the amount of deviation between current dietary practices of the population and the new recommendations. The second part will be the development of a Et-HEI and brief food FQS. These tools for assessing diet quality will evaluate Adherence to FBDG [45; 50]. Once developed, the Et-HEI and FQS will be evaluated among women of reproductive age living in rural and urban settings in different country regions.

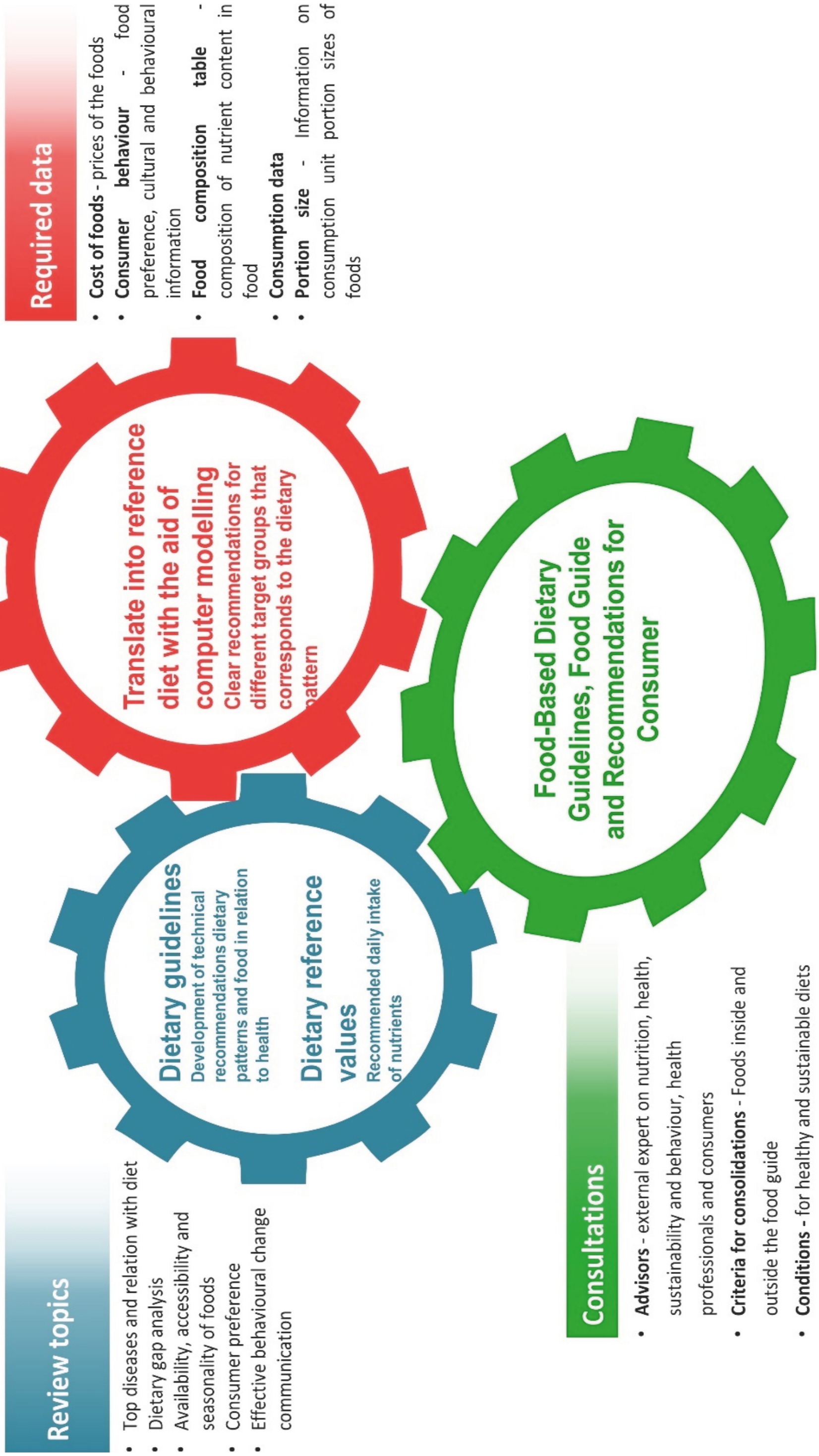

Figure 2.1. Methodological framework for the development of Ethiopian FBDG

Developing FBDG for Ethiopia by systematic reviews and data analysis of global and national datasets

A two-step approach will be followed to determine Ethiopia's evidence-based dietary guidelines. First, the top ten diet-related diseases will be identified. The data sources that will be used for estimation of the total number of deaths, years living with disability (YLDs), and disability-adjusted life years (DALYs) in Ethiopia will be obtained from the Global Health Data Exchange (http://ghdx.healthdata.org/). The Global Burden of Disease (GBD) team developed the comparative risk assessment framework to estimate the 2016 GBD levels and trends in exposure, attributable deaths, and disability-adjusted life-years (DALYs) for behavioural and metabolic risks or clusters of risks. The data sources, collation, and computation process for 2016 GBD risk factors have been published in The Lancet 2017 [(51)]. Based on the average ranking of the total number of deaths, YLDs, and DALYs of the top 20 diseases in Ethiopia, the top 10 diet-related diseases will be identified from this GBD database.

Additional secondary data analysis on trends in nutrition status and dietary intake gap will be conducted using 2000, 2005, 2011, and 2016 Ethiopian demographic and health surveys [(6; 52; 53; 54)], the most recent national food consumption survey of 2011, and other national health, nutrition, and dietary data available. The national food consumption survey is a national representative cross-sectional survey conducted to provide information about food access and utilization in Ethiopia's lean season, representing just one season's food pattern. A total of 8267 households composed of 8133 women (98% response rate), 8079 children (97% response rate), and 380 men were included across all regions of Ethiopia[1]. A single 24-hour dietary recall used in the survey is assumed to be appropriate to capture the diversity of foods at the national and sub-national levels [(4)]. The Ethiopian food composition table will estimate the nutrient values of consumed food. The amount of foods consumed will be converted into an amount of nutrients. To define the distribution of consumption across the country between regions and compare actual nutrient intakes with reference values, the variance ratio of between-person values for Ethiopia will be combined with the within-person values available

[1] Ethiopia is a Federal state with 11 regional states, 2 city administration, 800 districts/woredas and around 15,000 villages/kebeles (5,000 Urban & 10,000 Rural) that present diverse eating patterns.

from a recent survey in Uganda, a neighbouring country[55]. The development of technical recommendations of the FBDG will be based on the secondary data analysis of the top 10 diet-related diseases, nutrient gaps, food availability, accessibility and seasonality, and systematic review.

Second, a systematic literature review will be conducted by searching meta-analyses and systematic reviews of the impact of dietary interventions on the prevention of the identified top ten diseases. Suppose there is no strong meta-analysis or systematic review (studies that fulfil our screening criteria and the AMSTAR (A MeaSurement Tool to Assess systematic Reviews) quality appraisal) available. In that case, the review team will search for randomized control trials or prospective cohort studies. An initial search of PUBMED, SCOPUS, and CAB abstracts will be undertaken, followed by screening the titles and abstracts and the index terms used to describe the article. This will inform the development of a search strategy tailored for each information source (PubMed, SCOPUS, and CAB abstracts) and paper screening criteria for further revision. The review will consider studies that include age groups above 2 years and studies that evaluate dietary patterns, foods or nutrients with diet-related health outcomes. The quality of systematic review and meta-analysis will be assessed by two individuals separately using the AMSTAR checklist before extracting the results and recommendations [56]. The primary outcomes will be a dietary risk of cardiovascular diseases, type 2 diabetes, protein-energy deficiency, and micronutrient deficiencies (vitamin A, zinc, calcium, and folate). Intermediate outcomes will be identified during the review process of selected studies by considering the most reported indicators. Studies published in English since 2014 will be included. In general, the formulation of guidelines will only be based on strong evidence (meta-analysis, systematic review, randomized control trials, and prospective cohort studies) as it's explained on the hierarchy of clinical evidence (Figure 2.2)[57]. Recommendations on meal frequency and portion size for Ethiopia will be cross-checked with guideline messages designed for other developing countries.

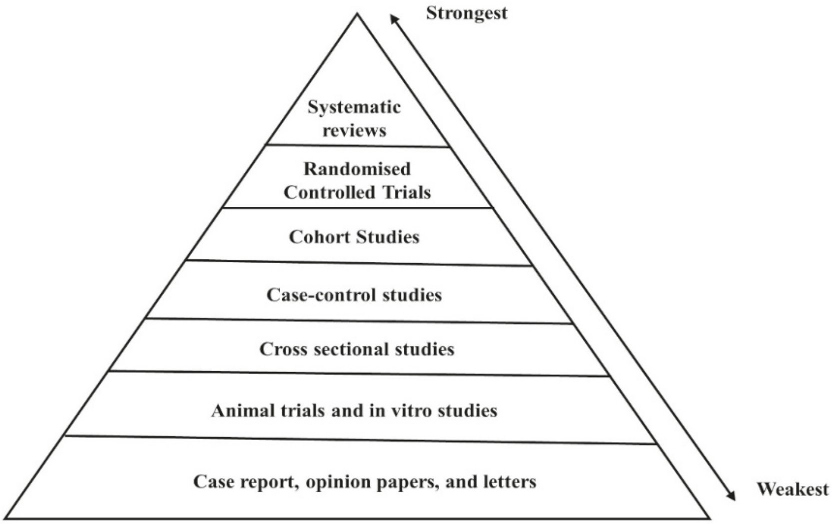

Figure 2.2. The hierarchy of clinical evidence adapted from Anthony L. Rosner [57]

Translating the general FBDG into daily practical food choices for specific sub-population groups: Diet optimization modelling

Linear mathematical programming will be used to model the FBDG for the general population above 2 years into everyday healthy food choices for specific sub-population groups, such as women of reproductive age (WRA) (15-49 years), adolescent girls, school-age children, and the adult population.

Identification of local foods for the modelling will be made using most commonly consumed foods; foods contributing five percent or more of total energy intake (comparable to what has been used in another study [58]) by different sub-population groups from the most recently conducted national food consumption survey from 2011 as well as potentially beneficial underutilized foods and nutrient-dense foods. To come up with an affordable diet, the modeling will consider the prices of the foods that are most commonly consumed. The cost of each identified most frequently eaten food item will be taken from the most recent conducted, 2016 Household Income Consumption Expenditure (HICE) survey, an additional market survey (composed of both urban and rural, and big supermarket, medium and small open market) will be conducted in case there is missing information on costs for specific food items from the HICE survey. The recommended energy and nutrients intake for WRA and other population sub-groups set by WHO will be used for nutrient optimization with minimum cost [(59)]. The recommended daily meal frequency and portion sizes will be taken into consideration from the newly developed evidence-based dietary guidelines during diet optimization. Different scenarios (e.g., only foods including nutrient-dense and underutilized foods, foods plus the national fortification program into consideration, foods plus the national fortification and supplementation program into considerations) will be considered for optimum food planning for WRA, adolescent girls, school age children and adult population. To prevent inclusion of excessive (unrealistic) amounts of any food items, the upper and lower consumption bounds will be set based on the habitual (usual) intake of WRA and other population sub-group in Ethiopia.

Feasibility study for adherence to FBDG

The main goal of the feasibility study is to evaluate cultural appropriateness, acceptability, consumer understanding, and practicality of making daily food choices that adhere to the FBDG. The WRA group will represent the consumer at a community level. Focus group discussions and key informant interviews will be conducted with different experts, implementers, and community groups to evaluate the FBDG. The summary of focus areas, key questions, possible outcomes, and target study population, as stated in Table 2.1, is adapted from a method on feasibility studies designed by Bowen et al. [(60)].

The Focus Group Discussions (FGDs) will assess the cultural appropriateness and acceptability of the FBDG by nutrition experts and consumers. Preparation for the FGD will be done by interviewing a few (maximum 5) individual nutrition experts with a good understanding of Ethiopian food systems and dietary habits. The FGDs will be conducted among high-level local nutrition experts, frontline community health extension workers, and consumers. At the community level, at least 30 WRA groups who are married and live with their husbands in urban and rural settings will be invited to participate in the FGDs. WRA from urban Addis Ababa and rural Amhara, Oromia, Tigray, and SNNP regions will be selected to provide a representative picture of the areas of Ethiopia. Experienced moderators will lead the FGDs from EPHI who are trained on how to conduct FGDs and a note-taker will also be assigned for each session. Key informant interviews will be conducted with high-level local nutrition experts, media experts, frontline community health workers, and community representatives to understand better whether the FBDG translated into daily food choice are understood and the feasibility of Adherence. For both FGD and key informant interviews (as described in the table below), the level of saturation will be checked during data collection by assessing the degree of repetition in the new data compared to previous data. The data collection will be stopped when the level of saturation is reached, and no new information is acquired.

A total of 6 focus group discussion sessions (1 FGD with high level experts, 2 FGDs with frontline community health extension workers, 2 FGDs with community representatives of WRA in rural areas and 1 FGD with community representatives of WRA in urban areas) will take place. Each of the 6 FGDs will take a maximum of 90 - 120 minutes and 10-12 participants per group. Consumer, community health workers, and high-level experts will have a separate FDG session. Amharic will be the language of communication; the interview will be recorded with permission, then transcribed and translated into English by two people separately for the same record to maintain the meaning in the translation process. A third person can be brought into the discussion if there is no agreement. After the translation, grammar will be verified by a native English language speaker. Analysts will read all transcripts and develop and implement a coding frame through discussion and consensus. Then the codes will be categorized into themes and sub-themes to understand the meanings of each response about the guidelines among participants. QSR International's NVIVO-11 software will facilitate the analysis.

Area of focus	The feasibility study asks …	Outcomes of interest	Sample study design	Target population
Cultural appropriateness	To what extent are the words and images used in the FBDG appropriate to the community?	• Appropriateness of words used in the messages for different communities • Appropriateness of images used in the food guide for different communities	• **Focus groups** in target population	• High-level local experts • Frontline community health extension workers
Acceptability	To what extent can the guideline messages in the FBDG be judged as suitable, satisfying, or attractive to program deliverers and to program recipients?	• Satisfaction • Intent to continue use • Perceived appropriateness • Fit within organizational culture • Perceived positive or negative effects on organization • Actual use • Expressed interest or intention to use • Perceived demand	• **Focus groups** in target population participants to understand how the recommendations would fit to daily-life activities	• High-level local experts • Frontline community health extension workers • Community representative (WRA who are married and live in their own house).
Frontline health workers and consumer understanding	To what extent do consumers understand the key messages in the guidelines? How are the messages transferred by different implementers?	• Understanding of the messages and images used for the FBDG by health extension workers (HEWs) • Understanding of the messages and images used for the FBDG by media • Understanding of the messages and images used for the FBDG by consumers	• **Key- informant** interviews	• Front line community health extension workers • Community representative (WRA who are married and live in their own house).

Chapter 2

The practicality of the key messages	To what extent can the key message be implemented by the target population using existing means, resources, and circumstances and without outside intervention?	• Amount, type of resources needed to implement • Factors affecting implementation ease or difficulty • Efficiency, speed, or quality of implementation • Positive/negative effects on target participants • Ability to implement what is recommended by individual guidelines	• Small-scale demonstration study to examine predicted cost, burden, and benefit because of appropriate intensity, frequency, duration of the intervention, using **key- informant** interviews to gather data	• High-level local experts • Frontline community health extension workers • Community representative WRA who are married and live in their own house).

Development and Evaluation of the Ethiopian Healthy Eating Index (Et-HEI)

Developing the Ethiopian healthy eating index

HEI is a tool that will assess the adherence of the population to FBDG[48]. The Ethiopian HEI (Et-HEI) has multiple healthy eating components, representing the foods in the guidelines, with scoring that expresses the extent of adherence to the relevant component. Assigning foods into food groups will be conducted based on food grouping in the FBDG before choosing the scoring system. Depending on the component, the scoring system will be proportional or dichotomous. Each proportionally scored component of the healthy eating index will have a minimum score of 0 and a maximum score between 5 and 20. The components will be scored in a way that a higher value indicates better Adherence to the FBDG. The total Et-HEI score will range from 0 to 100, with higher scores indicating higher diet quality. The Et-HEI will be categorized into adequacy, optimum, moderation, and ratio components based on the healthier options provided in the food group of FBDG (Figure 2.3)[48].

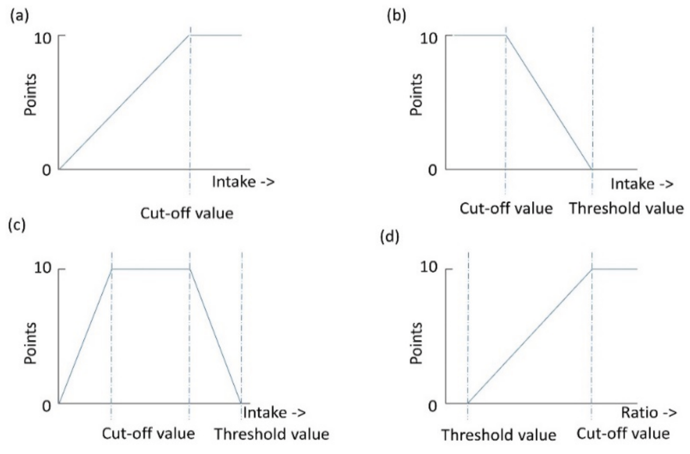

Figure 2.3. Graphic presentation of scoring for the Et-HEI for the different type of components: adequacy component (a), moderation component (b), optimum component (c), and ratio component (d) [48].

The 24-hour dietary recall data from the national food consumption survey data collected in 2011 will be used to develop the Et-HEI. The completeness and quality of the 24-hour data will be checked prior to the start of the data analysis. Selection of foods and nutrients will be made based on public health importance and availability of the nutrient list of the Ethiopian food composition table. If there is missing data in the food composition table for Ethiopia, food composition table data will be borrowed from other sources. The scoring of the adequacy components for each individual will be computed based on the following formula (figure 2.3a);

$$\textbf{Scoring of the intake from 0 – max. value (5-20)} = \frac{\text{The reported intake}}{\text{Cut-off value}} \times \text{max. value (5-20)}$$

For moderation components (e.g., fat, sugar, salt), the threshold value will be determined based on 85th percentile of average intake of the sample population if there is lack of evidence on the cut-off value. Zero will be taken as above the threshold and maximum value will be taken as the cut-off (Figure 2.3b). In this case, the score will decrease when the intake is increased. The scoring for each individual intake will be computed using the formula;

$$\textbf{Scoring between the threshold and cut-off values} = \frac{\text{The reported intake value – cut-off value}}{\text{Threshold value - Cut-off value}} \times \text{max. value (5-20)}$$

For the optimum component, zero will be taken for no intake and maximum value will be taken if intake is within the given range (Figure 2.3c). In this case, the score will increase when the intake is increased within the given range for that component. The scoring for each individual intake will be computed using the following two formulas;

$$\textbf{Scoring (intake lower than the cut-off value)} = \frac{\text{The reported intake value}}{\text{The lower cut-off value}} \times \text{max. value (5-20)}$$

$$\textbf{Scoring between the threshold and higher than the cut-off value} = \frac{\text{The reported intake value – cut-off value}}{\text{Threshold value - Cut-off value}} \times \text{max. value (5-20)}$$

For the ratio component, zero will be taken as below the threshold and maximum value will be taken as the values above the cut-off (Figure 2.3d). The cut-off and threshold values of the ratio components will be set to calculate the ratio. In this case, the score will increase when the ratio is increased. The scoring for each individual intake will be computed using the formula;

$$\textbf{Scoring between the cut-off and threshold values} = \frac{\text{The ratio - threshold value}}{\text{Cut-off value - threshold value}} \times \text{max. value (5-20)}$$

The data will be analysed using the latest version of STATA software. Correlation, association and other appropriate advanced statistical techniques will be applied as needed to answer the questions under this study.

Evaluate the Ethiopian healthy eating index

The Et-HEI will be evaluated by comparing the healthy eating index score calculated based on 24-hour recalls with a healthy eating index score calculated based on food frequency questionnaire for population characteristics (such as age, education level, income, household food security) and micro-and macronutrient intake with or without adjusting for energy intake. Associations of Et-HEI scores with intakes of macro and micronutrients, intake biomarkers such as urinary protein, nitrogen, sodium, potassium, sugar, creatinine excretion, and thiamine and BMI measurements will be determined. An Et-HEI based on food frequency data is chosen for comparison because FFQ is the most frequently used in epidemiological nutrition studies due to the questionnaire's easiness and related reporting [(61)]. As mentioned in the Et-HEI development, the required amount of consumption stated in the guidelines will be used as a cut-off for the maximum score. The minimum zero score point will be given for no intake except intake of moderation component. A dichotomous scoring system might be applied when the cut-off value becomes lower than the dietary recommendation.

The 2016 EDHS dietary intake data and anthropometric data, and the national food consumption survey of 2011 will be used to evaluate the healthy eating index. Additional primary data on 24 hr dietary recall and FFQ, as well as 24-hour urine, will be collected from 500 HHs from four regions (Amhara, Oromia, Tigray, and South nation nationality) and one city administration, Addis Ababa for Evaluation of Et-HEI.

Developing and Evaluation of brief food frequency questionnaire to check diet quality and Adherence with Ethiopian FBDG

Once the country specific FBDG are developed and implemented, it is important to monitor the implementation/adherence to improve the eating behaviour towards a healthier diet. To do so, the use of a healthy eating index is very useful, but implementation is time-consuming and costly, especially in a clinical setting and public health interventions. Therefore, we will develop a brief FQS tool that should require only 10 – 15 minutes to complete. In addition, the FQS should be at a lower cost than Et-HEI to administer and reduce the respondent burden. The FQS will be used for scoring the Et-HEI and can be used during diet counselling and public health interventions to assess and monitor the Adherence to FBDG by individuals. During Evaluation, the target population group at the household level will be healthy WRA (15–49 years).

The FQS will be developed using 24-hour dietary recall data of Ethiopian women of reproductive age. Foods that contribute most to the level and variation of intake of the foods in the FBDG are selected for the food list of the FQS; this is similar as was done for the Dutch FQS [62; 63]. The food items representing the food groups in the FBDG will also be included in the selected food items lists for FQS. Then we will add food items that contribute significantly to the between-person variation in nutrient intakes from 24 hr dietary recall. The questionnaire will be designed including those selected food items. The answer will have a category range from never to every day. Portion size will be estimated using commonly used household [64] measures. The HH measures were converted and standardized into standard measurements during the national food consumption survey.

For the Evaluation of FQS, we will use primary data to be collected in four regions (Amhara, Oromia, SNNPR, and Tigray) and one city administration (Addis Ababa). Each region and administrative city will have 100 HHs randomly selected from a total of 10 districts. Two districts per region will be purposively selected to consider different living scenarios. Of the four regions, the first district will have a relatively high agricultural productivity and the second district a relatively low agricultural productivity. These will be selected in consultation with the regional agriculture bureau. From the Addis Ababa city administration two districts will be selected; the first district will have a relatively high living standard, and the second will be an urban slum area. These districts will be selected in consultation with the Addis Ababa city administrative office. At district level, villages will be randomly selected, and a fresh listing of HH will be conducted. From listed HHs, 50 HHs will be selected using systematic random sampling. From each selected HH woman of reproductive age (15-49 years) will be enrolled as a study participant. For the target study population, dietary data, anthropometry measurement, socio-demographic, and lifestyle characteristics will be collected together with both the brief FQS and repeated 24 hr recall. The brief FQS and repeated 24-hour recall will be administered alternatively within two-month time on the same study participants with 24-hour urine sample collection for biomarker analysis.

Dietary gap assessment based the newly developed FBDG in Ethiopia: policy recommendations

Adequate national food supply (both production and import) is critical for a country to adhere to country specific FBDG. This part of the study aims to assess whether Ethiopia has an adequate food supply and the needed diversity for the population to respond positively to the newly designed FBDG.

The methodology of this study is adapted from Kuyer et al. [58] who conducted a similar study in Cameroon. The FAO food balance sheet data will be used by cross checking the accuracy of the data with the national data from technical reports to come up with an estimate of the country food supply in different food groups included in the FBDG. The food groups and serving sizes (converted into grams) determined in the FBDG and current population supply estimation (g/c/day) for Ethiopia will be used to estimate the target food supply or the demand. The gaps will be estimated by analyzing the difference between the recommendation and supply of foods from each food group by comparing the current food supply with recommended healthy eating in the FBDG. This is expected to contribute to policy recommendations on agriculture production, food trade, consumption and other issues related to the food system of Ethiopia for healthy eating [65]. The dietary gap assessment study was part of the development of a methodological framework, but it is not included in this thesis.

Patient and Public Involvement

Patients were not involved in developing the research question, design of the study, and setting outcome measures. Patients will be involved in the data collection process by providing information during data collection. The findings from this study will be translated into food-based dietary guidelines, shared through conferences, reports, and mass media (TV and radio).

Ethics and Dissemination

The study is a collaboration of Wageningen University and Research [66], Food and Agriculture Organization of the United Nations (FAO), Ethiopian Public Health Institute (EPHI), and International Food Policy Research Institute (IFPRI). The overall protocol is received ethical clearance from the Scientific and Ethical Review Office (SERO) at EPHI. Informed consent will be taken before an interview and collecting biological samples. Findings will be used to develop FBDG and Et-HEI for Ethiopia and inform policy recommendations toward a healthier diet. A dissemination workshop will be organized with key implementing sectors of the food system for a healthier diet (http://a4nh.cgiar.org/our-research/research-flagships/) with key public and private partners.

Strengths and limitations of this study

- The systematic reviews and secondary data analysis on the five selected topics (priority diseases and relation with diet, dietary intake gap analysis, food availability, accessibility and seasonality, consumer preference, and effective behavioural change communication) will provide the science-based evidence for developing the technical dietary recommendations of the FBDG.
- The methodological framework applied to develop and evaluate the FBDG and Et-HEI for Ethiopia will set a good example for other developing countries interested in developing FBDG.
- The findings from the national dietary gap assessment targeting the Adherence of FBDG will provide policy recommendations for the Ethiopian food system for a healthier diet of the general population.

- A limitation of the study is the time availability of the Ethiopian nutrition stakeholders; the FBDG development process requires a significant engagement of their time, which may be challenging due to competing priorities and demanding workload.
- A second limitation is the availability of only one nationally representative quantitative dietary intake survey from 2011.

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Chapter 3

Dietary recommendations for Ethiopians based on priority diet-related diseases and causes of death in Ethiopia: A review of systematic reviews

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ABSTRACT

Food-based dietary guidelines (FBDG) need to be based on scientific evidence. As part of the development of Ethiopian FBDG, we reviewed systematic reviews to synthesize existing evidence and develop dietary recommendations. Protein-energy malnutrition, deficiency of vitamin A, zinc, calcium, or folate, and cardiovascular diseases (CVD), type 2 diabetes mellitus (T2DM) were selected as priority diseases. Systematic reviews were eligible if they investigated the impact of foods, food groups, diet, or dietary patterns on priority diseases. After a search, 1513 articles were identified in PubMed, SCOPUS, and Google Scholar published from January 2014 to December 2021. The results showed that 19 out of 164 systematic reviews reported on the impact of diet on protein-energy malnutrition or micronutrient deficiencies. Daily 30-90g whole grains consumption reduces the risk of CVD and T2DM. Pulses improve protein status, and 50-150g/day pulse consumption is associated with a reduced incidence of CVD and T2DM. Nuts are a good source of minerals, and consuming 15-35g/day of nuts and seeds improves antioxidant status and is inversely associated with CVD risk. A daily intake of 200-300 ml of milk and dairy foods is a good source of calcium and contributes to bone mineral density. Limiting processed meat intake to less than 50g/day reduces CVD risk. Fruits and vegetables are good sources of vitamin A and C. Milk prevents stunting in young children. CVD and T2DM risks are reduced by consuming 200-300g of vegetables plus fruits daily. Daily sugar consumption should be below 5-10% of total energy to lower the risk of obesity, CVD, and T2DM. Plant-based fat has favorable nutrient profiles and modest saturated fat content. The association of saturated fatty acids with CVD and T2DM is inconclusive, but intake should be limited because of the LDL-cholesterol-raising effect. Plant-based diets lower the risk of CVD and T2DM but reduce micronutrient bioavailability. The review concludes with nine key dietary recommendations proposed to be implemented in the Ethiopian FBDG.

Keywords: healthy diet; dietary recommendations; FBDG; malnutrition, non-communicable diseases

Introduction

Unhealthy diets contribute to the burden of all forms of malnutrition and diet-related non-communicable diseases (NCDs) [1; 2; 3; 4], which are major public health problems in low-and-middle-income countries (LMIC), including Ethiopia [5; 6; 7; 8]. According to the 2016 Ethiopian demographic and health survey, the prevalence of stunting, underweight, and wasting among under-five year children were 38%, 24%, and 10%, respectively [9]. Similarly, the 2016 Ethiopia NCDs Report revealed that most deaths in Ethiopia, 44%, are due to NCDs, which might have been prevented with a healthy diet [10]. According to the 2019 global burden of disease, which include Ethiopia, dietary risk factors such as low intakes of fruits, vegetables, legumes, whole grains, and a high intake of processed meat are among the top five causes of mortality (3.48 million, 95% CI: 2.78–4.37) deaths among female and (4·47 million, 95% CI: 3·65–5·45) among men[3]. Understanding how foods, food groups, and dietary patterns impact nutrition, health, and well-being can help design diet-based prevention strategies and develop dietary recommendations [11].

Dietary recommendations provide advice about habitual healthy dietary intake based on scientific knowledge intended to prevent malnutrition in all its forms, diet-related diseases, and diet-related causes of death [12; 13; 14]. Food-based dietary guidelines (FBDG) are a set of country-specific simple advisory statements that provide consumers with advice on healthy eating patterns. This includes the type of food or food groups or sometimes nutrients (e.g., sodium) that need attention to promote better nutrition and well-being and address diet-related health conditions in a country [11]. Such FBDG considers the dietary reference values for nutrients and will aid consumers in making informed food choices for healthy eating [13]. They also support multi-stakeholder efforts to improve the food system for a diet that improves human health [15].

In 2018, Ethiopia started its first FBDG development process with a coordinated effort of the Ethiopian Public Health Institute (EPHI) in collaboration with Wageningen University and Research (WUR), the Food and Agriculture Organization of the United Nations (FAO), and the International Food Policy Research Institute (IFPRI). The development process was adapted from the Joint FAO/WHO report 'Preparation and use of food-based dietary guidelines' [14] and the Dutch food-based dietary guidelines development process [16]. One of the critical phases in the Ethiopian FBDG development process was to set up technical dietary recommendations based on relationships between diet and priority diseases, based on reviewing evidence from secondary data analysis and systematic reviews. Ethiopia's priority diseases were identified from the 2017 GBD database (http://ghdx.healthdata.org/) (Appendix B: Figures B1 and B2), and the list was finalized after additional discussions with the Ethiopian nutrition stakeholders. The Ethiopian FBDG technical committee selected CVD, T2DM, protein-energy malnutrition, and the micronutrient deficiencies of vitamin A, zinc, calcium, and folate.

This review aims to synthesize the evidence and develop dietary recommendations for preventing and controlling selected priority diet-related diseases in Ethiopia among the population of 2 years and above. For this purpose, we reviewed systematic reviews, as recommended to understand a broad topic area and when several outcomes are considered [17]. The final recommendations derived from this review will be useful to set the objectives and key messages of the Ethiopian FBDG together with other additional evidence.

Materials and Methods

Literature search

The current review is registered on PROSPERO international prospective register of systematic reviews in 2019, available at: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019125490. Systematic reviews, meta-analyses and narrative review published in English from January 1, 2014, up to December 31, 2021, were identified in the following databases: (1) PubMed; (2) SCOPUS, and (3) Google and Google Scholar. Initially, 1513 articles were identified from a search strategy in PubMed and SCOPUS databases, including additional articles from Google scholar. For title and abstract searching, we used the keywords of the selected priority diseases and causes of death in Ethiopia: CVD, T2DM, protein-energy malnutrition, and micronutrients (vitamin A, zinc, calcium, and folate; see Appendix A). Each alternative keyword term was combined using ‘OR’, and all the different strings of keywords were connected using the ‘AND’ operator. We included findings on overweight and obesity if they were reported as intermediate outcomes of CVD or T2DM.

Study selection criteria and quality assessment

Two reviewers independently conducted the title and abstract screening based on defined inclusion and exclusion criteria. The first reviewer searched through all three databases (PubMed, SCOPUS, and Google/Google Scholar) and checked for duplicates. To be included in the review of systematic reviews, the systematic review or meta-analysis or narrative reviews had to be conducted on food, food groups, diet, or dietary patterns concerning CVD, T2DM, or nutritional status (protein-energy, vitamin A, zinc, calcium, folate) and performed in human participants of 2 years and older. The second reviewer screened 10% of the number of papers, which were randomly selected. Cohen's kappa between the two reviewers for identifying the same papers was 0.8, an acceptable level of agreement [(18)]. An agreement was reached on the mismatched articles during the title and abstract screening through discussion between the two reviewers and co-authors.

For further screening, the first reviewer assessed the full texts of selected articles based on the title and abstract. Systematic reviews were excluded in the title and abstract and full-text review when not including food or diet, or dietary pattern (n=377), not including priority diseases (n=404), investigating supplementation (n=212), or other types of interventions (n=154), or fortification (n=34) or other reasons (Figure 3.1.). Five articles were excluded because the full paper was not accessible for detailed screening and inclusion in this review. Finally, a total of 164 systematic reviews and meta-analyses were included. The selected citations were organized in EndNote.

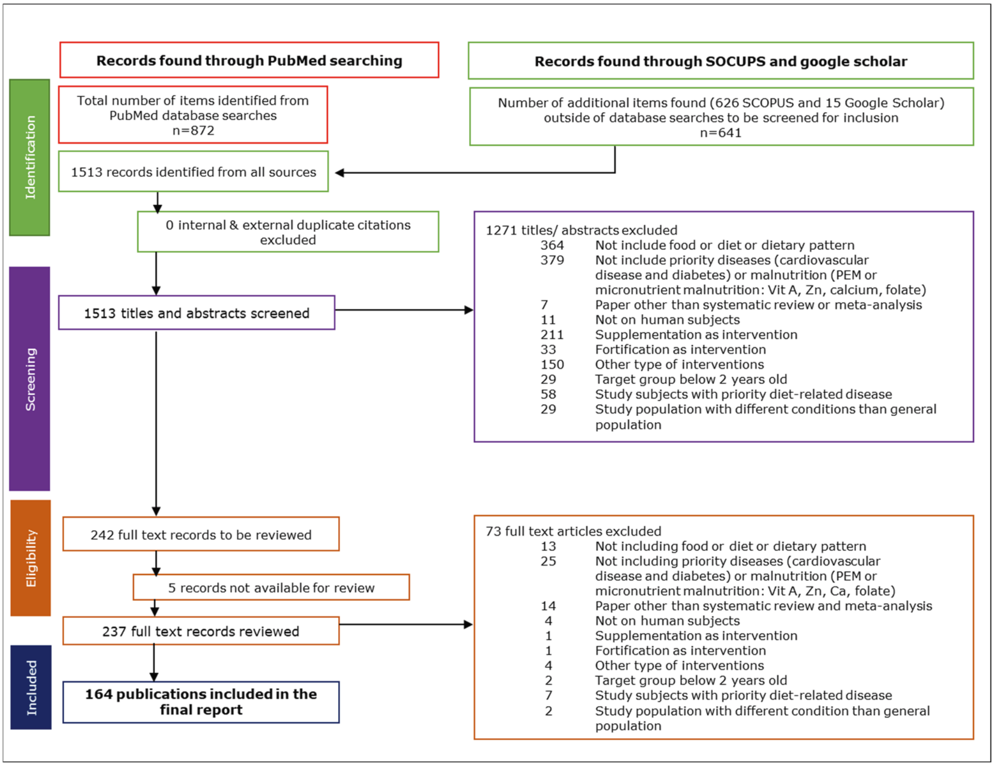

Figure 3.1. Flowchart of evidence search and selection process.

Two reviewers independently evaluated the publication quality using the checklist "Assessing the Methodological Quality of Systematic Reviews 2 " (AMSTAR2) [19], and the discrepancies were discussed and agreed upon. The scores were used to interpret the findings. Results on the seven domains that impact the validity of a review (item 2 on review method, item 4 on comprehensive literature search, item 7 on exclusions, item 9 on risk of bias, item 11 on meta-analysis, item 13 on accounting risk of bias in individual studies, and item 15 on publication bias) were used to rate the overall quality, graded as high, moderate, low, and critically low [19]. Two authors were contacted to provide additional information or data needed. If the systematic review and meta-analaysis quality was low or critically low, it was reported in the results but not taken forward in the final dietary recommendations.

Data extraction and synthesis

After the full-text screening stage, the following information was extracted into a Microsoft Excel spreadsheet for each included systematic review and meta-analysis: citation identification number (ID), title, source, identifier, journal, study location included in the article, total sample, study design, method/procedure used in the study, population group, age of a sample, mean (SD) of the outcome measures, food(group) reviewed (minimally processed whole grain, fruits, vegetables, nuts, pulses, fish, dairy products (yogurt, milk, cheese), red meat and poultry, egg, edible oil, coffee, fermentation, processed meat, refined grains, starch, added sugar, salt, trans fat, alcohol), primary outcomes (protein-energy malnutrition, deficiencies of vitamin A, zinc, calcium, and folate, and CVD, T2DM), conclusions, limitations, notes for discussion items, notes for introduction items and relevance. The extracted findings were synthesized using a descriptive approach. The main results from the review were synthesized per food group.

Results

The review included 164 systematic reviews and meta-analyses of primary studies with participants over 2 years. The eight food groups reviewed included grains, roots, and tubers; pulses; nuts and seeds; milk and dairy foods; meat, poultry, fish, and egg; fruit and vegetables; sweets and added sugars; fats and oils. Figure 3.2. shows the number of reviews per dietary pattern and food group with the primary outcome of interest. About 90% of the 164 systematic reviews and meta-analyses focused on NCDs. Dietary patterns were included in 54 systematic reviews, followed by animal-source foods, i.e., 29 systematic reviews on meat, poultry, fish, and egg, and 25 systematic reviews on milk and dairy products.

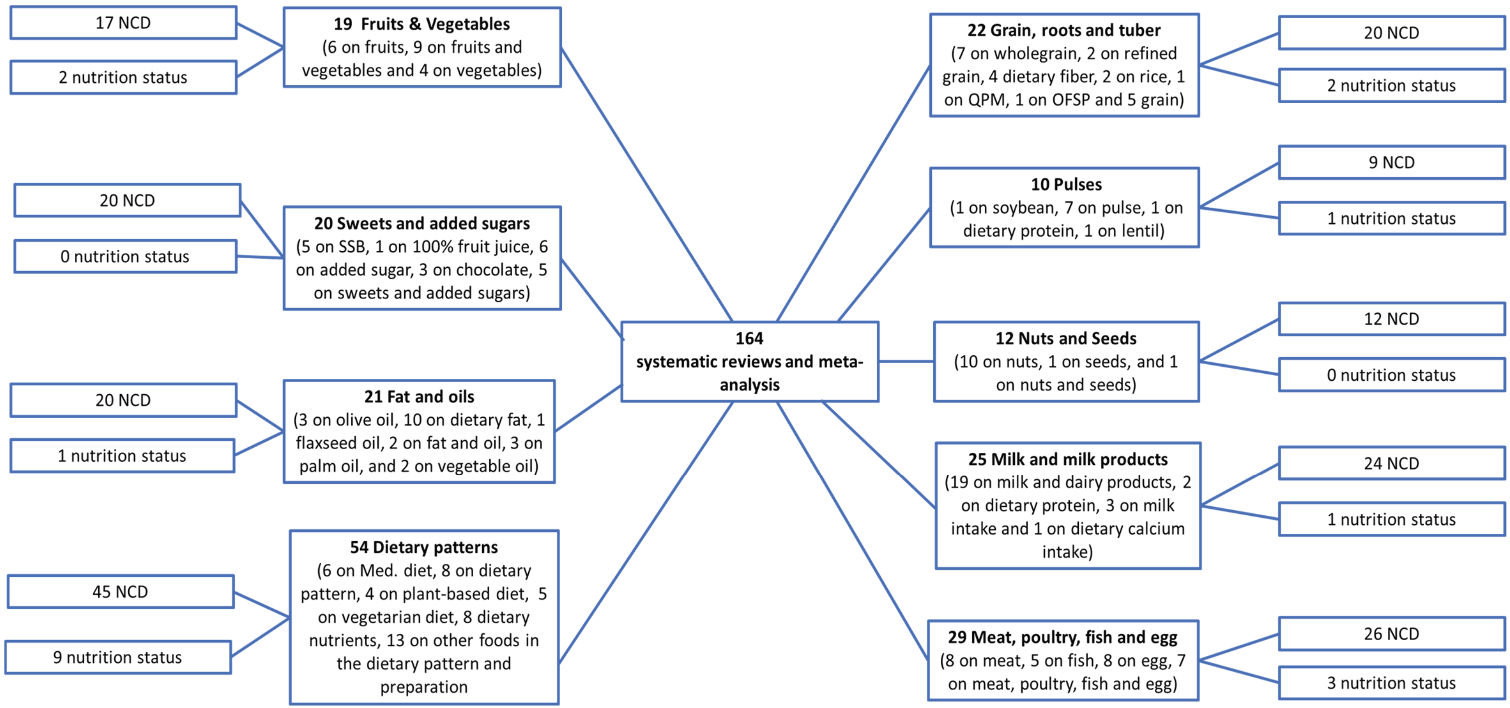

Figure 3.2. Number of selected systematic reviews and meta-analyses according to food group or dietary pattern and primary outcome of interest

Based on AMSTAR quality evaluation, 17% were given a high rating, 36% of the review articles were given a moderate rating, 27% were given a low rating, and 21% were given a critically low rating.

Grains, roots, and tubers

Cereals, roots, and tubers are the primary sources of energy and minerals in the diet [16; 20]. However, only two reviews included this food group's impact on protein-energy and selected micronutrient deficiencies (Figure 3.2.). Quality protein maize (QPM) contains 70 to 100 percent more lysine and tryptophan than non-QPM. According to a critically low-quality systematic review of observational studies, compared to non-QPM-based diets, QPM-based diets resulted in a 12% weight gain and a 9% height gain in young children [20]. QPM has been introduced as a potential for eradicating protein-energy malnutrition as a primary source of energy and protein in Ethiopia. The other systematic review addressed orange-fleshed sweet potato (OFSP) [21]. OFSP is a low-cost crop that is a year-round source of vitamin A in most of Sub-Saharan Africa's staple foods. The β-carotene content of OFSP varies from 3000–16000μg per 100 g, resulting in 250–1300μg of Retinol Activity Equivalents per 100 g. As a result, consuming OFSP can help boost vitamin A levels, increase the bioavailability of various micronutrients such as Zn, Ca, Fe, and Mg, reduce vitamin A deficiency, and reduce the child mortality rate by 23% to 30% [21].

Twenty papers were found for grain, roots, and tuber and NCD risk. In a review of observational studies, a daily intake of 30–45 grams of whole grain was associated with a lower body mass index (BMI) and slower weight gain over time [22]. Higher whole grains consumption was associated with a lower risk of CVD mortality (relative risk/RR 0.81; 95% CI: 0.75-0.89; P = 0.001, I^2= 56.9%). Similarly, there was a 26 percent decrease in CVD mortality with every 3 servings (90 g/day) rise in whole-grain consumption [23; 24]. A high-quality review found that consuming 2 to 3 servings of whole grains per day (45 g) reduced the risk of CVD (range of RR 0.63-0.79), T2DM (range of RR 0.68-0.80), and led to a modest decrease in body weight (0.06 kg), waist circumference (1.2 cm), and body fat mass (0.48%) [25]. A meta-analysis of 123 studies indicated an inverse association between whole grain intake on coronary heart disease (CHD) (RR: 0.95; 95% CI: 0.92–0.98) and heart failure (HF) (RR: 0.96; 95% CI:0.95–0.97) [26]. The potential benefits suggest that eating 2 to 3 servings of whole grains per day (30- 45 g) is a reasonable public health goal [25]. Scientific evidence supports the recommendation to consume at least 60–90 g of wholegrain foods daily to help prevent T2DM (16; 22; 27). There was also evidence of a non-linear dose-response relationship; increasing whole grain intake to 50 g/day reduced the risk of T2DM by 25%, after which there were only minor benefits to increase intake further (27; 28; 29).

Dietary fiber intake was associated with reduced CVD incidence and mortality (30; 31). A 10:1 ratio of total carbohydrate to dietary fiber (g/serving) is a suggested indicator for selecting healthier grain alternatives (32). Those who consume more dietary fiber have a lower risk of developing T2DM (33; 34). Consumption of refined grains was not associated with a higher risk of stroke, according to a meta-analysis (35). Regarding refined grains, a low quality review indicated that white rice intake is associated with CVD risk factors such as metabolic syndrome and T2DM (36) and that the consumption of 200–400 g of refined grains per day was associated with a 6–14% increase risk of T2DM (28). Parallel to this, reducing processed grains and starches is a significant dietary priority for cardiometabolic well-being because of their risk for NCDs and pervasiveness in modern diets (16; 32; 37; 38).

Pulses

Pulses such as beans, soybean, lentils, chickpeas, peas, and grass peas are commonly consumed and source important nutrients. For example, a 50g serving of lentils contains 3.7–4.5 mg of iron (Fe), 2.2–2.7 mg of zinc (Zn), and 22–34µg of selenium (Se) (39). They are also a good source of protein, carbohydrates, and vitamins (folate) (32). A low-quality narrative review indicated that lentils are a good candidate for micronutrient biofortification because of their various health benefits, high yield, and nitrogen gain in food systems; however, biofortification research is restricted to a few crops (39). Pulses may assist in the reduction of protein-energy malnutrition and micronutrient deficiencies (32; 39). Consumption of red lentils improved the Fe nutritional status of anemic children in Sri Lanka (39).

A diet of 150 g of pulses daily (minimum-maximum: 54-360 g/day; cooked) improved blood lipid profile, blood pressure, inflammation biomarkers, and body composition (40). Consumption of up to 4 servings (400 g) of pulses a week was associated with a reduced risk of T2DM (RR: 0.78; 95%CI: 0.50-1.14) (32). In a high-quality review of twelve prospective cohorts, the highest and lowest pulses consumption groups showed no significant difference in T2DM incidence (RR: 0.96; 95% CI: 0.87–1.05, I^2 = 85%) (28). A moderate quality meta-analysis of observational studies found a strong inverse association between soy consumption and the risk of T2DM (RR: 0.77; 95% CI: 0.66-0.91; I^2=91.6%). In subsequent subgroup analyses a significant protective effect of soy intake was observed in women (RR = 0.65; 95% CI: 0.49–0.87), in cross-sectional studies (RR = 0.45; 95 % CI: 0.30–0.67), and in Asian populations (RR = 0.73; 95% CI: 0.61–0.88) [(41)]. The summary RR for high vs. low soy intake in eight cohort studies was 0.87 (95%CI: 0.74–1.01; I^2 = 86.6) for incidence of T2DM. Also, in this meta-analysis, soy products were protective factors against T2DM in women with a RR of 0.74 (95% CI: 0.59–0.93) [(42)].

Pulses may lower CVD risk by enhancing satiety, improving glycemic control, and lowering blood pressure and inflammation [(40; 43)]. Consumption of up to 4 servings (400 g) of pulses a week decreased the risk of stroke (RR: 0.98; 95% CI: 0.84-1.14), and CHD (RR: 0.86; 95% CI: 0.78-0.94) [(32)]. Eating whole pulses significantly lowered low-density lipoprotein cholesterol (LDL-C) (-0.17 mmol/L, 95% CI: -0.25 to -09), which is a causal risk factor of CHD, but did not meaningfully influence high-density lipoprotein cholesterol (HDL-C), non-HDL-C or apolipoprotein B [(16; 43)].

Nuts and seeds

Peanuts, walnuts, almonds, hazelnuts, cashew nuts, pistachios, macadamia nuts, Brazil nuts, pecans, sunflower seeds, Niger seeds, and sesame seeds are among the most widely consumed globally [(44)]. Nuts and seeds are a good source of minerals, proteins, and plant-based fats rich in phenolic compounds, improving diet quality and benefiting health [(32; 45)]. A review of trial studies showed no substantial variations between walnut-enriched diets and control diets in terms of change in body weight (weighted mean difference/WMD: -0.12 kg; 95 % CI: -2.12 to -1.88 kg) or BMI (WMD: - 0.11; 95 % CI: -1.15 to 0.92) [(44)]. In the overall analysis of evidence, tree nuts (including almonds, Brazil nuts, cashews, hazelnuts, pecans, pistachios, and walnuts) did not significantly minimize waist circumference (MD: -0.62 cm; 95 % CI: -1.54, 0.30 cm, I^2 = 67 %) [(46)]. When comparing 45-day intervention studies with 60-day intervention studies, a review found that 35g of sesame oil showed a greater increase in antioxidants measured in plasma, such as in vitamin E (increased by 90%) and beta-carotene (by 113%) [(47)].

Walnut-enriched diets lowered total blood cholesterol by a mean difference of -6.99 mg/dL (95%CI: -9.39 to -4.58 mg/dl) compared to the control group, habitual or Mediterranean or without nut diet [(44)]. When comparing to a control diet intervention, 49 g/day of tree nuts

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consumption lowered fasting blood glucose (MD= -0.8 mmol/L, 95% CI: -0.16 to -0.5 mmol/L), and triglycerides (MD=-0.06 mmol/L, 95% CI: -0.09 to -0.03 mmol/L) to moderate extent [46]. In PREDIMED intervention, a daily serving of 15 - 30 g of nuts reduced CVD incidence [16]. Nut consumption lowered CHD risk (RR: 0.67 95%CI: 0.43-1.05) and LDL cholesterol in a meta-analysis of randomized controlled trials [16; 26; 48]. Based on the highest versus lowest analysis [49] and dose-response analysis [28; 47], nut consumption was not associated with the risk of T2DM (RR=0.98; 95% CI: 0.84-1.15, I^2=67.7%). Another meta-analysis of cohort studies and RCTs indicated that nut consumption reduced the risk of coronary heart disease (CHD) (RR=0.76; 95% CI: 0.69-0.84) and T2DM (RR=0.87; 95% CI: 0.81-0.94)[32]. A critically low-quality review indicated that increased intake of areca nut causes acute toxicity, high blood pressure, and high cholesterol [50]. Arecoline, an alkaloid found in areca nut, seems to interfere with the fat metabolism resulting to T2DM, metabolic syndromes and unstable blood lipid levels through multiple pathways [50].

Milk and dairy foods

Dairy foods come in various forms, flavors, and compositions, even though all are originally from milk. Milk and dairy foods are primary sources of fat, calcium, and other essential nutrients such as vitamin B12 and protein. In some countries, iodine in milk is obtained due to feeding iodine-containing feed to cows [16; 51; 52; 53]. Both meat and milk have been recognized as effective for reducing childhood stunting. Milk has a specific growth-promoting effect in young children. This effect is seen in developing and developed countries, suggesting it has mechanisms beyond energy and nutrient intake, possibly via IGF-1 stimulatory effects [52; 53]. A review of longitudinal cohort studies and randomized trials indicates that milk consumption does not affect body weight in children or adults [53]. Several intervention studies showed Yogurt intake led to less weight gain [53; 54]. There was evidence of a positive effect of milk and dairy consumption on bone mineral density, but no association was found with the risk of bone fracture [51; 53; 54]. After one year of increasing calcium intake from dietary sources to more than 800mg/day in the adult population (over 50 years old), bone mineral density (BMD) increased by 0.6-1.0% at the total hip and 0.7-1.8 % in the whole body. There was no effect on BMD in the forearm. The authors concluded that increasing calcium intake from dietary sources produces small, nonprogressive increases in BMD, which are unlikely to lead to a clinically significant reduction in fracture risk [55]. A low-quality review indicated that nations that consume the most milk and calcium also have the highest rates of hip fractures, although this was likely influenced by confounding factors [53]. Plant-based drinks are getting more popular and partly replace dairy drinks in the nutrition recommendations in several countries. However, cow's milk and plant-based beverages differ in nutritional content, and health impacts [51], and more human research is needed on calcium-fortified plant-based beverages.

The impact of saturated fat from dairy or other foods may not exclusively predict the risk of CVD and T2DM as other constituents from the diet may influence the metabolic risk factors [56]. There was no or only a poor inverse association between dairy intake and CVD relative risk [57]. However, replacing dairy fat with polyunsaturated fats, mainly from plant-based foods, may benefit health [52; 58; 59]. In a meta-analysis of Korean studies of moderate quality, high triglyceride and low HDL-C were associated with milk and dairy consumption [48]. The evidence suggests that consuming 200 to 300 ml/day of milk and dairy foods does not increase CVD risk [51; 60]. Cheese intake was inversely associated with CHD (RR 0.96; 95% CI: 0.93–0.98) per 20 g higher intake/day, whereas high-fat milk was positively associated with CHD (RR 1.08; 95% CI: 1.00–1.16) per 200 g higher intake/day [60]. Two reviews report an inverse association between dairy foods intake and the risk of hypertension or stroke [51; 61]. Hence, there is no consistent evidence of an elevated risk of CVD from a high intake of milk or dairy foods [16; 51; 62; 63].

Total dairy product intake (RR: 0.89; 95%CI: 0.84–0.94, I^2 = 48.8), whole milk consumption (RR: 0.87; 95%CI: 0.78–0.96, I^2=52.2), and yoghurt consumption (RR: 0.83 95%CI: 0.70–0.98, I^2=62.1) were all inversely associated with risk of T2DM [42; 52]. The summary RRs of 17 cohort studies on T2DM in a dose-response meta-analysis study were 0.93 (95 % CI: 0.87–0.99) per 400 g overall dairy products/day, 0.98 (95%CI: 0.94–1.03) per 200 g high-fat dairy products/day, 0.91 (95%CI: 0.86–0.96) per 200 g low-fat dairy products/day, 0.87 (95%CI: 0.72–1.04) per 200 g milk/day, 0.92 (95%CI: 0.86–0.99) per 50 g [64]. Another review indicated that consumption of dairy products reduces the risk of T2DM by 8% to 12% [64; 65]. Milk had a relative risk of 0.89 (95% CI: 0.82-0.97). In the case of low-fat dairy intake, the reduction varied from 11 to 19% (RR=0.81; 95% CI: 0.68-0.96)[65]. Each additional 200 g of dairy product consumed daily was associated with a reduction in T2DM risk (RR: 0.97; 95 % CI: 0.94–0.99, I^2 = 74%). Yogurt has a relative risk of 0.74 (95 % CI: 0.65-0.84)[28]. Another review also revealed that drinking milk reduces the risk of T2DM by 11% (RR= 0.89; 95% CI: 0.82-0.97) and (rate ratio=1.07; 95% CI: 0.93-1.24), but the association was

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not statistically significant [66]. Since studies on different dairy subgroups are lacking, it is impossible to derive a definitive statement regarding their impact on T2DM risk [16; 32; 59; 64; 66]. However, there is growing evidence of a lower risk of T2DM associated with fermented dairy foods, especially yogurt [16; 48; 51; 53; 54; 59; 62; 64; 67; 68; 69]. A meta-analysis of 14 studies found that the relative risk for T2DM risk was 0.80 (95% CI: 0.69–0.93) and 0.91 (95% CI: 0.82–1.00), respectively, for 30 g/day cheese and 50 g/day yogurts [64].

Meat, poultry, fish, and egg

Red meat comes from cows, calves, pigs, goats, sheep, camels, venison, etc.; white meat includes chicken and turkey. Meat, eggs, and fish are highly nutritious since they contain high-quality protein, fat, and vital micronutrients such as iron, zinc, and vitamin B12 [70; 71]. Higher dietary animal-source protein consumption (such as beef, pork, lamb, chicken/poultry, sheep, goat, fish, and seafood) may protect lumbar spine bone mineral density compared with lower protein intake (percentage change: 0.52%; 95% CI: 0.06-0.97%, $I^2 = 0\%$), but no effect was observed for total hip, femoral neck, or total body BMD [72]. A review of seven high-quality articles found that five observed an association between animal meat consumption (85–300 g/day) and iron status. However, the optimum amount and frequency of meat consumption to maintain or attain a nutritional iron status are unknown [73]. Fish is a good source of essential components such as vitamin D, iodine, selenium, and long-chain polyunsaturated fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [16; 71; 74]. A low-quality systematic review indicated that fish or seafood was listed as the primary source of dietary protein and a good source of iodine in five of the six small-scale studies in the Pacific Island countries that looked at the contribution of 9–19 g/day fish consumption [75]. Fermented fish products were high in EPA and DHA, antioxidants, and essential nutrients [69].

Meat consumption was associated with an increased risk of elevated/high total cholesterol (OR:1.14; 95%CI: 1.06–1.22)[48]. For preservation, meat is often smoked or salted, or preservatives such as nitrate or nitrite are added, resulting in processed meat [16; 71]. Saturated fats, cholesterol, salt, nitrite, haem iron, polycyclic aromatic hydrocarbons, and heterocyclic amines can be elevated by consuming up to 50g/day of processed meat [76]. A positive association was shown between red meat and CHD (RR:1.15; 95% CI:1.08–1.23), stroke (RR:1.12; 95%CI: 1.06–1.17), HF(RR:1.08; 95% CI: 1.02–1.14), and processed meat on

CHD (RR:1.27; 95%CI: 1.09–1.49), stroke (RR: 1.17; 95% CI:1.02–1.34), HF (RR: 1.12; 95% CI:1.05–1.19)[26]. When comparing the highest vs lowest intake of white meat the pooled OR was 0.94 (95% CI: 0.90 - 0.97) for all-cause mortality, 0.95 (95% CI: 0.89-1.01) for CV mortality, and 0.99 (95% CI: 0.95-1.02) for non-fatal CV events [77].

The effects of egg consumption on NCDs are controversial [78; 79]. Eggs exhibit a range of pro- and anti-inflammatory characteristics, which might have major consequences for the pathophysiology of a number of chronic illnesses but also immunological responses to acute injury [57; 80]. Eggs are high in dietary cholesterol and protein (200 mg of cholesterol and 5-7.5 g of total protein per egg). Intake of 100 mg of cholesterol from eggs raises LDL cholesterol by 0.05mmol/l [16]. Egg consumption was associated with a lower risk of hypertension (OR: 0.89; 95% CI: 0.79–0.99) and low HDL cholesterol (OR: 0.84; 95 % CI: 0.78–0.91) in Korean studies [48]. A meta-analysis indicated a positive association between egg consumption and HF (RR:1.16; 95% CI:1.03–1.31)[26]. High egg consumption (more than 1 egg/day) was associated with decreased coronary artery disease (hazard ratio/HR: 0.89; 95% CI: 0.86-0.93; $I^2 = 0\%$) but not with increased CVD (HR: 0.99; 95% CI: 0.93-1.06; $I^2 = 72.1\%$) [81].

Moderate fish intake (two or three servings a week) was associated with a lower risk of fatal CHD (RR: 0.79; 95% CI: 0.67-0.92) compared to little or no consumption [16; 26; 32]. The HRs of stroke for subjects who reported fish consumption 1, 2–4, and at least 5 times per week were 0.86, 0.91, and 0.87, respectively [26; 82]. In seven prospective cohort studies, the overall relative risk of atrial fibrillation (AF) was 1.01 (95% CI: 0.94–1.09) for the highest vs. the lowest group of fish intake with no heterogeneity ($I^2 = 0.0\%$) [83]. Six studies were combined to investigate the dose-response association between fish intake and AF risk, the summary RR was 0.99 per serving/week (95 % CI: 0.96–1.02; P = 0.26, $I^2 = 23.0\%$) [83]. Consumption of 2-5 servings of fish per week may reduce the risk of CVD in a moderate quality review of observational studies[74; 84].

The average RR and 95% CI for red meat consumption and the risk of T2DM for high vs. low red meat intake was 1.22 (95% CI: 1.09-1.36, $I^2 = 51.1\%$) [42]. Additional data is needed, especially for processed meat, as there exists an association between red and processed meat intake with the risk of T2DM and CVD [16; 52; 67; 70; 71; 76; 85; 86]. According to a review of prospective cohort studies, the risk of T2DM increases as red meat consumption increases by 100g/day and processed meat consumption increases by 50g/day [27; 28]. In a meta-analysis of

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eleven cohort studies, high vs. low processed meat intake was associated with the incidence of T2DM with an overall RR of 1.39 (95%CI: 1.29–1.49, I^2 = 49.3%) [42]. More research is needed to determine the effect and association of each red meat subtype (fresh/unprocessed or processed) on T2DM [70].

In two meta-analyses egg consumption was associated with a higher risk of T2DM as the RR of T2DM of egg/day 1.13; 95% CI: 1.04–1.22 reported by Tamez et al. [85; 87]. Another study found egg consumption has associated with a lower risk of T2DM (RR: 0.89; 95% CI: 0.84-0.94, I^2=91.1%) [42]. There was no significant association between T2DM comparing the highest and lowest fish consumption group (RR: 1.04; 95% CI: 0.95–1.13, I^2 = 76%), or each additional regular 100 g (RR: 1.09; 95 % CI: 0.93–1.28, I^2 = 84%) [28; 42].

Fruits and vegetables

Multiple nutrient deficiencies are common in low-and middle-income countries (LMICs) due to limited production and consumption of fruits and vegetables. Fruits found in Ethiopia include banana, papaya, lemon, watermelon, avocado, mango, pineapple, orange, and strawberry. Fruits are a source of vitamins such as folate, β-carotene, vitamin C, and vitamin E [32; 88]. Brassica vegetables contain numerous micronutrients, such as carotenoids and minerals, and other beneficial components such as antioxidants, glucosinolates, and polyphenols. Among brassica vegetables, kale is a popular vegetable in Ethiopia, both in poor and wealthy households. Although high in vitamins A, K, C, folate, essential minerals (potassium, calcium, magnesium), and dietary fiber, kale also contains anti-nutrients such as oxalate, phytate, and tannins [39]. Other vegetables often consumed are onion, green pepper, lettuce, carrot, tomato, head cabbage, and pumpkin. According to a low-quality review, certain vegetables, such as mushrooms, significantly affect weight reduction and complications [89].

Although many wild fruits and vegetable species are available in Ethiopia, very little is known about their consumption. Underutilized fruits and vegetables (wild fruits and vegetables) have several advantages: they are easy to grow and hardy; they can be a solution for social health and nutrition problems; they can provide nutrition to the poor and needy community; and they are high in carbohydrate, fat, protein, energy, vitamins A, B1, B2, B3, B6, B9, C, folic acid, and minerals – Ca, P, Fe, and dietary fiber [90]. However, contamination with potentially pathogenic organisms, notably Escherichia coli, requires caution [91].

Consuming 100 g of fruit per day has been shown to reduce the risk of CHD (RR 0.94; 95%CI, 0.91-0.98) and stroke (RR: 0.84; 95% CI: 0.75-0.91) [26; 32]. Avocados, pomegranate, grapes, and other common fruits may prevent CVD by controlling body weight, plasma lipid profile, oxidative stress, and inflammation [88; 92]. Fruit intake was associated with a lower risk of elevated blood pressure (OR: 0.52; 95%CI: 0.37-0.73) and elevated triglyceride levels (OR: 0.84; 95%CI: 0.73-0.96) in the meta-analysis of observational studies of Korean population [48]. A meta-analysis of RCTs indicated that berries including the juice of barberry, cranberry, grape, pomegranate, powder of blueberry, grape, raspberry, and freeze-dried strawberry significantly reduced systolic blood pressure by 3.68 mmHg with 95% CI: 6.79 to− 0.58; P = 0.02 and diastolic blood pressure by 1.52 mmHg with 95% CI: 2.87 to − 0.18, P = 0.04[93]. Fruits and vegetables intake reduce the risk CHD (RR: 0.97, 95% CI: 0.96–0.99), and HF (RR:0.94, 95% CI: 0.90–0.97) [26]. A meta-analysis of observational studies of adults found a lower risk of CHD (RR: 0.88; 95%CI, 0.8-0.98) and stroke (RR: 0.82; 95%CI: 0.72-0.93) for the highest compared with the lowest tertile of lutein intake. Lutein is synthesized in dark green leafy vegetables such as spinach and kale [91]. Several biological mechanisms have been proposed for the potential beneficial effect of lutein on cardiometabolic health, including vascular changes, antioxidant effects, and effects on immune response and inflammation [91; 94].

Fruit consumption of 200-300g/day decreased the risk of T2DM by 10%, although no additional benefit for higher intake was observed [28]. Consumption of berries was associated with an 18% reduction in risk (RR: 0.82; 95%CI: 0.76-0.89, I^2=48.6%) [95]. A subgroup analysis from this review indicated that this finding is significant in both European and US populations but not significant in male populations. Citrus fruit consumption was not associated with T2DM risk (high vs. lowest analysis) RR 1.02 (95%CI: 0.96-1.08, I^2=0.0%)[96]. A modest inverse association between fruit intake and risk of T2DM was observed, but not between total vegetable intake and biomarkers of metabolic diseases and incidence of T2DM [28; 97]. Although fruit and vegetable consumption was not associated with T2DM risk, a dose-response meta-analysis indicated a threshold of 2-3 servings of vegetables and 2 servings of fruit per day, after which the risk of T2DM did not decrease any more [98]. Another review also indicated a significant inverse association between fruit and green leafy vegetable intake and the risk of T2DM [99; 100]. A meta-analysis conducted on four cohort studies reported that consumption of cruciferous vegetables was associated with a reduced

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incidence of T2DM (highest vs. lowest intake) RR 0.84 (95%CI: 0.73-0.96, I^2=54.4%) [96]. High lutein intake was associated with a lower risk of metabolic syndrome (RR: 0.75; 95%CI: 0.60-0.92), comparing the highest with the lower tertile, and no significant heterogeneity was observed between studies. There was no significant association between lutein intake and risk of T2DM (RR: 0.97; 95%CI: 0.77-1.22) [94].

Regarding fruit juice, it was concluded that whole fruits are preferable to 100% juice which should be limited to 1 serving/day (1/2 cup) due to high sugar content [32]. There is a modest, long-term weight gain from 100% fruit juice intake in young children and adults [101]. The intake of sugar-sweetened fruit juice but not 100% fruit juice is associated with an increase in the incidence of T2DM [32].

Sweets and added sugars

All monosaccharides and disaccharides added to foods and beverages by the manufacturer, cooker, consumer, and sugars naturally present in honey, syrups, unsweetened fruit juices, and fruit juice concentrates are referred to as "added sugars" [102; 103]. Sugar is naturally present in intact fruits and lactose in human milk, cow milk, or goat milk, whereas unsweetened milk products do not contain added sugar. To reduce the risk of obesity, consumers should limit their intake of added sugar and sugar-sweetened beverages (SSB) to less than 10% of their total energy [104]. Increased consumption of SSB and added sugar reduces dietary diversity resulting in nutrient deficiency [102]; thus, sugar should preferably be consumed as part of the main meal and in a natural form as human milk, milk, unsweetened dairy products, and fresh fruits, rather than as SSBs, fruit juices, smoothies, or sweetened milk products. Sugar-sweetened beverages should be replaced by water or unsweetened milk drinks [32].

Sugar-containing beverages/added sugars increase the risk of overweight/obesity and dental caries, lead to nutritional deficiency and poor dietary diversity, and may be associated with an increased risk of CVD and T2DM [16; 27; 28; 32; 57; 105; 106]. The risk of obesity increased by 12% (RR:1.12; 95% CI: 1.05–1.19, I^2=67.7%) and 21% (RR:1.21, 95% CI: 1.09–1.35, I^2=47.2%) for every 250 mL/d increase in SSB and artificially sweetened beverages (ASB)[107]. A positive association between SSB consumption and risk of CHD (RR:1.17; 95%CI:1.11–1.23), stroke (RR: 1.07; 95%CI: 1.02–1.12), and HF (RR: 1.08; 95%CI:1.05–1.12) was observed[26]. T2DM risk increased by 19% (RR:1.19; 95% CI: 1.13–1.25, I^2=82.4

%) and 15% (RR:1.15, 95% CI: 1.05–1.26, I^2=92.6%) with each 250 mL/d increase in SSB and ASB [107]. In contrast, moderate chocolate consumption might have a preventive effect on CVD risk due to the presence of polyphenols [108; 109; 110]. With moderate heterogeneity, the total CVD risk ratio for the highest vs. lowest category of chocolate intake was 0.77 (95 % CI: 0.71–0.84)[108]. However, the level of added sugar and chocolate's energy and fat content should be considered.

Because of the links to long-term weight gain and NCDs, consuming 100% fruit juice (more than one serving per day) is not advisable [32; 101]. A position paper review on sugar advised that free sugar consumption should be minimized to around 5-10% of energy intake in children and adolescents aged 2 to 18 years. Water or unsweetened milk drinks should substitute liquid with added sugar [102; 111].

Fats and oils

Fat-rich foods, consisting of a mixture of fatty acids, include butter, margarine, and oil. Fat products improve nutritional status, quality of life, and health among the elderly [112]. Fried food consumption was positively associated with a risk of weight gain, although the oil type used may modify this association [113]. On the other hand, high olive oil intake was neither negatively nor positively associated with an increased risk of becoming overweight or obese [113]. Cooking green vegetables with fat increases vitamin A bioavailability because fats aid in absorbing fat-soluble vitamins, including carotenoid, vitamin D, E, and K [112]. A high-quality systematic review showed probable evidence for a moderate direct association between total fat intake and body weight [114]. However, focusing on limiting total fat does not consider the health advantages of high intakes of plant-based fats or the risks of processed carbohydrates, which are the alternatives for dietary fat [32]. There was no conclusion in a review on the relationship between dairy fat intake and overweight or obesity [115].

Systematic reviews and meta-analyses of moderate and high quality showed that dairy fat consumption and CVD or T2DM are not associated in cohort studies [114; 115; 116]. A low-quality review of large-scale cohort studies in western countries failed to show a strong association between fat consumption and the development of T2DM [117]. A systematic review by Mozaffarian indicated that butter appears to be neutral for cardiometabolic health and detrimental for long-term weight management [32]. Virgin oils (e.g., extra virgin olive oil, virgin soybean oil) may be preferred due to their low-temperature refinement, which may help retain trace phenolic components [32]. Daily 10-gram olive oil consumption is associated with a reduced risk of T2DM (RR: 0.91, 95% CI: 0.87-0.9)[118] and prevents CVD, although there have been mixed results regarding its influence on blood biomarkers [118; 119; 120]. A review of cohort and RCTs studies indicated that virgin olive and flaxseed oil considerably decreases the incidence of CVD and T2DM [113; 121]. Another meta-analysis also indicated that the highest olive oil intake category showed a 16% reduced risk of T2DM [119]. Consumption of nut oil is associated with a lower risk of CVD [120]. Palm oil contains palmitic acid, a naturally occurring saturated fatty acid; however, the associated risk of CVD and T2DM is controversial [122; 123]. The main reasons are heterogeneity, the difference in selection criteria, wider age range, and direct confounding were not well controlled [122].

Saturated fatty acids increase total and LDL cholesterol levels in the blood, risk factors for coronary heart disease (CHD) [16; 124]. A review of randomized controlled trials indicated no effect on CHD incidence (RR:1.0, 95% CI: 0.8-1.2) but a reduction in serum cholesterol among the intervention group: administration of vegetable oil, replacement of saturated fat with vegetable oil, and an approximate 20% fat in the diet [124]. On the other hand, evidence suggests that saturated fat should account for 7-10% of daily energy in the dietary recommendations [16]. High-refined-carbohydrate diets often replace a reduction in total and saturated fat consumption, leading to atherogenic dyslipidemia, increased blood levels of small dense LDL particles, decreased HDL-cholesterol, and increased triglycerides are risk factors for CHD [114; 125]. In general, vegetable fats and oils contain a modest amount of saturated fatty acids while being a good source of unsaturated fatty acids. However, the exception of palm oil, coconut fat, and cocoa butter is due to higher saturated fatty acids [16; 123]. Partially hydrogenated oils are food additives that typically have 30% to 60% trans fatty acids with well-documented adverse consequences, notably an increased risk of CHD and sudden death, for public health [32; 126].

A high unsaturated fatty acid diet, combined with the Mediterranean diet (MedDiet), reduces the risk of CVD and T2DM [116; 119]. The risk of CVD is reduced when saturated fatty acid is partially replaced by polyunsaturated fatty acids (PUFAs), especially in men [114]. According to a low-quality review, omega-6 fatty acids appear protective against T2DM risk [127]. Both n-6 and n-3 PUFAs help lower the risk of CVD, though more research is needed to identify the optimal quantities [112; 120]. Consumption of flaxseed oil has been suggested to decrease insulin resistance in T2DM and pre-diabetes [127]. A decrease in T2DM incidence was observed with a high intake of vegetable fat and a healthy dietary pattern which is partly characterized by a high ratio of unsaturated fatty acids to saturated fatty acids (27). On a nutrient level, increasing alpha-linolenic acid consumption and fatty fish intake s lower the risk of T2DM by two to seven-time, but this was not observed in all cohorts included in the review (128). The n-3 FA consumption is negatively associated with the risk of T2DM in the Asian population but positively associated with the risk in the Western population (128).

Dietary Patterns

Though intake of specific foods and nutrients may elevate the risk of NCDs, dietary guidelines should focus on total dietary consumption rather than particular foods or nutrients (32; 129). The contemporary emphasis on dietary patterns can be viewed as a more holistic approach to studying how long-term consumption of various food combinations affects health. Because it is simpler for individuals to adopt full or adjusted dietary patterns rather than including or excluding single nutrients from their diets, this "dietary pattern" approach lends itself more readily to practical implementation in public health promotion (130; 131).

The primary reason for the wide prevalence of iron, zinc, iodine, and vitamin A deficiency is the low dietary intake of these nutrients combined with poor bioavailability of these micronutrients from plant-based foods due to the presence of dietary inhibitors as low-quality review indicated (132). Grains, roots, tubers, and pulses are the staples of the Ethiopian diet. These include components that enhance and inhibit mineral bioavailability, of which the latter are predominant (133). In general, plant-based diets are high in inositol phosphates, which reduce P, Ca, and trace elements Zn and Fe bioavailability in humans and monogastric animals by forming low digestible complexes (134). Indeed, adult vegetarians have considerably lower serum ferritin levels than non-vegetarian controls, according to a meta-analysis of pooled data from 24 cross-sectional studies (-29.71 mg/L, 95% CI: -39.69 to -19.73). The reduction of serum ferritin more clear in men (-61.9 mg/L, 95% CI: -85.6, -38.2) than in premenopausal women (-17.7 mg/L, 95% CI: -29.8, -5.6) or all women (-13.5 mg/L, 95% CI: -23.0 to -4.04) (135). Diet with increase in folate for every 10% has an impact on blood folate concentration; 6% (95% CI: 4%-9%) increase in red blood cell (RBC) and 7% (95%CI: 1%-12%) serum/plasma (136). Potential enhancers of micronutrient bio-accessibility are sulfur compound-rich spices – onion (at the dietary level of 15 g / 100g of the staple grain) and garlic (2.5 g/100 g of staple grain) which are generally present in the Ethiopian diet (133).

Diet might be carefully prescribed, like other therapies, but it might only be one part of preventing and managing malnourished children [137].

In observational studies, a diet high in meat consumption has consistently been associated with higher serum ferritin levels [132]. The beneficial effects of ascorbic acid and meat on iron absorption may be counteracted by simultaneously ingesting inhibitory foods and nutrients. Dietary treatments that include a variety of specific dietary variables to increase iron status tend to be more successful than single-nutrient or single-food approaches [138]. Also, in preventing and treating obesity, the dietary approach is shifting towards the effect of healthy diets and dietary patterns on the complex physiological determinants of long-term weight regulation [32].

Higher intake of plant foods has been associated with a lower likelihood of becoming obese, lower BMI, and smaller waist circumference. A plant-based diet leads to weight loss comparable to conventional low-calorie diets but better overall weight management [130; 139]. Obesity, T2DM, hypertension, stroke, and CHD have all emerged due to changes in food habits and physical activity patterns, the so-called Westernization [140]. In China, for example, high consumption of meats and edible oil, low consumption of cereals and vegetables, increasing consumption of SSB, increased sedentary time, and growing obesity rates have an inverse influence on the incidence and development of T2DM [141]. The following are some of the most well-known dietary patterns and their characteristics (table 3.1.).

Table 3.1. The most well-known dietary patterns with their distinct features.

Dietary pattern	**Feature**
Mediterranean diet	A high consumption of vegetables, fruit, cereals, and olive oil, a moderate to high consumption of fish, a moderate consumption of dairy, wine, eggs, and poultry, and a low consumption of meat and sweets [142].
"Prudent pattern"	A high consumption of fruits, vegetables, whole cereal foods, pulses, and fish [143].
"Western pattern"	A high consumption of refined grains ,processed meat, red meat, butter, high-fat dairy foods, eggs, fried foods, sweetened beverages, and sweets [144].
Dietary Approaches to Stop Hypertension (DASH) diet	A high consumption of vegetables, fruit, whole cereal foods, fish, poultry, nuts, seeds, vegetable oils and lean meats, and low consumption of salt, sweetened beverages, and high- fat dairy foods [57].
The Seventh-day Adventist diet	A vegetarian diet including vegetables, fruit, legumes, whole grains and nuts [130]. The followers abstain from alcohol intake.

Vegetarian or vegan diet	A vegetarian diet excludes meat, poultry, and seafood, and a vegan diet does not contain any animal source foods [145; 146].

MedDiet has been associated with decreased mortality and CVD-related mortality [57]. Recent reviews supported that MedDiet's reduces the risk of chronic illnesses and related mortality, including T2DM and CVD inside and outside the Mediterranean region [142; 143; 144; 145; 146; 147; 148; 149]. A review of 22 RCTs indicated that there is still some uncertainty regarding the effects of a MedDiet on CVD prevention; evidence of moderate quality showed prevention, whereas evidence of low quality showed no or little prevention of CVD risk [150].

The 'healthy' dietary patterns containing vegetables, fruits, and whole grains were significantly associated with a reduced risk of T2DM (RR: 0.86; 95%CI: 0.82-0.90), whereas the 'unhealthy' diets with higher amounts of red and processed meats, high-fat dairy, and refined grains were associated with higher risk (RR: 1.30; 95%CI: 1.18-1.43) [151]. Compared to individuals in the lowest group of the Healthy/Prudent pattern, those in the highest category had a 15% decreased risk of T2DM (95%CI: 0.80-0.91) [152]. In the linear dose-response meta-analysis, six of the 12 food groups exhibited a significant relationship with T2DM risk, three of them showing a decrease in risk with increasing intake (whole grains, fruits, and dairy), and three showing an increase in risk with increasing consumption (red meat, processed meat, and SSB). Compared to non-consumption, optimal consumption of the risk-decreasing food groups resulted in a 42% reduction, whereas consumption of the risk-increasing food groups resulted in a threefold increase in T2DM risk [28]. A healthy eating pattern consisting of higher intakes of plant-based foods, low-fat dairy, lower intakes of fried foods, and red and processed meat was consistently associated with an 18–65% lower risk of coronary artery disease [153]. In the Asian cohort, adhering to a Western diet pattern was associated with a 37–64% higher risk of CHD [153]. High consumption of plant-based foods, moderate consumption of dairy products, fish, and poultry, and low consumption of processed foods are similar characteristics across the 4 "healthy" dietary patterns (the Mediterranean, DASH, Prudent, and Seventh Day Adventist) that reduce risk of cardiometabolic health [57; 130; 154; 155; 156].

A vegetarian eating pattern was significantly associated with lower CHD mortality (RR: 0.78; 95%CI: 0.69-0.88) and incidence (RR: 0.72; 95%CI:0.61-0.85), but not CVD mortality (RR: 0.92; 95%CI: 0.84, 1.02) or stroke mortality [157]. Overall, plant-based dietary patterns were associated with a 20–25 percent reduced risk of CVD and a corresponding lower risk of

T2DM [139; 154; 158; 159; 160], although the effect of a vegan diet on CVD prevention was classified as uncertain due to insufficient information to conclude [161]. . A review of vegetarian diets in children concluded that the existing evidence, based on a small sample and with high heterogeneity, does not allow for solid conclusions on current vegetarian diets' health benefits or risks on children and adolescents' nutritional or health status [162].

Those who adhere to low carbohydrate and high protein diets have an increased risk of all-cause mortality (HR: 1.06; 95%CI: 1.04-1.09; $I^2 = 8.2$ %). No significant association between low carbohydrate high protein (LCHP) diets and risk of CVD was found (HR: 1.01; 95%CI: 0.98-1.03; $I^2 = 24.0\%$) [163]. A meta-analysis of randomized trials showed that compared to usual diets, low carbohydrate and low-fat diets had similar effects on weight loss (4.63 vs. 4.37 kg), and reductions in systolic (5.14 mm Hg vs. 5.05 mm Hg), and diastolic (3.21 vs. 2.85 mm Hg) blood pressure after six months [164]. The optimal macronutrient ratios for preventing and treating T2DM are unclear [165].

Intakes of other foods and food preparation

Tea and coffee - Tea and coffee are Ethiopia's most frequently used nonalcoholic beverages after water. The content of Co, Cu, Fe, Mn, Mo, and Zn in tea beverages ranges from 3.04-58.44µg/g; it may not be possible to predict the nutritional effects of habitual drinking of this beverage since the bioavailability of micronutrients in tea infusions is low [166]. Three to 4 cups of tea per day lower the risk of CVD and T2DM compared to none and no harm to micronutrient status [32; 166]. Coffee consumption did appear to have a nonlinear dose-response relationship with hypertension. With each one cup/day increase in coffee consumption, the risk of hypertension was lowered by 2% [167]. An inverse association was found between coffee intake and CVD (OR: 0.71; 95%CI: 0.52–0.97) and elevated/high TG (OR: 0.84; 95%CI: 0.78–0.90) [48]. Both caffeinated and decaffeinated coffees are associated with a lower incidence of T2DM in a dose-dependent fashion. The lowest risk is seen at 3-4cup/day[32].

Sodium - The risks of all-cause mortality and CVD events were reduced in usual sodium vs. low sodium intake and increased in high sodium vs. regular sodium intake, consistent with a U-shaped association between sodium intake and health outcomes [168]. Two narrative reviews reported that in normotensives, salt reduction advice resulted in minor decreases in systolic blood pressure and stroke [155; 169].

Alcohol - Besides social harm and high energy, alcohol (3.5-10% weight/volume) consumers had significantly higher total cholesterol than controls, increased risk of arterial hypertension and AF but no differences in blood pressure or other inflammation biomarkers [57; 170; 171]. Moderate alcohol intake (10-15g of alcohol/day) may reduce the incidence of T2DM (HR:0.75; 95% CI: 0.67-0.83), the incidence of CVD, and overall mortality [27; 110; 172]. An intervention to reduce alcohol consumption did not affect the overall mortality (RR: 0.72; 95% CI: 0.16-3.17) or CVD events compared to the control group [173]. The risk of CVD, heart failure, and all causes of mortality was associated with higher alcohol intake (>100g of alcohol/week) [171; 172].

Water - A meta-analysis of 6 studies indicated that water intake was inversely associated with the risk of T2DM (RR: 0.94; 95% CI: 0.91-0.97, I^2 = 24%) [174]. There is no review found on water intake on CVD. The findings support recommendations for water as part of a healthy diet.

Glycemic index - Several studies concluded that the optimal macronutrient combination to improve metabolic health needs more research. Diets high in refined dietary carbohydrates (especially those with a high glycemic index [GI]), such as those rich in refined dietary carbohydrates (some sugars and rapidly digested starches), may increase the risk of T2DM. Foods that contain low-GI carbohydrates (such as pulses, vegetables, and fruits), cereal fiber, and resistant starch should be prioritized to prevent T2DM [175].

Frying - There is strong evidence that when fried foods are consumed more often, there is an increased risk of chronic diseases such as T2DM, heart failure, obesity, and hypertension [57]. A lack of detailed information on the types of oils used for frying foods, stratification of the different kinds of fried food, temperature and duration of frying, and a lack of consideration of overall dietary patterns are, however major gaps in the current literature [113; 176]. Fried food consumption more than 2-4 times/ week showed a risk of high blood pressure by 18%, T2DM by 27%, and 23% increased CHD risk [57].

Food processing - Heat treatment has been shown to enhance plant foods' bioavailability of iron and carotene. Cooking practices usually adopted for plant-based foods involve boiling in water (ca 100ºC) or pressure-cooking (ca 115ºC) at 15 p.s.i. for about 5 to 15 min depending on the type of food [133]. The use of sprouting, fermentation, and malting can improve the bioavailability of iron and zinc from food grains and pulses [133; 134; 177].

Fermented foods are also popular in many nations worldwide, including Ethiopia. Fermentation is an ancient, environmentally friendly, and low-cost method of preserving food, which can enrich the fermented food with certain nutrients, such as folate and manganese [(177)]. Food additives and neo-formed contaminants formed during processing, such as advanced-glycation end-products, may influence CVD risk [(178)].

Discussion

This review aims to support the development of Ethiopian FBDG using the most recent evidence of systematic reviews and meta-analyses on foods, food groups, and dietary patterns in improving nutritional status and preventing T2DM and CVD. The current burden of malnutrition, micronutrient deficiencies, and emerging NCDs in Ethiopia is due to dietary and lifestyle changes [(179; 180; 181)]. By implementing dietary interventions on major dietary risk factors and improving diet quality, the adverse health and nutrition conditions that are currently prevalent may be counteracted [(182; 183)]. According to our review, systematic reviews and meta-analyses predominantly focus on NCDs rather than diet-related nutritional status (figure 3.2.), and only a few are available from LMICs.

A key finding is that a plant-based diet, including animal-source foods, can help prevent malnutrition and diet-related NCDs. For instance, QPM indicated increased weight and height in children. Although the evidence was presented in a narrative review, QPM is one of the biofortified crops that the Ethiopian government widely introduced to improve nutrition security [(184)]. Pulses improve protein and iron status, nuts are a good source of minerals, and plant-based fat has favorable health profiles and modest saturated fat content. Milk prevents stunting in young children, and meat improves the iron status. Fruits and vegetables are good vitamin A and C sources and other healthy dietary components, such as minerals, antioxidants, and polyphenols.

Regarding animal-source food consumption and its contribution to the overall diet quality, the Ethiopian FBDG technical recommendations encourage consuming meat and dairy foods to prevent prevalent protein, zinc, calcium, vitamin B12, and vitamin A deficiencies [(132)]. On the other hand, excessive processed meat intake contributes to the risk of NCDs [(42)], and meat consumption contributes to extensive environmental degradation [(185)]. Animal-based diets are vital, especially in sub-Saharan Africa, in preventing protein-energy and micronutrient deficiencies [(132)]. Finding the right balance between plant and animal-source foods is important to prevent diet-related NCDs while fulfilling the daily energy and nutrient requirements. Besides such review for prevention of diet-related health and nutrition problems, diet optimization to fulfill the dial calorie and nutrients requirement is crucial [186].

Our review also identifies which foods, food groups, and dietary patterns are relevant for preventing diet-related NCDs, indicating the optimal amounts to be consumed. For example, 30-90 grams of whole grains daily lowers the risk of CVD and T2DM. Pulses intake of 400 grams per week reduces the risk of CVD and T2DM; intake of 15-35 grams of nuts per day lower CVD risk; 200-300 grams of dairy foods per day lowers the risk of T2DM; limited processed meat intake below 50 grams per day reduces the risk of CVD. Moderate fish consumption (2-3 servings per week) lowers the risk of CHD. SSB and added sugar intake of more than 5% of total energy may raise the risk of obesity, nutrient deficiencies, CVD, and T2DM. Despite their low micronutrient bioavailability, plant-based diets reduce the risk of obesity and diet-related NCDs. Following a Mediterranean or vegetarian diet lowers the risk of CVD and T2DM. Lower than usual sodium intake and consumption of coffee reduced CVD risk. Although no association was found between drinking alcohol and overall CVD, there was an association between alcohol consumption and heart failure and hypertension.

Most of the dietary recommendations derived from this review as the main findings are aligned with country-specific and global recommendations except for the use of animal source foods and differences in the recommended amount. Indeed, some dietary recommendations from 90 country-specific FBDG appear nearly universal across countries [13]. These universal dietary recommendations are to consume a variety of foods; to consume some types of foods within a food group in higher proportion than others; to consume more fruits and vegetables, legumes, and animal-source foods; and to limit the intake of sugar, fat, and salt.

The WHO, GBD, and EAT-Lancet diets include fruits and vegetables, animal source foods, fat intake, and sugar and sugar-containing products (Table 3.2.) . In our review, those food groups are also included but differ in the recommended amounts. For example, the WHO healthy diet fact sheet recommends at least 400g of fruits and vegetables per day, a little higher than the amount concluded (200-300g) from this review [187]. WHO has similar recommendations on legumes, nuts, and whole grains, with our review a certain difference in the amount. The recommended intake of sugars by the WHO is 10% energy, equivalent to 25g per day for a healthy body weight consuming at least 2000 kilocalories per day, but it is ideally recommended to be less than 5% of total energy intake for additional health benefits which are similar to our review [187].

The dietary recommendations for GBD are based on dietary consumption of key foods and nutrients across 195 nations, primarily from Europe and the USA [188]. The GBD dietary recommendations are mostly within the range of the quantity proposed for different food groups, including fruits (250 g), vegetables (360 g), legumes (60 g), whole grains (125 g), nuts, and seeds (21 g), milk (435 g). In addition, GBD recommendation includes fiber (24 g), calcium (1.25 g), omega-3 fatty acids (250 mg), PUFAs (11%), TFA (0.5%), and sodium (3 g), which do not directly propose from our review as our review mainly focus on foods and dietary patterns whereas a diet high in red meat (23 g), processed meat (2 g), SSB (3 g) part of this review conclusion.

The EAT-Lancet commission diet aimed to provide a healthy diet based on a sustainable food system [4]. The EAT-Lancet diet includes a daily intake of 200 (100-300) grams of fruits, 300 (200-600) grams of vegetables, 232 grams of whole grain, 50 (0-100) grams of legumes, 25 (0-75) grams of nuts, 7 (0-10) grams of beef and lamb, 29 (0-58) grams of chicken, and other poultry, 13 (0-25) grams of egg, 28 (0-100) grams of fish, 250 (0-500) grams of whole milk, 6.8 (0-6.8) grams of palm oil, 40 (20-80) grams of unsaturated oil, 31(0-31) grams of all sweeteners, and 5 (0-5) grams of lard. Processed meat, a risk factor and thus food to limit, is only included by GBD and our review. The plant's whole grains and protein sources are recommended only by GBD and EAT-Lancet.

Salt intake is not included in the EAT-Lancet recommendations, whereas we consider it in our review as it is relevant for preventing NCDs. The WHO also recommends consuming less than 5 grams (1 teaspoon) of salt daily and using iodized salt [189]. WHO member states have agreed to reduce global salt consumption by 30%, halt the rise in diabetes and obesity, and reduce the risk of premature death from CVD, diabetes, or chronic respiratory illness by 25% by 2025 [190].

Table 3.2. The recommended amount of nutrient, food, or food group per day from our review in comparison with global recommendations

Food or Food group or nutrients	Our review	The recommended amount per day		
		WHO	**GBD optimal intake (range)**	**EAT lancet**
Whole grain	At least 30-90 g	-	125 g (100–150)	232 g (total gains 0–60% of energy) and tuber or starchy vegetables 50 g (0-100)
Pulse	50-150 g	-	60 g (50–70)	
Nuts and seeds	15-35 g	-	21 g (16–25)	25 g
Milk and dairy foods	200-300 g	-	435 g (350–520)	250 g (0-500)
Red meat		≤350-500g/week of unprocessed red meat	23 g (18–27)	7 g (0-14) for beef or pork 29 g (0-58) for chicken 13 g (0-25) egg
Processed meat	< 50 g		2 g (0–4)	
Fruits	200-300 g	400g	250 g (200–300)	200 (100 – 300)
Vegetables			360 g (290–430)	300 g (200-600)
Added sugar	5-10% of total energy	At most 10% of energy		31 g (0-31)
Sugar-sweetened beverages		<5% energy free sugar	3 g (0–5)	-
Fiber	-	25g	24 g (19–28)	-
Sodium	-	-	3 g (1–5)*	-
Salt	<5 g	<5 g		-
Fish and seafood	1-5 serving/week		250 mg (200–300) - omega-3 fatty acids	28 g (0-100)
Fat and oil	10g virgin oil	<30% of energy <10% of energy saturated fat	11% (9-13) total energy from liquid vegetable oil	6.8 g (0-6.8) palm oil 40 g (20-80) unsaturated oil 5 g (0-5) Lard

* 24 h urinary sodium measured in g per day;
The energy requirement assumed for WHO and GBD – 2000 kcal/day; EAT-Lancet – 2500 kcal/day. Our review – only based review on priority diet related diseases and cause of death in Ethiopia with no assumption on daily energy intake

The Ethiopian FBDG technical committee has set two main objectives for the Ethiopian FBDG; the first objective is to provide dietary recommendations to the Ethiopian population two years and older for increased diet quality, including diversity and food safety for optimal health. Per the Ethiopian FBDG's first goal, 11 key public messages and tips were developed and accompanied by a graphic illustration. A qualitative study has evaluated the dietary guidelines, tips, and food graphics for acceptability, cultural appropriateness, understanding, and practicality. The second objective is to promote broad food system actions supporting diet quality and being sensitive to sustainability in the Ethiopian diet [191]. A food systems approach involves multiple sectors, including the agriculture and health sector, to develop a national food system roadmap to support FBDG and the national food and nutrition program [192; 193]. Future frontiers in FBDG development include incorporating environmental sustainability and increased attention to sociocultural factors, including changing dietary trends [194]. Besides this review, diet optimization based on current eating habits was conducted to fill the evidence gap for developing a feasible healthy diet [186]. It's essential to address the availability, accessibility, affordability, sustainability, seasonality, and the entire food system for consumers to follow the dietary recommendations [195; 196; 197].

Conclusions

Based on the review, we concluded the following nine key dietary recommendations to be considered in the Ethiopian FBDG in combination with other local evidence and diet modeling work.

The nine key technical dietary recommendations
1. Cereals (especially whole-grain cereals), roots, and tubers are good sources of energy and nutrients. Biofortified cereals, including quality protein maize, and roots, such as orange flesh sweet potatoes, are good sources of protein and vitamins. Consumption of 30-90 grams of whole grains daily reduces the risk of CVD and T2DM.
2. Pulses are good sources of protein and minerals, such as zinc. Pulse consumption of 50-150g per day or four servings (400g) per week reduces the incidence of CVD and T2DM.
3. Consumption of 15-35 grams of nuts and seeds per day increases antioxidant blood levels such as vitamin E and A, lowers the risk of CVD, and lowers blood sugar levels.

4. Milk and dairy foods are good sources of calcium, which improves bone mineral density among adults and prevents stunting in children. Consuming 200-300 ml dairy products daily does not increase CVD risk. Fermented dairy foods may reduce the risk of T2DM.
5. Meat, fish, and eggs are high-quality protein sources. In addition, meat is high in zinc and vitamin B12. Vitamin D, iodine, selenium, and long-chain polyunsaturated fatty acids are all found in fish. Processed meat intake should be limited to 50 grams per day, and non-fried fish consumption should be increased by 1-5 servings/week to reduce CVD risk.
6. Fruits and vegetables are high in vitamins and minerals. CVD plus T2DM risks are reduced when 200-300 grams of vegetables and fruits are consumed daily. 100% fruit juice counts as fruit intake but should be limited to half a cup daily.
7. Sugar consumption should be less than 5-10% of total energy daily to lower the risk of obesity, CVD, and T2DM.
8. Fat and oil are energy sources and increase the bioavailability of carotenoids, vitamin D, E, and K during vegetable cooking. Plant-based oil with modest saturate fat will reduce the risk of CHD. 10 gram daily virgin olive oil intake reduces the risk of CVD and T2DM.
9. Plant-based diets lower the risk of obesity and NCDs but also reduce micronutrient bioavailability. Meat-rich diets increase micronutrient statuses such as iron and folate, but processed meat intake increases the risk of NCDs. Overcooking should be avoided, processed foods should be consumed in moderation, and intake of fermented foods, particularly dairy foods, should be encouraged. Other recommendations include limiting alcohol and salt intake and encouraging water intake to affect NCDs prevention positively.3-4 cups of tea or coffee daily will lower the risk of CVD and T2DM.

Strength and limitations

To our knowledge, this is the first review to attempt to synthesize the evidence on how dietary interventions affect the triple burden of malnutrition (underweight, overweight, and micronutrient deficiencies) and diet-related NCDs (CVD and T2DM). Such a review is relevant for Ethiopia and most other LMICs, where the triple burden of malnutrition and diet-related non-communicable diseases coexists. The evidence on overweight and obesity was not explicitly searched; this review synthesized evidence on overweight and obesity reported as CVD and T2DM risk factors.

Although this analysis mainly focuses on priority diseases and causes of mortality in Ethiopia, it can also be helpful for many LMICs as the review is based on available international evidence. The review included systematic reviews and meta-analyses of various dietary interventions and cohorts from different countries. Differences in environment and study population may limit comparing the dietary impact. Countries with similar health and nutrition problems are advised to contextualize this evidence further in consultation with in-country experts based on related studies.

Positive impact studies are more likely to be published than those with null findings, and this publication bias was not directly addressed in our review. We used the AMSTAR tool for a quality check of the papers. The recommended amounts of food intake were derived from a meta-analysis of selected review papers. Thus, the recommended amounts in this review will help determine the recommended amounts for the final FBDG, as well as insight from diet modeling. Regardless, the technical recommendations from our review helped Ethiopia develop key public messages for the Ethiopian FBDG by combining the evidence from this review with local evidence on dietary patterns, food availability, accessibility and seasonality, and determinants of cultural and religious factors related to dietary habits.

Supplementary Materials: Appendix A. Searching Strategy, Appendix B. Priority Diseases, and Cause of Death in Ethiopia - Global Burden of Diseases (figure 1A and figure 2A), Table S1. Summary of recommended foods per food group and their possible health and nutritional outcomes.

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Appendix A: Search Strategy

PubMed

Filters: Meta-Analysis; Review; Scientific Integrity Review; Systematic Reviews; Publication date from 2014/01/01

Date of search: December 31, 2021

Dietary pattern

Search	Query
#1	Eating [MeSH] OR Drinking [MeSH] OR “Consumer behavior”[MeSH] OR "food choice behavior"[tiab] OR “Feeding behavior”[MeSH] OR “Food preferences”[MeSH] OR “Healthy lifestyle”[MeSH] OR Meals[MeSH] OR breakfast OR lunch OR dinner, snacks OR “Dietary pattern”[tiab] OR “Meal pattern”[tiab] OR “Eating habit” [tiab] OR “Eating custom” [tiab] OR “Eating practice” [tiab] OR “Nutrition transition”[tiab] OR "Dietary Pattern" [tiab] OR "Dietary habit"[MeSH] OR "Feeding Behaviors"[tiab] OR "Dietary habit"[tiab] OR "Eating Behavior"[tiab] OR "Eating Behaviors"[tiab] OR "Feeding Patterns"[tiab] OR "Feeding Pattern"[tiab] OR "Food Habits"[tiab] OR "Food Habit"[tiab] OR "Eating Habits"[tiab] OR “Eating Habit"[tiab] OR "Dietary Habits"[tiab] OR "Diet* Habits"[tiab] OR "Diet Habit"[tiab]

Food/diet

Search	Query
#2	meal[tiab] OR meals[tiab] OR nourishment[tiab] OR Diet[MeSH] OR Foods[tiab] OR “processed foods”[tiab] OR “diet* quality”[tiab] OR “Diet* diversity”[tiab] OR “Food consumption”[tiab] OR “Dietary intake”[tiab] OR “Food intake”[tiab] OR “Serving size”[tiab] OR “Portion size”[tiab] OR “Nutritive value”[tiab] OR “Food quality”[tiab] OR “Functional foods”[tiab] OR "Fast foods”[MeSH] OR water[tiab] OR alcoholic[MeSH] OR Beverages[tiab] OR vegetables[tiab] OR seeds[tiab] OR nuts[tiab] OR "fish products"[tiab] OR “red meat” [tiab] OR poultry[tiab] OR meat[tiab] OR fruit[tiab] OR flour[tiab] OR eggs[tiab] OR margarine[tiab] OR “ice cream” [tiab] OR yogurt[tiab] OR cheese[tiab] OR milk[tiab] ghee[tiab] OR butter[tiab] OR dairy[tiab] OR chocolate[tiab] OR injera[tiab] OR bread[tiab] OR Food [MeSH] OR Eating [MeSH] OR “Energy intake”[MeSH] OR “Diet western”[MeSH] OR “Diet* surveys”[MeSH] OR cereals[tiab] OR legumes[tiab]

Dietary pattern OR Food/Diet

Search	Query
#3	#1 OR #2

Nutrition deficiency (PEM and Micronutrient malnutrition)

Search	Query
#4	"Nutrition deficiency"[tiab] OR "Protein-Energy Malnutrition"[MeSH] OR "Protein Energy Malnutrition"[tiab] OR "Protein-Calorie Malnutrition"[tiab] OR "Protein Calorie Malnutrition"[tiab] OR Marasmus[tiab] OR kwashiorkor[tiab] OR "Iodine deficiency"[tiab] OR "Vitamin A deficiency"[MeSH] OR "Vitamin A Deficiencies"[tiab] OR "Anemia, Iron-Deficiency"[MeSH] OR "Iron-Deficiency Anemia"[tiab] OR "Iron Deficiency Anemia"[tiab] OR "Iron-Deficiency

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	Anemias"[tiab] OR "Iron Deficiency Anemias"[tiab] OR zinc[MeSH] OR "Zinc deficiency"[tiab] OR “folate deficiency”[tiab] OR “calcium deficiency” [tiab] OR “iron deficienies”[tiab] OR “iron deficiency”[tiab]

Diabetes

Search	Query
#5	"Diabetes Mellitus"[tiab] OR "Diabetes Insipidus"[tiab] OR "Prediabetic State"[tiab] OR "Scleredema Adultorum"[tiab] OR "Glucose Intolerance"[tiab] OR Gastroparesis[tiab]

Cardiovascular disease

Search	Query
#6	"Cardiovascular diseases"[MeSH] OR Cardio*[tiab] OR "Cardiovascular diseases"[tiab] OR "Rheumatic heart disease"[MeSH] OR "heart disease"[tiab] OR "Rheumatic Heart Diseases"[tiab] OR "Bouillaud's Disease"[tiab] OR "Bouillaud Disease"[tiab] OR "Bouillauds Disease"[tiab] OR "Ischemic heart disease"[tiab] OR "Cerebrovascular Disorders"[MeSH] OR cerebro*[tiab] OR "Cerebrovascular disease"[tiab] OR "Cerebrovascular Disorder"[tiab] OR "Intracranial Vascular Disease" [tiab] OR "Intracranial Vascular Diseases"[tiab] OR "Intracranial Vascular Disorders"[tiab] OR "Intracranial Vascular Disorder"[tiab] OR "Cerebrovascular Diseases"[tiab] OR "Brain Vascular Disorders"[tiab] OR "Brain Vascular Disorder"[tiab] OR "Cerebrovascular Occlusion"[tiab] OR "Cerebrovascular Occlusions"[tiab] OR "Cerebrovascular Insufficiency"[tiab] OR "Cerebrovascular Insufficiencies"[tiab] OR "Ischemic stroke"[tiab] OR "Hemorrhagic stroke"[tiab] OR "Hypertensive heart disease"[tiab] OR Cardiomyopathies[MeSH] OR Cardiomyopathy[tiab] OR "Myocardial Diseases"[tiab] OR "Myocardial Disease"[tiab] OR Myocardiopathies[tiab] OR Myocardiopathy[tiab] OR "Secondary Cardiomyopathies"[tiab] OR "Secondary Cardiomyopathy"[tiab] OR "Secondary Myocardial Diseases"[tiab] OR "Secondary Myocardial Disease"[tiab] OR "Primary Cardiomyopathies"[tiab] OR "Primary

Nutrition deficiencies OR cardiovascular diseases OR diabetes

Search	Query
#7	#4 OR #5 OR #6

(Dietary pattern OR Food/Diet) AND (Nutrition deficiencies OR cardiovascular diseases OR diabetes)

Search	Query
#8	#3 AND #7

SCOPUS

Filters: Review, Publication date from 2014/01/01
Date of searching: December 31, 2021

((((TITLE-ABS-KEY (eat* OR drink* OR "consumer behavior" OR "food choice behavior" OR "feeding behavior" OR "food preferences" OR "healthy lifestyle" OR meal* OR breakfast OR lunch OR dinner OR snack* OR "diet* pattern" OR "meal pattern" OR "eating habit*" OR "eating custom" OR "eating practice*" OR "nutrition transition" OR "feeding behavior*" OR "eating behavior*" OR "feeding pattern*" OR "food habit*" OR "diet* habit*")) OR (TITLE-ABS-KEY (meal* OR nourishment OR diet* OR food* OR "processed food*" OR "diet* quality" OR "diet* diversity" OR "food consumption" OR "diet* intake" OR "food intake" OR "serving size" OR "portion size" OR "nutritive value" OR "food quality" OR "functional food*" OR "fast food*" OR water OR alcoholic OR beverages OR vegetable* OR seed* OR nut OR nuts OR "fish product" OR "fish products" OR "red meat" OR poultry OR meat OR fruit OR flour OR egg* OR margarine OR "ice cream" OR yogurt OR cheese OR milk OR ghee OR butter OR dairy OR chocolate OR injera OR bread OR "energy intake" OR "diet western" OR "diet* surveys" OR cereals OR legumes))) AND ((TITLE-ABS-KEY ("nutrition deficiency" OR "protein-energy malnutrition" OR "protein energy malnutrition" OR "protein-calorie malnutrition" OR "protein calorie malnutrition" OR marasmus OR kwashiorkor OR "Iodine deficiency" OR "Vitamin A deficienc*" OR "anemia, iron deficiency" OR "iron-deficiency anemia*" OR "iron deficiency anemia*" OR zinc OR "zinc deficiency" OR "folate deficiency" OR "calcium deficiency")) OR (TITLE-ABS-KEY ("diabetes mellitus" OR "diabetes Insipidus" OR "prediabetic state" OR "scleredema adultorum" OR "glucose intolerance" OR gastroparesis OR diabetes)) OR (TITLE-ABS-KEY ("cardiovascular diseases*" OR cardio* OR "rheumatic heart disease" OR "heart disease" OR "bouillaud* disease" OR "ischemic heart disease" OR "cerebrovascular disorder*" OR cerebro* OR "intracranial vascular disease*" OR "intracranial vascular disorder*" OR "cerebrovascular diseases" OR "brain vascular disorder*" OR "cerebrovascular occlusion*" OR "cerebrovascular Insufficienc*" OR "ischemic stroke" OR "hemorrhagic stroke" OR "hypertensive heart disease" OR cardiomyopath* OR "myocardial disease*" OR myocardiopath* OR "secondary cardiomyopath*" OR "secondary myocardial disease*" OR "primary cardiomyopath*" OR "primary myocardial disease*" OR myocarditi* OR carditis OR "alcoholic cardiomyopathy" OR "atrial fibrillation" OR "auricular fibrillation*" OR "atrial fibrillations" OR "persistent atrial fibrillation*" OR "familial atrial fibrillation*" OR "paroxysmal atrial fibrillation*" OR "aortic aneurysm*" OR "peripheral artery disease*" OR endocarditi* OR "Infective Endocarditi*")))) AND (TITLE-ABS-KEY ("meta-analysis" OR "systematic review"))) AND NOT (INDEX (medline)) AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014)) AND (LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE, "English"))

Google Scholar

Date of searching: December 31, 2021
Filters: Searched the first 10 pages, publication date from 2014/01/01
Diets AND (calcium OR zinc OR calcium OR folate OR “vitamin A” OR “protein deficiency” OR “energy deficiency OR diabetes OR “cardiovascular disease”) “AND "systematic review"

Appendix B: Priority Diseases and Cause of Death in Ethiopia - Global Burden of Diseases

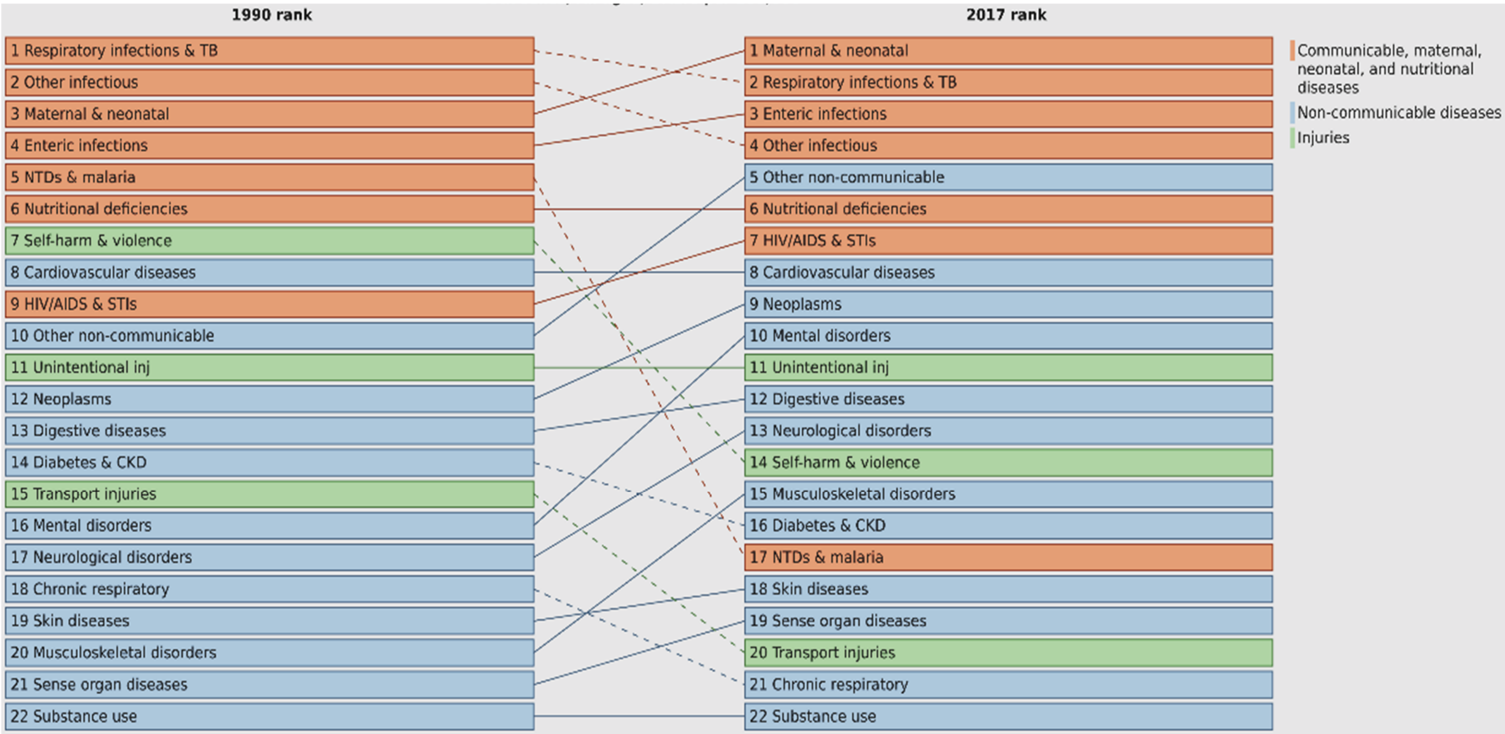

Figure B1. Priority disease lists among all ages and sex in Ethiopian, DALY per 100,000 in 2017

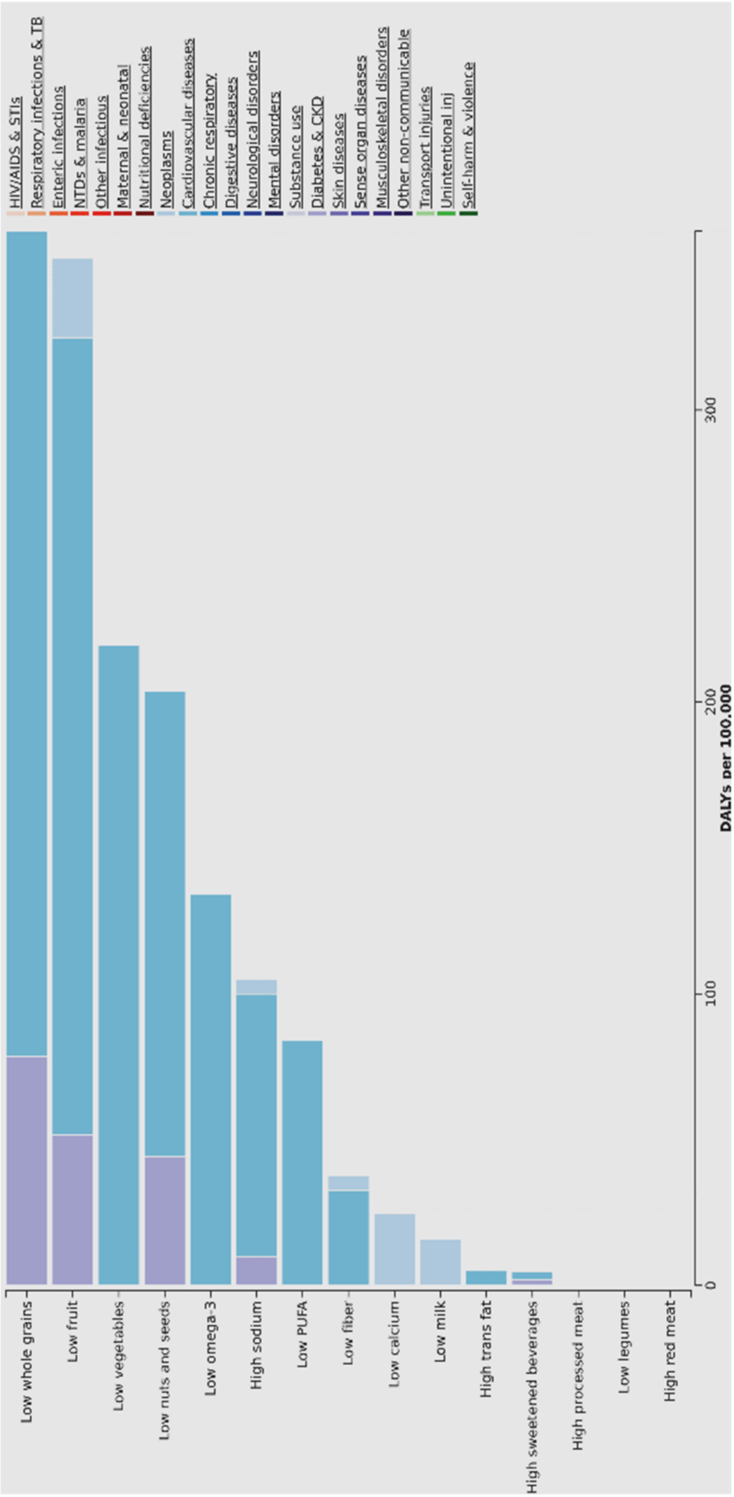

Figure B2. Dietary risk factors for the priority disease of all ages and sex in 2017

Chapter 4

The feasibility of implementing the Ethiopian food-based dietary guideline's messages and food graphics: a qualitative study

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Submitted to the journal

Abstract

This study aimed to test the acceptability, cultural appropriateness, consumers' understanding, and practicality of the Ethiopian food-based dietary guideline's messages, tips, and food graphics. A qualitative study design was applied with focus group discussions and key informant interviews. Four different participant groups were included: 40 consumers, 15 high-level nutrition experts, 30 frontline community health extension workers (HEWs), and 15 agriculture extension workers (AEWs) to incorporate different stakeholder perspectives. Data collection was conducted using 7 focus group discussions (FGDs) and 30 key informant interviews (KIIs). Collected data were coded and analysed using QSR International NVivo V.11 software. Most of the study participants were highly interested in implementing the dietary guidelines once these guidelines are officially released. Based on the participants' views, most of the messages align with the current nutrition education materials implemented in the country except the messages about physical activity and alcohol intake. However, participants suggested defining technical terms such as ultra-processing, whole grain, safe and balanced diet in simpler terms for a better understanding. Practicality, affordability, availability, and access to the market were the major barriers reported for adherence to the guidelines. To be more inclusive of cultural and religious beliefs, findings show that the guideline should address fasting and traditional cooking methods. In conclusion, the dietary guidelines were well received by most stakeholders. They are thought to be feasible once feedback on wording, affordability, availability, and access is considered in the messages, tips, and graphic designs.

Introduction

Ethiopia strives to end undernutrition and prevent the rising burden of overweight/obesity and non-communicable diseases. This is done through different policy instruments, including a multisectoral food and nutrition policy and strategy, a nutrition-sensitive agriculture strategy, and a health and agriculture transformation plan[1; 2]. These policies and programs include actions to improve healthy lifestyles and availability, accessibility, and consumption of healthy diets[3]. One priority action was developing, testing, and implementing food-based dietary guidelines (FBDG). FBDG has been described as 'consistent and easily understandable translations of population nutrient goals into simple public messages, encouraging healthy habitual food choices to improve public health' [4]. The primary goal of the FBDG is to encourage consumers to make healthy food choices to reduce the risk of chronic diseases and malnutrition. FBDG can also be used to inform actions to improve the food system, including practices by food industries to promote better consumption patterns. According to the United Nations Food and Agriculture Organization [4], national FBDG should define context-specific sustainable healthy diets by considering the social, cultural, economic, ecological, and environmental circumstances.

Under current practices, FBDG develops technical guidelines accompanied by public messages and visual food graphics to facilitate consumers' understanding[5]. The development of the FBDG is a lengthy evidence-informed stepwise process[6; 7]. Technical guidelines need to be translated into public practical education messages and materials that the consumers can understand, remember, accept, and apply. It is important to investigate how well the dietary guidelines and illustrations are understood, well accepted and whether they are culturally appropriate and practical to consumers [8]. As a result of such studies, FBDG will be more context-specific and effective in improving knowledge, attitude, and practice toward a healthier diet during implementation [9]. Research by Love (2002) showed that nutrition education tools, such as FBDG and visual food guides, are often misunderstood or not used appropriately by consumers [10]. The FAO and WHO have recommended consumer testing in the development of FBDG[4] and the involvement of experts and program professionals to ensure the messages are correct and relevant to the public.

Furthermore, the FBDG should be understandable and acceptable by the frontline workers who implement the guidelines to the public. Across different countries, several testing studies of FBDG for specific target groups have already been conducted [6; 11; 12; 13; 14; 15]. The Ethiopian FBDG will be presented for the first time in this study, with its feasibility. The approach for investigating the feasibility study for Ethiopian FBDG was taken from proposed design[16]. Similar studies during FBDG development benefit especially countries with diverse cultures, socioeconomic and dietary pattern exist to contextualize the guideline for effective implementations.

This research aimed to test the acceptability, cultural appropriateness, consumer understanding, and practicality of Ethiopian FBDG, which EPHI has recently developed in collaboration with FAO and Wageningen University. The first component (acceptability) looks at whether FBDG and food guides motivate consumers to change their behaviour[17]. The second component (cultural appropriateness) examines various factors that influence the cultural appropriateness of FBDG[4], taking current food habits into account. Guidelines that propose radical changes from the current diet or undermine religious or cultural beliefs will not be appropriate[18]. The third component (understanding) tests whether FBDG is written in an understandable manner[18], considering population literacy. The terminology should be simple, self-evident, and refer to foods instead of nutrients. The general population should readily understand visual representations of the FBDG and be easy to remember. The fourth component (practicality) recognizes the social, economic, agricultural, and environmental conditions associated with the foods and eating patterns[18]. Considering the geographical variation, the recommended food groups should be widely available and accessible to most people.

Eleven key public messages for Ethiopian FBDG and tips and food graphics were tested for acceptability, cultural appropriateness, understanding, and practicality. Out of the 11 public messages, the first 7 encourage consumers to implement healthier dietary practices habitually, whereas the last 4 public messages advise limiting certain food groups to stay healthy (Figure 4.1). The detailed food guide, including the tips for every message and food graphics that characterize different food groups, is supplementary to this paper.

Figure 4.1. The 11 public messages for the Ethiopian Food-Based Dietary Guidelines.

Method

Participants and setting

To incorporate different stakeholder perspectives and involved interests, four participant groups were included: high-level nutrition experts, frontline community health extension workers (HEWs), frontline community agriculture extension workers (AEWs), and consumers in a selected rural setting of Amhara regional state and urban setting of the capital city, Addis Ababa. The high-level nutrition experts (n=15) were selected based on their role in nutrition leadership and experience in developing communication materials for nutrition behaviour change in Ethiopia. The public messages and graphics for the Ethiopian FBDG and the data collection tools to test the feasibility were revised based on the input from these high-level nutrition experts. This step is considered a pre-test for the data collection questionnaires and a final revision of the guidelines before being tested at the community level. These are the country experts who can give technical input for the work. Their overall collected data were included in the analysis of the other dataset for further analysis.

A total of 30 HEWs (15 from Amhara and 15 from Addis Ababa) and 15 AEWs (from Amhara) participated in this study. Field supervisors and health and agriculture office heads selected these health and agriculture extension workers at random from available lists in selected woredas (districts). The HEWs and AEWs were included in this study because of their role in delivering nutrition behaviour change communication, health extension packages, and agriculture extension packages at the community level[19; 20].

Consumers were represented by women of reproductive age (15-49 years). This choice was made because of the predominant role of mothers as the ones in the household responsible for purchasing, preparing, and allocating the food for consumption[21]. Furthermore, HEWs and AEWs target women for nutrition intervention programs and behavioural change communications. A total of 40 women (15 from Addis Ababa and 25 women Amhara regions) participated. To be included, women needed to be between 15-49 years old, married and living with their families in urban or rural settings. Individuals were excluded from the study if they were a household member working in the health care, nutrition, or fitness industry, on a medically prescribed diet, or considered a nutrition expert. The women were recruited in collaboration with health extension workers using purposive sampling.

Study design and data collection

A qualitative study design was applied in this study. Data were collected through focus group discussions (FGDs) and key informant interviews (KIIs) using structured discussion topics and questionnaires. An overview of the KIIs and FGDs conducted is represented in Table 4.1 below. All FGDs and KIIs were carried out in Amharic except one FGD (carried out in English) by experienced interviewers (master's degree holders in public health nutrition with experience collecting qualitative data) trained for 5 days. The dietary guidelines that are ready for evaluation were also translated into Amharic. The study focus areas, key questions, possible outcomes, and the target study population were adapted from a method on feasibility studies designed by Bowen et al. [7; 16].

1.1.1. Focus group discussions

The perspectives on the cultural appropriateness and acceptability of the FBDG were expressed through FGD. In the focus group discussions, participants were encouraged to speak freely, express their understanding and feelings about specific topics in-depth, and react or build on the opinions of other participants[14].

In total, 7 FGDs were conducted. The discussions took place at locations that were easily accessible to the participants. At every FGD, at least one moderator facilitated the discussion, and one observer was responsible for taking notes, recording the discussion, and taking photos. The sessions lasted for a range of 90-120 minutes (5 minutes of opening, 10 minutes of transition into the main discussion, 60-90 minutes of the main discussion, 10 minutes of summary, and 5 minutes of acknowledging the participants) and had a range of 10-12 participants per group. All sessions were recorded with permission.

1.1.2. Key Informant Interviews

Key informants were selected based on their skills, position within society, or ability to provide a deeper insight into the research topic. The key informant interview (KII) questions were loosely structured, allowing a free flow of information[22]. The goal was to get insight into whether the FBDG were understood and practiced to translate into daily food choices. The initial KII questionnaire was developed based on a literature review about the understanding and practicality of the FBDG. The draft questionnaire was pre-tested in a household different from the study and subsequently fine-tuned. In total, 30 key informant interviews were conducted; 5 among high-level nutrition experts, 10 HEWs, 5 AEGs, and 5 women (Table 4.1).

Table 4.1. Overview of Focus Group Discussions and Key Informant Interviews conducted

	WRA		**Nutrition Experts**	**HEWs in urban and rural**	**AEWs in rural**	**Total**
	urban	**rural**				
FGDs (number of participants)	1 (n=10)	2 (n=20)	1 (n=10)	2 (n=10)	1 (n=10)	7 (n=70)
KIIs number of participants	n=5	n=5	n=5	n=10	n=5	n = 30
Total	**40**		**15**	**45**		**100**

FGDs: focus group discussions, KII: key informant interviews, WRA: women of reproductive age, HEWs: health extension workers, AEWs: Agriculture extension workers

At each interview, the enumerators gave key informants the food guide, which included key messages, tips, and food graphics, to read for 10-15 minutes. The enumerators then spent 5 minutes reading the material. The data collectors read the messages and tips for consumers who could not read them and showed them the dietary guidelines and graphics. After data collection, the saturation level was checked for both FGDs and KIIs by comparing the degree of repetition in the new data to the previous data to ensure that the sample size was adequate.

Data analysis

The KIIs and FGDs were transcribed and translated from Amharic into English. All transcriptions and translations were checked and adjusted by the two research coordinators. Data analysis was done using QSR International's NVivo V.11 software. Both FGDs and KIIs were analysed together since the information complemented each other and showed the complete picture of the four components (acceptability, cultural appropriateness, understanding, and practicality). After the initial series of component mind mapping, defining, and refining, the dominant themes and sub-themes were discussed within the research team until consensus was attained. Responses were coded under these themes and sub-themes to synthesize the information.

Results

The findings from the FGD and KII are presented in four main sections: acceptability, cultural appropriateness, understanding, and practicality. The four main sections are subdivided into high-level nutrition experts, health and agriculture extension workers, and women of childbearing. Table 4.2 included the study participant's group, gender, age, the main finding's supporting quotes, and respondent ID.

Table 4.2. Supporting quotes for dietary guideline acceptability, cultural appropriateness, understanding, and practicality by subgroup, gender, and age in a year

Group	Gender (age)	Supporting quote	ID	Quote number
HLNE	Woman (46)	"I'm excited to see this initiative because I haven't had any country-specific dietary guidelines to discuss with my students for many years when teaching about a healthy diet or dietary diversity at the university..."	42	1
HLNE	*Woman (38)*	"I think the idea of the pictures with faces is very attractive and makes it more interesting. It's less text… more illustration, fun faces, bright colours. You know the fine-tuning of the illustrations and changing some of them based on the feedback and revising the messages needs to be considered."	43	2
HEW	Woman (26)	"I missed out on demonstration on food preparation and recipes for pregnant women. I want mothers to have a proper diet to have a healthy baby during their pregnancy period..."	60	3
HEW	Woman (31)	"Cooking skills require knowledge, understanding, and skill! This has to be taken into consideration in the guideline. The skill itself is the main one! ..."	64	4
RW	Woman (35)	"As I have seen it today, what I understand here is, peas and beans are protein, and it is good for us. We see pineapple in Debre Birhan, but we don't know its benefits. But when we look at it, and what we see here in the pictures, I am now looking and realizing that it is healthy and suitable for us..."	15	5
UW	Woman (34)	"Most of the time children, babies would use it (sugary foods), and sometimes mothers do not prevent them from using it. They would use candy a lot. It's a matter of awareness".	21	6
HLNE	Woman (37)	"The message about legume consumption tells me, I have to consume legumes in every meal every day. However, it doesn't say much about in what form I can consume such as roasted, boiled, Shiro(powder) form, germinated and boiled/roasted..."	40	7
HEW	Woman (29)	"The community doesn't allow cabbage to be eaten by pregnant women because of parasites. Normally, a pregnant woman can't take medicine in early pregnancy. The message has to give information on how pregnant women can consume vegetables and fruits."	59	8

Group	Gender (age)	Supporting quote	ID	Quote number
RW	Woman (27)	"Coffee, for example, is now required to be included as one of the foods/drinks? There's coffee, but where does it fit? There is no mention of it. Do we put it in the grain category, or do you mean inside the drink? We had no idea which category it belonged to".	30	9
RW	Woman (41)	"... The diagrammatic illustrations look modern and should be made according to our culture. I mean that these foods are ours, but the characters are modern. This dietary guide is prepared for the community to understand it by reading rather than observing its diagrammatic illustrations."	37	10
HLNE	Man (52)	"Only experts in the field know what the term ultra-processing means. It's good to find a simple description of ultra-processing.....like removing the upper cover of cereals. ..."	51	11
HLNE	Woman (37)	"...I am a bit lost about the way how to apply these messages. The foods I will eat in every meal every day are too much. I am not sure if I'll eat legumes every day; it seems boring..." – High-level nutrition expert	40	12
HEW	Woman (24)	"We, health extension workers, should work on increasing the communities awareness about a balanced diet by educating them to work with the available foods such as cabbage, carrot, potato, legumes, cereals, and animal source foods so that people can eat healthier.."	46	13
HEW	Woman (27)	"There are different treatment methods for drinking water such as filtration, using chemical (aqua tap), and boiling. When people keep drinking water, it should be covered in a container narrow at the top. Water has to be kept and served in a clean environment so that people can prevent water-borne disease such as diarrhea."	49	14
UW	Woman (21)	"It is about moving my hands and feet for 30 minutes. Sport is not just about standing and running; it is also sport when I work at home. Moving up and down to work in the house is also an exercise...".	21	15
UW	Woman (43)	"Diversifying or balancing means vegetables may not be available daily, but we can get vegetables weekly; if we buy bananas, we can make it for four times or more for a family..."	16	16
HLNE	Woman (61)	"...this guideline says eat or drink animal source foods every day. We know how expensive animal source foods are at the moment. Instead of saying eat or drink animal source foods, It's better to say add animal source foods to your daily diet."	44	17

Group	Gender (age)	Supporting quote	ID	Quote number
HLNE	Man (47)	"...Most of the time, alcohol is consumed out of working hours and consumed the time that should have been spent with family. The money used for alcohol intake costs to be shared with other family members...."	48	18
HLNE	Man (52)	"... it's good to strengthen the market linkage for better access of certain food groups such as fruits and vegetables....The market linkage can be achieved by creating cooperation of youth and farmers through credit associations."	51	19
AEW	Man (34)	"...the community should know about home gardening of vegetables and fruits. This will help them eat healthily and not worry about buying at a high price."	71	20
UW	Woman (39)	"I think this dietary guide may not be practical to our society because money is needed to implement this dietary guide. Therefore, applying all the messages listed under this dietary guide is difficult. In general, it can be a little difficult in terms of money and the cost of living we have currently."	19	21
RW	Woman (33)	"Here, we can't get meat daily because we bought it from the market. We use eggs at home because there are chickens in the house. The egg doesn't cost much. It is difficult to get meat every day, but if we have from the house, we will use it".	25	22
UW	Woman (36)	"... it is important to plant garden vegetables to implement this dietary guide is not functional for urban dwellers but better for rural dwellers. For example, we are here in Addis Ababa; we can't plant vegetables because we live in a rented house and don't have our backyard in general".	13	23
RW	Woman (45)	"Now, every time the children go to school and return, half of us will not succeed in giving them a nutritious meal. We focus on our work, and when our children arrive, the time is already run out."	29	24

AEW: Agriculture Extension Worker, **HEW**: Health Extension Workers, **HLNE**: High-Leve Nutrition Experts, **RW**: Rural Women, **UW**: Urban Women

Acceptability of the Ethiopian food-based dietary guidelines

The acceptability of the FBDG was determined by the attractiveness of the graphics design, consistency with other nutrition messages, interest in using the food guide, and consumer adequacy to use the FBDG (Figure 4.2). According to the summary from this section, most of the participants in this study expressed an eagerness to put the dietary guidelines into practice once they were officially released. Most of the messages in the dietary guidelines are consistent with current nutrition behaviour change communication materials. There is a need for more practical examples of physical activities and cooking demonstrations. According to the participants, the current version should be revised to make it user-friendly to implementers and end-users. The detailed participant-suggested revisions are broken down into sub-sections below.

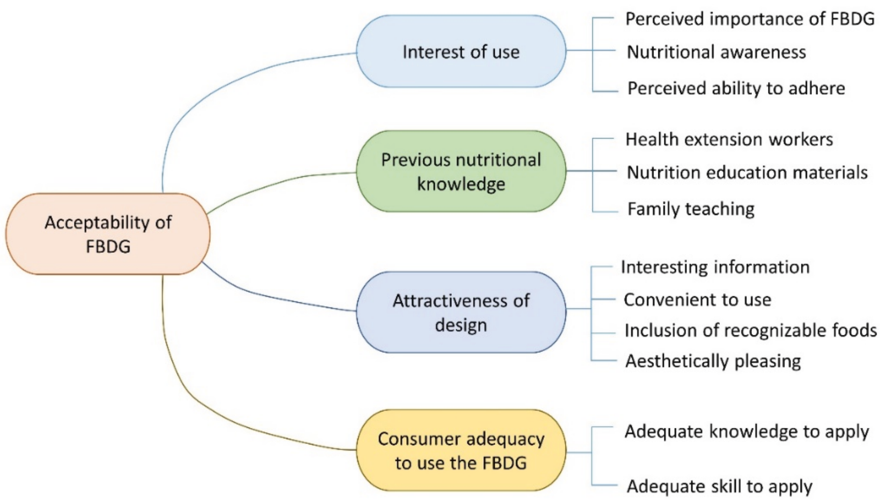

Figure 4.2. Mind map of responses given on the acceptability of the Ethiopian FBDG

A. High-level Nutrition Experts

All participants in this category mentioned that they are interested in using the new FBDG in their professional work once it is completed and officially released for implementation. There are a variety of nutrition education materials available that are not harmonized for a common set of messages and are targeted specifically at mothers or children. The nutrition expert group agreed it was worth having one standard national food-based dietary guideline as a reference.

"I'm excited to see this initiative because I haven't had any country-specific dietary guidelines to discuss with my students for many years when teaching about a healthy diet or dietary diversity at the university. I was mostly referring to the dietary guidelines of Canada, the United Kingdom, or South Africa, which are in a completely different situation than Ethiopia. Because our country's nutrition problem is so severe, I'm very interested in advising the general public based on this guideline once it's completed." – (High-level nutrition expert, ID42)

For each food group, mascot images with a human character are used in the dietary guidelines' graphics design. Some nutrition experts thought the graphics were appropriate for both children and adults, while others thought they were only appropriate for children because the food representation of human characters deviates from the food's natural look, which adults may not find appropriate for communicating a healthy diet.

"I think the idea of the pictures with faces is very attractive and makes it more interesting. It's less text… more illustration, fun faces, bright colors. You know the fine-tuning of the illustrations and changing some of them based on the feedback and revising the messages needs to be considered"– (High-level nutrition expert, ID43)

Most of the nutrition experts mentioned that the messages in the food-based dietary guidelines were in line with the country's current food and nutrition policy and strategic plan. Most dietary guideline messages are used in the present communication materials for behavioral nutrition change. There are new messages in the FBDG, such as encouraging physical activity and limiting sugar and fat consumption. Furthermore, the balanced diet or diet diversity advice, which suggests eating at least 4 out of 6 food groups every day, suggested being checked against other countries and WHO recommendations and whether the minimum energy and nutrient requirements can be met with this advice. Most respondents stated that the physical activity messages require more explanation with practical examples, considering the various target populations for implementation. The urban and rural communities have different lifestyles and work environments and therefore need targeted advice on types of physical activities, intensity, and duration.

B. Health and Agriculture Extension Workers

The health and agriculture extension workers believe that this guideline is relevant to the community. Based on their view, it is well aligned with the existing nutrition education materials and has additional information that will help to prevent non-communicable diseases through a healthy diet. However, they also stated that these dietary recommendations, tips, and graphics illustrations do not consider pregnant or breastfeeding women. They stated that because they are part of the population above two years, it is critical to incorporate a message specifically for them.

"I missed out on demonstration on food preparation and recipes for pregnant women. I want mothers to have a proper diet to have a healthy baby during their pregnancy period. I do not want to see a generation affected by stunting."– (Health extension worker, ID60)

According to health extension workers, nutrition awareness is still lacking at the community level, and the level of awareness varies by location and level of education. They also believe that following this guideline will help them better understand a healthy diet to teach their community. Some participants suggested that some of the messages need a detailed explanation and more practical examples to implement at the household level. Other participants did not agree with this idea.

"Cooking skills require knowledge, understanding, and skill! This has to be taken into consideration in the guideline. The skill itself is the main one! For example, skill is a matter of preparing the food in the right way with adequate knowledge. If we say we are cooking the food, while the food stays on fire for a long time, the food content will be lost." – (Health extension worker, ID64)

C. Women of reproductive age (Consumer) both in the urban and rural setting

Both rural and urban women agreed that having a dietary guideline is important for healthy eating and preventing malnutrition and disease. The dietary guideline was seen as useful by women because it can teach them why certain foods are healthy. The majority also stated that the dietary guideline would encourage them to include the listed foods in their diets while also informing them about their importance.

"*As I have seen it today, I understand that peas and beans are protein, and it is good for us. We see pineapple in Debre Birhan, but we don't know its benefits. But when we look at it, and what we see here in the pictures, I am now looking and realizing that it is healthy and suitable for us. What I am realizing and understanding now is that it has gone from our community, and we see it comes back as very useful*". – (Rural woman, ID15)

The dietary guideline was mostly in line with what the women had previously heard from health extension workers. In all three FGDs, the women did recognize the nutritional information stated in the food guide, and they said that much of the information was not new to them. The urban women, however, mentioned some contradictions. The message about not overcooking vegetables ran counter to previous advice, which stated that foods should be thoroughly cooked. In addition, one of the women seemed to find the message about eating fats and oils in moderation to be contradictory. She claims she was told that 'fat things' should not be used.

According to rural and urban women, the dietary guideline is convenient and interesting. The main reasons given are the presented variety of familiar foods and different options from the food group. The women were enthusiastic about the aesthetics of the guide and expressed with words such as beautiful, satisfying, and appealing. According to a rural woman, the dietary guideline appeals to her because it includes a list of alternatives, such as the different kinds of fruits and vegetables. One of the urban women remarked that the first page of the dietary guideline is uninteresting and not attractive to those with less money to spend.

According to the responses of many of the women, awareness of the causal relationship between nutrition and health is necessary for these guidelines to be used by the community. If this awareness is not there, the intrinsic motivation to apply such guidelines will be lacking.

"Most of the time children, babies would use it (sugary foods), and sometimes mothers do not prevent them from using it. They would use candy a lot. It's a matter of awareness". – (Urban participant, ID21)

Even though the women are willing to make a dietary change, lack of skills and knowledge might be a barrier. Besides having awareness, having a positive and open attitude towards the guidelines is vital. Even if people have limited resources, the community should feel responsible for following these guidelines. Focusing on what is possible within their limitations is needed to make it easier to adopt the guidelines.

Cultural appropriateness of the Ethiopian food-based dietary guidelines

The cultural appropriateness of the FBDG was determined by the normative practices, cultural values, beliefs, language used, and graphical design reflecting the cultural identity (Figure 4.3). The summary from this section indicated that Ethiopians are accustomed to fasting, and animal-source foods are prohibited during the fasting period in the Ethiopian Orthodox Church. The dietary guidelines include recommendations on cooking healthy, avoiding overcooking, not pouring water after boiling vegetables, and limiting the amount of salt and oil used. Dietary guidelines consider cultural values and beliefs to promote a healthy diet. The cultural appropriateness is detailed into three sub-sections below.

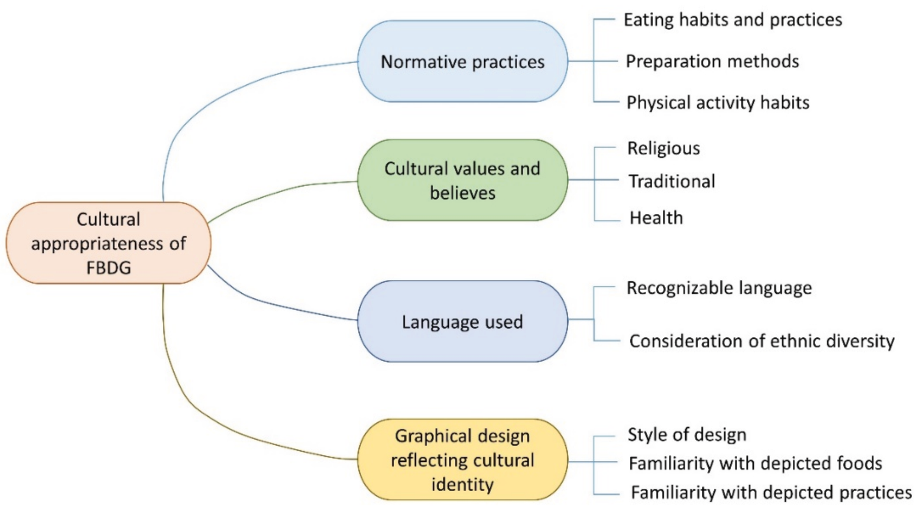

Figure 4.3. Mind map of responses given on the cultural appropriateness of the Ethiopian FBDG

A. High-level Nutrition Experts

The majority of experts' feedback indicated that it is critical to consider Ethiopia's fasting tradition and foods that are allowed or prohibited due to religious practices. Dietary guidelines will be more culturally appropriate if translated into various local languages. According to the nutrition experts, adapting food lists based on agroecological zones and availability will benefit the country's diverse communities.

The nutrition experts group highlighted that food safety has to be communicated to the public to handle food better. They also mentioned that it is relevant to integrate food safety messages like accessing safe and clean water and keeping the foods as part of traditional food preparation. According to the participants in the study, it is more appropriate to improve overcooking.

"The message about legume consumption tells me, I have to consume legumes in every meal every day. However, it doesn't say much about in what form I can consume such as roasted, boiled, Shiro(powder) form, germinated and boiled/roasted..." – (High-level nutrition expert, ID40)

According to a few experts, it is critical to promote wild fruits and vegetables as part of traditional diets in Ethiopia. The way graphics are designed and messages translated into Amharic, according to some participants, has to be more culturally suitable for various population groups.

B. Health and Agriculture Extension Workers

According to some health extension workers, certain foods are prohibited by the community without any scientific evidence. This guideline has to change those beliefs by mentioning the correct way of consuming different foods to have the right information.

"The community doesn't allow cabbage to be eaten by pregnant women because of parasites. Normally, a pregnant woman can't take medicine in early pregnancy. The message gives information on how pregnant women can consume vegetables and fruits."- (Health extension worker, ID59)

Most agriculture and health extension workers mentioned that Ethiopia has diverse ethnic groups and a larger population who do not speak the national language. Many households, restaurants, and hotels serve high fat and oil content food. According to one of the respondents, there should be a clear message to change this cooking tradition. It is critical to translate this guideline into various local languages, at the very least Oromiffa and Tigrigna.

C. Women of reproductive age (Consumers) both in the urban and rural setting

The majority of the women said that the food guidelines reflect the traditional Ethiopian diet, full of fresh products and do not include many packaged and foreign foods. Some rural women did mention some products not represented in the dietary guideline yet were often used by them. These are coffee, tea, and honey, but it was unclear what the nutritional advice was concerning these traditional Ethiopian food products.

"*Coffee, for example, is now required to be included as one of the foods/drinks? There's coffee, but where does it fit? There is no mention of it. Do we put it in the grain category, or do you mean inside the drink? We had no idea which category it belonged to*". – (Rural woman, ID30)

Most of the women believe the dietary guideline does fit their religious beliefs as they are easy to adapt to the different religions in Ethiopia. Women who consider themselves orthodox-Christians and practice fasting also believed the dietary guideline fits their faith well. The main reason for this was the separation of the fasting foods from the non-fasting foods within the guidelines.

Some women expressed their belief that these food guides only needed to be followed when someone was not in good health. It was not clear to them that the guidelines function as prevention measures and therefore help them prevent certain diseases. Most women believed that processed and packaged foods were inherently unhealthy. They tended to think that homemade and fresh foods and beverages were inherently healthy or not harmful.

Participants unfamiliar with all the foods shown in the dietary guideline did not see it as a problem. The language used within the dietary guideline was familiar or not disrupting to them, apart from the foods they had not been familiar with before. They were aware that different foods are produced within other areas and communities in Ethiopia, and different eating habits are dominant.

Although the women were generally positive about the overall design, some were issues with how the illustrations were designed. Those women believed the graphics illustrations were not designed based on their culture as they were designed too modern. This modern graphics design makes the guide mostly suitable for those who can read.

"*... The diagrammatic illustrations look modern and should be made according to our culture. I mean that these foods are ours, but the characters are modern. This dietary guide is prepared for the community to understand it by reading rather than observing its diagrammatic illustrations.*"- (Rural woman, ID37)

To retain iodine, salt should be added at the end of the cooking process rather than at the beginning, as most participants do. According to a participant, it is more typical to use salt when cooking.

Understanding the Ethiopian food-based dietary guidelines

The understanding of FBDG covers personal understanding of the messages, food graphics, and unique context (Figure 4.4). The technical terms used in the dietary guidelines, such as balanced diet, ultra-processed, whole grain, and safety, require a simple definition. Since half of the adult population in rural areas cannot read or write, the graphics illustration should be self-explanatory and use a familiar image—the detail described in the three sub-sections below.

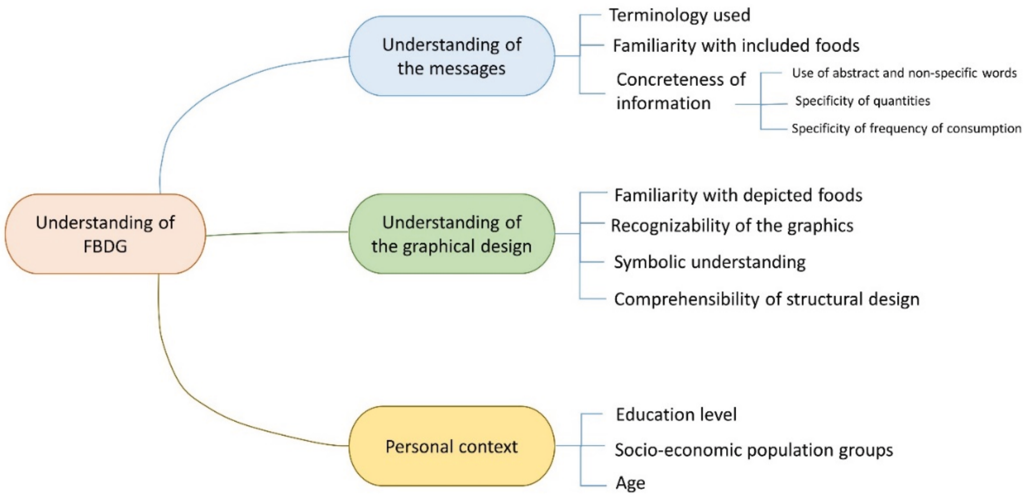

Figure4. 4. Mind map of responses given on the acceptability of the Ethiopian FBDG

A. High-level Nutrition Experts

A majority of the respondents believed that the 11 public messages were comprehensive. Still, the illustration used in the public messages and the tips and the food graphics combined for every message is not clear enough. According to the majority of respondents, some of the terminologies, words, and phrases used for illustration may change the interpretation of the main message of the dietary guideline. In addition, some of the technical terms and phrases used in the messages, such as diet diversity, whole grain, sparingly, limit, safe, clean, and ultra-processing, need a simplified definition.

"Only experts in the field know what the term utral-processing means. It's good to find a simple description of ultra-processing.....like removing the upper cover of cereals. In Amharic, we call it 'Yetefetege' meaning removing the cover for cereals and 'Yetekeka' meaning split for legumes." – (High-level nutrition expert, ID51)

In addition to Amharic, the respondents suggested that the final food-based dietary guidelines be translated from English to other local languages. According to the experts, the most important aspects that require extra attention during translation are sentence structure and word choice. The color and shape of the foods in the graphics are not similar to those of natural foods. Half of the Ethiopian population in rural areas cannot read or write; graphic illustrations are important to recognize without text. No graphic indicate food safety. Incorporating food safety advice is important, especially for fruit and vegetable consumption and food preparation and consumption. The packages used for salt, milk, yogurt, and the serving utensils for water and cheese are unfamiliar in Ethiopia.

They also mentioned that users might be confused by how the circle resembles a plate, used for each graphic illustration of the 11 messages. They suggested the graphics in the dietary guideline might be easier to understand if we use the traditional plate (mesob) to represent both the urban and rural communities. The second sentence at the top of the dietary guideline says that "foods that are not mentioned in the graphics can be eaten sparingly," which is not specific enough to understand what type of foods and the portion size be consumed.

"...I am a bit lost about how to apply these messages. The foods I will eat in every meal every day are too much. I am not sure if I'll eat legumes every day; it seems boring. Eating meat every day doesn't seem realistic. There should be a way to use alternatively with portion size..." – (High-level nutrition expert, ID40)

Most experts stated that the quantity of every food or food group that needs to be consumed every meal or day has to be incorporated in the final messages. They also mentioned there should also be a minimum possible portion size stated for the message that limits intake. The portion size has to be noted to understand and implement it easily. The guideline about water intake in message 6 is more focused on quality than quantity. However, the quality and quantity of drinking water are equally important in Ethiopia to mitigate water-borne disease, malnutrition, and non-communicable diseases. The alcohol message also needs clarification. The last message of the guideline says to avoid alcohol consumption, whereas, in the illustration, it recommends not more than one glass per day. It is better to make the graphics consistent with the message about alcohol intake to avoid confusion.

B. *Health and Agriculture Extension Workers*

Some extension workers stated that consuming a diverse range of foods daily may be difficult unless the simplest method is described in detail, along with the appropriate amount and cost. Ethiopians prepare fermented bread (enjera) and serve it with other food groups. They also mentioned that explaining a healthy diet or a varied diet using enjera, a common Ethiopian dietary habit, might be simple.

"We, health extension workers, should increase the community's awareness about a balanced diet by educating them to work with the available foods such as cabbage, carrot, potato, legumes, cereals, and animal source foods so that people can eat healthier. We should do it by considering what is available in the community." – (Health extension worker, ID46)

Certain foods such as anchote, cassava, and grass pea were unfamiliar to most participants in the two regions. They also indicated that graphics need a major improvement so that people from the rural who can't read the text can easily understand the advice with minimum support. The message on drinking clean water every day is important for health. Water-borne diseases are one of the major causes of malnutrition in Ethiopia. Therefore, more detail should be on how people clean drinking water if their drinking water sources are not clean enough.

"There are different treatment methods for drinking water like filtration, chemical (aqua tap), and boiling. When people keep drinking water, it should be covered in a container narrow at the top. Water has to be kept and served in a clean environment so that people can prevent water-borne disease such as diarrhea." – (Health extension worker, ID49)

According to extension workers, limiting salt and sugar in our diet is a message that is new in this guideline. Normally, people know about it from the media. However, it is not incorporated in the previous nutrition education materials. Normally, salt intake is high, and people also more sugar from time to time.

C. Women of reproductive age (Consumers) both in the urban and rural setting

Not all participants were familiar with the foods mentioned in the food guide, which hindered understanding. The most commonly unfamiliar foods were anchote, cassava, and kocho (or false banana). Only some rural women seemed to be unfamiliar with melon and peanuts. All participants were unfamiliar with the term 'processed meat' regarding the tips on message 5: avoid processed meat regularly. Many women explained the importance of being physically active with responses, including 'It relaxes the body, helps with digestion, or protects against diseases'. Yet, putting it into practice was not clear to all women.

"It is about moving my hands and feet for 30 minutes. Sport is not just about standing and running; it is also sport when I work at home. Moving up and down to work in the house is also an exercise. So, it is not a difficult task unless you are not aware of it. But there may be an awareness problem". – (Urban woman, ID21)

Most of them also explained diverse eating as consuming different types of foods through the timeslot in which these foods should be eaten unambiguous. Some women stated that eating different foods for breakfast, lunch, and dinner every week is important. In contrast, others indicated that eating different foods for breakfast, lunch, and dinner every day is important.

"Diversifying or balancing means vegetables may not be available daily, but we can get vegetables weekly; if we buy bananas, we can make it four times or more for a family. Then, papaya for another day since it does not stay longer once cultivated. Although we don't get it every day, we can serve vegetables at our weekly meals." – (Urban woman, ID16)

Several women did not understand the recommended frequency of consuming certain food groups. In the context of the dietary guideline tips (Foods that do not appear in the food graphic can be eaten sparingly), the Amharic translated the word "sparingly" was interpreted by the participants as "processing, cleaning, and preparing your food hygienically and carefully".

All women seemed to understand the importance of limiting the use of salt. Terms used to explain their salt consumption are "in moderation, proper usage or limitation." All women seemed to be well aware of the health consequences of eating excess sugar. Most women understand that the FBDG recommended not drinking alcohol; others believed the message was about moderate or occasional consumption. The women had a different understanding of how often water should be consumed. One talked about drinking water every hour, whereas another woman said 'always' drinking water was unhealthy and indicated the presence of disease.

The dietary guideline mentions eating legumes instead of animal products on days of fasting. Yet, when asking about the food to replace meat, legumes were not often the first food mentioned to be eaten. Most women, especially rural women, said they eat certain vegetables instead. Urban women sometimes mentioned legumes.

The practicality of the Ethiopian food-based dietary guidelines

The practicality covers affordability, availability, accessibility suitability, and favorability of the FBDG (Figure 4.5). In both urban and rural areas, affordability has become a major concern. The long-distance between home and market is seen as a major impediment to putting the guidelines into practice daily. Seasonality and low productivity can limit the availability of various fruits and vegetables. More efforts should be made to improve the agricultural production of those fruits and vegetables. To enhance low micronutrient intake, fortified products, improved seeds like orange flesh sweet potato, orange maize, and biofortified legumes should be promoted. Physical activity and limiting added salt and oil during food preparation require a more detailed explanation and consideration to change current practice.

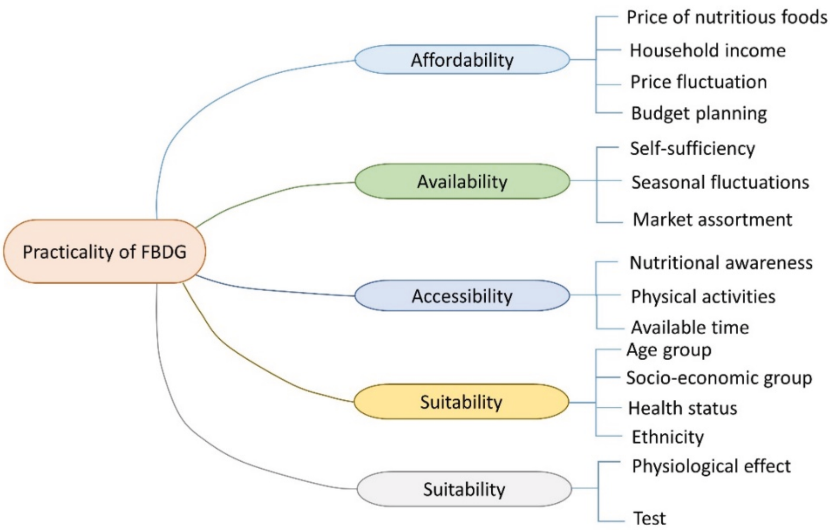

Figure 4.5. Mind map of responses given on the practicality of the Ethiopian FBDG

A. High-level Nutrition Experts

According to the respondents, some of the key determinants of practicality to implement the food-based dietary guidelines are price, availability, accessibility, seasonality, religion, and culture. They also indicated that these guidelines' practicality in the urban areas would differ from rural areas. According to them, the urban population will have relatively good access to different foods. However, most low-income people cannot afford some of the food groups. The low-income rural community will have both accessibility and affordability as a challenge. The rural middle and high-income groups will have limited access to healthier diets.

"*...this guideline says eat or drink animal source foods every day. We know how expensive animal source foods are at the moment. Instead of saying eat or drink animal source foods, It's better to say add animal source foods to your daily diet.*" – (High-level nutrition expert, ID44)

According to the experts, legume consumption is practical and familiar to the community compared to animal-sourced foods, fruits, and vegetables. They also mentioned physical activity is difficult to communicate for different living conditions in urban and rural settings. Alcohol intake is part of the tradition in Ethiopia on different occasions. They suggested that limiting their intake to 1 or 2 glasses per day is more practical advice. It might be impractical for the public to avoid alcohol intake.

"...Most of the time, alcohol is consumed out of working hours and consumed the time that should have been spent with family. The money used for alcohol intake costs to be shared with other family members. By explaining those disadvantages, it's possible to bring a behavioural change and minimize the intake." – (High-level nutrition expert, ID48)

The experts thought the practicality of these guidelines would be more challenging for pastoralists who live mostly with their indigenous culture and eating habits in remote areas. They also indicated a special need for further adaptation for the FBDG for the pastoralism community. This may require an anthropologic study to understand better their eating habits and access to recommend a healthy diet to the specific context.

"... it's good to strengthen the market linkage for better access of certain food groups such as fruits and vegetables....The market linkage can be achieved by creating cooperation of youth and farmers through credit associations" – (High-level nutrition expert, ID51)

Some of the experts mentioned limited agricultural production and lack of nutrition knowledge could also limit the ability of the population to follow the FBDG. The suggested providing fruit and vegetable seeds every year by strengthening seed multiplication centres and encouraging researchers to produce new varieties of seeds are suggested as solutions for production improvement. They also indicated that when there is a high production of certain fruits and vegetables during specific seasons, food processing will help to reduce food loss and price fluctuations. According to the nutrition experts, it is important to include the biofortified verity of orange flesh sweet potato, orange maize, and improved verity of legumes and mung beans biofortified with zinc and iron. And they advised developing a manual for food processing technologies that can be easily applied in the country. The existence of important traditional food processing and preservation techniques is also mentioned. They suggested it is good to check their effectiveness and promote these to solve seasonality effects.

Thee nutrition experts indicated that food safety is one of the limiting factors for consumption, especially for fruits and vegetables. They believe it is good to establish a national cold chain for fruits and vegetables, and there has to be enforcement of rules on proper handling throughout the supply chain. A message about overcooking vegetables needs to be included in the guideline while cooking vegetables is promoted. In addition, experts consider fasting a limiting factor in consuming sufficient animal source foods and water. They suggested including alternative protein sources in the diet and encouraging people to drink more water with their meals during fasting periods.

Health and Agriculture Extension Workers

Most of the respondents mentioned that some of the foods such as animal source foods, fruits, and vegetables are not affordable to the majority of the low-income population. They even mostly consume a lower quantity of cereals and legumes in general. The current COVID-19 problem is also a big challenge for the low-income community. Their level of poverty is even worsening due to the pandemic.

"...the community should know about home gardening of vegetables and fruits. This will help them eat healthily and not worry about buying at a high price." – (Agriculture extension worker, ID71)

According to extension workers, meat is consumed more frequently and in larger quantities during the holidays. Some stated that high-income people prefer to eat meat almost every day, despite leading an unhealthy lifestyle. They reasoned that the wealthier one becomes, the more likely one will become overweight or obese in Ethiopia. Most of them indicated that most people consume fruits infrequently or do so without completely understanding their importance for health, rather because they are readily available and affordable.

Some extension workers mentioned limiting the amount of fat is easy to implement since it does not cost anything for the consumers. Few extension workers indicated that people use solid palm oil because of less cost, which is not good for their health. They mentioned that people tend to eat too much fat during the holidays. There should be a way to explain why limiting fat intake is beneficial, reducing fat intake, and replacing solid oils with liquid oils. Providing training on cooking and handling the food will help prevent food and nutrient losses. The traditional way of cooking has more fat and overcooking. Few health extension workers also mentioned that time for cooking is a challenge, especially for most urban communities.

Most of the extension workers agree the message about not drinking alcohol requires self-control. This is possible if we can persuade the consumer with our message. Few extension workers indicated people who consume alcohol should first be aware of the risks to their health. They also said that alcohol consumption has economic and social consequences. Incorporating those three aspects is critical in persuading consumers to stop drinking.

Most of the extension workers mentioned people with disabilities, those who live in extreme poverty, those who live in a remote area, and those who do not speak Amharic might face greater challenges than the general population. They suggested this population group will require extra assistance to implement the guidelines fully.

B. Women of reproductive age (Consumers) both in the urban and rural setting

The biggest practical barrier for urban and rural women was the affordability of the foods mentioned in the guidelines. Many women said they did not have the economic capacity to follow the guidelines.

"*I think this dietary guide may not be practical to our society because money is needed to implement this dietary guide. Therefore, applying all the messages listed under this dietary* *guide is difficult. It can be a little difficult in terms of money and the cost of living we have currently.*" – (Urban woman, ID19)

This was especially the case for the guideline stating to add animal products in everyday meals. Rural women were less problem adding other animal products, such as milk, eggs, or cheese, into their daily meals. This was because they often had chickens or cows that produced milk for them, of which they made their cheese and yogurt.

"Here, we can't get meat daily because we bought it from the market. We use eggs at home because there are chickens in the house. The egg doesn't cost much. It is difficult to get meat every day, but if we have from the house, we will use it". – (Rural woman, ID25)

Rural and urban women agreed that most foods found in the dietary guideline are available in the market. However, the market is often further away for rural women than for urban women, so it's not easy to get there. This and their constraining budget causes the rural women to be more dependent on the foods they grow and their livestock. They should go to the market to purchase other foods they do not produce themselves to have a more varied diet. Some of the women mentioned how they extend the availability of foods by growing some vegetables in their garden. According to them, this gives them easy access to certain fruits and vegetables, and at the same time, it saves them money. However, not all urban women saw this as a good option since many urban families have a rented house with no backyard.

"... it is important to plant garden vegetables to implement this dietary guide is not functional for urban dwellers but better for rural dwellers. For example, we are here in Addis Ababa; we can't plant vegetables because we live in a rented house and don't have our backyard in general". – (Urban woman, ID13)

Even though most foods are available at the market, as the AEWs point out, their accessibility may be limited. Especially the ill, weak, disabled, and older people are less capable of adhering to the guidelines. The main reasons for this were the market's geographical distance or a lack of strength, energy, or ability to travel there. In addition, a lack of time was mentioned as a barrier to purchasing and preparing these different foods.

"Now, every time the children go to school and return, half of us will not succeed in giving them a nutritious meal. We focus on our work, and when our children arrive, the time is already run out." – (Rural woman, ID29)

Some women said that a certain level of knowledge was needed to apply this food guide. Knowing how to read and prepare or combine certain foods was often mentioned as a prerequisite. Therefore, they thought the guidelines to be less accessible to illiterate, old, and homeless people. Some participants found it hard to eat or drink certain foods because of their taste. Eating dishes with a little salt or consuming more water were examples of which taste is the limiting factor in adhering to the guideline. Some participants mentioned abstaining from certain foods, which gave them physical discomfort. According to them, this was especially true with foods like beans, peas, or cabbage.

Women in the study mentioned that their age and physical status might be barriers to being physically active. The body was also seen as a constraining factor when doing physical activity. The overall consensus was that the content of the guidelines was suitable for and adaptable to the different generations and population groups. According to the women, children, pregnant or breastfeeding women, adults, the elderly, and even those suffering from illnesses such as diabetes could have their nutritional needs met.

Discussion

This qualitative study focused on four areas to better understand the factors influencing the feasibility of implementing Ethiopian FBDG, including acceptability, cultural appropriateness, understanding, and practicality. The majority of high-level nutrition experts, health and agriculture extension workers, and consumer representatives were enthusiastic about using the new dietary guidelines, according to the findings from the acceptability of the FBDG. Most key messages in the dietary guidelines are similar to those conveyed in existing nutrition behaviour change communication materials used in Ethiopia. However, the current behavioural change messages mainly focus on vulnerable population groups; infant and young children and their mothers(23). In comparison, the current FBDG includes the key messages, tips, and graphics for the general population above 2 years, which may address dietary risk factors in the entire population (24; 25). The food graphics should be more appealing, considering Ethiopian foods' natural colour, size, and shape. Unfamiliar foods, such as anchote and cassava, should be replaced with more commonly consumed foods in most regions of Ethiopia. More practical examples of physical activities and ways to improve traditional food preparation methods may improve the acceptability. High-level experts suggested changes to the wording of the messages, particularly on the key messages related to meat consumption and alcohol intake.

The study team developed the topic guide for the focus group discussions and key informant interview questionnaire after conducting an extensive literature review on the acceptability, cultural appropriateness, understanding, and practicality of FBDG. In addition, similar studies conducted in other African countries were examined for their FBDG testing methodology and components[10; 26; 27; 28]. Advice on socially acceptable norms that determine eating behaviour, such as traditional and religious celebrations and socializing, may be useful in influencing healthy food choices[26]. A feasibility study on South African food-based dietary guidelines indicated that a single FBDG is appropriate for all South Africans[10]. Whereas in our research, it is suggested to have separate FBDG for pastoralist community and further feasibility study while adapting the FBDG at a regional level. Because half of the adult population in Ethiopia cannot read or write, the graphics illustrations are suggested to be self-explanatory to users[29]. In South Africa and this study, low economic status is a limiting factor for adherence to the guideline[27].

According to this study and other findings, dietary guidelines reflect cultural values and beliefs [30]. For example, our study suggested considering the most common fasting practices in Ethiopian dietary guidelines to improve the nutrient adequacy of Ethiopian dietary habits. According to the Ethiopian Orthodox Church, animal-source foods should not be consumed, and most people stay without food and water until 3:00 p.m. during fasting days which are more than 140 days/year[31; 32]. Individuals may practice fasting in different ways, such as fasting only until lunchtime (1:00 p.m.) and not eating animal-based foods. Other people avoid all animal-source foods except fish and follow a vegan diet during fasting days[32]. According to a longitudinal study conducted in Ethiopia's northern region, fasting harms maternal and child nutritional status and dietary patterns. The study recommended that existing multisectoral nutrition intervention strategies in Ethiopia sustainably include religious institutions to reduce maternal malnutrition [33; 34]. Therefore, including religious belief, fasting in dietary guidelines will assist the general public in improving their dietary habits and moving toward a healthier diet. Furthermore, more research on current dietary patterns during the fasting period among the fasting population group will assist in mitigating some of the issues mentioned.

The technical terms used in the dietary guidelines should be simplified for better comprehension. When translating the English version of the FBDG into Amharic, special care should be taken with the technical terms used. A nutrition brochure text and graphics study showed that more concrete nutrition education materials improved immediate recall of information presented after reading the materials [35]. The current FBDG material lacked information on portion size, which study participants identified as a gap and suggested including the recommended amount for different food groups in the final version of FBDG. The study team decided to test the dietary guidelines without amount on purpose. Because the suggested revisions from this study may be used as input for assumptions and social acceptability constraints or scenarios for the diet modelling work to develop the recommended amount[11; 36], describing the recommended amount using the household or local measurement units and example recipes will assist implementers and consumers in understanding and implementing the dietary guidelines [11]. Aside from providing information on the type and frequency of food consumed during the day, portion sizes play a role in preventing nutrient deficiencies, undernutrition, and non-communicable diseases [37].

The study suggested to includes tips on cooking healthily, such as not overcooking vegetables or pouring water after boiling vegetables, and limiting salt and oil. According to literature, cooking and food skills include meal patterns; food preparation methods and techniques and cooking frequency; general cooking confidence or cooking ability (with foods, method, specific meals, etc.); planning food shopping and writing lists (frequency and responsibility); cooking attitudes and enjoyment of cooking; purchasing and shopping behaviours (label reading, etc.). Cooking and food skills also include food choices, menu and meal planning behaviours (including advanced food preparation behaviours), food safety and hygiene practices and behaviours (hand-washing, thawing food waste correctly, etc.), nutrition knowledge. Health consciousness and confidence relating to choosing foods and feeding others; food budgeting; barriers to cooking and food choices (time, equipment, etc.); utilization and confidence with recipes; food practices (adding salt, etc.); food preparation complexity (specific number of ingredients, etc.); food management (ensuring food lasts adequately, etc.); and source of learning to cook are important factors to consider when it comes to cooking and food skills[38]. Besides, maintaining the cultural elements such as conviviality, culinary activities, physical activity, and adequate rest while adopting a healthy lifestyle and a healthy diet will improve adherence to the FBDG [(39)].

According to our study, the ability of participants to adhere to the FBDG might be influenced by affordability, availability, seasonality, and accessibility. Seasonality and low productivity can limit the availability of various fruits and vegetables [(40)]. To combat social inequalities in nutrition and health, finding nutrient-dense, affordable, and appealing food patterns should be a top priority [(41; 42)]. A study indicated that home gardening and chicken roosting could help increase access to and consumption of animal-source foods, fruits, and vegetables in a marginalized population [(43)]. To meet the demand in Ethiopia for a healthier diet, there should be a strategy to improve animal farming, innovation on improved seed varieties, crop productivity, and diversity[(3)]. Creating market linkages improves access to and affordability of nutritious foods while increasing income for the local community by providing business opportunities. To improve low micronutrient intake at a low cost, fortified products such as fortified milk, biofortified crops such as orange flesh sweet potato, orange maize, and legumes should be promoted[(44)]. A more strategic approach to the country's food system will improve the affordability, availability, and accessibility of a healthy diet [(45)]. Overall, a better understanding of the sustainable food system and the development and implementation of policies and programs will result in a more sustainable implementation of the FBDG to a healthier diet [(46; 47)]. The diet optimization (modelling the current diet to satisfy calorie and nutritional requirements at the lowest possible cost) of the FBDG will take into account food availability, affordability, and fasting vs. non-fasting scenarios based on the result of this study.

Furthermore, environmental sustainability specific to the country context, such as cooking with alternative energy sources, reducing food waste, developing a seasonal calendar for seasonal fruits and vegetables, and preventing post-harvest losses, should be addressed in future research related to these dietary guidelines to avoid unintended consequences due to climate change. Most participants believed that the Ethiopian FBDG could be feasible for implementation once feedback on illustration, appropriateness, affordability, availability, and access was incorporated into the dietary guideline and tips development and graphic designs. The study's findings will be used to revise the final FBDG's messages, graphics, and tips for better comprehension, acceptability, cultural appropriates, and practicality by sharing the findings and working closely with the FBDG committee.

Strengths and limitations

The sample of high-level nutrition experts in this study are representative of the entire country because these experts have central and regional leadership and a coordination role, which is important as Ethiopia has the second largest population in Africa, with a diverse ethnic population and a 1.1 million square kilometres land area [(48)]. We included women of reproductive age and health and agriculture extension workers from Addis Ababa and Debre Birhan representing the urban and rural setting. However, this study sample may not represent the feasibility of the FBDG to the entire population. Other subpopulation groups such as men and adolescents may need to be included in a future feasibility study as their involvement in the overall implementation of the Ethiopian FBDG is crucial. In addition to women, adult men and adolescents administer income, contributing to food security and diet diversity. Consumption out of home is diversified in urban settings[(49)]. Men have a crucial role in deciding how much money to spend on food and how much of a household's agricultural output should be consumed rather than sold. More testing and adaptation of the national FBDG may also be necessary for pastoralists and other indigenous populations living in remote areas of the country due to their difference in lifestyle and eating habits. In addition, because of the subjective nature of qualitative research methods, researchers shape the interactions with participants and their understanding of the data during the process. Different researchers may not always reach the same conclusions [(50)].

Conclusion

In conclusion, the dietary guidelines were well received by most stakeholders. They are thought to be feasible once feedback on wording, affordability, availability, and access is considered in the messages, tips, and food graphic designs.

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Chapter 5

Developing feasible healthy diets for Ethiopian women of reproductive age during fasting and non-fasting - A linear goal programming approach

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Abstract

Improving diet quality is a priority intervention to prevent malnutrition and diet-related non-communicable diseases (NCDs) in Ethiopia. The aim of this study is to develop a healthy diet for Ethiopian women closely resembling their current diet and taking fasting periods into account while tracking the cost difference. Linear goal programming models were built for three scenarios (non-fasting, continuous fasting, and intermittent fasting). Each model minimized a function of deviations from nutrient reference values for 11 nutrients (protein, calcium, iron, zinc, folate, and the vitamins A, B1, B2, B3, B6, and B12). Five regions are included in the urban and rural areas of Ethiopia. Two non-consecutive 24-hour dietary recalls (24 HDR) were collected from 494 Ethiopian women of reproductive from November-December 2019. Women's mean energy intake was well above 2000 kcal across all socio-demographic sub-groups. Compared to the current diet, the estimated intake of several food groups was considerably higher in the modelled diets, i.e., milk and dairy foods (396 versus 30 g/day), nuts and seeds (20 versus 1 g/day), and fruits (200 versus 7 g/day). Except for calcium and vitamin B12 intake in the continuous fasting diet, the proposed diets provide an adequate intake of the targeted micronutrients. The proposed diets had a maximum cost of 120 Ethiopian birrs ($3.5) per day, twice the current diet's cost. The modelled diets may be feasible for women of reproductive age as they are close to their current diets and fulfil their energy and nutrient demands. However, the costs may be a barrier to implementation.

Keywords: Diet modelling, optimization, continuous fasting, intermittent fasting, cost of diet

Introduction

Ethiopia has prioritized improving the diet to combat malnutrition and NCDs[1; 2], and special focus should be given to the diet of women, future mothers, and young children[3; 4]. The nutritional status of Ethiopian women is currently characterized by inadequate intake of micronutrients, attributable to lack of nutrition knowledge, low access to a healthy diet, and heavy daily workload [5; 6]. Dietary recommendations are needed for Ethiopian women of reproductive age to meet their dietary requirements for foods and beverages and prevent malnutrition and diet-related NCDs.

Differences in women's nutritional status and dietary intake between urban and rural areas and between the fasting and non-fasting seasons have been well recognized in Ethiopia[7; 8]. Between 1990 and early 2010, the prevalence of underweight had reduced more in urban areas than in rural areas [9]. Moreover, the prevalence of overweight and obesity was consistently higher in urban areas than rural areas[10]. Therefore, differences in nutritional status and dietary intakes between areas should be considered when developing dietary recommendations. In addition, women's health is also influenced by fasting[11], especially in the Ethiopian Orthodox Church, which is attended by 43% of the total population. In Ethiopia, fasting refers to avoiding animal foods (such as meat, dairy, and eggs) and not eating or drinking before 3 p.m. There are generally two types of fasting: continuous fasting (fasting for 2-8 weeks) and intermittent fasting (2 days fasting per week on Wednesdays and Fridays). The annual number of fasting days can amount to up to 140 and range from only single days to a more extended period of consecutive days[12]. Because of its high frequency, fasting periods should be considered when planning Ethiopian diets[13].

Developing the Ethiopian Food-based dietary guidelines(FBDG) is an important part of the public health strategy. FBDG recommends the appropriate amount of foods and food groups that need to be consumed daily by certain subpopulations with specific nutrient requirements[14]. Mathematical dietary optimization models support the development of such guidelines by creating food plans that most closely resemble current dietary habits while meeting predetermined nutritional, cost, and sometimes environmental constraints[15]. Previously, expert consultations were used to develop optimal diets using a "trial and error" approach, but nowadays, more rigorous mathematical modelling allows this process to be done more efficiently[16].

Both linear and nonlinear programming has been used to inform dietary recommendations[17]. In Asia, for example, Anderson and Earle (1983) used goal programming to balance nutrients in the daily diet of the Thai people[18]. In North America, Foytik (1981) used linear programming to establish a new diet plan for American low-income families[19]. Since then, modelling has been used more often among different population groups[20]. In the current study, a linear goal programming technique was used, derived from the model developed by Gerdessen and de Vries[21]. The goal programming technique was used in previous studies to optimize individual diets in the Netherlands and Tanzania[22; 23]. This study aims to develop a healthy diet for Ethiopian women of reproductive age that closely resembles their current eating habits while meeting predetermined nutrients and cost constraints using mathematical modelling.

Methods

Tailored linear programming models for non-fasting, continuous, and intermittent fasting scenarios were created. All models were solved with FICO Xpress 8.10. This section explains the models textually, while the mathematical formulation is in Appendix 1.

Study population

The models were run using data from two non-consecutive days of 24HDR. The 24HDR data were collected in 494 women of reproductive age in five Ethiopian regions (Amhara, Oromia, Southern Nation and Nationalities, Tigray, and Addis Ababa) between November and December 2019. A total of 100 households were assigned to one of the five regions. Fifty households from low agriculture productivity district areas (based on the agriculture office annual report) and 50 households from high agriculture productivity district areas were sampled from each region. In Addis Ababa (the capital city), 50 households were chosen from urban slum areas, and 50 were assigned to areas with better living conditions. The households were selected using systematic random sampling from the selected district's household lists. One woman of reproductive age from each selected household participated in the nutrition study.

Data collection, market survey, and additional data input

The dietary recall appointments followed a schedule that included all days of the week at the group level. A multiple-pass 24HDR method was used to improve recall[24]. The standard questionnaire and prompt techniques were applied for the in-person interview. Data collectors (bachelor's and master's graduates in nutrition or public health), trained in conducting interviewer-administered 24HDR, collected a quick list of all foods consumed in the previous 24 hours from study participants.

After the quick food list, specific questions about the recipes and types of foods used in each dish were asked. To improve the amount estimation of ingredients, all ingredients were measured on a digital food weighing scale after measuring a known weight. Every food item was measured twice to check the accuracy of the measurements. Substitutes, such as water, were weighed and converted using conversion factors if an ingredient was unavailable or impossible to measure[24]. Standard portion sizes were used to determine the amount of ingredients when measuring the actual food was not possible or appropriate. The data was cleaned for missing values, conversion factors for liquid foods measurements, edible, and raw-to-cooked. The data on conversion and edible factors of the foods were collected during 24HDR data collection, and raw-to-cooked factors were taken from Ethiopia's 2011 National Food Consumption Survey. The data were linked to the Ethiopia food composition table[25], revised during the 2011 national food consumption survey. Finally, the food intake was converted into energy and nutrients using Compleat software (www.compleat.nl). Additionally, socio-demographic and household food security were collected[26]. Data collectors collected price data for all ingredients consumed by the women at three different retailers from the community's main marketplace, averaged, and converted them to a price per 100 grams of the food.

The food items from the 24HDR were divided into 12 categories based on the women's minimum diet diversity (MMD-W) score and adapted to the actual consumption, as detailed in Appendix 2. The MDD-W is a validated tool most often used to assess diet quality and food grouping to report dietary intake[27]. The nutrient reference values (Table 5.1.) were derived from the harmonized reference values proposed by Allen et al. [28] and derived by calculating an average over age categories (15-17, 18-24, and 25-50 years) and consultation with the Ethiopian FBDG committee after considering different available nutrient reference values.

Table 5.1. Nutrient reference values considered in the diet modelling for women of reproductive age (15-49 years)

	Nutrient	EAR	RDA	UL
1.	Protein (g/kg/d)	0.68	0.82	2.00
2.	Calcium (mg/d)	900	1100	2250
3.	Iron (mg/d)	8.03	17.0	45.0
4.	Zinc (mg/d)	6.97	8.30	25.0
5.	Vitamin A (µg RAE/d)	495	700	3000
6.	Thiamin (mg/d)	0.90	1.07	-
7.	Riboflavin (mg/d)	0.90	1.07	-
8.	Niacin (mg/d)	11.0	14.0	35.0
9.	Vitamin B6 (mg/d)	1.07	1.27	25.0
10.	Folate (µg/d)	323	400	1000
11.	Vitamin B12 (µg/d)	2.0	2.4	-

Based on Allen et al, 2020[28]. Explanation of Nutrient Reference values: Estimated Average Requirement (EAR; intake at which an individual's risk of inadequacy is 50%), Recommended Dietary Allowance (RDA; intake at which an individual's risk of inadequacy is 2% to 3%), Tolerable Upper Intake Level (UL; the intake at which adverse effects may occur)

General description of the linear goal programming model

The current diets of the Ethiopian women in this study's sample were optimized by running the diet model developed specifically for this study on each woman. The diet model was formulated according to the linear goal programming approach described in Appendix A of Gerdessen & De Vries [21]. This approach aims to find a so-called Pareto-optimal solution, in which the adequacy of one nutrient's intake cannot be improved without compromising the adequacy of another nutrient's intake. The approach finds a Pareto-optimal diet for each woman by quantifying the extent to which the diet violates the nutrient intake constraints and minimizing a so-called achievement function of these violations. It is assumed that the adequacy of a diet is determined by the adequacy of the bottleneck nutrient, i.e., the nutrient that has the most inadequate intake. Therefore, in this research, the achievement function minimizes the largest unwanted nutrient intake deviation (MinMax) (see Appendix 1). To ensure optimized diets closely resemble observed diets, upper bounds are defined for the percentage differences in food intake in grams per food group and food subgroup between the observed diet and optimized diet.

Quantifying deviations from nutrient reference values

To quantify the deviations from nutrient reference values, constraints are formulated via adequacy curves[21]. As an example, the adequacy curve of calcium is shown in Figure 5.1. The four characteristic points are defined as follows: A is the lower intake level (LL) below which an intake could lead to health risk in most individuals; B is the Estimated Average Requirement (EAR) that meets the nutrient needs of half of the healthy individuals; C is the Recommended Daily Amount which is sufficient for nearly all people; D is the upper intake level (UL) that is unlikely to pose a risk of adverse health effects. A nutrient intake is considered fully adequate if it is between the EAR and the RDA (adequacy equals 1), and fully inadequate if it is below the LL or above the UL (adequacy equals 0). Between the LL and the EAR a linear increase of the adequacy is assumed, and between the RDA and the UL a linear decrease for all selected micronutrients. For instance, a calcium intake of 820 mg is assigned a probability of an adequacy of 0.6.

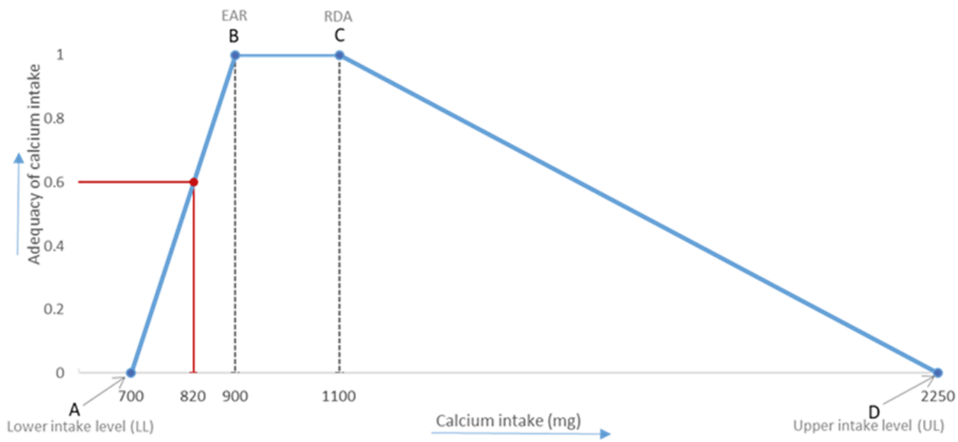

Figure 5.1. Adequacy curve for calcium intake.

Constraints to limit the deviation of food consumption from the current diet

To keep the optimized diets attainable, constraints are set to limit the deviation of food consumption from the current diet in terms of food groups and food subgroups. If the current diet is not adequate, a low allowed deviation leads to realistic outcomes but lower dietary adequacy. A high allowed deviation leads to non-realistic outcomes but higher dietary adequacy.

On the food group level, the total amount of foods consumed in the food group in the optimized diet was allowed to deviate 10% from the current consumption. On the food subgroup level, this amount was allowed to deviate by up to 15%. For example, if a woman consumed 40 grams of food subgroup *Other fruit* in her current diet, the consumption of *Other fruit* in her optimized diet could vary from 34 grams to 46 grams. As long as this constraint is met, all of the food items that belong to this food subgroup are interchangeable. A more extensive numerical example is shown in Appendix 3 (Table 5.7.). According to a sensitivity analysis, allowing more deviation than described above did not improve the adequacy of the diet enough to justify an increased deviation from the current diet. Moreover, a constraint was set on the energy intake. As this study did not aim to change women's energy intake, the energy intake in optimized diets could only deviate 5% from the current diet.

Handling barely consumed food groups

The consumption data showed that food groups nuts and seeds, milk and dairy, fish and shellfish, meat and eggs, and fruits were barely consumed by the sample population (Table 5.5.). For these food groups the constraints that limit the differences between current and optimized diet would prevent that these foods are included in the optimized diet. To assess the impact on micronutrient intakes of including these food groups in optimized diets model runs were set up that allowed the inclusion of these food groups, not by using constraints but by defining lower and upper bounds for each of them. These bounds were based on the Global Burden of Disease (GBD) study recommendations[29], and as shown in Table 5.2., models included lower bounds of 0%, 50%, or 75% and upper bounds of 50%, 75%, or 100% of the total grams/day of the GBD recommendations, respectively. This was done to show what would happen to the adequacy of diets if food items from uneaten food groups are included in the diets. There were no additional constraints on the division of these recommended grams on sub group level. Furthermore, a model run was set up in which no GBD recommendations were applied.

Table 5.2. Assumptions used for barely consumed foods groups, based on the Global Burden of Disease daily food group consumption recommendations[(29)] included in each of the model runs (0-50% GBD, 50-75% GBD, 75-100% GBD).

Food group name[a]	GBD (g/d)	0-50% GBD		50-75% GBD		75-100% GBD	
		Lower bound (g/d)	Upper bound (g/d)	Lower bound (g/d)	Upper bound (g/d)	Lower bound (g/d)	Upper bound (g/d)
Nuts and seeds	21	0	10	10	15	15	21
Milk and dairy	435	0	218	218	326	326	435
Fish & shellfish + Meat & eggs[b]	23	0	11	11	17	17	23
Fruits	250	0	125	125	188	188	250

[a]For the food groups not mentioned here, the number of grams included in the optimised diet is allowed to deviate 10% from the number of grams in the current diet.
[b]The GBD recommendations of the food groups Fish and shellfish and Meat and eggs are combined.

Fasting models

Models were set up to account for non-fasting, continuous fasting, and intermittent fasting periods. The non-fasting model is the diet model as explained so far. For the continuous fasting model, all 24HDR data was used as input, but animal-based foods were excluded from optimized diets since the majority of the study population consumed a plant-based diet during fasting. All 24HDR data was used as input because in practice the study population barely consumed any animal products on non-fasting days either. The energy requirements remained unchanged. Furthermore, vitamin B12 and calcium constraints were disregarded, as it turned out to be impossible to meet their requirements without consuming animal-based foods.

The intermittent fasting model composed a weekly diet including two fasting days (Wednesday and Friday)[(12)] and five non-fasting days (Monday, Tuesday, Thursday, Saturday and Sunday). Animal-based foods were excluded from diets on fasting days. The main difference with the other two models is that calcium and vitamin B12 requirements were considered on a weekly and not on a daily basis. In that way, inadequate calcium and vitamin B12 intakes on fasting days could be compensated on non-fasting days.

Analysing the impact of the model on intake and cost

Additional statistical analysis of the optimized diet results was undertaken using Stata 17. The mean or median consumption and the prevalence of inadequate nutrient consumption were compared for current and modelled diets. Mean energy intake differences across socio-demographic sub-groups were analysed using a one-way ANOVA. Energy and nutrient intake differences between the current and modelled diets were analysed using Dunn's Test.

Results

The two 24HDR were collected during the harvest season, when food is abundant, with the intention to capture the different foods available in Ethiopia. This resulted in an overall high energy intake (above 2000 kcal) (Table 5.3.). The youngest women, between the ages of 15 and 25 years, had a higher energy intake than the older age group, and energy intake was higher in households with a higher level of food security. Religion was also associated with total energy intake, possibly due to more frequent holidays during the data collection period than other months of the year.

Table 5.3. Mean (standard deviation) and median energy (inter-quartile range) intake in the current diet of women of reproductive age by socio-demographics based on a 2-days 24HDR

N=494	n	Energy kcal		P-value*
		mean (SD)	Median (IQR)	
Age group (y)				
15-25	126	2857 (985)	2703 (1385)	<0.001
26-35	200	2743 (1009)	2602 (1401)	
36-49	162	2448 (882)	2341 (1206)	
Women's level of education				
No education	253	2732 (979)	2632 (1312)	
Primary	153	2690 (956)	2569 (1338)	0.169
Secondary	68	2499 (1048)	2428 (1167)	
College and above	14	2315 (573)	2370 (573)	
HH family size				
≤ 3	87	2781 (990)	2597 (1233)	0.205
4 – 5	155	2567 (959)	2480 (1463)	
≥ 6	246	2705 (977)	2598 (1265)	
HH food insecurity				

Secure	131	2801 (972)	2632 (1316)	0.009
Mild insecure	133	2820 (955)	2692 (1071)	
Moderate insecure	116	2542 (979)	2481 (957)	
Sever insecure	108	2484 (960)	2278 (2127)	
Religion				
Orthodox	350	2786 (986)	2632 (1247)	<0.001
Muslim	58	2437 (963)	2030 (1186)	
Protestant	69	2222(725)	2367 (1191)	
Other	11	3003 (1167)	2958 (1547)	

*P-values is based on one-way ANOVA to determine the mean difference between categories within groups.

Comparison of the current diet with modelled diets

A total of 494 women had complete data from two 24 HDR. In addition, for 461 women in Model 1, 415 women in Model 2, and 425 women in Model 3, a feasible diet was achieved for the target nutrients as defined in Figure 5.1. Table 5.4. shows the median nutrient intake and percentage of women with an inadequate intake of nutrients in the current diet and the three modelled diets. For riboflavin, vitamin B6, and iron, <10% of women had an inadequate current dietary intake. The median values for the other nutrients, such as vitamin A, vitamin C, niacin, and folate, showed an improvement in the three modelled diets compared to the current diet. Because calcium and vitamin B12 were not optimized in Model 2 (continuous fasting), the percentage of people below EAR of these nutrients was comparable with the current diet. Similarly, for zinc, only a slight increment in the percentage of women with inadequate intakes was seen for Model 2 compared to the current diet.

Table 5.4. Daily median (interquartile range) intake of nutrients and percentage of women with inadequate intakes for current and optimized diets

Micronutrients in mg	Current diet		Model 1 or non-fasting diet (n=461)		Model 2 or continuous fasting diet (n=415)		Model 3 or intermittent fasting diet (n=425)[+]		EAR[d] (mg/day)
	Median (IQR)	Percent (<EAR)	Median (IQR)	Percent (<EAR)	Median (IQR) in mg	Percent (<EAR)	Median (IQR)	Percent (<EAR)	
Vitamin B1	1.42 (0.79)	22.9	1.30 (0.43)**	12.6	1.39 (0.56)	10.7	1.41 (0.48)	7.1	1.0
Vitamin B2	1.36 (0.91)	8.90	1.98 (0.54)**	0.0	1.40 (0.59)*	0.0	1.95 (0.58)**	0.0	0.7
Vitamin B3	12.8 (8.12)	14.2	14.8 (6.35)**	0.0	18.9 (8.22)**	0.0	16.5 (6.36)**	0.0	8.0
Vitamin B6 [a]	2.14 (1.10)	5.30	1.89 (0.76)**	0.0	1.93 (0.76)**	0.0	2.10 (0.92)	0.2	0.9[a]
Vitamin B12 [a]	0.00 (0.18)	94.7	2.42 (0.51)**	0.0	0.11 (0.07)**	84.0	2.00 (0.00)**	5.1	1.6[a]
Vitamin A [ab]	95.6 (649.3)	62.8	495 (0.00)**	0.0	495 (0.00)**	0.0	495 (0.00)**	0.0	290[ab]
Vitamin C	30.8 (28.0)	74.1	122 (33.5)**	0.0	109 (36.3)**	0.0	104 (38.6)**	0.0	45.7
Calcium	591 (414.1)	79.6	900 (55.4)**	6.9	700 (0.00)	77.5	900 (0.00)**	12.8	900
Iron	23.3 (13.5)	5.70	19.6 (6.0)**	0.6	20.3 (5.40)**	0.0	23.1 (4.30)	0.2	8.0
Folate [a]	418 (308.8)	32.4	323 (26.9)**	7.5	323 (13.8)**	12.4	347 (76.3)*	8.5	323[a]
Zinc	13.2 (8.63)	16.2	8.60 (2.83)**	8.7	7.70 (1.89)**	19.8	9.61 (3.96)**	5.3	7.0

[a]*µg*, [b]*retinol activity equivalence*, [c]*gram/kg body weight*, [d]*Allen et al., 2020*
*P<0.05 and **P<0.001– indicates mean difference between the current and modelled diet from unadjusted and adjusted Dunn's test (using Holm-Sidák)
[+]Model3 or intermittent fasting diet – an average of 5 non-fasting and 2 fasting days per week.

Figure 5.2. shows the current and modelled diet's median energy and macronutrient intake. By design, the current and modelled diets' median daily energy intake did not differ. In terms of daily protein consumption, Models 1 and 3 (non-fasting and intermittent fasting) but not Model 2 (continuous fasting) resulted in higher intakes than the current diet. The current diet had the lowest median fat intake; less than 1% of the population had a fat intake of 40-45 energy percent, while 89% had a fat intake below 20 energy percent. In the modelled diets, the majority of the study population consumed less than 20% of their total energy fat (86% for Model 1, 55% for Model 2, and 83% for Model 3). The median daily carbohydrate intake of the modelled diets was lower than that of the current diet, especially for Models 1 and 3.

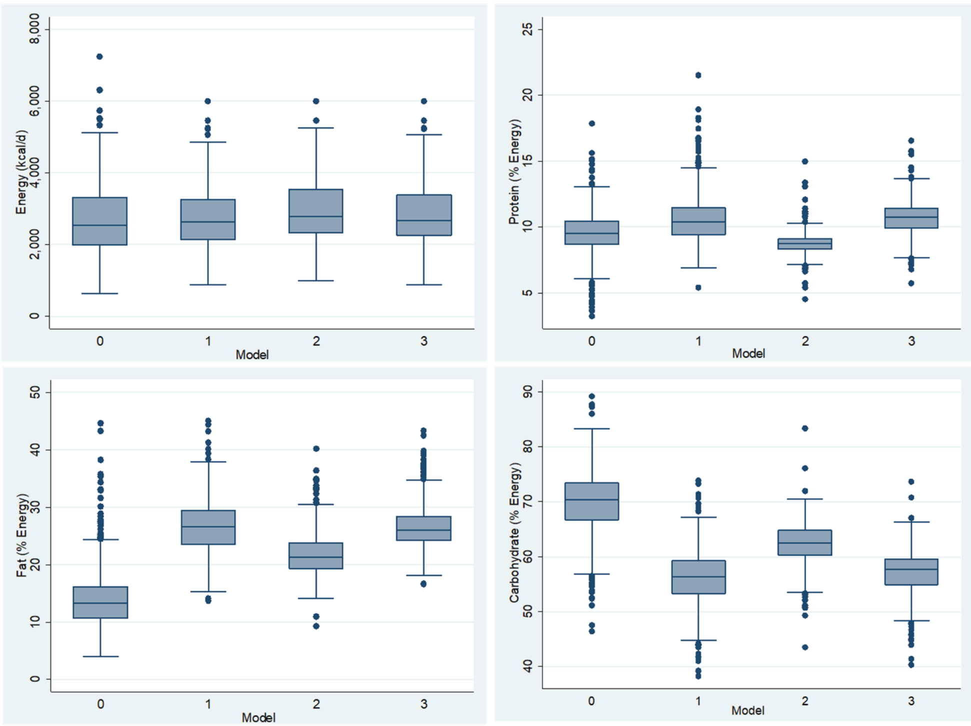

Figure 5.2. The distribution of energy and macronutrients in the current and modelled diets (x-axis represents the different models: 0=current diet, 1=non-fasting diet, 2= continuous fasting diet and 3= intermittent fasting diet).

Table 5.5. shows the results per food group. The contribution of nuts and seeds was higher in the modelled diets than in the current diet. The recommended amount of milk and dairy in Model 1 (396 g/day) and Model 3 (298 g/day) was much higher than in the current diet (31

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g/day). In contrast, the recommended amount of vegetables in Models 1 (129g/day), Model 2 (135 g/day), and Model 3 (132g/day) did not deviate much from the current diet (137 g/day). The contribution of fruits increased in all modelled diets compared to the current diet.

Table 5.5. The proposed amount in grams/day in Ethiopia's modelled diets for women of reproductive age and their current intake at the food groups level

Food groups	**Current diet**	**The recommended amount obtained from modelled diet**		
		Model 1 or non-fasting diet	**Model 2 or** continuous fasting	**Model 3 or** intermittent fasting
1. Grain, white roots and tubers	608	568	611	588
2. Pulses	91	88	92	90
3. Nuts and seeds	1	20	20	21
4. Milk and dairy foods	31	396	0	298
5. Meat, fish and egg	12	22	0	16
6. Fruits	7	195	202	194
7. Vegetables	137	129	135	132
8. Fats and oils	15	17	15	16
9. Sugar sweetened beverages (SSB)	30	29	30	28
10. Beverages, spices and other	346	322	338	337

The cost of a healthier diet

Models 1, 2, and 3 were calculated to cost 112 ETB (Ethiopian Birr), 79 ETB, and 105 ETB, respectively, whereas the current diet costed 56 ETB (Figure 5.3.). Ethiopia's high cost of milk and dairy foods contributes to the cost of diet in the non-fasting and intermittent fasting diets. Fruits and vegetables make up a larger proportion of the cost in the modelled diets than the current diet. In the current and modelled diets, the 'beverages, spice and other' food group, which includes pepper, coffee, tea, other (non) alcoholic beverages, spices, and salt, contributed to a larger proportion of the cost. Similarly, in all diets, the food group including cereals, roots, and tubers contributed about 20% of the cost. The overall cost of a continuous fasting diet (Model 2) is lower than that of the other two modelled diets but still higher than that of the current diet. The maximum daily cost of the proposed modelled diet is less than 120 ETB, or less than 3.5 USD per the exchange rate during the market survey.

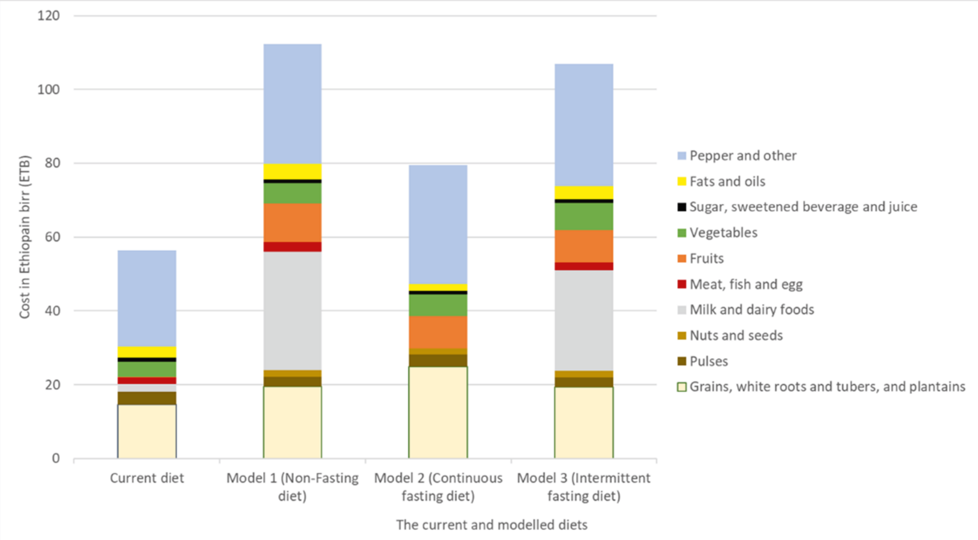

Figure 5.3. Average cost per food group per day for current and modelled diets. The Y-axis shows the cost of food group in birr per day

Discussion

The ultimate goal of dietary recommendations is to inform the public about healthy eating so that consumers can achieve their optimal energy and nutrient intake while minimizing health risks[(30)]. In addition, the dietary recommendations will inform policies and programs since the food supply and environments need to be supportive for dietary guidelines to be useful[(31)]. To support these recommendations, we aimed to optimize the current diet of Ethiopian women of reproductive age by targeting 11 micronutrients based on their public health importance in three different diet modelling scenarios (non-fasting diet, continuous fasting diet, and intermittent fasting). The results showed that these three optimized diets meet daily energy and nutrient requirements, except for calcium and vitamin B12 in the continuous fasting model. The prevalence of women with inadequate intakes of the other targeted nutrients was less than 15% in the modelled diets, which is a big improvement for Ethiopian women compared to the current diet. The current energy intake was close to the estimated daily energy requirement of Ethiopian adult women, 2500 kcal/day[(32)].

The diet for continuous fasting (Model 2) failed to meet the recommended intake of vitamin B12 and calcium as those two nutrients are mainly supplied by animal-source foods[(33; 34)]. Vitamin B12 deficiency contributes to hyperhomocysteinemia, which has been identified as an atherothrombotic risk factor and a risk factor for dementia[35; 36]. Vitamin B12 is also important for synthesizing red blood cells, which is important to transport oxygen to function in the nervous system[37]. Calcium deficiency contributes to rickets in young children and osteoporosis in the elderly, especially in women[38]. Fasting communities should have their vitamin B12 levels checked at least once a year to allow for timely intervention to the high risk of deficiency[39]. Although some plants contain easily absorbed calcium, the amount of vegetables required to meet the calcium requirements makes a plant-based diet unattainable for most people. Dietary components that reduce calcium absorption, such as salt, protein, phytate, and caffeine, may be abundant in a continuous fasting diet[40]. Individuals who engage in fasting may benefit from vitamin B12 and calcium-fortified plant-based foods or supplements[41]. Model 2, or the continuous fasting diet, was restricted to include only plant-based oils and fats, considered healthier than animal-derived oils and fats (except solid plant oils like palm oil)[42]. Additionally, it had 20 times (20g vs. 1g) the amount of nuts and seeds compared to the current diet. Besides contributing to daily energy and nutrient requirements, studies revealed a lowered or no risk of NCDs such as cardiovascular disease and type 2 diabetes in subjects with nuts and seeds consumption up to 28 g/day[43], an intake level equivalent to the result of the modelled diets.

The modelled intake of SSB (sugar-sweetened beverages), fats, and oils did not differ from the current diet in our study. Low or moderate consumption of SSB, fats, and oils (especially saturated fats) has been shown to reduce the risk of cardiovascular disease and diabetes[44]. Based on this, the current and modelled diets can be considered healthy. The non-fasting diet (Model 1) showed large deviations from the current diet, with 10 times the amount of milk and dairy foods (equivalent to 1 cup of milk per day) and 30 times the amount of fruit compared to the current diet. Despite these major dietary deviations, the resulting recommendations are consistent with Ethiopia's current nutrition policies, which aim to fill those dietary gaps.

In the intermittent fasting situation (Model 3), nuts and seeds, milk and dairy products, and fruits are recommended to be consumed at 21 times (21g vs. 1g), 9 times (298g vs. 31g), and 27 times (194g vs. 7g) higher amounts than in the current diet, respectively. Consumption of those three food groups is also critical for meeting nutrient requirements and reducing the risk of diet-related NCDs[33]. This is the first paper we are aware of that has attempted, for the intermittent fasting scenario, to compensate for inadequate calcium and vitamin B12 intake during the two fasting days by increasing the intake on the five non-fasting days per week. The assumption is that these nutrients can be stored in the body and used later, as indicated in the methods section. Human bodies contain around 1.2 kg of calcium, mainly stored in our bones and teeth. Plasma concentration is closely regulated, and the skeleton serves as a reserve store(45). About 3-5mg of vitamin B12 is stored in human bodies, with the liver accounting for 80% of the total(46).

The recommended daily intake of cereals in the modelled diets was equivalent to or slightly lower than the current consumption (608 g/day), which may be easier to adhere to as it does not require much emphasis on nutrition education and agricultural production when compared to other food groups such as fruit, dairy foods, and nuts. Pulses and vegetables are also easy to incorporate because the amount in the modelled diets was comparable to the current diet. Most vegetable consumption in the current diet consists of onions and tomatoes, but a range of vegetables should be promoted since the consumption of a variety of green leafy and other types of vegetables is required to meet nutritional needs and will prevent NCDs such as type 2 diabetes(47). Nuts and seeds, milk and dairy products, and fruits require more emphasis on nutrition promotion and agriculture production so that the required increase in intake of these food groups can be achieved. The intake of fats and oils, SSB, salt, and alcohol should be limited while promoting a healthy diet.

The modelled diets were developed using 24-hour quantitative intake data from two-day recalls, which is a strength because the two-days consumption provides a better approximation of the habitual intake than a single 24-hour dietary recall. The days of the week were evenly distributed across the entire study group, including working and weekend days and fasting and non-fasting days. The use of linear goal programming allows for optimizing the intake of an individual and estimating the prevalence of inadequate nutrient intake at the population level. The method enabled us to include some of the current diet's practical issues, such as the fact that some food groups are barely consumed in the current diet, for instance, dairy and meat. Because of this, we assumed a specific proportion (75-100%) of the GBD recommendation for the food groups consumed in minimal quantities and analysed the contribution to the optimal diet. The presented findings in models 1-3 are based on 75-100% GBD recommendations for barely consumed food groups since this gave us the maximum possible number of feasible solutions for diet optimization.

The 24HDR and price data were only collected during the harvest season. This is a limitation of this study, as we do not consider seasonal variation in dietary intake or price volatility. According to a study published in 2020, the national average cost of the foods to achieve nutrient adequacy during the observation period (2002-2016) was $1.34[48]. Over one year, the price peaked in late August, two months before the harvest season in November. The magnitude and timing of these price peaks reflect the limited degree to which different foods can substitute for one another to provide all the nutrients required throughout the year[48]. Another limitation relates to the generalizability of the study. The data collection did not cover the entire country and only focused on Ethiopia's five major regions, so it did not include the pastoralist communities in other parts of the country. Since this dietary intake dataset is the most recent data presenting the current usual intake, it is possible to combine the findings from this study with other similar modelling work using previous dietary datasets to reach the final recommended amount for the Ethiopian FBDG.

The findings from this study are used as input for dietary recommendations at the population level. As a result, most of the model's assumptions are at the population level, such as using EAR, 10-15% deviation at the food group level, and using GBD recommendations as a basis for modelling rarely consumed food groups.

Even though the modelled diets had a maximum cost of less than 120 Ethiopian birr ($3.5) per day, half of the population would not be able to afford them due to poverty (https://dataafrica.io/profile/ethiopia/PovertyByGender). Using ten different definitions of a healthy diet published by the United Nations (UN), the Member States, the range of the cost of healthy diets globally is between USD 3.27 and USD 4.57 per day, with a point estimate based on median costs of USD 3.75[49]. Intermittent and continuous fasting diets are less expensive than the EAT-Lancet cost of a global median of USD 2.84 per day in 2011, but the maximum cost of the non-fasting diet was higher[50]. The cost of the Model 1 and 3 diets was twice that of the current diet (56.4 ETB or 1.5 USD), and the cost of the Model 2 diet was 1.5 times that of the current diet. According to a study on the cost of healthy diets, women's earnings were consistently lower than men's, making the diet relatively more costly [49]. As a result, the country's ongoing socioeconomic development, social SafetyNet programs, food and nutrition policy and strategy, and the national food system transformation plan should all be strengthened to reduce the cost of diet and improve income[41]. The recommended healthy diets in this study will be included in the country's food-based dietary guidelines, used as nutrition education, and a target-setting tool by various nutrition stakeholders. The model diet will need further translation into local menu development and to be experimented in practice.

Conclusion

The model's recommended diets (Model 1 or non-fasting, Model 2 or continuous fasting, and Model 3 or intermittent fasting) may be feasible for women of reproductive age because they are close to their current diets and fulfil their energy and nutrient demands. However, during continuous fasting, the proposed diet failed to provide enough calcium and vitamin B12, whereas the intermittent fasting diet compensated for those two nutrients on non-fasting days of the week. The recommended diet price is a point of attention. But considering the economic growth potential, current food and nutrition policy, and efforts to fill the gaps in providing affordable and healthy diets, the proposed diet might improve daily eating habits.

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Appendix 1 – Mathematical formulation of models

The mathematical formulation of non-fasting diet model (Model 1) as explained textually below. The adaptations made to this model to formulate the continuous fasting and intermittent fasting models are also given below.

Basic model (Model 1 – non-fasting)

Outline

The model used in this research aims to optimize the nutrient intake of each individual diet while restricted by palatability constraints. With the set of available foods, no diet can be formulated that complies with all constraints. Therefore, the model is formulated according to the linear goal programming approach as described by Gerdessen & De Vries (2015). This approach aims to find a so-called Pareto-optimal solution, which is a solution in which the adequacy of a nutrient intake cannot be improved without worsening the adequacy of another nutrient intake. The approach of Gerdessen & De Vries (2015) finds the Pareto-optimal diet by quantifying the extent to which the diet violates the constraints, after which a function of these violations is minimised. This function of violations is called the achievement function. It is assumed that the adequacy of a diet is determined by the adequacy of the bottleneck nutrient, which has the largest unwanted nutrient intake deviation.

Nutrient intake constraints – adequacy curves

To determine the largest unwanted nutrient intake deviation, nutritional constraints are formulated via adequacy curves, as introduced in Gerdessen & De Vries (2015). As an example, the adequacy curve of calcium is shown in figure 5.1. The four characteristic points of an adequacy curve are defined as follows: A is the lower intake level (LL) below which an intake could lead to risk in most individuals; B is the Estimated Average Requirement (EAR) that meets the nutrient needs of half of the healthy individuals; C is the Recommended Daily Amount (RDA) which is sufficient for nearly all people; D is the upper intake level (UL) that is unlikely to pose a risk of adverse health effects (Gerdessen & De Vries, 2015). A nutrient intake is considered fully adequate if it is between the EAR and the RDA (adequacy equals 1), and fully inadequate if it is below the LL or above the UL (adequacy equals 0). A nutrient intake is considered fully adequate if it is between the EAR and RDA, and fully inadequate if it is below the LL or above the UL. Between the LL and the EAR a linear increase of the adequacy is assumed, and between the RDA and the UL a linear decrease. For instance, the adequacy of a calcium intake of 820 mg is estimated to be 0.6. The nutrient reference values used are shown in table 1.

Mathematically, the adequacy of each nutrient is calculated by the following constraints:

Decision variables

NIA_j Nutrient Intake Absolute; Quantity of nutrient *j* consumed in optimal diet in absolute values (for instance kcal or grams, dependent on the nutrient *j*)

$ndEAR_j$ negative deviation EAR; the normalized negative intake deviation of nutrient *j* with regard to the EAR

$pdEAR_j$ positive deviation EAR; the normalized positive intake deviation of nutrient *j* with regard to the EAR

$ndRDA_j$ negative deviation RDA; the normalized negative intake deviation of nutrient *j* with regard to the RDA

$pdRDA_j$ positive deviation RDA; the normalized positive intake deviation of nutrient *j* with regard to the RDA

Indices

j (1..J) nutrients

Parameters

ll_j Lower Limit intake level of nutrient *j*

ear_j Estimated Average Requirement intake level of nutrient *j*

rda_j Recommended Daily Amount intake level of nutrient *j*

ul_j Upper Level intake level of nutrient *j*

Mathematical formulation

$$NIA_j + (ear_j - ll_j) * ndEAR_j - (ear_j - ll_j) * pdEAR_j = ear_j \qquad \forall j \qquad (1a)$$

$$ndEAR_j \leq 1 \qquad \forall j \qquad (2a)$$

$$NIA_j + (ul_j - rda_j) * ndRDA_j - (ul_j - rda_j) * pdRDA_j = rda_j \qquad \forall j \qquad (3)$$

$$pdRDA_j \leq 1 \qquad \forall j \qquad (4)$$

Constraints (1a) and (2a) normalize the negative or positive deviations ($ndEAR_j$ or $pdEAR_j$) of the nutrient intake NIA_j from the EAR. Note that a negative nutrient intake deviation from the EAR, so a nutrient intake that is lower than the EAR, is unwanted. These constraints determine the adequacy of a nutrient intake. For instance, for a calcium intake of 820 mg as shown in figure 5.1. the $ndEAR_j$ is calculated as follows: 820 + (900-700)*$ndEAR_j$ – (900-700)*$pdEAR_j$ = 900. As the sum of the deviations ($ndEAR_j$ and the $pdEAR_j$) is minimized in the achievement function as explained below, this means that in this case the $ndEAR_j$ = 0.4 and the $pdEAR_j$ = 0. The adequacy of a calcium intake of 820 mg is therefore 1 - 0.4 = 0.6. Note that only $ndEAR_j$ has an upper bound of 1 (constraint 2a); $pdEAR_j$ can be as large as needed.

Constraints (3) and (4) normalize the negative or positive deviations (*ndRDAj* or *pdRDAj*) of the nutrient intake *NIAj* from the RDA. Note that a positive nutrient intake deviation from the RDA, so a nutrient intake that is higher than the RDA, is unwanted. However, in this research, nutrient intakes below the EAR are prioritised over nutrient intakes above the RDA. Therefore, nutrient intakes above the RDA but below the UL are not considered to impact nutrient adequacy.

Achievement function

The achievement function as defined in the model is formulated as follows:

$$\text{minimize}(MAXDEV + 0.001*SUMDEV)$$

In this research, an optimal diet is defined as a diet that minimises the bottleneck nutrient intake, which is the largest unwanted nutrient intake deviation of the micronutrients (*MAXDEV*). An unwanted nutrient intake is an intake that is below the EAR or above the RDA, as seen in **Error! Reference source not found.**. Hence, the model aims to keep the nutrient intake levels between the EAR and RDA. Note that before optimizing a diet, it is not known which nutrient becomes the bottleneck nutrient. A small fraction of the sum of the total nutrient intake deviations (*SUMDEV*) is added to the achievement function as a tie-breaking term to make sure that of the alternatives that have the lowest maximum deviation (*MAXDEV*), the alternative that has the lowest sum of unwanted deviations (*SUMDEV*) is picked by the model.

The *MAXDEV* and *SUMDEV* are calculated as follows:

Decision variables (in addition to those mentioned in previous section)

MAXDEV	Largest unwanted nutrient intake deviation
SUMDEV	Sum of the total nutrient intake deviations

Mathematical formulation

$$MAXDEV \geq ndEAR_j \qquad \forall\, j \in \{\text{micronutrients of interest}\} \quad (5a)$$

$$SUMDEV = \sum_{j \; in \; moi}^{J} \left(ndEAR_j + pdRDA_j\right) + \sum_{2..j}^{J} 0.01 * (ndEAR_j + pdEAR_j + ndRDA_j + pdRDA_j) \quad \forall\, j \qquad (6)$$

Constraints (5) calculate the maximum unwanted nutrient intake deviation (*MAXDEV*). In other words, the *MAXDEV* is the deviation from the EAR of the bottleneck nutrient intake. Only the micronutrients of interest (moi) are considered for calculating the *MAXDEV*. In this research, the micronutrients of interest are protein, calcium, iron, zinc, vitamin A, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin B12, and vitamin C. Note that protein is not a micronutrient, but is considered in determining the MAXDEV.

Constraints (6) calculate the sum of nutrient intake deviations (*SUMDEV*). Recall that the *SUMDEV* is added to the achievement function as a tie-breaking term. The unwanted nutrient intake deviations are the intakes of the micronutrients of interest (moi) below the EAR ($ndEAR_j$) and above the RDA ($pdRDA_j$). In the first part of the equation, extra weight is assigned to these deviations. The second part of the equation sums both negative and positive deviations of both the EAR and the RDA ($ndEAR_j$, $pdEAR_j$, $ndRDA_j$, $pdRDA_j$).

Food consumption constraints
The mathematical formulation of the constraints that limit the deviation of food consumption from the current diet in the model are as follows:

Decision variables

X_i	Quantity of regular food item *i* in optimal diet (in grams)
QFG_g	Quantity Food Group; Quantity of food items of food group *g* consumed in optimal diet (in grams)
QSG_s	Quantity Sub Group; Quantity of food items of food subgroup *s* consumed in optimal diet (in grams)
NIA_j	Nutrient Intake Absolute; Quantity of nutrient *j* consumed in optimal diet in absolute values (for instance kcal or grams, dependent on the nutrient j)

Indices

p	(1..P) persons. The model computes an optimal diet for one fixed person *p* at a time, but is executed in a loop. Therefore, this index is solely used to retrieve the current consumption data (qip_{ip}) of the person for whom an optimal diet is computed at that time.
i	(1..I) regular food items
j	(1..J) nutrients
g	(1..G) Each food group *g* consists of several food subgroups *s*, which consist of food items *i*. For instance, *g=7* (*Fruits*) consists of subgroups *s=7.1*, *s=7.2* and *s=7.3*.
s	(1..S) Each food subgroup *s* belongs to a food group *g* and consists of several *i*. For instance, *s=7.3* (*Other Fruits)* belongs to *g=7* (*Fruits*) and consists of *i=2* (*Banana)*, *i=174* (*Avocado)*, and *i=257* (*Watermelon)*.

Parameters

cij_{ij} Composition Item Nutrient; Food composition database with the quantity of nutrient *j* in 100 grams of each food item *i* (nutrients *j* are expressed in their common absolute units such as kcal, gram, or miligram; e.g. *j=1* is energy in kcal)

qip_{ip} Quantity Item Person; Quantity of food item *i* consumed by person *p* (in grams). Note that this parameter is only used to retrieve the data on the current food consumption of person *p* from the data file.

qg_g Quantity Group; Quantity of food items consumed in food group *g* (in grams). This parameter is calculated by summing the amount of food items consumed by a person in a food group (qip_{ip}) for each food group, like this; $qg_g = \sum_{i\ in\ g} qip_{ip}\ \forall g, p$

qs_s Quantity Subgroup; Quantity of food items consumed in food subgroup *s* (in grams). This parameter is calculated by summing the amount of food items consumed by a person in a food subgroup (qip_{ip}) for each food group, like this; $qs_s = \sum_{i\ in\ s} qip_{ip}\ \forall s, p$

ckal Current energy in Kcal; This parameter is calculated by summing the amount of kcal consumed by a person in all food items, like this; $kcal = \sum_{i=1}^{I}(cij_{i,j=1}/100) * qip_{ip}$

gdev Group Deviation; Allowed deviation of food group consumption in the optimal diet from the current diet (in a percentage)

sgdev Subgroup Deviation; Allowed deviation of food subgroup consumption in the optimal diet from the current diet (in a percentage)

kcaldev Kcal Deviation; Allowed deviation of kcal consumption in the optimal diet from the current diet (in a percentage)

Mathematical formulation

Food group level constraints:

$$QFG_g = \sum_{i\ in\ g} X_i \qquad \forall\ g \qquad (7)$$

$$QFG_g \geq qg_g * (1 - gdev) \qquad \forall\ g \qquad (8a)$$

$$QFG_g \leq qg_g * (1 + gdev) \qquad \forall\ g \qquad (9a)$$

Food subgroup level constraints:

$$QSG_s = \sum_{i\ in\ s} X_i \qquad \forall\ s \qquad (10)$$

$$QSG_s \geq qs_s * (1 - sgdev) \qquad \forall\ s \qquad (11a)$$

$$QSG_s \leq qs_s * (1 + sgdev) \qquad \forall\ s \qquad (12)$$

Energy level constraints:

$$NIA_{j=1} \geq ckcal * (1 - kcaldev) \tag{13}$$

$$NIA_{j=1} \leq ckcal * (1 + kcaldev) \tag{14}$$

Constraints (7), (8) and (9) limit the deviation of food group consumption from the current diet. Constraints (7) calculate the total amount of food items consumed in a food group in the optimal diet (QFG_g) for each food group. This is done by summing the amount of regular food item i in grams in the optimal diet (X_i) of food group g. Constraints (8) and (9) make sure that the quantity of food items in group g in the optimal diet (QFG_g) deviates no more than *gdev* from the amount of food items consumed in group g in the current diet (qg_g). In this research this deviation may be at most 10% (*gdev*=0.10), so QFG_g lies between 0.9*qg_g and 1.1*qg_g. Constraints (10), (11) and (12) work the same way as constraints (7), (8), and (9) respectively, but limit the deviation of food subgroup consumption instead of food group consumption. In this research the subgroup consumption deviation may be at most 15% (*sgdev*=0.15), so QSG_s lies between 0.85*qs_s and 1.15*qs_s.

Constraints (13) and (14) limit the deviation of energy intake from the current diet. $NIA_{j=1}$ is the energy intake in kcal in the optimised diet, which can deviate no more than *kcaldev* from the current kcal intake (*ckcal*). In this research, the energy intake deviation may be at most 5% (*kcaldev*=0.05), so $NIA_{j=1}$ lies between 0.95**ckal* and 1.05**ckal*.

Incorporating GBD recommendations

The consumption data show that some food groups (Nuts and seeds, Milk and dairy, Fish and shellfish, Meat and eggs, and Fruits) are barely consumed by the sample population, as stated before in (reference Handling barely consumed food groups). To still include food items of these food groups in some of the model runs, a lower and upper bound are set for the number of grams of each of these barely consumed food groups. These bounds are based on the recommendations of the Global Burden of Disease[24]. As shown in (table 5.2.) and as stated before in the main text, model runs are set up in which the lower bound is set to 0%, 50%, or 75% and the upper bound to 50%, 75%, or 100% of the number of grams of the GBD recommendations, respectively. There are no additional constraints on the division of these recommended grams on sub group level. Furthermore, a model run is set up in which no GBD recommendations are applied.

In order to incorporate these bounds, the following parameters and constraints are added to the model:

Parameters

$fg\_con\_min_g$	Food group consumption minimum; Quantity of food group g that should at least be included in the optimized diet (in grams)
$fg\_con\_max_g$	Food group consumption maximum; Quantity of food group g that should at most be included in the optimized diet (in grams)
$sg\_con\_max_s$	Subgroup consumption minimum; Quantity of subgroup s that should at most be included in the optimized diet (in grams)

Mathematical formulation

Food group level constraints:

$$QFG_g = \sum_{i\ in\ g} X_i \qquad \forall\, g \qquad (7)$$

$$QFG_g \geq qg_g * (1 - gdev) \qquad \forall\, g \notin \{\text{GBD food groups}\} \qquad (8a)$$

$$QFG_g \leq qg_g * (1 + gdev) \qquad \forall\, g \notin \{\text{GBD food groups}\} \qquad (9a)$$

$$QFG_g \geq fg\_con\_\min_g \qquad \forall\, g \in \{\text{GBD food groups}\} \qquad (8b)$$

$$QFG_g \leq fg\_con\_max_g \qquad \forall\, g \in \{\text{GBD food groups}\} \qquad (9b)$$

Subgroup level constraints:

$$QSG_s = \sum_{i\ in\ s} X_i \qquad \forall\, s \qquad (10)$$

$$QSG_s \geq qs_s * (1 - sgdev) \qquad \forall\, s \notin \{\text{GBD subgroups}\} \qquad (11a)$$

$$QSG_s \leq qs_s * (1 + sgdev) \qquad \forall\, s \notin \{\text{GBD subgroups}\} \qquad (12)$$

$$QSG_g \leq sg\_con\_max_s \qquad \forall\, s \in \{\text{GBD subgroups}\} \qquad (11b)$$

Constraints (8b) are strict lower bounds that ensure that the number of grams of the minimum food group requirement set ($fg\_con\_min_g$) are included in the optimized diet (QFG_g), for each food group g for which the GBD recommendations are used. These GBD food groups are

Nuts and seeds, Milk and dairy, Fish and shellfish, Meat and eggs, and Fruits. Constraints (9b) are the strict upper bounds. Constraints (11b) apply similar strict upper bounds ($sg\_con\_max_s$) on subgroup level.

Fasting models

Model 2 - Continuous Fasting

For the continuous fasting model, three sets of constraints are added to the basic model:

Food group level constraints:

$$QFG_g = 0 \qquad \forall\, g \in \{\text{Animal-based food groups}\} \qquad (15)$$

Subgroup level constraints:

$$QSG_s = 0 \qquad \forall\, s \in \{\text{Animal-based subgroups}\} \qquad (16)$$

Food item level constraints:

$$X_i = 0 \qquad \forall\, i \in \{\text{Animal-based food items}\} \qquad (17)$$

Constraints (15), (16), and (17) make sure that no animal-based food groups, subgroups, and food items, respectively, are included in the optimized diets. An example of an animal-based food item that does not belong to an animal-based food group or subgroup is honey. In this model, vitamin B12 and calcium are excluded from the *SUMDEV* and *MAXDEV* in the achievement function.

Model 3 - Intermittent fasting

The intermittent fasting model calculates optimized diets on a weekly basis. For the two fasting days, food consumption constraints as in the continuous fasting model are used. For the five non-fasting days, food consumption constraints as in the non-fasting model are used. Therefore, the food consumption constraints are formulated as follows:

Decision variables

$X_{i,d}$ Quantity of regular food item i in optimal diet (in grams) on a non-fasting day (d=1) or fasting day (d=2)

Indices

d non-fasting day d=1, or fasting day d=2.

Mathematical formulation

Food group level:

$$QFG_{g,d} = \sum_{i\ in\ g} X_{i,d=1} \qquad \forall\, g, d \qquad (18)$$

Non-fasting days:

$$QFG_{g,d=1} \geq qg_{g,d=1} * (1 - gdev) \qquad \forall\, g \qquad (19)$$

$$QFG_{g,d=1} \leq qg_{g,d=1} * (1 + gdev) \qquad \forall\, g \qquad (20)$$

Fasting days:

$$QFG_{g,d=2} \geq qg_{g,d=2} * (1 - gdev) \qquad \forall\, g \notin \{\text{Animal-based food groups}\} \qquad (21)$$

$$QFG_{g,d=2} \leq qg_{g,d=2} * (1 + gdev) \qquad \forall\, g \notin \{\text{Animal-based food groups}\} \qquad (22)$$

$$QFG_{g,d=2} = 0 \qquad \forall\, g \in \{\text{Animal-based food groups}\} \qquad (23)$$

Subgroup level:

$$QSG_{s,d} = \sum_{i\ in\ s} X_{i,d} \qquad \forall\, s \qquad (24)$$

Non-fasting days:

$$QSG_{s,d=1} \geq qs_{s,d=1} * (1 - sgdev) \qquad \forall\, s \qquad (25)$$

$$QSG_{s,d=1} \leq qs_{s,d=1} * (1 + sgdev) \qquad \forall\, s \qquad (26)$$

Fasting days:

$$QSG_{s,d=2} \geq qs_{s,d=2} * (1 - sgdev) \qquad \forall\, s \notin \{\text{Animal-based food groups}\} \qquad (27)$$

$$QSG_{s,d=2} \leq qs_{s,d=2} * (1 + sgdev) \qquad \forall\, s \notin \{\text{Animal-based food groups}\} \qquad (28)$$

$$QSG_{s,d=2} = 0 \qquad \forall\, s \in \{\text{Animal-based food groups}\} \qquad (29)$$

Energy level constraints:

$$NIA_{j=1,d} \geq ckcal * (1 - kcaldev) \qquad \forall\, d \qquad (30)$$

$$NIA_{j=1,d} \leq ckcal * (1 + kcaldev) \qquad \forall\, d \qquad (31)$$

In this model, calcium and vitamin B12 requirements are considered on a weekly basis. In that way, inadequate calcium and vitamin B12 intakes on fasting days can be compensated on non-fasting days. To do this, the computation of the *MAXDEV* is adapted. Before, one nutrient intake for each nutrient was used to compute the nutrient intake deviations from the EAR. In the intermittent fasting model, a differentiation is made between nutrient intakes on non-fasting days, fasting days, and average nutrient intakes on a weekly basis (for calcium and vitamin B12). The intermittent fasting model aims to find an optimized diet in which the largest deviation from the EAR of these three nutrient intake types is as small as possible.

The constraints formulated to compute these deviations and the *MAXDEV* are formulated as follows:

Decision variables

$nfNIA_j$	Non-fasting Nutrient Intake Absolute; Quantity of nutrient *j* consumed in optimal diet in absolute values (for instance kcal or grams, dependent on the nutrient *j*) on non-fasting days.
$fNIA_j$	Fasting Nutrient Intake Absolute; Quantity of nutrient *j* consumed in optimal diet in absolute values (for instance kcal or grams, dependent on the nutrient *j*) on fasting days.
$avgNIA_j$	Average Nutrient Intake Absolute; Quantity of nutrient *j* consumed in optimal diet in absolute values (for instance kcal or grams, dependent on the nutrient *j*) on average per week (5 non-fasting days and 2 fasting days)

nf_ndEAR_j	non-fasting negative deviation EAR; the normalized negative intake deviation of nutrient *j* with regard to the EAR
nf_pdEAR_j	non-fasting positive deviation EAR; the normalized positive intake deviation of nutrient *j* with regard to the EAR
f_ndEAR_j	fasting negative deviation EAR; the normalized negative intake deviation of nutrient *j* with regard to the EAR
f_pdEAR_j	fasting positive deviation EAR; the normalized positive intake deviation of nutrient *j* with regard to the EAR
avg_ndEAR_j	average negative deviation EAR; the normalized negative intake deviation of nutrient *j* with regard to the EAR
avg_pdEAR_j	average positive deviation EAR; the normalized positive intake deviation of nutrient *j* with regard to the EAR

Mathematical formulation

$$nfNIA_j + (ear_j - ll_j) * nf\_ndEAR_j - (ear_j - ll_j) * nf\_pdEAR_j = ear_j \quad \forall j \qquad (1b)$$

$$nf\_ndEAR_j \leq 1 \quad \forall j \qquad (2b)$$

$$cfNIA_j + (ear_j - ll_j) * cf\_ndEAR_j - (ear_j - ll_j) * cf\_pdEAR_j = ear_j \qquad \forall\, j \qquad (1c)$$

$$cf\_ndEAR_j \leq 1 \qquad \forall\, j \qquad (2c)$$

$$avgNIA_j + (ul_j - rda_j) * avg\_ndEAR_j - (ul_j - rda_j) * avg\_pdEAR_j = ear_j \qquad \forall\, j \qquad (1d)$$

$$avg\_ndEAR_j \leq 1 \qquad \forall\, j \qquad (2d)$$

$$MAXDEV \geq nf\_ndEAR_j \qquad \forall\, j \in \{\text{micronutrients of interest}\} \qquad (5b)$$

$$MAXDEV \geq cf\_ndEAR_j \qquad \forall\, j \in \{\text{micronutrients of interest}\},\ \forall\, j \neq \text{calcium, vitamin B12} \qquad (5c)$$

$$MAXDEV \geq avg\_ndEAR_j \qquad \forall\, j \in \{\text{micronutrients of interest}\},\ \forall\, j = \text{calcium, vitamin B12} \qquad (5d)$$

Constraints (1b) – (2d) operate in the same way as Constraints (1a) and (2a) as explained before. However, in this case a differentiation is made between nutrient intakes on non-fasting days, fasting days, and average nutrient intakes per week.

Constraints (5b) – (5d) compute the *MAXDEV*. In Constraints (5c), on fasting days, calcium and vitamin B12 are not considered for the calculation of the MAXDEV. Instead, calcium and vitamin B12 intakes are considered on a weekly basis in Constraints (5d). Thus, a lack of calcium and vitamin B12 intake on fasting days can be compensated on non-fasting days.

Model runs

Model runs were set up for each combination of model (3 models) and GBD recommendations applied (4 scenarios). In total, 3*4=12 model runs were conducted as shown in table 5.6.

Table 5.6. Model runs conducted in this research

	GBD recommendations used (lower-upper bound)			
Model used	Not used	0-50%	50-75%	75-100%

1-Non-fasting	run 1	run 2	run 3	run 4
2-Continuous fasting	run 5	run 6	run 7	run 8
3-Intermittent fasting	run 9	run 10	run 11	run 12

Appendix 2. List of foods, food group and sub-groups used in the model

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
1	Grains, white roots and tubers	1.1	Grain	9	Barley flour black unrefined, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	4	Barley flour black/white mix unrefined, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	12	Barley flour white unrefined, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	6	Barley grains germinated, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	7	Barley grains, roasted
1	Grains, white roots and tubers	1.1	Grain	211	Barley split grains black, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	213	Barley split grains black/white mixture, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	212	Barley split grains white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	217	Biscuit
1	Grains, white roots and tubers	1.1	Grain	147	Bread recipe Amhara
1	Grains, white roots and tubers	1.1	Grain	266	Injera firfir recipe Addis
1	Grains, white roots and tubers	1.1	Grain	180	Injera recipe Addis
1	Grains, white roots and tubers	1.1	Grain	144	Injera recipe Amhara Debub
1	Grains, white roots and tubers	1.1	Grain	169	Injera recipe Amhara Secota
1	Grains, white roots and tubers	1.1	Grain	177	Injera recipe Oromia
1	Grains, white roots and tubers	1.1	Grain	176	Injera recipe Tigray, Kaya Azebolaga
1	Grains, white roots and tubers	1.1	Grain	179	Injera recipe Tigray, Merere
1	Grains, white roots and tubers	1.1	Grain	247	Kita, unfermented bread generic
1	Grains, white roots and tubers	1.1	Grain	203	Maize and millet whole grain mix, raw RTboiled/baked

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
1	Grains, white roots and tubers	1.1	Grain	182	Maize and sorghum flour, raw RTboiled
1	Grains, white roots and tubers	1.1	Grain	284	Maize flour white, raw
1	Grains, white roots and tubers	1.1	Grain	199	Maize flour white, raw boiled/baked
1	Grains, white roots and tubers	1.1	Grain	65	Maize flour yellow , raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	206	Maize white and wheat flour, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	207	Maize white, wheat and barley flour, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	202	Maize whole grains white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	64	Maize whole grains yellow , raw RTboiled/roasted
1	Grains, white roots and tubers	1.1	Grain	20	Millet finger flour black, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	118	Millet finger flour black/red, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	71	Millet finger flour black/white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	70	Millet finger flour white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	201	Millet finger whole grain mixed, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	72	Millet finger whole grain red, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	74	Oat flour, raw RTboiled
1	Grains, white roots and tubers	1.1	Grain	165	Pasta wheat white, boiled
1	Grains, white roots and tubers	1.1	Grain	261	Porridge recipe generic
1	Grains, white roots and tubers	1.1	Grain	100	Potato Irish, raw RTboiled
1	Grains, white roots and tubers	1.1	Grain	101	Potato Irish, raw RTboiled and fried
1	Grains, white roots and tubers	1.1	Grain	256	Rice brown flour, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	108	Rice whole grain brown , raw RTboiled
1	Grains, white roots and tubers	1.1	Grain	245	Rice with carrot generic

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
1	Grains, white roots and tubers	1.1	Grain	121	Sorghum flour red, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	183	Sorghum flour red/white mix, raw RTboiled
1	Grains, white roots and tubers	1.1	Grain	285	Sorghum flour white, raw
1	Grains, white roots and tubers	1.1	Grain	120	Sorghum flour white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	214	Teff and rice flour, raw RTbaked
1	Grains, white roots and tubers	1.1	Grain	208	Teff and wheat flour, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	127	Teff flour red, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	129	Teff flour red/white mixture, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	130	Teff flour white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	254	Teff, sorghum and fenugreek flour, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	205	Teff, wheat, maize flour mixture, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	168	Wheat and chickpea mixture, roasted
1	Grains, white roots and tubers	1.1	Grain	282	Wheat flour black, raw
1	Grains, white roots and tubers	1.1	Grain	142	Wheat flour black, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	281	Wheat flour white, raw
1	Grains, white roots and tubers	1.1	Grain	139	Wheat flour white, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	141	Wheat flour white/black mixture, raw RTboiled/baked
1	Grains, white roots and tubers	1.1	Grain	151	Wheat whole grain white boiled
1	Grains, white roots and tubers	1.1	Grain	161	Wheat whole grain white roasted
1	Grains, white roots and tubers	1.2	Roots/tubers	210	Kocho, bread ready to eat
1	Grains, white roots and tubers	1.2	Roots/tubers	126	Potato sweet, raw RTboiled
1	Grains, white roots and tubers	1.2	Roots/tubers	243	Stew potato carrot generic

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
1	Grains, white roots and tubers	1.2	Roots/tubers	160	Stew potato recipe Amhara
2	Pulses	2.1	Pulses	278	Bean broad flour, raw
2	Pulses	2.1	Pulses	17	Bean broad flour, raw RTboiled
2	Pulses	2.1	Pulses	16	Bean broad flour, raw RTboiled and fried
2	Pulses	2.1	Pulses	209	Bean broad whole dried roasted and boiled
2	Pulses	2.1	Pulses	122	Bean soy whole, raw RTboiled and baked
2	Pulses	2.1	Pulses	230	Green bean, raw RTboiled
2	Pulses	2.1	Pulses	53	Hilbet recipe Amhara
2	Pulses	2.1	Pulses	58	Lentil split red, dried RTboiled
2	Pulses	2.1	Pulses	57	Lentil whole black, dried RTboiled
2	Pulses	2.1	Pulses	280	Pea chick flour, raw
2	Pulses	2.1	Pulses	242	Pea chick flour, raw RTboiled
2	Pulses	2.1	Pulses	33	Pea chick whole, dried RTroasted
2	Pulses	2.1	Pulses	279	Pea field flour, raw
2	Pulses	2.1	Pulses	92	Pea field flour, raw RTboiled
2	Pulses	2.1	Pulses	91	Pea field flour, raw RTboiled and baked
2	Pulses	2.1	Pulses	98	Pea/bean flour mixture, raw RTboiled
2	Pulses	2.1	Pulses	93	Pea/bean flour mixture, raw RTboiled and baked
2	Pulses	2.1	Pulses	99	Pea/bean/chickpea flour mixture, raw RTboiled
2	Pulses	2.1	Pulses	90	Peas field whole, dried RTboiled
2	Pulses	2.1	Pulses	89	Peas field whole, dried RTboiled and baked
2	Pulses	2.1	Pulses	241	Shiro flour recipe Addis

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
2	Pulses	2.1	Pulses	270	Stew cabbage recipe Addis
2	Pulses	2.1	Pulses	248	Stew potato with bean splitted recipe generic
2	Pulses	2.1	Pulses	249	Stew potato with dried meat recipe Amhara
2	Pulses	2.1	Pulses	250	Stew potato with split pea recipe generic
2	Pulses	2.1	Pulses	240	Stew shiro recipe Addis
2	Pulses	2.1	Pulses	162	Stew shiro recipe Amhara
2	Pulses	2.1	Pulses	269	Stew shiro recipe Tigray
2	Pulses	2.1	Pulses	148	Stew split bean recipe Amhara
2	Pulses	2.1	Pulses	271	Stew split lentil recipe Addis
2	Pulses	2.1	Pulses	156	Stew split lentil recipe Amhara
2	Pulses	2.1	Pulses	159	Stew split pea recipe Amhara
2	Pulses	2.1	Pulses	264	Vetch flour, raw RTbaked
3	Nuts and seeds	3.1	Seeds	226	Ajwain seeds, dried
3	Nuts and seeds	3.1	Seeds	272	Chibito recipe Addis
3	Nuts and seeds	3.1	Seeds	228	Cumin seeds, dried
3	Nuts and seeds	3.1	Seeds	154	Erito recipe Amhara
3	Nuts and seeds	3.1	Seeds	236	Fennel seeds, dried
3	Nuts and seeds	3.1	Seeds	157	Linseed and nigerseed stuffed pancake recipe Amhara
3	Nuts and seeds	3.1	Seeds	61	Linseed paste, raw
3	Nuts and seeds	3.1	Seeds	59	Linseed white, dried
3	Nuts and seeds	3.1	Seeds	60	Linseed white, dried RTboiled
3	Nuts and seeds	3.1	Seeds	215	Mustard seeds, raw RTboiled

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
3	Nuts and seeds	3.1	Seeds	73	Niger seed, roasted RTboiled
3	Nuts and seeds	3.1	Seeds	233	Sesame seed, dried
3	Nuts and seeds	3.1	Seeds	170	Sunflower seeds, dried
3	Nuts and seeds	3.2	Nut	143	Almonds nuts
3	Nuts and seeds	3.2	Nut	232	Peanut butter
4	Milk and dairy	4.1	Milk	175	Milk cow fresh, raw
4	Milk and dairy	4.1	Milk	40	Milk cow fresh, raw RTboiled
4	Milk and dairy	4.1	Milk	146	Whey cow
4	Milk and dairy	4.2	Yoghurt and cheese	31	Cheese cottage cow
4	Milk and dairy	4.2	Yoghurt and cheese	145	Yoghurt whole milk cow
5	Fish and shellfish	5.1	Fish and shellfish	253	Fish tilapia, raw RTbaked
5	Fish and shellfish	5.1	Fish and shellfish	252	Fish tilapia, raw RTboiled
6	Meat and eggs	6.1	Meat	274	Beef fried recipe Addis
6	Meat and eggs	6.1	Meat	41	Beef, dried RTboiled and baked
6	Meat and eggs	6.1	Meat	67	Beef, dried RTfried
6	Meat and eggs	6.1	Meat	219	Beef, raw
6	Meat and eggs	6.1	Meat	198	Beef, raw RTfried
6	Meat and eggs	6.1	Meat	15	Beef, raw RTfried and boiled
6	Meat and eggs	6.1	Meat	194	Camel meat, raw RTboiled
6	Meat and eggs	6.1	Meat	193	Goat meat, raw RTboiled

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
6	Meat and eggs	6.1	Meat	239	Kitfo recipe Addis
6	Meat and eggs	6.1	Meat	192	Mutton meat, raw RTboiled
6	Meat and eggs	6.1	Meat	153	Stew dried meat dried recipe Amhara
6	Meat and eggs	6.1	Meat	149	Stew meat and split bean recipe Amhara
6	Meat and eggs	6.1	Meat	158	Stew meat recipe Addis
6	Meat and eggs	6.2	Poultry	32	Chicken meat whole, raw RTboiled
6	Meat and eggs	6.2	Poultry	273	Stew chicken generic
6	Meat and eggs	6.3	Egg	42	Egg chicken, raw RTboiled/fried
6	Meat and eggs	6.3	Egg	277	Eggs scrambled recipe Addis
7	Fruits	7.1	Vitamin A rich fruits	231	Papaya, fresh
7	Fruits	7.2	Vitamin C rich fruits	222	Lemon, fresh
7	Fruits	7.2	Vitamin C rich fruits	218	Orange, fresh
7	Fruits	7.3	Other fruits	174	Avocado, raw
7	Fruits	7.3	Other fruits	2	Banana, raw
7	Fruits	7.3	Other fruits	257	Melon water, raw
8	Vegetable	8.1	Dark green leafy vegetables	227	Broccoli, raw RTfried
8	Vegetable	8.1	Dark green leafy vegetables	56	Kale Ethiopian, raw RTboiled

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
8	Vegetable	8.1	Dark green leafy vegetables	223	Lettuce, raw
8	Vegetable	8.1	Dark green leafy vegetables	262	Salad mix
8	Vegetable	8.1	Dark green leafy vegetables	188	Scallion, raw RTboiled
8	Vegetable	8.1	Dark green leafy vegetables	189	Scallion, raw RTfried
8	Vegetable	8.1	Dark green leafy vegetables	238	Stew Ethiopian kale recipe Addis
8	Vegetable	8.1	Dark green leafy vegetables	224	Swiss chard, raw RTboiled
8	Vegetable	8.2	Vitamin A rich vegetables	19	Beetroot red, raw RTboiled
8	Vegetable	8.2	Vitamin A rich vegetables	18	Beetroot red, raw RTfried
8	Vegetable	8.2	Vitamin A rich vegetables	216	Carrot, raw

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
8	Vegetable	8.2	Vitamin A rich vegetables	29	Carrot, raw RTboiled
8	Vegetable	8.2	Vitamin A rich vegetables	30	Carrot, raw RTfried
8	Vegetable	8.2	Vitamin A rich vegetables	104	Pumpkin yellow, raw RTboiled
8	Vegetable	8.2	Vitamin A rich vegetables	275	Stew beef (key wat) recipe Oromia
8	Vegetable	8.2	Vitamin A rich vegetables	251	Stew pumpkin recipe generic
8	Vegetables	8.3	Other vegetables	25	Cabbage, raw RTboiled
8	Vegetable	8.3	Other vegetables	27	Cabbage, raw RTfried
8	Vegetable	8.3	Other vegetables	229	Endive, raw
8	Vegetable	8.3	Other vegetables	47	Garlic, raw
8	Vegetable	8.3	Other vegetables	46	Garlic, raw RTboiled
8	Vegetable	8.3	Other vegetables	45	Garlic, raw RTfried

Chapter 5

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
8	Vegetable	8.3	Other vegetables	48	Ginger root, raw RTboiled
8	Vegetable	8.3	Other vegetables	88	Onion bulb red, raw
8	Vegetable	8.3	Other vegetables	86	Onion bulb red, raw RTboiled
8	Vegetable	8.3	Other vegetables	87	Onion bulb red, raw RTfried
8	Vegetable	8.3	Other vegetables	106	Pumpkin white, raw RTboiled
8	Vegetable	8.3	Other vegetables	136	Tomato green, raw
8	Vegetable	8.3	Other vegetables	135	Tomato red, raw
8	Vegetable	8.3	Other vegetables	133	Tomato red, raw RTboiled/fried
8	Vegetable	8.3	Other vegetables	255	Tomato sauce
9	Sugar, sweetened beverage and juice	9.1	Baked	265	Cake white cream recipe Addis
9	Sugar, sweetened beverage and juice	9.2	Sugar sweetened beverage	152	Coffee with sugar
9	Sugar, sweetened beverage and juice	9.2	Sugar sweetened beverage	260	Mango juice packed
9	Sugar, sweetened beverage and juice	9.2	sugar sweetened beverage	163	Soft drink, fanta, mirinda etc

FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
9	Sugar, sweetened beverage and juice	9.3	Other sweet	259	Candy, hard and soft
9	Sugar, sweetened beverage and juice	9.3	other sweet	54	Honey
9	Sugar, sweetened beverage and juice	9.3	other sweet	125	Sugar refined
10	Fats and oils	10.1	Fats and oils	24	Butter unspiced, raw
10	Fats and oils	10.1	Fats and oils	173	Oil niger seed
10	Fats and oils	10.1	Fats and oils	76	Oil palm, refined
10	Fats and oils	10.1	Fats and oils	81	Oil sesame
10	Fats and oils	10.1	Fats and oils	171	Oil soybean manufactured
10	Fats and oils	10.1	Fats and oils	75	Oil sunflower
10	Fats and oils	10.1	Fats and oils	84	Oil vegetable
11	Pepper	11.1	Pepper	234	Pepper paste recipe Tigray
11	Pepper	11.1	Pepper	184	Pepper red powder mix recipe Tigray
11	Pepper	11.1	Pepper	235	Pepper red powder, dried
12	Other	12.1	Other	276	Assorted, bayayinte
12	Other	12.1	Other	197	Baking powder
12	Other	12.1	Other	225	Baking soda
12	Other	12.1	Other	14	Basil holy, raw
12	Other	12.1	Other	200	Bouillon cube
12	Other	12.1	Other	28	Cardamom, fresh and dried
12	Other	12.1	Other	38	Coffee without sugar

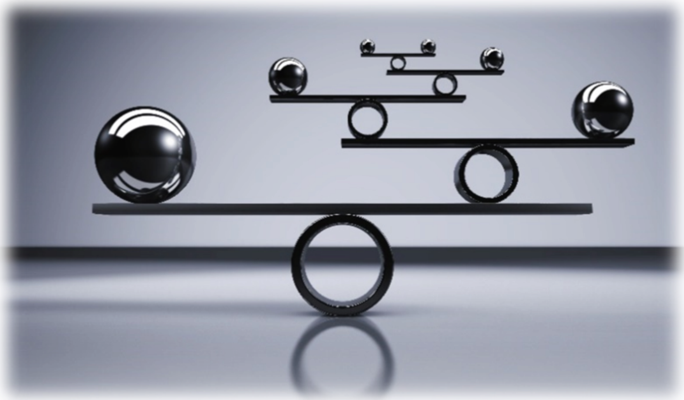
FG code	Food Group	FSG code	Food Sub-group	Food Code	Food Name
12	Other	12.1	Other	186	Fenugreek seeds flour
12	Other	12.1	Other	268	Leaves moringa, raw RTboiled
12	Other	12.1	Other	267	Leaves thymes, raw RTboiled
12	Other	12.1	Other	35	Pepper chili green, raw
12	Other	12.1	Other	34	Pepper chili green, raw RTboiled
12	Other	12.1	Other	181	Pepper chili green, raw RTfried
12	Other	12.1	Other	204	Rue, dried
12	Other	12.1	Other	113	Salt, iodized
12	Other	12.1	Other	111	Salt, plain
12	Other	12.1	Other	167	Tea with sugar recipe Amhara
12	Other	12.1	Other	221	Turmeric dried
12	Other	12.1	Other	187	Yeast fresh
12	Other	12.2	Alcohol	150	Beer bottled commercial local
12	Other	12.2	Alcohol	55	Katikala local alcoholic beverage
12	Other	12.2	Alcohol	220	Tej, honey wine
12	Other	12.2	Alcohol	39	Tella local alcoholic beverage

Appendix 3 – Food substitutions

Table 5.7. Example of grouping and possible substitutions within a food group in an optimised diet. fg = food group; sg = subgroup.

<table>
<tr><th colspan="3">Grouping of food group 7; Fruits [a]</th></tr>
<tr><th>Food group level
10% deviation, is the sum of the subgroups</th><th>Subgroup level
15% deviation, is the sum of the food items</th><th>Food item level
freely interchangeable within subgroup</th></tr>
<tr><td rowspan="9">fg7: Fruits
if current 100 g,
optimized 90-110 g</td><td rowspan="2">sg7.1: Vitamin A rich fruit
if current 40 g,
optimized 34-46 g</td><td>Papaya</td></tr>
<tr><td>sum of these food items is equal to the sum of foods consumed in sg7.1</td></tr>
<tr><td rowspan="3">sg7.2: Vitamin C rich fruit
if current 60 g,
optimized 51-69 g</td><td>Lemon</td></tr>
<tr><td>Orange</td></tr>
<tr><td>sum of these food items is equal to the sum of foods consumed in sg7.2</td></tr>
<tr><td rowspan="3">sg7.3: Other fruit
if current 0 g,
optimized 0 g</td><td>Avocado</td></tr>
<tr><td>Banana</td></tr>
<tr><td>Watermelon</td></tr>
<tr><td>sum of these sg's is equal to the sum of foods consumed in fg7</td><td>sum of these food items is equal to the sum of foods consumed in sg7.3</td></tr>
</table>

[a] An example of possible substitutions in food group and subgroups are given in *italics*.



Chapter 6

Development of the Ethiopian healthy eating index (Et-HEI) and evaluation in women of reproductive age

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Abstract

Ethiopia developed and officially launched its first Food-Based Dietary Guidelines (FBDG) on March 15, 2022. This study aims to develop and evaluate the Ethiopian healthy eating index (Et-HEI) based on these guidelines and data collected from 494 Ethiopian women of reproductive age sampled from households of different regions (Amhara, Oromia, Tigray, Southern Nations Nationality) and Addis Ababa. The Et-HEI consists of 11 components, and each component was scored between 0 and 10 points, the total Et-HEI score ranging from 0 as a minimum to 110 as maximum adherence to the FBDG. The Et-HEI score was evaluated against the Minimum Dietary Diversity for Women (MDD-W) and the probability of nutrient adequacy. The average Et-HEI score for women of reproductive age was 49 out of 110. Adherence to the recommendations for grains, vegetables, legumes, fat and oils, salt, sugar, and alcohol contributed most to this score. Most women had low scores for fruits, nuts, or animal-sourced foods, indicating low intake. The low mean Et-HEI score agreed with a low mean score of the MDD-W (3.5 out of 10). Also, low nutrient adequacies confirmed poor adherence to nutrient-dense components of the FBDG. The Et-HEI was not associated with intake of vitamin B12, vitamin B1, vitamin C, calcium, and zinc in this study population. Women who completed secondary school and above had relatively lower Et-HEI scores. Our results show that the newly developed Et-HEI is able to estimate nutrient adequacy while also assessing adherence to the Ethiopian FBDG.

Keywords: healthy diet, diet quality, dietary index, dietary guidelines

Introduction

As part of the 2018 food and nutrition policy, the Ethiopian Government started developing the first food-based dietary guidelines (FBDG) in collaboration with international and local partners(1). The Ethiopian FBDG comprises 11 messages based on scientific evidence, i.e., to consume sufficient but not excessive amounts of whole grains; fruits and vegetables; milk and dairy foods; salt; meat, fish, and eggs; legumes, nuts, and seeds; fats and oils; added sugars; non-alcoholic and alcoholic beverages. To arrive at these recommendations regarding food group and amount, extensive reviews and secondary data analyses of local and global evidence combined with diet optimization were conducted (Figure 6.1. and the description in Appendix 1). The individual and population diet optimizations were performed using data from 24-hour dietary recalls (24HDR) collected among Ethiopian women from November to December 2019 and from the 2011 national food consumption survey(2; 3). The FBDG was launched in March 2022 as an entry point for the national food system roadmap to make healthy diets more accessible, affordable, available, and desirable to Ethiopians.

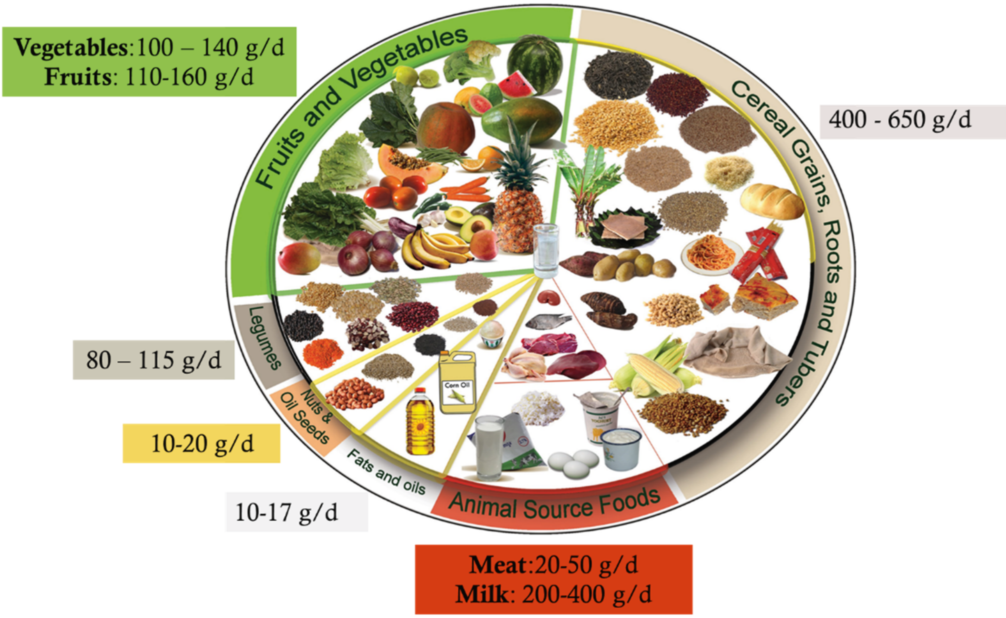

Figure 6.1. Ethiopian food guide, healthy plate (in Amharic Teenama MaĒD)

Several global and country-specific indices are available to evaluate diet quality(4). The global indices are usually based on global dietary recommendations, nutrient adequacy of the diet, or the prevention of non-communicable diseases. The country-specific indices are based on national food-based dietary guidelines to assess adherence to these recommendations. A country-specific index can be used to compare diet quality across different subpopulations, investigate dietary intake trends, and further study diet-disease relationships to inform public health interventions and policy actions[5; 6]. To assess the impact of the Ethiopian FBDG, the Ethiopian Healthy Eating Index (Et-HEI) was developed[1]. The Et-HEI assesses diet quality by determining the population's adherence to the Ethiopian FBDG in the population above 2 years of age.

Each healthy eating index has a unique total score based on the number of components and the ratings assigned to each component. The scores for each component show the adherence to dietary guidelines for each food group or specific foods or nutrients, combined to provide a total healthy eating score [5; 7]. Besides dietary components, a healthy eating index may include a non-dietary component such as physical activity or environmental sustainability. However, LMICs data on lifestyle and environmental sustainability is frequently missing; thus, non-dietary components are usually not considered[5; 8]. The score for each component is determined by the amount of food consumed compared to the recommended intake. A healthy eating index that estimates the amount against the recommended quantity is preferred over qualitative estimates, despite the challenges of measuring portion sizes and lacking diet optimization modelling in LMICs[5].

The Et-HEI was compared to another score, the Minimum Dietary Diversity for Women (MDD-W), the most commonly used index to assess nutrient adequacy in Ethiopia and other LMICs [9]. This study aimed to define the Et-HEI based on the 2022 Ethiopian FBDG and to evaluate it against the probability of nutrient adequacy and the MDD-W in women of reproductive age (15-49 years).

Methods

Study design and participants

The Et-HEI score was calculated using two non-consecutive 24HDR, collected from 494 women of reproductive age in November and December 2019, residents of four out of eleven of Ethiopia's regions (Amhara, Oromia, Tigray, and Southern Nation Nationalities) and the capital city (Addis Ababa). Data were collected in two districts from each region, one district with surplus agriculture production and one district with relatively low agriculture production, based on government agriculture performance measurements in 2017/2018. Additionally, two districts from Addis Ababa, one in high socio-economic and one in urban slum areas, were selected. The data collectors selected fifty households in each of the 10 districts using a systematic random sampling method from newly listed households. One woman of reproductive age (household mother) from each selected household participated in the study. Six of the 500 women had incomplete data on dietary intake and were thus excluded from the final data analysis. Before the data collection started, the data collectors and field supervisors received one week of theoretical and practical training.

Study participants were asked about their age, religion, school attendance, level of education, family size, land size, the main source of drinking water, and information about their house. The household food insecurity experience scale (FIES) was used to determine the extent the household experienced food insecurity in the past 12 months(10). Then a quantitative multiple-pass 24HDR was conducted twice in women of reproductive age(11). To improve the amount estimation of ingredients, all ingredients were measured on a digital food weighing scale after measuring a known weight. Every food item was measured twice to check the accuracy of the measurements. Substitutes, such as water, were weighed and converted using conversion factors if an ingredient was unavailable or impossible to measure. Standard portion sizes were used to determine the amount of ingredients when measuring the actual food was not possible or appropriate. Additionally, the data collectors measured height and weight of study participants using height boards to the nearest 0.1 cm and weighing scales to the nearest 0.1kg. BMI was calculated from height and weight data.

Body composition was measured using Bodystat 1500 (bioelectrical impedance analysis device) to calculate the fat-free mass index (FFMI). FFMI (kg/m^2) was calculated from the weight of fat-free mass (kg) by the height squared (m^2). The body measurement devices were calibrated daily for a precise estimate. Before measurements, women were asked to remove all metal accessories and electronic devices. Measurements were taken within ten minutes after the reading was begun to ensure consistency because the change in body position or movement would also affect the readings.

After the data collection, the data was cleaned for missing values, conversion factors for liquid foods measurements, edible, and raw-to-cooked. The data on conversion and edible factors of the foods were collected during 24HDR data collection, and raw-to-cooked factors were taken from Ethiopia's 2011 National Food Consumption Survey. The data were linked to the Ethiopia food composition table, revised during the 2011 national food consumption survey. Finally, the food intake was converted into energy, protein, fat, carbohydrates, dietary fiber, calcium, iron, zinc, retinol, β-carotene, vitamin B1, vitamin B2, vitamin B6, vitamin B12, vitamin C, folate, vitamin B3, and vitamin A, determined in the form of retinol activity equivalent (RAE) using Compl-eat[(12)].

Developing the Ethiopian Healthy Eating Index (Et-HEI)

The Et-HEI, based on the Ethiopian FBDG, has 11 dietary components and 1 component on physical activity (Table 6.1.). Depending on the type of recommendation, three types of scoring were used (A. adequate, B. moderate, and C. optimum, Figure 6.2.). Whole grains, roots and tubers, vegetables, fruits, legumes, nuts and seeds, and physical activity are adequacy components. A higher intake of these components reduces the risk of micronutrient deficiencies or chronic diseases such as type 2 diabetes and cardiovascular disease[(13)]. The consumption of added sugars and sugar-sweetened beverages, salt, and alcohol should be limited due to their adverse health effects and were therefore categorized as moderation components[(13)]. Milk and dairy foods, meat, fish, and eggs were categorized as optimum components as they may have both positive or negative health risks, depending on the amount consumed. For example, meat is a good source of iron and vitamin B12, but red and processed meat consumption is negatively associated with chronic diseases[(13)]. The recommended intake amounts for the 11 dietary components for the general population are based on individual diet optimization of women of reproductive age and population diet optimization combined with additional local evidence and expert opinions[(14)]. The description of the 11 dietary components is annexed (Annex 2). In the present study, physical activity was not evaluated because the evaluation focuses on diet quality, and data on the level of physical activity of this study population was not available.

Table 6.1. Et-HEI components with their classification for healthiness, type of scoring, and recommended values in g/day for the population groups of 2 years of age and older, as well as minimum and maximum scores.

No.	Dietary component	Relationship with health	Types of scoring	The amount for minimum score (0)	The amount for maximum score (10)
1	Whole grains, roots, and tubers	Protective	Adequacy	0	≥570
2	Vegetables	Protective	Adequacy	0	≥130
3	Fruits	Protective	Adequacy	0	≥150
4	Milk and dairy foods	Protective	Optimum	0 or ≥600	200-400
5	Meat, fish and egg	Protective	Optimum	0 or ≥70	20-50
6	Legumes	Protective	Adequacy	0	≥90
7	Nuts and seeds	Protective	Adequacy	0	≥15
8	Fats and oils	Limit	Optimum	0 or ≥27	10-17
9	Added sugar and SSB	Limit	Moderation	≥60	0-30
10	Salt	Limit	Moderation	≥8	0-5
11	Alcohol+	Limit	Moderation	≥150	0-50
12	Physical activity*	Protective	Adequacy	0	≥3

+Alcohol guidelines doesn't apply to children below 18
***moderate physical in number of days/week at least for 30 min, SSB: sugar-sweetened beverage**

Description of the Et-HEI components

The Et-HEI Scoring

As all components are assumed to be equally important, they were similarly scored from 0 (minimum) to 10 (maximum), depending on the adherence to the FBDG. The summing of the separate scores resulted in a total score between 0 (no adherence to the guidelines) and 110 (maximal adherence to the guidelines). The following formulas for the different components were used, as indicated in Figure 6.2.

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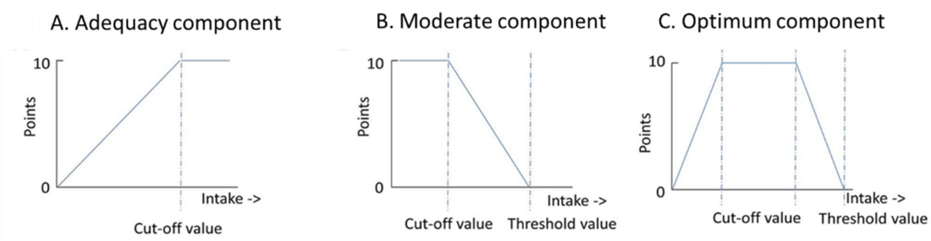

Scoring adequacy component from 0 to maximum value (10)

$$= \left(\frac{\text{The reported intake}}{\text{cutoff value}}\right) x \text{ maximum value } (10) \qquad \text{(A)}$$

Scoring moderation component between threshold and cutoff values

$$= \left(\frac{\text{The reported intake} - \text{cutoff value}}{\text{Threshold value} - \text{cutoff value}}\right) x \text{ maximum value } (10) \qquad \text{(B)}$$

Scoring optimum component from 0 to lower cutoff values

$$= \left(\frac{\text{The report intake}}{\text{The lower cutoff value}}\right) x \text{ maximum value } (10) \qquad \text{(C)}$$

Scoring optimum component between cutoff to threshold values

$$= \left(\frac{\text{The report intake} - \text{cutoff value}}{\text{Threshold value} - \text{cutoff value}}\right) x \text{ maximum value } (10) \qquad \text{(C)}$$

Figure 6.2. The formulas and graphic presentation of scoring for the Et-HEI for the different components: adequacy component (a), moderation component (b), optimum component (c)

Evaluation of the Et-HEI by comparing it with the MDD-W

The MDD-W is a dichotomous dietary quality indicator developed for women of reproductive age (15-49 years) and is related to micronutrient adequacy of the diet[9; 15]. It assesses the consumption of 10 food groups consumed during the last 24 hours: starchy staples, beans and peas, nuts and seeds, dairy foods, flesh foods, eggs, vitamin A-rich dark green leafy vegetables, other vitamin A-rich vegetables and fruits, other vegetables, and other fruits. Women consuming foods from five or more food groups are more likely to meet their micronutrient needs. Although the intake is assessed individually, the indicator is designed for population-level dietary assessments. The MDD-W is valid for predicting the adequacy of micronutrient intakes and is widely used, but NCD risk is not strongly correlated with the score[16]. The two 24HDR were also used to estimate the MDD-W score. For this purpose, the consumed food items were grouped into 10 food groups of the MDD-W. The contribution to each food category was identified based on local recipes for dishes containing several food groups. If these recipes were unavailable, the grouping was made using a similar local dish's recipe. The MDD-W score was then computed for each participant depending on how many food categories they consumed out of ten food groups.

Statistical analysis

Intakes of energy, nutrients, and food groups were averaged over the two collection days. For each participant in the sample, the probability of adequacy was estimated for the 11 selected micronutrients (vitamin A, vitamin B1, vitamin B2, vitamin B3, folate, vitamin B6, vitamin B12, vitamin C, calcium, iron, and zinc) taking their age category into account. The mean probability of adequacy (MPA) of all 11 micronutrients was calculated. Allen et al. (2020)[17] provided estimated average requirements (EARs) for the age groups for the various nutrients, and CVs from Allen et al. (2006)[18] were used to compute the standard deviation (SD) using the formula: SD is equal to CV*EAR/100. The Wiesmann et al. (2009) approach, described in their table A6-2[19], was applied to calculate the probability of iron adequacy for women of reproductive age. For example, the probability of adequacy will be 0 if the usual iron intake in adult women is <15.91 mg/d (5% bioavailability).

The Et-HEI was assumed to provide enough variation in scores to detect a meaningful difference in diet quality and adherence to the dietary guidelines in the population like other indexes with a similar purpose[20; 21]. Energy, carbohydrate, protein, and fat intake were reported using mean values, and selected micronutrient intakes reported the probability of adequacy. Differences in age, BMI, FFMI, the probability of adequacy for each nutrient, and MPA across the Et-HEI and MDD-W categories were analysed using ANOVA. ANCOVA was used to adjust for energy intake across quartiles of Et-HEI and MDD-W. For the categorical variables household food insecurity experience scale (HFIES) and level of education, the differences between dietary index quartile were tested using the Kendall's tau statistic . The association between the total score of Et-HEI and MDD-W and between their corresponding components was analysed using Kendall's tau statistic. All statistical analyses were carried out with STATA version 14.2, using a P-value of < 0.05 for statistical significance.

Results

Characteristics of the study population

The women's main characteristics and the differences across the Et-HEI quartiles are presented in Table 6.2. The average age was 31 years, and the majority had no (52%) or primary (31%) education. Most women (65%) had a normal body weight (BMI: 18.5-25 kg/m^2) or were underweight (23% with BMI<18.5 kg/m^2).

The mean Et-HEI score was 49, ranging from 24 to 71 out of 110 points. Mean ages did not differ between the Et-HEI quartiles. BMI was lower in the highest Et-HEI quartiles, while women in secondary school and above scored were more frequent in the lower Et-HEI quartiles. MDD-W score was higher in the highest quartiles of the Et-HEI score.

Table 6.2. Differences in characteristics across Et-HEI quartiles among women of reproductive age

Characteristics	**N**	**Quartiles of Et-HEI**				***p-value**
		Q1 (n = 124)	Q2 (n= 123)	Q3 (n= 124)	Q4 (n= 123)	
Et-HEI, mean (SD)	494	37.5 (4.5)	46.2 (1.8)	51.5 (1.4)	59.9 (4.4)	-
Age (year) , mean (SD)	489	32.6 (7.8)	32.3 (7.9)	31.3 (7.8)	31.0 (7.7)	0.316
BMI (kg/m^2) , mean (SD)	482	22.0 (4.5)	21.0 (3.7)	21.1 (3.7)	20.1 (3.0)	0.002
FFMI (kg/m^2), mean (SD)	474	15.5 (1.7)	15.4 (1.7)	15.6 (1.6)	15.2 (1.7)	0.273
Level of education						<0.001
No formal education, n (%)	254	53 (21)	60 (24)	69 (27)	72 (28)	
Primary education, n (%)	153	40 (26)	39 (25)	41 (27)	33 (22)	
Secondary education, n (%)	68	24 (35)	21 (31)	11 (16)	12 (18)	
Higher education, n (%)	14	7 (50)	3 (21)	3 (21)	1 (7)	
HFIES						0.865
Secure, n (%)	131	38 (29)	33 (25)	31 (24)	29 (22)	
Mild insecure, n (%)	133	31 (23)	29 (22)	37 (28)	36 (27)	
Moderate insecure, n (%)	117	25 (21)	32 (27)	33 (28)	27 (23)	
Severe insecure, n (%)	108	30 (28)	29 (27)	23 (21)	26 (24)	
MDD-W, mean (SD)	494	3.3 (0.7)	3.2 (0.5)	3.4 (0.6)	3.7 (0.6)	<0.001

Et-HEI: Ethiopian Health Eating Index, SD: Standard Deviation**, BMI**: Body Mass Index (number of women in Q1=122, Q2=121, Q3=122, and Q4=117), **FFMI**: Fat-Free Mass Index (Q1=121, Q2=119, Q3=120, Q4=114**), HFIES**: Household Food Insecurity Experience Scale,
*P-value from ANOVA for continuous variables: age, BMI, and FFMI and Kendal's tau statistic for categorical variables: level of education and HFIES.

Figure 6.3. shows the scores of the 11 dietary components of the Et-HEI, each with a potential maximum of 10 points. Women generally scored low mean points out of a maximum of 10 points for the components fruits (0.3), milk and dairy foods (1.0), meat, fish, and eggs (1.0), and nuts and seeds (0.4) due to very low adherence to the recommended intake of these food groups. Conversely, most women scored much higher on the components of whole grain, root, and tuber (8.5), vegetables (7.3), added sugar, and sugar-sweetened beverages (SSB) (8.7), and alcohol consumption (7.1), showing a better adherence to these components than to the other components. If the women consumed milk and dairy foods and meat, fish, and eggs, they often met the recommended intake, but this was not the case if they consumed fruit, nuts, and seeds.

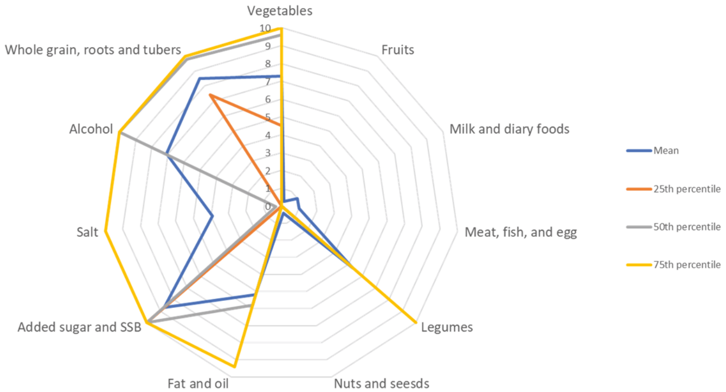

Figure 6.3. The scoring of 11 dietary components of the Et-HEI in women of reproductive age scored between 0 and 10 points.

Association of energy and macronutrient intake and micronutrients adequacy with the Et-HEI

Table 6.3. shows the mean energy, carbohydrate, protein, and fat intake across Et-HEI quartiles and the probability of adequately meeting micronutrients requirements for both unadjusted and energy-adjusted intakes among women. Energy (on average 2570 kcal/day), carbohydrate (444 g/day), and protein (1.2 g/kg of body weight/day) were different between the Et-HEI quartiles, with higher levels in the highest quartiles. These differences remained after adjusting for energy intake.

The probability of adequacy was high for vitamin B6 (0.9), folate (0.8), iron (0.9), vitamin B1 (0.8), and zinc (1.0), but much lower for vitamin A (0.3), vitamin B12 (0.0), vitamin C (0.1), and calcium (0.3). The mean probability of adequacy (MPA) was 0.5 in the first and second, and 0.6 in the third and fourth Et-HEI quartiles of the 11 micronutrients. Energy, carbohydrate, and protein intake were positively associated with Et-HEI. After energy adjustment, carbohydrate and protein intake remained associated, whereas fat intake was inversely associated with Et-HEI. Vitamin B1, B6, and iron remained positively associated with ET-HEI after energy-adjustments. Associations of Et-HEI with vitamin B2, B3, and folate were reduced after energy adjustment. MPA was higher in the higher Et-HEI quartiles, especially before energy adjustment.

Table 6.3. Median energy, carbohydrate, protein, and fat and probability of adequacy (PA) for nutrient intake across Et-HEI quartiles

Unadjusted energy and nutrient intake	**PA** (n=494)	**Quartiles of Et-HEI**				***p-value**
		Q1 (n=124)	Q2 (n= 123)	Q3 (n=124)	Q4 (n=123)	
Energy (kcal/d)	2678.1	2581.2	2486.7	2779.6	2865.1	0.009
Carbohydrate (g/d)	466.9	440.1	431.1	489.0	507.5	0.001
Protein (g/kg/d)	1.3	1.2	1.2	1.3	1.5	<0.001
Fat (g/d)	40.7	43.0	37.5	40.6	41.8	0.093
Micronutrients						
Vitamin A (RAE, μg/d)	0.3	0.2	0.3	0.3	0.3	0.406
Vitamin B6 (mg/d)	0.9	0.8	0.8	0.9	0.9	<0.001
Vitamin B12 (ug/d)	0.0	0.0	0.0	0.0	0.0	0.479
Vitamin C (mg/d)	0.1	0.1	0.1	0.1	0.0	0.206
Calcium (mg/d)	0.3	0.3	0.3	0.3	0.3	0.585
Folate (ug/d)	0.8	0.8	0.8	0.8	0.9	0.009
Iron (mg/d)	0.9	0.8	0.9	0.9	0.9	<0.001
Vitamin B3 (mg/d)	0.6	0.6	0.6	0.7	0.7	0.021
Vitamin B2 (mg/d)	0.6	0.5	0.5	0.6	0.6	0.049
Vitamin B1 (mg/d)	0.8	0.8	0.8	0.9	0.9	<0.001
Zinc (mg/d)	1.0	1.0	1.0	1.0	1.0	0.502
MPA	0.6	0.5	0.5	0.6	0.6	<0.001
Energy-adjusted macronutrients						
Carbohydrate (g/d)		457.1	464.7	471.2	474.6	<0.001
Protein (g/kg/d)		1.2	1.3	1.3	1.4	0.002
Fat (g/d)		44.1	39.7	39.4	39.7	0.021

Unadjusted energy and nutrient intake	PA (n=494)	Quartiles of Et-HEI				***p-value**
		Q1 (n=124)	Q2 (n= 123)	Q3 (n=124)	Q4 (n=123)	
Energy-adjusted micronutrients						
Vitamin A (RAE, µg/d)		0.2	0.3	0.3	0.3	0.283
Vitamin B6 (mg/d)		0.8	0.8	0.9	0.9	0.037
Vitamin B12 (ug/d)		0.0	0.0	0.0	0.0	0.575
Vitamin C (mg/d)		0.1	0.1	0.1	0.0	0.083
Calcium (mg/d)		0.3	0.3	0.3	0.3	0.854
Folate (ug/d)		0.8	0.8	0.8	0.8	0.218
Iron (mg/d)		0.9	0.9	0.9	0.9	0.005
Vitamin B3 (mg/d)		0.7	0.6	0.6	0.7	0.241
Vitamin B2 (mg/d)		0.5	0.6	0.5	0.6	0.426
Vitamin B1 (mg/d)		0.8	0.8	0.9	0.9	0.002
Zinc (mg/d)		1.0	1.0	1.0	1.0	0.897
MPA		0.6	0.6	0.6	0.6	0.031

* ANOVA was used for the mean difference of energy intake and energy-adjusted and unadjusted macronutrient intake, and micronutrients probability of adequacy

The mean intake of energy, carbohydrate, protein, and fat across quartiles of the MDD-W and the probability of micronutrient adequacy are summarized in Table 6.4. There was a positive association between energy and MDD-W. After adjusting for energy intake, carbohydrate and fat intake were positively associated with MDD-W. However, protein intake per kg body weight was not different across quartiles of MDD-W. Vitamin A, B12, and iron were all positively associated with MDD-W before and after adjusting energy intake. After adjusting for energy intake, the positive associations of vitamin B1, B3, B6, and calcium with MMD-W disappeared. MPA based on the 11 micronutrients was strongly associated with MDD-W and increased across the MDD-W quartiles.

Table 6.4. Median energy, carbohydrate, fat, and protein intake and probability of adequate nutrient intake across MDD-W quartiles

Unadjusted energy and Nutrients	**Quartiles of MDD-W**				***p-value**
	Q1 (n = 209)	Q2 (n= 151)	Q3 (n= 93)	Q4 (n= 41)	
Energy (kcal)	2562.0	2659.6	2936.4	2752.3	0.024
Carbohydrate (g/d)	454.9	460.4	510.7	452.4	0.073
Protein (g/kg/d)	1.2	1.3	1.4	1.3	0.005
Fat (g/d)	35.5	40.9	47.0	53.5	<0.001
Micronutrients					
Vitamin A (RAE, µg/d)	0.2	0.3	0.5	0.4	<0.001
Vitamin B6 (mg/d)	0.8	0.9	0.9	0.9	0.008
Vitamin B12 (ug/d)	0.0	0.0	0.1	0.2	<0.001
Vitamin C (mg/d)	0.1	0.1	0.1	0.1	0.087
Calcium (mg/d)	0.3	0.3	0.4	0.5	0.024
Folate (ug/d)	0.8	0.8	0.9	0.9	0.278
Iron (mg/d)	0.8	0.9	0.9	0.9	0.002
Vitamin B3 (mg/d)	0.6	0.7	0.8	0.7	0.003
Vitamin B2 (mg/d)	0.5	0.5	0.6	0.6	0.370
Vitamin B1 (mg/d)	0.8	0.8	0.9	0.9	0.006
Zinc (mg/d)	1.0	1.0	1.0	1.0	0.258
MPA	0.5	0.6	0.6	0.6	<0.001
Energy-adjusted nutrients intake					
Carbohydrate (g/d)	475.5	463.7	465.0	439.2	<0.001
Protein (g/kg/d)	1.3	1.3	1.3	1.3	0.128
Fat (g/d)	36.8	41.1	43.8	52.7	<0.001
Micronutrients					
Vitamin A (RAE, µg/d)	0.2	0.3	0.5	0.4	<0.001
Vitamin B6 (mg/d)	0.8	0.9	0.9	0.9	0.170
Vitamin B12 (ug/d)	0.0	0.0	0.1	0.2	<0.001
Vitamin C (mg/d)	0.1	0.1	0.1	0.1	0.285
Calcium (mg/d)	0.3	0.3	0.3	0.4	0.115
Folate (ug/d)	0.8	0.8	0.8	0.8	0.610
Iron (mg/d)	0.9	0.9	0.9	0.9	0.032
Vitamin B3 (mg/d)	0.6	0.7	0.7	0.7	0.179
Vitamin B2 (mg/d)	0.6	0.5	0.5	0.6	0.612
Vitamin B1 (mg/d)	0.8	0.8	0.9	0.9	0.105
Zinc (mg/d)	1.0	1.0	1.0	1.0	0.471
MPA	0.5	0.6	0.6	0.6	<0.001

* ANOVA was used for the mean difference of energy intake and energy-adjusted and unadjusted macronutrient intake, and micronutrients probability of adequacy

The correlation between Et-HEI and MDD-W

Table 6.5. shows the Et-HEI median, 25th percentile (P25), and 75th percentile (P75) values and the correlation between Et-HEI and MDD-W. The MDD-W score does not include fats, oils, added sugar, SSB, salt, or alcohol. The Spearman correlation between the total score of Et-HEI and MDD-W was moderate (r = 0.30). The Kendall's tau correlation between the components, fruits ($\tau = 0.91$), milk and dairy foods ($\tau = 0.94$), and nuts and seeds ($\tau = 0.97$) were high. Legumes ($\tau = 0.62$) were strongly associated with Et-HEI and MDD-W.

Table 6.5. Median, interquartile range indices, and the correlation of the components of Et-HEI with corresponding food groups of MDD-W and total score

Components	**Et-HEI** Median (P25, P75)	**MDD-W** Median (P25, P75)	τ
Whole grains, roots, and tubers	9.8 (7.4, 10)	1 (1, 1)	0.07
Vegetables	9.6 (4.5, 10)	NA	NA
Dark green leafy vegetables	NA	0 (0, 1)	0.43**
Vitamin A-rich vegetables and Fruits	NA	0 (0, 0)	0.18**
Other vegetables	NA	1 (1, 1)	0.20**
Fruits	0 (0, 0)	NA	NA
Vitamin A-rich vegetables and Fruits	NA	0 (0, 0)	0.14*
Other fruit	NA	0 (0, 0)	0.91**
Milk and dairy foods	0 (0, 0)	0 (0, 0)	0.94**
Meat, fish and eggs	0 (0, 0)	NA	NA
Eggs	NA	0 (0, 0)	0.27**
Legumes	5.2 (1.3, 10)	1 (0.5, 1)	0.62**
Nuts and seeds	0 (0, 0)	0 (0, 0)	0.97**
Fats and oils	5.8 (0, 9.4)	NA	NA
Added sugar and SSB	10 (10, 10)	NA	NA
Salt	0.3 (0, 10)	NA	NA
Alcohol	10 (0, 10)	NA	NA
Total score+	49 (43, 54)	3.5 (3, 4)	0.30**

+Spearman correlation is applied for the correlation between the total score of Et-HEI and MDD-W
*P-value<0.05 and **P-value<0.05 NA: Not Applicable

Chapter 6

Discussion

The Et-HEI is expected to assess adherence to healthy dietary patterns, capture dietary diversity and nutrient adequacy, and reduce the risk of NCD similar to other HEI[22; 23]. In Ethiopia, energy and nutrient adequacy remains a key issue as most low-income people's diets are low in nutrient-dense foods and dominated by starchy staple foods[24]. The Et-HEI quantitatively evaluated how well an index estimates the diet quality based on selected nutrients and how comparable the performance was with MDD-W, indicating a need for further adjustment[25].

We found a positive correlation between the Et-HEI and MDD-W, and both scores were relatively low. These low Et-HEI and dietary diversity scores agreed with the low probability of women's adequate vitamin A, vitamin B12, vitamin C, and calcium intake. Similarly, we observed a positive association between the Et-HEI and MPA. However, there was no difference in the mean probability of adequate vitamin A, vitamin B12, and calcium intake between Et-HEI quartiles before and after adjusting for energy intake. This might be due to the low intakes of vitamin A, vitamin B12, and calcium in our study population; mean vitamin A, vitamin B12, and calcium intake were about one-fifth of the EAR in our study, which agrees with previous study findings[3; 26]. In contrast, MDD-W was associated with unadjusted and energy-adjusted vitamin A intake; this may be because MDD-W includes a separate subgroup on dark green leafy vegetables rich in vitamin A [25]. Sub-dividing vegetables into dark green leafy vegetables and other vegetables in Et-HEI may improve the estimation of vitamin A adequacy as the Ethiopian diet is mostly plant-based [27; 28]. Overall associations of micronutrient with MDD-W were stronger than for Et-HEI, while for macronutrients such as carbohydrate and protein more positive association with Et-HEI than MDD-W were observed. In addition, the association between fat with Et-HEI was more negatively associated than with MDD-W. These findings indicate that Et-HEI takes into account dietary patterns related to NCDs besides nutrient adequacy.

The Et-HEI found a difference between quartiles of the total scores in BMI status and level of education. It was found that women with a higher BMI were more likely to be in the first and second quartile of Et-HEI, a finding replicated in research including the US-based HEI[29]. However, in our study, women with higher education were also more likely to be in the first and second quartiles, which was unexpected and needs further investigation.

Additional analysis of the Et-HEI components showed that women who completed secondary school or above consumed relatively more vegetables, fruits, and grains, and alcohol and salt, whereas dairy, meat, legumes, and nuts were more consumed by women who did not attend formal education or completed primary school.

Women of reproductive age had a median Et-HEI of less than half of the maximum score with an IQR (25th - 75th percentile) of 49 (43-54) out of 110. Ethiopian women's diets consisted primarily of grains, vegetables, legumes, fats, and oils. Fruits, meat, fish, eggs, dairy, nuts, and seeds were occasionally consumed. Low consumption of fruits, vegetables, nuts, and seeds resembles an unbalanced diet and is associated with several non-communicable diseases related to increased mortality rates[30; 31]. Maintaining the current intake of whole grains, roots, tubers, legumes, and vegetables and the current practice of limiting added sugar, SBB, and alcohol consumption must be encouraged. For better adherence to the Ethiopian FBDG, it is important to substantially increase the intake of fruits, milk, and dairy foods, meat, fish, eggs, nuts, and seeds. The lower Et-HEI score was explained by mainly consuming plant-based and less diversified food sources, similarly to previous dietary assessment findings that indicated low dietary diversity in Ethiopia[26; 32].

Vitamin B12 is found in animal-sourced foods[33], and a low intake of animal-sourced foods is considered a public health problem in Ethiopia [26; 34]. Because of that, the consumption of red meat, fish, egg, and dairy foods should be encouraged[26; 35], as recommended in the 2022 Ethiopian FBDG. Ethiopia's low consumption of fruits in the whole population is probably the cause of the low vitamin C intake (31.0 mg/day)[36]. Future research should evaluate vitamin C, vitamin A, and calcium intake in women consuming high amounts of fruit and vegetables to investigate to what extent requirements can be met[27; 28]. The inadequate nutrient intake reflects poor overall diet quality or low food group intake, which reflects on the Et-HEI score.

According to the Et-HEI, obtaining the maximum score (110) is impossible if no animal-sourced foods are consumed. On average, 20-50g/day of meat, fish, and eggs should be consumed to receive a maximum of 10 points, and 200-400 g/day of milk and dairy foods should be consumed for another 10 points. The Ethiopian Orthodox Tewahedo Church has around 43.5% followers in the population and practices up to 140 fasting days a year[37]. Fasting means avoiding animal-sourced foods or following a vegan diet and staying with no food and drinks for a certain time during the day throughout the fasting days. In the FBDG, this is accounted for in the recommendations by the advice to replace animal-sourced foods with legumes, nuts, and seeds during fasting. According to the current Et-HEI, a fasting person could only obtain a maximum score of 90 points, even if good replacers are included in the diet. In future, collecting dietary and related data during fasting should allow scoring of different combination of food groups than in the current Et-HEI such as legumes, nuts, and seeds different to better assess the diet quality and adherence to the FBDG during fasting. For example, the American HEI-2010 and HEI-2005 classify beans as protein or vegetables depending on whether they are the main protein source [(20)].

Due to a lack of data and the study's focus on evaluating Et-HEI for diet quality, the physical activity component was not included in the Et-HEI. Other comparable evaluations do not consider physical activity for the same reason[(8; 16; 25)]. Nevertheless, physical activity is part of the Ethiopian FBDGs and Et-HEI because it is important to maintain energy balance and a healthy body weight[(38)]. Both Et-HEI and MDD-W were weakly positively associated with energy intake. It may not be beneficial if the Et-HEI provided higher scores for people having simply a higher consumption of the unhealthy component of Et-HEI food groups because the goal of the guidelines is to improve diet quality for optimal health[(29)] and to keep body weight stable. Besides the higher energy intake, the source, whether the extra energy comes from healthy or unhealthy components, and the dietary and non-dietary mitigation is appropriate. Therefore, the possibility of including the level of physical activity or energy expenditure to balance energy intake should be investigated further.

Et-HEI is the first healthy eating index targeted at a specific country developed on the African continent based on FBDG. Only a few low and middle-income African countries have such an index[(5)], mainly because they do not have FBDG[(39)]. In most African nations with FBDG, their dietary guidelines lack the recommended amount due to a lack of quantitative dietary intake data and expertise in diet optimization. Therefore, the findings of this study will serve as an important example for other LMICs, particularly in Africa and other African nations, as they can use the Et-HEI with minor adaptations. For Ethiopia, the Et-HEI results will be used to establish a target for Ethiopian FBDG adherence, which will be relevant for designing, implementing, and evaluating public health programs and policies.

A limitation of our study is that the evaluation of the Et-HEI used only two non-consecutive 24HDR, which could be considered small compared to the population size of 494 women. Our results may thus have been different if the assessment was conducted in another population group which may influence our conclusion. Further research is advised to assess Et-HEI in various subpopulation groups based on the recommendations in the FBDG to use Et-HEI for individual nutrition counselling. However, based on our study, the Et-HEI can also be used to monitor and evaluate Ethiopian FBDG implementation's impact on the population at large because the Et-HEI was developed based on the FBDG recommendations for the general population of 2 years and older. In addition, in the Ethiopian FBDG, women of reproductive age were categorized as requiring medium amounts of energy which can be considered an average for the general population. Therefore, the Et-HEI can be used to assess the diet quality of the population by administering the Et-HEI at an individual level and reporting at the population level[40]. Environmental sustainability was impossible to include due to the absence of reliable data on the life cycle analysis of commonly consumed foods in Ethiopia[41]. However, the sustainability of a healthy diet in Ethiopia is a key area for further research.

Finally, the Et-HEI can be used to evaluate adherence to the Ethiopian FBDG as it shows an association with energy and nutrient adequacy in women of reproductive age. The Et-HEI showed a positive association with the MDD-W scores and a correlation between the food groups of MDD-W with the Et-HEI components. Using dietary intake data from other subpopulations (preschool children, school children, men, and the older population), the index could be further improved to assess adherence at the individual level.

Conclusion

The Et-HEI we developed was able to indicate nutrient adequacy while determining adherence to FBDG. The total Et-HEI score was low, indicating the study population's consumption patterns had poor adherence to the 2022 Ethiopian FBDG. The low Et-HEI score was reflected by a low MDD-W score, a high score for only the plant-based components in the diet, and little diet diversity (almost zero fruits, nuts, and seeds and lack of animal source foods). Poor adherence to the Ethiopian FBDG was underlined by a low probability of adequate vitamin A, vitamin B12, vitamin C, and calcium intake. The Et-HEI may be a useful index to monitor and evaluate the implementation of the Ethiopian FBDG and other dietary interventions.

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Ethics of human subject participation

The current study followed the Declaration of Helsinki's standards. Before performing this study, the Ethiopian Public Health Institute's institutional review board (IRB) granted ethical permission and the appropriate administrative approval from the regional health and agriculture bureau. The study's aims, data collection procedures, confidentiality, and data usage and management were all adequately explained to the participants. Before the data collection, all individuals gave their oral consent. Participants were informed that they had the opportunity to withdraw from the study without reason.

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Appendix 1. Description of the Et-HEI components based on the Ethiopian FBDG

No	Components	Description
1.	***Whole grains, roots, and tubers***	Teff (Ethiopian cereal), potato, wheat, rice, maize, and sweet potato are part of this component. In the FBDG, grains, roots, and tubers are recommended to be consumed in combination with other food groups. Ultra-processed cereal products, such as cookies and potato chips, should be avoided in favour of roasted cereals (kollo) as a healthy snack. A daily intake of 400-650 g is recommended in the Ethiopian FBDG, and the amount of 570 g/day or more is given the maximum score.
2.	***Vegetables***	Ethiopian kale, onion, green pepper, lettuce, carrot, tomato, head cabbage, and pumpkin are commonly consumed vegetables in Ethiopia. FBDG messages include choosing vegetables in season, eating various vegetables of different colours every day, and washing vegetables with clean water before eating them. Vegetables provide essential vitamins and minerals that protect from diseases. A daily intake of at least 130 g is recommended.
3.	***Fruits***	Banana, papaya, lemon, watermelon, avocado, mango, pineapple, orange, and strawberry are common fruits in Ethiopia. It is suggested that fruits be washed with clean water before eating them, to choose seasonal and diverse fruits of different colours daily. Since eating more fruits lowers the risk of chronic diseases such as type 2 diabetes, at least 150 grams should be consumed daily.
4.	***Milk and dairy foods***	Yogurt, milk, and cottage cheese are common dairy products in Ethiopia. The guidelines list dairy, meat, fish, and eggs as animal-sourced food. Every day, at least one meal containing dairy products is recommended. Furthermore, dairy products provide minerals such as calcium, essential for bone health. Milk and dairy foods should be consumed 200 to 400 grams daily.
5.	***Meat, fish, and egg***	Chicken, fish, beef, eggs, and dried meat fall into this category. It is recommended to include animal-sourced foods in daily meals and replace them with legumes during fasting. They are good sources of protein, vitamins, and minerals. An average daily intake range from 20-50g/day is recommended.
6.	***Legumes***	Beans, chickpeas, lentils, split peas, shiro, and peas are among the legumes mostly consumed in Ethiopia. Legumes are recommended to be added to kollo and nifro (a mix of boiled cereals and legumes). Different legumes should be added to the traditional Ethiopian stew (Shiro), made from various legumes, and mouldy legumes should be avoided. Consumption of legumes provides a good source of protein. At least 90 grams of legumes should be consumed per day.
7.	***Nuts and seeds***	Niger, flaxseed, peanut, and sunflower seeds are examples of nuts and seeds consumed in Ethiopia. Nuts should be used the same way as legumes in the healthy snack called kollo (a mix of nuts and other cereals). Nuts and seeds are also recommended as a good source of

		protein, minerals, and unsaturated fat. Average daily consumption of at least 15 g is recommended.
8.	***Fats and oils***	In Ethiopia, butter, meat fat, palm oil, sunflower oil, soy oil, and vegetable oil are common fat and oil sources. While using them sparingly, liquid vegetable oils such as sunflower, soya, and nut oils with relatively less saturated fat should be chosen. Furthermore, eating some fats and oils is advised to provide energy, help protect organs and keep the body warm. Fats and oils should be limited to 10–17 grams/day.
9.	***Added sugar and sugar-sweetened beverages (SSB)***	Sugar, sweets, soft drinks such as leslasa, and packed juice should be consumed in moderation. According to the FBDG, sugar and sweeteners should also be avoided in milk, fruit juices, tea, and coffee. It is recommended to consume less than 30 g per day
10.	***Salt***	Salt is recommended to be iodized and added after cooking (not during the process). The daily consumption of salt should be no more than 5 grams, according to the Ethiopian FBDG.
11.	***Alcohol***	Alcoholic beverages such as tella, tej, beer, and areka should be consumed in moderation, with no more than 2 glasses per week. For pregnant or lactating women and children, alcohol consumption should be avoided.

Chapter 7:

General Discussion

This thesis describes the development and evaluation of first Ethiopia's food-based dietary guidelines (FBDG) and country-specific healthy eating index (Et-HEI). This chapter will synthesize and discuss the key results (see Figure 7.1), position them in the transition of the Ethiopian food system to a healthier diet, and provide conclusions.

Summary of main findings

In **Chapter 2,** we described the methodological framework for developing and evaluating Ethiopian FBDG and the Et-HEI. The development of the methodological framework was informed by the FAO/WHO FBDG preparation guidelines, the experience of other countries (including South Africa, the Netherlands, and Brazil), discussions with Ethiopia's current nutrition program implementation platforms, and the stakeholders involved, with support from several international organizations, i.e., the Food and Agriculture Organization of the United Nations (FAO)[(1)], Wageningen University and Research (WUR), and International Food Policy Research Institute (IFPRI). Based on the technical recommendations from the methodology development stage, we identified the evidence gaps and defined the development process into three phases. The first phase consisted of the development of technical recommendations for dietary patterns and foods associated with context-specific health implications, based on reviews of evidence gaps that were considered crucial to be addressed for the development of dietary guidelines. The second phase consisted of the translation of the technical dietary recommendations into reference diets for subpopulations with diet modelling. And the third phase included the compilation of the FBDG, food guide, food graphics, and the final discussion with stakeholders. Figure 7.1 shows the main findings of the thesis. This thesis addresses specifically phase 1 and phase 2. Furthermore, the proposed methodological framework included additional activities not reported in this thesis. These are the development of an FFQ to collect data for the estimation of the Et-HEI, and the assessment of key dietary gaps, reflecting deviations from the developed FBDGs in Ethiopia. Work on these activities will continue and are of utmost importance for monitoring and evaluation of adherence to FBDG, and for targeting of interventions to the populations most vulnerable to sub-optimal diets.

The first phase included a systematic review of priority diseases and diet relationships, addressed in this thesis (**Chapter 3).** Based on results of the global burden of disease database specific to Ethiopia and in consultation with experts, we selected the following priority diseases and causes of death in Ethiopia: nutritional status (focused on protein-energy, vitamin A, zinc, calcium, and folate status), cardiovascular diseases, and type 2 diabetes. We reviewed systematic reviews published in international literature since 2014 to identify dietary risk and preventive factors associated with these diseases and risk factors. **Chapter 3** showed that whole grains intake is associated with a reduced risk of cardiovascular diseases (CVD) and type 2 diabetes (T2DM). Cereals (especially whole-grain cereals), roots, and tubers are good sources of energy and nutrients. Biofortified cereals, including quality protein maize, and roots, such as orange flesh sweet potatoes, are good sources of protein and vitamins. Consumption of nuts and seeds improves antioxidant status, such as vitamin E and A, and lowers cardiovascular disease and blood glucose levels. Pulses are good sources of protein and minerals, including iron, zinc, and selenium and pulse consumption may reduce the incidence of CVD and T2DM. Milk and dairy foods are good sources of calcium, which improves bone mineral density among adults and prevents stunting in children. Sugar consumption should be limited to lower the risk of obesity, CVD, and T2DM; intake of saturated fatty acids, fats, and oil is associated with several non-communicable diseases; daily vegetables and fruit intake are associated with lower risks of CVD and T2DM; plant-based diets lower the risk of obesity and non-communicable diseases while they may also reduce micronutrient bioavailability which may contribute to micronutrient deficiencies(2).

This review resulted in nine technical dietary recommendations. Based on these recommendations, combined with additional evidence (not reported in this thesis) on dietary intake gaps, determinants of food preference, food availability and accessibility, and effective nutrition communication, the FBDG technical committee, in collaboration with FAO, WUR, and IFPRI experts, identified the most pressing diet-related issues and recommendations. These were transformed into two main goals and 11 dietary guidelines for the general public (Annex 1). The 11 dietary guidelines were further substantiated with information on the health benefits of following the respective guidelines, and more detailed tips on implementing the guidelines supported by food graphics. For example, the dietary guideline "Diversify your diet in every meal, days and weeks" translates how consumers can diversify their diet during meals and in their daily and weekly intake by using the different food groups. **Chapter 4** shows that when these dietary guidelines were tested, most study participants showed a strong desire to follow them. According to their opinions, most key messages (or dietary guidelines) correspond with the current nutrition education materials deployed throughout the country, except for the physical activity and alcohol use messages that are normally not addressed in nutrition education material in Ethiopia. On the other hand, the qualitative study also showed that study participants did not understand words like ultra-processing, whole grain, and a healthy and balanced diet and that they need further explanation in simplified terms for greater comprehension. The biggest challenges in adhering to these guidelines perceived by the study participants were affordability, availability, practicality, and accessibility. It was also concluded that the dietary guidelines should consider fasting and traditional cooking practices to be more inclusive of the Ethiopian cultural and religious values.

The second phase consisted of modelling of diets to optimize for nutrient adequacy (**chapter 5**). Besides using the revised dietary guidelines, tips, and graphics based on the feasibility study findings, we also used results from **Chapter 4**, such as information on intake during the fasting period, for the diet modelling assumptions. The diet modelling study described in **Chapter 5** proposed three optimized diets : 1. Non-fasting diet, 2. Continuous fasting diet (vegan diet for a longer time), and 3. Intermittent fasting diet (2 days per week vegan diet) for women of reproductive age. For this purpose, we collected data from 494 women of reproductive age using two non-consecutive 24-hour dietary recalls per person. The model's recommended diets were assumed to be feasible for women of reproductive age because the diets are close to their current diets, as planned, and fulfil women's energy and nutrient demand. However, the proposed diet used during fasting failed to provide enough calcium and vitamin B12. The intermittent fasting diet compensated for those two nutrients on non-fasting days of the week, an approach that, to our knowledge, is used for the first time in diet modelling. The results also showed that the costs of the recommended diets are a point of attention.

In addition to our modelling of women's diets, the Ethiopian FBDG technical committee conducted population-based diet modelling using the most commonly consumed foods selected from the 2011 national food consumption survey (not reported in this thesis). The individual women's diet (**Chapter 5**) and these population-based diet models provided information on the recommended amounts of food groups for the general and specific subpopulations (categorized into three energy levels). The three energy levels in the specific subpopulation diet were characterised as low (1250 kcal/day representative for preschool children, 2-5 years old), medium (2300 kcal/day representative for school-age children, 6-18 years and older people, +65 years old), and high (2700 kcal/day representative for adult men and women 19-64 years old)[3]. Finally, based on these general dietary recommendations for individuals above 2 years old from the Ethiopian FBDG we developed the Et-HEI to assess adherence to these FBDG (**Chapter 6**). The median Et-HEI score for women of reproductive age was 49 out of 110. The low Et-HEI score was also reflected by a low MDD-W score (3.5 out of 10), a high score for only the plant-based components, and little diet diversity (almost zero fruits, nuts, and seeds consumption). Poor adherence to the Ethiopian FBDG was underlined by a low probability of adequate vitamin A, B12, C, and calcium intake. **Chapter 6** concludes that the Et-HEI is a useful index to monitor and evaluate the implementation of the Ethiopian FBDG and other interventions that have improvement of diets or reaching healthy diets as (one of the) an outcome.

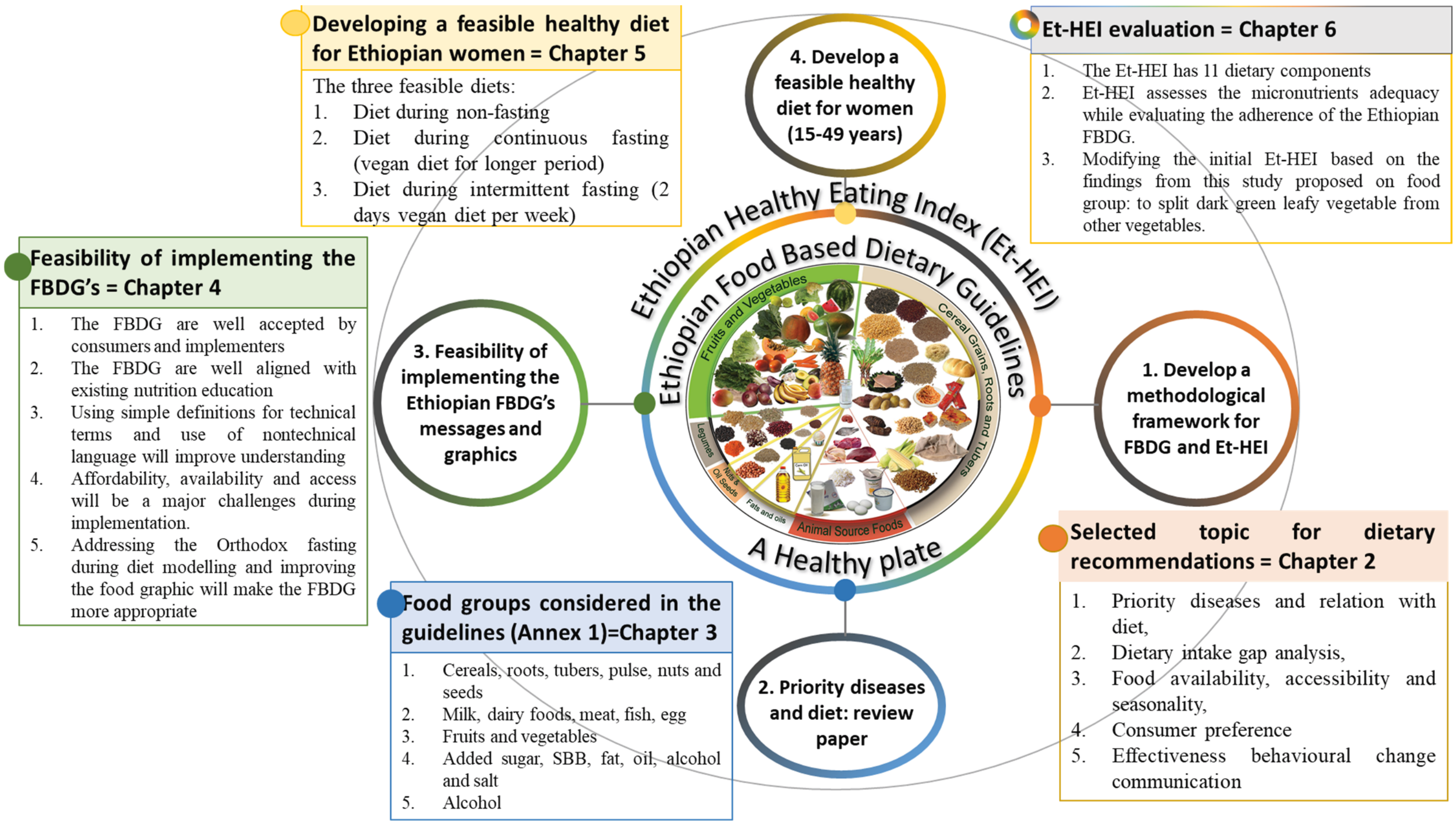

Figure 7.1. Summary of findings from this thesis

scenarios, one diet for continuous and one for intermittent fasting. This, to our knowledge, is the first time fasting is taken into account in diet modelling. However, further research on the health and nutrition implication of continuous fasting and the inclusion of alternative foods such as biofortified or fortified foods in modelling will benefit the development of a more targeted, healthier fasting diet with adequate diet quality.

The importance of this study to the Ethiopian food system for a healthier diet

The development and evaluation of Ethiopian FBDG was supported by an, on its turn, strengthened several key policies and programmes in Ethiopia. First, the work on FBDGs was initiated under the flagship program on Food System for Healthier Diets of the CGIAR funded research programme on Agriculture for Nutrition and Health (A4NH) with technical support from FAO, IFPRI, and WUR[1; 4; 5]. A4NH focused on food system transformation from a consumer perspective by understanding consumers' eating behaviour, diet quality, risk of an unhealthy diet, and the food system's major drivers. This is contrary to the general approach to food systems which mainly targets increasing food production and productivity [6; 7]. The A4NH program is implemented in four countries; two countries in Africa (Ethiopia and Nigeria) and two countries in south-east Asia (Bangladesh and Vietnam). In Ethiopia, the flagship program started by looking at what drives the food system and what options and constraints exist, testing innovations and interventions to improve diet quality, and bringing stakeholders together to share and discuss information[5; 8]. This consumer-focused food system approach supported us to design the first Ethiopian FBDG's methodological framework (**Chapter 2**) in line with Ethiopia's major food system challenges and opportunities identified during the process and in several (nutrition) policies and strategies [4].

Secondly, a multistakeholder approach was used in the development of the FBSGs. Key stakeholders such as nutrition program implementors, academia, non-government organizations, communication experts, and religious leaders were member of the FBDG Working Group and were closely involved in the FBDG development process. This increased the ownership of the developed FBDGS enhancing the probability the FBDGs will be implemented.

Thirdly, the development and evaluation the Ethiopian FBDG and Et-HEI recognized the life cycle approach, aiming to break the vicious circle of malnutrition[9; 10], as prioritized by the country's multi-sectoral nutrition implementation platform. Most nutrition programs in Ethiopia primarily target the first 1000 days of life (from pregnancy up to 2 years)[11]. The population group below 2 years is given special attention and care as the vulnerability to malnutrition and related disease and death in this age group are high[12]. The effect of programmes at this stage will also impact the health and nutritional status during adulthood[13]. There are well-designed nutrition programs and intervention strategies that target Ethiopia's first 1000 days of life [11; 14]. However, there was a gap in interventions for the general population above 2 years old, and the FBDG aim to provide evidence and targets to address this population group.

The Ethiopian FBDG, developed based on evidence provided by the research reported on in this thesis, is considered as a tool to inform actions of different food system actors f to promoting positive food systems transformation for (sustainable) healthy diets[15]. This diet-centred approach has been presented in the Ethiopian food systems transformation pathway that emerged from the United Nations Food System Summit of 2021[16]. This pathway or roadmap adopted FBDG as an integral part of the food systems transformation in Ethiopia, being one of the 22 game-changing solutions clustered [16]. In addition, The Coalition of Action on Healthy Diets was established as a result of the United Nations Food Systems Summit (UNFSS) 2021, and the Ethiopian government has decided to deliver on this call. Hence, besides aiming to inform the general public on what to eat to stay healthy, the Ethiopian FBDG has a second objective to promote, inform the design and implementation of broad food system actions that enhance diet quality for optimal health. These include, but are not restricted to, nutrition-sensitive agriculture programs, the SEQOTA Declaration (a program designed to eradicate undernutrition in Ethiopia), the Social SafetyNet program (a program that targets low-income households), school feeding programs, and other food and nutrition programs by setting targets and dietary standards [17; 18]. However, the potential of FBDGs to stimulate coherent actions within the food system that accelerate impact on the quality of diets is still underused and research is needed to build the evidence on the impact of using the guidelines in public policies and investments on improving healthy diets. .

Further adaptation of the Ethiopian food-based dietary guidelines

Ethiopia has the second largest population in Africa and has 13 regional states and more than 80 ethnic groups with diverse languages and cultures[27]. More than 90% of the people follow certain religions and among these 67% follow Christianity, 31% follow Islam, and 2% follow traditional and other faiths (https://www.cia.gov/the-world-factbook/countries/ethiopia/). The majority of the population (80%) lives in rural areas, with the majority involved in agriculture and animal farming activities. 12-15 million pastoralists inhabit 60% of the land, accounting for 60% of the overall population[28]. Ethiopia's six agro-ecological zones differ in altitude, temperature, and agricultural production, influencing dietary habits [29]. Food habits depend on many factors, for example where they live, which religion they have, what their income is, determining the availability, accessibility, affordability and desirability of food. Also our respondents from the nutrition experts group enrolled in the feasibility study of FBDG (**Chapter 4**) suggested that it may require further anthropologic studies to understand better different community eating habits and food access that need to be considered in adapting the national FBDGs to the specific communities. Hence, considering Ethiopia's diverse population, geographic distribution, and lifestyle, adapting the Ethiopian FBDG to a particular subpopulation is of high importance to ensure that recommended diets are within reach and individuals can adhere to the dietary guidelines[30; 31].

Further work is already initiated to adapt the Ethiopian FBDG to the pastoralist community. The process included reviewing and incorporating the dietary habits, way of living, culture, and other related factors in adapting the FBDG. In addition, the FBDG should be further adapted considering episodically consumed foods for different reasons such as limited availability and affordability, or lack of information on the nutrition and health benefits [32]. The adaptation will improve the adherence to the FBDG.

Affordability, availability, accessibility, and sustainability of the healthy diet

Healthy diets remain beyond reach for 3 billion or 38% of the global population[33], and in Sub-Saharan Africa and Southeast Asia, 57% of the population cannot afford nutritious food. In addition diets with adequate nutrients were unaffordable for many demographic groups, especially women and girls[35] Also in our study (**Chapter 5**), the modelled non-fasting, continuous, and intermittent fasting diets were estimated to cost 112 ETB (Ethiopian Birr), 79 ETB, and 100 ETB, respectively, much higher compared to the current diet costs of 56

ETB. A previous study indicates that healthy diets that are both adequate and have a low risk for non-communicable disease are more expensive than diets that are only nutrient-adequate or only energy-sufficient [34]. Globally, one of the main reasons for a high variation in diets between countries is income; compared to high-income countries, low-income countries rely more on staple foods and less on fruits, vegetables, and animal sources [1]. More research is needed on how low-income populations will have better access to a healthy diet at an affordable cost, considering their income. These include both urban and rural populations, as evidence indicates that also rural households rely on market purchases for a healthy diet[36; 37]. Implementation of FBDG should assess and monitor the affordability of a healthy diet, and therefore food prices should be frequently monitored.

According to a study in Ethiopia, Malawi, and Tanzania, the seasonality of some of the most commonly consumed fruits and vegetables remains a key factor in the availability, accessibility, and affordability of a healthy diet[34]. COVID also contributes to increasing the affordability of a healthy diet because due to COVID and related measures, 66% of household income is lower, increased household food insecurity by 11%, and increased food price because of the exchange rate, inflation, and crude oil price [18; 38; 39]. Access to a healthy diet will be improved by establishing a strong food supply chain and a market linkage between producer and consumer[36; 37]. The cost of a healthy diet is further influenced by costs of meal preparation, availability of clean water, fuel, and cooking time[40; 41].

In the optimized diet (**Chapter 5**), the high price of milk and dairy foods in Ethiopia contributed significantly to the costs of the non-fasting and intermittent fasting diets, which were twice as expensive as the current diet cost. Another study showed that distance from the market influences food costs and healthy eating habits in rural low and middle-income nations[42]. In Ethiopia, where the rural community often has to travel far to their nearby market and is poorly connected to the suppliers, nutritious food prices are high. Distribution (transportation) costs and the costs of losses due to the perishability of nutritious food such as fruits, vegetables, dairy foods, and eggs contribute to the high price of healthy diets. Besides reducing prices of nutritious foods, also raising incomes of the poor may support affordability of healthy diets. Strengthening Ethiopia's Productive SafetyNet Program (PSNP) will help low-income households increase their purchasing power[18]. PSNP provides payment to low-income families for participation in labour-intensive public work. To guarantee that a healthy diet is affordable and available to all, the Ethiopian government focusses on improvement of the households' income targeting women and enhances the social SafetyNet program with more emphasis on improving the nutritional status of the household members[34; 43].

Food fortification and supplementation are important complementary alternative activities of FBDG to prevent inadequate micronutrient intake[44; 45]. In the development of Ethiopian FBDG, food fortification and supplementation were not considered. The diet modelling study (Chapter 5) optimized the current diet based on estimated average requirements [3] for women of reproductive age, and the adequacy of intake for most of the selected nutrients were met. However, the optimized diet for continuous fasting did not meet the required intakes for vitamin B12 and calcium . Supporting food fortification and supplementation programs in addition to FBDG implementation may benefit in preventing micronutrient deficiencies. Harmonizing the implementation of FBDG with ongoing fortification and supplementation programs is important for the long-term use of FBDG and for improving diet quality. Considering short and long-term micronutrient intervention strategies parallel to FBDG will benefit the majority of the public to meet the nutrient adequacy[46].

Our diet modelling study could not consider environmental sustainability due to a lack of data on environmental impact of foods in Ethiopia. Future FBDG development should consider sustainability by generating supporting evidence and data to formulate a sustainable healthy diet. In low and middle-income nations, there are different approaches to ensuring the sustainability of a healthy diet[47]. For example, wood is the primary source of cooking energy in rural areas, and deforestation is widespread in Ethiopia[48]. Supporting homes to switch to a renewable energy source will increase forest density and assist the ecosystem[49; 50]. Ethiopia's other important sustainability concerns are postharvest loss and food waste[51; 52]. In Sub-Saharan Africa, postharvest losses and food waste of important food commodities can reach 50%[53; 54]. The sustainability of a healthy diet will be improved by establishing a strong food supply chain, such as a storage and cold chain and a market linkage[36; 37].

Implementation, monitoring, and evaluation of food-based dietary guidelines

FBDG aims to inform the general public on what to eat to remain healthy. It provides a framework for all other investments to enable consumers to make healthy choices. To guarantee the effective implementation of FBDG, the messages should be acceptable, understandable, and practical. The Ethiopian FBDG was revised based on the feasibility study findings. FBDG should be fully implemented, which requires the development of a variety of targeted consumer education strategies and their integration into several sectoral food and nutrition policies and programs[19; 55]. These policies and programs in Ethiopia include the food and nutrition policy and strategy, agriculture transformation plans, food regulations and standards, school feeding programs, health, and agriculture extension programs, and the new food system transformation roadmap[16]. Targeting a healthy diet is necessary to change consumer health and nutrition problems[56].

From our feasibility study (**chapter 4**), the availability of nutritious food such as fruits, vegetables, and animal sources might be a barrier to implementing the FBDG. Mostly, the agriculture sector focuses on increasing the production of staple crops such as cereals, roots, tubers, and legumes[57; 58]. Ethiopia grows various crops and grains, accounting for about 86% of the country's land area (16.5 million hectares) [59]. Because of that, cereals and legumes are relatively better accessible and affordable[60]. At the same time, the variety of fruits and vegetables, animal-source food production, and consumption is quite low compared to the need in Ethiopia[60; 61]. Improving the overall production quantity and diversity is important to ensure the implementation of dietary guidelines[42; 61]. The agriculture sector should meet the demand for a healthy diet and the export target for economic development. The food export and import policy and the local market trading system should provide market and physical access to a healthier diet at an affordable price.

The Seqota declaration implementation plan, school feeding program, and health and agriculture extension packages can start using the FBDG in the short term[36]. The simple consumer advice documents such as the FBDG booklet, posters, and brief food graphics with advice on food groups will inform harmonized nutrition education through communication channels across regional states[62]. It will also be useful to extend the implementation through electronic media through websites, social media, television, and radio programs[19; 62]. Defining the role and responsibility of nutrition stakeholders for the implementation of FBDG will allow efficient implementation, monitoring, and evaluation[19; 55]. Nutrition programs are normally implemented in Ethiopia using a multi-sectoral approach[9]. The current food system roadmap is also developed and opted to be implemented by multiple sectors such as the Ministry of Health, Education, Trade, and Social Affairs, which have a role in the country's food system. The private sector's part in transforming the food system towards a healthier diet is crucial as they have a major role in the current food system as being involved in cultivating, transporting, processing, and marketing nutritious foods to society[63], and, therefore should have a key role in the FBDG implementation[55]. Our study on Et-HEI indicated a low adherence (49 out of 110) to the FBDGS and a poor dietary diversity (3.5) among women of reproductive age. When evaluating the impact of future nutrition programs, it is often desirable to assess diet quality and adherence to dietary guidelines[64]. The impact of the FBDG should be considered once it has been completely implemented by providing an enabling food environment and healthy diet behavioural change communication[65]. However, since there is no or a limited valid dietary assessment tool available, finding information on the impact of FBDG is difficult, especially in low and middle-income countries. Tracking nutrient adequacy, NCD risk reduction, food safety, and sustainability are the most pressing concerns as they will allow for a better targeting of the evidence-based intervention[64; 66]. The Et-HEI, in this regard, will be a useful tool to assess the adequacy and healthiness of the diet by evaluating the adherence to the Ethiopian FBDG. In addition, tracking the different dietary patterns and the food environment and further investigating the relationship with priority diseases will allow the revision of the Ethiopian FBDG regularly and measure the impact of dietary interventions[65].

Promoting a healthy diet through a school feeding program will benefit school attendance and improve diet quality and children's nutritional status[67]. Access to education requires that children be able to attend school regularly and learn effectively when in school. However, for poor students from vulnerable communities, school enrolment, regular attendance, and learning ability are compromised by illness, hunger, and malnutrition[68]. The current school feeding programme should consider the implementation of FBDG at school that could be approached through the ongoing development of a national food system roadmap and engagement of multiple sectors [16; 19].

General conclusions

Based on our findings in the development of the Ethiopian FBDG and healthy eating index and discussions related to future implementation, we conclude the following:

1. The current diet of women of reproductive age in Ethiopia has poor diversity and quality, contributing to malnutrition and diet-related non-communicable diseases being a public health concern.
2. The review and additional secondary data analyses on the five selected topics (priority diseases and relation with diet, dietary intake gap analysis, food availability, accessibility and seasonality, consumer preference, and effective behavioural change communication) provided science-based evidence to develop 11 dietary recommendations.
3. Feasible fasting and non-fasting optimal diets for women of reproductive age can be developed that meet their daily energy and nutrient requirements except for calcium and vitamin B12 in the continuous fasting diet. During continuous fasting, alternative sources of calcium and vitamin B12 should be considered to complement the dietary recommendations.
4. The costs of the developed healthy diets during non-fasting and intermittent fasting are twice as high as that of the current diet.
5. The developed Et-HEI reflects nutrient adequacy while determining adherence to FBDG and presents an important tool for monitoring and evaluating the impact of interventions that target the improvement of diets or aim to reach healthy diets.

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Annex 1. Ethiopia Food-Based Dietary Guidelines

Guideline 1: Diversify your diet by selecting at least 4 food groups in every meal and 6 food groups every day.

Guideline 2: Every day, eat 80–120 grams of legumes such as beans, chickpeas, peas, or lentils.

Guideline 3: Eat 110–160 grams of various fruits and 100-140 grams of vegetables of different colours every day, such as bananas, papayas, kale, carrots, and tomatoes.

Guideline 4: Diversify your diet with 10–20 grams of nuts and oilseeds such as groundnuts and sunflower or sesame seeds.

Guideline 5: Add animal-sourced foods such as eggs and meat (60 grams) and dairy foods (300–400 grams) to your daily meals.

Guideline 6: Drink 8–10 large glasses of clean water daily.

Guideline 7: Be physically active for at least 30 minutes a day.

Guideline 8: Take up to 15–20 grams of fats and oils per day.

Guideline 9: Limit sugar, sweets, and soft drinks to below 30 grams per day.

Guideline 10: Limit salt intake to below 5 grams per day

Guideline 11: Limit alcoholic drinks – both factory-processed and homemade – to no more than 2 glasses per week.

Summary

Food-based dietary guidelines (FBDG) promote and maintain healthy eating in a population by providing country-specific guidance. However, many African countries like Ethiopia do not have FBDG. This thesis described the development and evaluation of Ethiopia's first food-based dietary guidelines (FBDG) and country-specific healthy eating index (Et-HEI).

Chapter 2 presents the methodological framework for developing Ethiopian FBDG and a healthy eating index described as a three-phase process. A multidisciplinary technical working group was established to develop FBDG for the general population above two years of age. Priority diet-related public health problems and risk factors and a systematic review of dietary patterns related to the identified priority health outcomes following a multi-step process.

In **Chapter 3** we reviewed systematic reviews and developed dietary recommendations for the general population above two years for the Ethiopian food-based dietary guidelines (FBDG). Systematic reviews or meta-analyses of experimental trials or observational studies were eligible if they investigated the impact of foods, food groups, diet, or dietary patterns on nutritional status (protein-energy, vitamin A, zinc, calcium, folate), cardiovascular diseases (CVD), or type 2 diabetes mellitus (T2DM). The results showed that not many studies on the impact of diet on protein-energy malnutrition or micronutrient deficiencies were published. Consumption of 30-90g of whole grains each day reduces the risk of CVD and T2DM. Consumption of 15-35g of nuts and seeds per day increases antioxidant levels such as vitamin E and A and lowers CVD and blood sugar levels. Pulse consumption of 50-150g per day or four servings (400g) per week reduces the incidence of CVD and T2DM. Milk and dairy foods are good sources of calcium and help improve bone mineral density among adults and children. Processed meat intake to less than 50 grams per day and eat more fish reduce CVD risk. Sugar consumption should be less than 5-10% of total energy daily to lower the risk of obesity, CVD, and T2DM. the association of saturated fatty acids with CVD and T2DM is inconclusive. CVD and T2DM risks are reduced when 200-300 grams of vegetables and fruits are consumed each day. Plant-based diets lower the risk of CVD and T2DM and reduce micronutrient bioavailability.

Chapter 4 reports on the test of the acceptability, cultural appropriateness, consumers' understanding, and practicality of the Ethiopian food-based dietary guideline's messages, tips, and food graphics. A qualitative study design was applied with focus group discussions

and key informant interviews. Four different participant groups were included: 40 consumers, 15 high-level nutrition experts, 30 health extension workers (HEWs), and 15 agriculture extension workers (AEWs) to incorporate different stakeholder perspectives. The results indicated that most of the study participants were highly interested in implementing the dietary guidelines once these guidelines are officially released. Based on the participants' views, most of the messages align with the current nutrition education materials implemented in the country, except the messages about physical activity and alcohol intake. However, participants suggested defining technical terms such as ultra-processing, whole grain, and safe and balanced diet in simpler terms for a better understanding. Practicality, affordability, availability, and access to the market were the major barriers reported for adherence to the guidelines. To be inclusive, findings showed that the dietary guidelines should address fasting and traditional cooking methods.

Chapter 5 describes the development of a healthy diet for Ethiopian women of reproductive age that closely resembles their current diet while tracking the cost difference. Linear goal programming models were built for three scenarios (Model 1 or non-fasting, Model 2 or continuous fasting, and Model 3 or intermittent fasting) using as input date of two days of 24-hour dietary recall (24 HDR). These data were collected from 494 Ethiopian women of reproductive age in November and December 2019. The model minimized a function of deviations from nutrient reference values. Women's mean energy intake was above 2000 kcal across socio-demographic characteristics. The amounts of milk and dairy foods (396 versus 30 g/day), nuts and seeds (20 versus 1 g/day), and fruits (200 versus 7 g/day) were higher in the modelled diets than in the current diet. Except for calcium and vitamin B12 in the continuous fasting diet, the proposed diets for Ethiopian women of reproductive age during non-fasting, continuous fasting, and intermittent fasting can provide an adequate intake of the targeted 11 micronutrients. The proposed diet had a maximum cost of 120 Ethiopian birr ($3.5) per day, which was twice the current diet's cost.

In **Chapter 6** the general population's Ethiopian healthy eating index (Et-HEI) for estimating adherence to the 2022 Ethiopian Food-Based Dietary Guidelines (FBDG) in women of reproductive age developed and evaluated. Ethiopian women of reproductive age were sampled from 494 households of different regions and cities (Amhara, Oromia, Tigray, Southern nations nationality, and Addis Ababa). The Et-HEI consists of 11 components, classified as adequacy, moderation, or optimum, based on the evidence on diet-disease relationships and contribution to nutrient adequacy. Each component was scored between 0 and 10 points, and thus the total Et-HEI scored from 0 (minimum) to 110 (maximum) for utmost adherence to the FBDG. The Et-HEI score was evaluated against the Minimum Dietary Diversity score for Women (MDD-W), the probability of nutrient intake adequacy, and differences in sociodemographic characteristics of the women. The average Et-HEI score for women of reproductive age was 49 out of 110. A low MDD-W (3.5) was also reflected. Most of the women consumed grains, vegetables, legumes, fat and oils, and salt components. Due to low intake as recommended, almost all women received a score of 10 for sugar and alcohol consumption. Most women did not consume fruits, nuts, or animal-sourced foods. The Et-HEI showed an increasing trend in the probability of nutrient adequacy across quartiles except for vitamin B12, thiamine, vitamin C, calcium, and zinc. Women who completed high school and above had lower Et-HEI, also when adjusting for energy intake. The Et-HEI score was low, indicating the study population's consumption patterns had poor adherence to the Ethiopian FBDG. Low nutrient adequacies confirmed poor adherence to the FBDG.

In **Chapter 7** the results are discussed and an overall conclusion is presented. Ethiopia's current diet is lacking in both quantity and quality. Malnutrition and diet-related non-communicable diseases are a public health concern due to insufficient dietary intake and other related factors. Except for calcium and vitamin B12 in the fasting diet, it is possible to develop a feasible optimal diet for fasting and non-fasting women of reproductive age that can meet their daily energy and nutrient requirements. Women of reproductive age should consider alternative calcium and vitamin B12 sources in addition to the recommended diet during the fasting period. Further adapting Ethiopian food-based dietary guidelines will help ensure that they are acceptable, understandable, culturally appropriate, and practical. Integrate FBDG into efforts to transform the food system, and ongoing research, monitoring, and evaluation of FBDG will aid in fully implementing the dietary guidelines. The most recent dietary intake data are necessary for this. The cost of a healthy diet is twice as much as the current diet. Healthy diets should be affordable, available, and accessible in Ethiopia, which hence requires food system changes. For a better context-specific FBDG at the community level, the Ethiopian FBDG should be adapted to different cultures, living conditions, and subpopulations, and including include environmental sustainability. The Et-

HEI is an important tool for monitoring and evaluating the impact of interventions that target the improvement of diets or reaching healthy diets (one of them) an outcome.

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About the author

Tesfaye Hailu Bekele was born in Addis Ababa, Ethiopia, on June 19, 1985. Tesfaye attended Medhanealem Elementary School and Addis Ketema Secondary School in Addis Ababa for his primary and secondary education. He obtained his bachelor's degree in Applied Chemistry in 2007 from Jimma University's Ambo College of Agriculture (now Ambo University). Tesfaye completed his bachelor's thesis on the water quality of the rivers surrounding Abmo city. In September 2007, he began working as a Junior Researcher at the Ethiopian Public Health Institute (EPHI, formerly known as Ethiopian Health and Nutrition Research Institute) in Food Science and Nutrition Research Directorate. Tesfaye worked at the institute as a laboratory quality officer and at various levels of the researcher’s career. Tesfaye started a master's degree in Applied Human Nutrition at Hawassa University, Ethiopia, in September 2011 and graduated in November 2013. As part of his master's degree requirements, Tesfaye researched "Correlation of maternal nutritional status with breast milk content of iron, zinc, and vitamin A in rural southern Ethiopia".

Since receiving his MSc, Tesfaye has been involved in various nutrition research and national surveys in Ethiopia. He has served at EPHI as a Food Science and Nutrition Research Directorate director. For the past four and half years, Tesfaye has been enrolled as a PhD candidate and conducted his PhD research on the Ethiopian Food-Based Dietary Guideline: Development, Evaluation and Adherence Monitoring. In his PhD, he aimed to develop the first country-specific food-based dietary guidelines and a healthy eating index based on available evidence and primary data collected at the household level in Ethiopia. Tesfaye took the initiative to develop a separate proposal for FAO to receive funding, about 300,000 USD, for the Ethiopian food-based dietary guideline development in addition to his PhD duties. He was also involved in the project coordination and FBDGs national committee. During his PhD training, Tesfaye assisted in MSc courses and supervised ten MSc thesis students and one ACT project. He was a member of the editorial board of Newtrition (the Division PhD and Post-doc newsletter) at the division of Human Nutrition and Health, Wageningen University and Research, and a scientific committee member in Agriculture and Nutrition (ANH) academic week annual conference organized by the London School of Hygiene and Tropical Medicine. Currently, Tesfaye is a postdoctoral researcher at Wageningen University.

List of Publications

Published in peer-reviewed journals

Moss C, Kuche D, **Bekele TH**, Salasibew M, Ayana G, Abera A, Eshetu S, Dangour AD, Allen E. Precision of measurements performed by a cadre of anthropometrists trained for a large household nutrition survey in Ethiopia. Current developments in nutrition. 2020 Sep;4(9):nzaa139.

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Gebru M, Remans R, Brouwer ID, Baye K, Melesse MB, Covic N, Habtamu F, Abay AH, **Bekele TH**, Hirvonen K, Kassaye T. Food systems for healthier diets in Ethiopia: Toward a research agenda. IFPRI Discussion Paper. 2018.

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Ayana G, **Bekele TH**, Kuche D, Abera A, Eshetu S, Petros A, Kebede A, Tessema M, Allen CM, Salasibew MM, Dangour AD. Linkages between health and agriculture sectors in Ethiopia: a formative research study exploring barriers, facilitators and opportunities for local level coordination to deliver nutritional programmes and services. BMC nutrition. 2017 Dec;3(1):1-7.

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Kennedy E, Tessema M, **Bekele TH**, Zerfu D, Belay A, Ayana G, Kuche D, Moges T, Assefa T, Samuel A, Kassaye T. Multisector nutrition program governance and implementation in Ethiopia: opportunities and challenges. Food and nutrition bulletin. 2015 Dec;36(4):534-48.

Submitted publications

Bekele TH, Trijsburg LE, Brouwer ID, de Vries JHM, Covic N, Kennedy G, Alemayehu D, Feskens EJM. Dietary recommendations for Ethiopians based on priority diet-related diseases and causes of death in Ethiopia: A review of systematic reviews. Submitted.

Bekele TH, Covic N, Alemayehu D, Trijsburg LE, Brouwer ID, Feskens EJM. [2], de Vries JHM. The feasibility of implementing the Ethiopian food-based dietary guideline's messages and food graphics: a qualitative study. Submitted.

Bekele TH, van Rooijen M, Gerdessen JC, Brouwer ID, Feskens EJM, Trijsburg LE, Alemayehu D, de Vries JHM. Developing Feasible Healthy Diets for Ethiopian Women of Reproductive Age during Fasting and Non-fasting - A linear goal programming approach. Submitted.

Bekele TH, de Vries JHM, Feskens EJM, de Weijer A, Brouwer ID, Covic N, Trijsburg LE. Development of the Ethiopian Healthy Eating Index (Et-HEI) and Evaluation in Women of Reproductive Age. Submitted.

Overview of completed training activities

Discipline specific activities	Organizer and location	Years
Modelling of habitual dietary intake	WUR, Wageningen	2017
Healthy and sustainable diets: synergies and trade-offs	WUR, Wageningen	2017
Workshop on Food system for healthier diet - A4NH	WUR, Wageningen	2017
Post graduate course "Healthy Food Design"	WUR, Wageningen	2018
Food system and climate change	Colombia, New York	2018
Agriculture for Nutrition and Health Academic Week	LSHTM/FAO, Accra	2018
FBDG development and evaluation workshop	EPHI, Addis Ababa	2018
Compact 2025 conference	IFPRI/FAO, Bangkok	2018
Decision Science 1	WUR, Wageningen	2021
FAO diet modeling solver package	FAO/EPHI/WUR, Rome	2021

General courses	Organizing institute	Year
The Essentials of Scientific Writing and Presenting	WUR, Wageningen	2017
VLAG PhD week	VLAG, Baarlo in Netherlands	2018
Philosophy and Ethics of Food Science and Technology	VLAG, Wageningen	2018
Information Literacy PhD including EndNote introduction	WUR, Wageningen	2018
Grant proposal Writing	WUR, Wageningen	2018
5th Annual WHO/Cochrane/Cornell Summer Institute for systematic reviews in nutrition for global policy-making	Cornell University, New York	2018
Teaching and Supervising BSc and MSc thesis students	WUR, Wageningen	2018
African Nutrition Leadership Programme	North West University of South Africa and ENLN, Bishoftu in Ethiopia	2019
Intensive Scientific Writing	WUR, Wageningen	2022

Optional courses and activities	Organizing institute	Year
Analyzing household income, consumption and expenditure survey	IFPRI/EPHI, Addis Ababa	2018
STATA Training	EPHI/IFPRI, Addis Ababa	2018
Global burden of disease national and sub-national result review workshop	University of Washington and EPHI, Bishoftu	2019
Facilitate Ethiopian Nutrition Leaders Training	MOH/ENLN, Bishoftu	2020

Teaching and Academic Advisor	Hours of work, location	Year
HNE- 39806 Hidden Hunger, Micronutrient deficits in developing country	40 hours, Wageningen	2018
Academic advisor for ACT project titled Sharing taste better: affordable meals from the world kitchen with high nutritional values and social impact	20 hours, Wageningen	2021
Supervised 9 MSc and 1 BSc students	540 hours, Wageningen	2017-2022

Colophon

The advisory committee for this research included:
Dr Inge D. Brouwer, Associate Professor at the Division of Human Nutrition and Health, Wageningen University.
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