Research Topics

Food-based dietary guidelines

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Food-based dietary guidelines

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Editorial: Food-based dietary guidelines

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Editorial on the Research Topic
Food-based dietary guidelines

Food-based dietary guidelines (FBDGs) are among the most widely used public health tools for translating nutrition science into practical advice for populations. By offering culturally adapted and evidence-based recommendations on food choices, portion sizes, and dietary patterns, FBDGs aim to promote health, prevent disease, and increasingly, address the sustainability of food systems. However, despite their global spread (more than 100 countries now have national FBDGs), challenges remain in ensuring their accessibility, cultural adaptability, methodological rigor, and integration into coherent food and nutrition policies.

This Research Topic, *Food-based dietary guidelines*, brings together diverse contributions that address key aspects of the design, application, and evaluation of dietary guidelines across different populations and settings. Together, the articles collected here highlight both persistent gaps and innovative approaches in the development and implementation of FBDGs, offering lessons that are highly relevant for researchers, policymakers, and practitioners.

The affordability of healthy eating is a cornerstone for the successful implementation of dietary recommendations, particularly in low- and middle-income countries. In their study, Gonzabay-Parrales et al. illustrated the stark economic barriers faced by families in Quito and Guayaquil, in Ecuador. The authors demonstrated that following a healthy diet requires almost half of the basic monthly salary, making it inaccessible to many households. This work underscores the urgent need for policies that improve access to healthy foods and incentivize local trade between producers and consumers. Without addressing economic constraints, FBDGs risk remaining aspirational rather than actionable.

Several contributions have highlighted how actual dietary behaviors align—or fail to align—with recommended guidelines. In Sweden, the study by Mulkerrins et al. assessed food intake among young adults with different dietary practices. Despite differences in consumption patterns—such as higher intakes of legumes and plant-based substitutes among vegans and vegetarians—the overall adherence to FBDGs was low, particularly for fruits, vegetables, nuts, and whole grains. Similarly, the study by Rohm et al., based on the third Bavarian Food Consumption Survey, revealed that a large proportion of adults in Bavaria, Germany, do not meet FBDG recommendations, echoing findings from two decades earlier. Although some improvements were observed, such as reduced meat and soft drink consumption, deficiencies in fruit, vegetable, and whole grain intake persist, with potential risks of nutrient insufficiency. Together, these studies remind us that dietary guidelines are only as effective as the population's capacity and willingness to follow them. Monitoring dietary behaviors over time remains essential for evaluating the impact of guidelines and identifying priority areas for intervention.

Another group of articles focused on tools to assess diet quality and their alignment with FBDGs. In Canada, Panahimoghadam et al. compared the Healthy Eating Index-Canada, the Diet Quality Index-International, and the Healthy Eating Food Index 2019. The authors showed that these indices vary in their discriminatory power and agreement, leading to different interpretations of children's diets. Their call for consensus highlights the importance of methodological alignment to ensure coherent dietary monitoring and policy guidance. In this sense, in the United States, Katz et al. introduced an adaptation of the Healthy Eating Index to better reflect multicultural dietary patterns. This innovation allows recognition of nutritional quality across diverse diets, moving toward more inclusive and equitable assessment tools.

Portion size guidance is a core yet often underexplored element of FBDGs. Two studies in this Research Topic addressed this issue directly. The article from Salesse et al. examined the methodological approaches to deriving portion sizes across 96 countries, finding limited variation by method but some regional differences, particularly for fish and shellfish. In a second, complementary study, the same authors revealed substantial inconsistencies across regions, especially in definitions and classifications of food groups. Both studies highlight the potential of harmonizing portion size recommendations to improve clarity and comparability. Supporting these efforts, Fallata et al. provided a structured approach for creating reliable food atlases. These visual tools, which include culturally relevant portion sizes and utensils, can play an important role in dietary assessment and in communicating guidelines to diverse populations once validated through further study.

Finally, two articles extended the discussion to the policy arena. The article from De Matteu Monteiro et al. highlighted the potential of risk–benefit assessment as a structured, evidence-based approach to guiding food and nutrition policy. Despite methodological advances, the translation of such assessments into concrete policies remains limited, calling for stronger integration between science and regulation. In Southeast Asia, Thanh Nguyen et al. evaluated national strategies against international standards. While progress has been made, important gaps remain, particularly in the inclusion of interventions for women and adolescents. This work emphasizes the importance of aligning national policies with global evidence while maintaining sensitivity to local contexts to ensure progress on reducing non-communicable diseases.

The contributions to this Research Topic underscore the complexity of designing, implementing, and evaluating FBDGs in a rapidly changing food environment. They demonstrate that, while methodological progress is being made—through harmonized portion size recommendations, improved diet quality indices, and adaptive tools—significant challenges remain in terms of affordability, cultural inclusivity, and policy alignment.

While the articles included in this Research Topic provide valuable insights into diet affordability, adherence, methodological frameworks, and policy alignment, other important aspects raised in the original call remain underexplored. Future research should address how best to communicate dietary recommendations through effective visual designs, the role and placement of ultra-processed foods within FBDGs, and additionally, the integration of traditional dietary patterns, social food behaviors, and culturally embedded practices. This integration is key to ensuring the relevance and uptake of guidelines across diverse populations. Finally, the incorporation of environmentally sustainable advice into FBDGs—balancing health, culture, and planetary boundaries—should be prioritized to align dietary recommendations with the urgent goal of transforming the food system. By advancing these areas, future research, with greater interdisciplinary collaboration, harmonization of methods across regions, and stronger integration with policies, can help ensure that FBDGs remain dynamic, inclusive, and impactful tools for improving public health, equity, and environmental sustainability.

Author contributions

CG: Writing – original draft, Conceptualization. GR: Conceptualization, Writing – original draft. NT: Conceptualization, Writing – original draft.

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Bridging the evidence-to-action gap: enhancing alignment of national nutrition strategies in Cambodia, Laos, and Vietnam with global and regional recommendations

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Nutrition policies are critical frameworks for tackling the triple burden of malnutrition, including undernutrition (i.e., stunting and wasting), overweight, and hidden hunger (i.e., micronutrient deficiencies). We examined (1) the alignment of recent National Nutrition Strategies and Action Plans (NNS) in Cambodia, Laos, and Vietnam with recent global and regional recommendations and standards with a focus on maternal, infant, and young child nutrition and (2) changes compared to the previous NNS. We extracted information regarding the context, objectives, interventions, indicators, strategies, and coordination mechanisms from the most recent NNSs in Cambodia (2019–2023), Laos (2021–2025), and Vietnam (2021–2030). Recent NNSs aimed to reduce malnutrition among priority populations and described program development, monitoring, and evaluation plans for the following interventions: breastfeeding promotion, improved complementary feeding, dietary diversity, safe water, food security, nutritional/health campaigns, strategies for vulnerable groups, and strengthening of policies related to food and nutrition. Direct interventions to improve women's general nutrition (outside of pregnancy) and adolescent nutrition were not the focus of any NNSs. Although some indicators (e.g., wasting and exclusive breastfeeding) were covered in all recent NNSs, other indicators (e.g., low birth weight and childhood overweight and obesity) were inconsistently incorporated. In comparison to the previous NNS, the following interventions were discontinued in three countries: dietary counseling, maintaining physical activity, monitoring weight gain during pregnancy, maternal micronutrient supplementation, and nutrition and HIV. Despite similarities in structure and content, the recent NNSs of Cambodia, Laos, and Vietnam do not consistently align with global and regional recommendations. Variations in the types of interventions and indicators included may reflect a shift in priorities, attention, or resources. In conclusion, the NNSs of Cambodia, Laos, and Vietnam exhibit both structural and content similarities; however, certain interventions and indicators vary across countries and differ from global and regional recommendations. Enhancing alignment while prioritizing country-specific needs, optimizing coordination, ensuring policy efficacy, and updating nutrition strategy data for cross-country comparisons and knowledge exchange is critical to ensure progress on reducing malnutrition in the region.

KEYWORDS

ASEAN, maternal, infant, and young child nutrition (MIYCN), national nutrition strategy (NNS), plan of action for nutrition, Southeast Asia

1 Introduction

Before the COVID-19 pandemic, most countries in the world were already facing a triple burden of malnutrition (1, 2). Globally, nearly 600 million, or 30% of all girls and women aged 15–49 years, are affected by anemia; almost 150 million, or 22% of all children aged 0–5 years, are stunted; and 2.2 billion people are overweight, of whom 772 million are obese (1). Since the COVID-19 outbreak and the war in Ukraine, the number of people facing food insecurity has increased from 148.6 million (in February 2020) to 344.5 million (in June 2022) (3). Food insecurity, both in general and in this specific crisis, has had a significant impact on the nutritional status of the entire population, particularly among those with lower socioeconomic status (3–5). Food insecurity during these crises has led to poor maternal and women's health outcomes, including increased rates of maternal depression, malnutrition, and death, as well as adverse pregnancy outcomes such as stillbirth and ruptured ectopic pregnancies. Additionally, it has contributed to childhood stunting, wasting, infectious diseases, and mortality (4, 5). To provide an overview of national nutrition policies, plans of action, and programs, the World Health Organization (WHO) conducted a *Global Nutrition Policy Review* in 2009–2010 and 2016–2017 (WHO, 2013, 2018) and, in 2012, adopted six Global Nutrition Targets (GNTs): stunting, anemia, low birth weight, exclusive breastfeeding, wasting, and childhood overweight (1, 2). Countries worldwide are off course on five out of six GNTs (i.e., stunting, anemia, low birth weight, wasting, and childhood overweight), as well as Sustainable Development Goals (SDGs) related to nutrition, including no poverty, zero hunger, good health, and well-being (6), and all diet-related non-communicable disease (NCD) targets (i.e., salt intake, high blood pressure, adult obesity, and diabetes) (1–3). At the current rate of progress, the challenges arising from the war in Ukraine, climate change, and the continued impact of COVID-19 preclude meeting the GNTs and SDGs by 2030 (1, 2).

Most countries in Southeast Asia are experiencing the triple burden of malnutrition, including undernutrition (i.e., stunting and wasting) overweight, and hidden hunger (i.e., micronutrient deficiencies) (7–11). Of the eleven Southeast Asian countries, nine exhibit a high or very high prevalence of stunting (≥ 20%) and wasting (≥ 5%), while five have a medium, high, or very high prevalence of overweight (≥ 5%) among children under 5 years of age (7, 10). Nearly half of children under the age of 5 in Southeast Asia experience micronutrient deficiencies (7, 8, 11). In this region, school-aged children and women also suffer from a high prevalence of malnutrition (7). In a data review of height for people born between 1896 and 1996 in 200 countries, seven of the 11 Southeast Asian countries belong to the lowest 20th percentile for height among adult men and women, and adults in the region showed minimal change in average height from 1896 to 1996 (12). Furthermore, malnutrition in this region is influenced by emerging factors such as inadequate social protection systems, limited access to clean water and sanitation, food insecurity, inadequate dietary quality, the impact of climate change, globalization, urbanization, and evolving agricultural production methods (7, 8, 11).

Comprehensive policies are acknowledged as a pivotal element in a country's approach to addressing the triple burden of malnutrition (11, 13, 14). Since the inaugural International Conference on Nutrition (ICN) in 1992, nations have adopted national nutrition strategies and action plans (NNS) to eradicate all forms of malnutrition (13, 14). The Association of Southeast Asian Nations (ASEAN) Member States agreed on a regional framework and strategic plan to *End all Forms of Malnutrition* (15). Recently, ASEAN members have endorsed the *Guidelines and Minimum Standards for the Protection, Promotion, and Support of Breastfeeding and Complementary Feeding* (hereinafter referred to as the ASEAN Guidelines) (16), while concurrently developing additional nutrition-related standards for women and children.

Data from the *Report on Nutrition Security in ASEAN* published in 2016 (8) and 2021 (11) shows insufficient progress toward meeting GNTs by 2025, suggesting that in most ASEAN Member States, children start life at a disadvantage, as high rates of stunting, wasting, and overweight are prevalent among children under 5 years of age. Individuals and families encounter a variety of obstacles—economic, physical, social, and cultural—in their pursuit of nutritious diets and access to adequate health and nutrition services, affecting both food environments and the availability of essential, high-quality nutrition services (11). We previously conducted an NNS review of Southeast Asia in 2017, which included Vietnam, Laos, and Cambodia as well as Brunei, Indonesia, Malaysia, Myanmar, the Philippines, and Timor-Leste (17). The review showed that all NNSs included interventions involving antenatal care, micronutrient supplementation during pregnancy, breastfeeding promotion, improved complementary feeding, nutrition in emergencies, and food fortification or dietary diversity. Furthermore, all NNSs had measurable indicators and targets for program monitoring and evaluation plans and addressed collaboration mechanisms, involvement, roles, and responsibilities among stakeholders and sectors. Items found in most, but not all NNSs, included micronutrient supplementation in young children, breastfeeding promotion during pregnancy and support at birth, school feeding, deworming, and treatment of severe acute malnutrition. This review found that despite similarities in the structure and content of Southeast Asian countries' NNSs, their interventions and indicators varied and did not consistently align with global and regional recommendations. Furthermore, these NNSs did not prioritize issues such as obesity and chronic diseases despite their emergence and burden in Southeast Asia. Some of the gaps identified included a lack of strategies for stakeholder engagement, costing data, and in some NNSs, indicators to track the prevalence of anemia, low birth weight, childhood overweight, breastfeeding, and wasting (17).

All NNSs in the previous review (17) have since been published and updated while the burden of malnutrition has increased. Therefore, a new analysis is needed to examine the progress made toward meeting new targets and aligning national targets with global and regional recommendations. In this paper, we reviewed the contents of the most recent NNS in Cambodia, Laos, and Vietnam; analyzed changes from the previous NNS, and examined their alignment with global and regional recommendations and norms, including the recently released nutrition standards (16) and *Report on Nutrition Security in ASEAN* (11).

1.1 Key messages

- National Nutrition Strategies and Action Plans (NNSs) in Cambodia, Laos, and Vietnam adopted a structure and incorporated content that is aligned with the guidelines established during the First International Conference on Nutrition in 1992.
- Recent NNSs are more closely aligned with global and regional recommendations, compared with previous NNSs.
- There is variation across country NNS interventions and indicators, showing inconsistent adherence to global and regional recommendations.

2 Subjects and methods

We conducted a desk review of the most recent NNS in Cambodia, Laos, and Vietnam with a focus on maternal, infant, and young child nutrition (MIYCN) (18–20). We extracted information using an extraction form from our previous publication (17), which was developed based on earlier literature (7, 13, 21–26). In addition, we integrated information from the ASEAN Guidelines (16). We heavily adapted the methods used in our previous publication (17) and provide a brief description of the methods as follows.

2.1 Policy identification

The full text of the latest NNS documents, as of March 31, 2022 (18–20), was acquired through collaboration with national stakeholders in Cambodia, Laos, and Vietnam. The NNSs were officially translated into English and released by their respective countries. The ASEAN Guidelines were obtained from the ASEAN websites (16). GNTs 2025 (27) and 2030 SDGs (6) were obtained online from the WHO and UN websites. We did not perform similar analyses in other Southeast Asian countries due to a lack of national stakeholders to identify, collect, and translate NNS documents, as well as validate the findings.

2.2 Information extraction form

The information extraction form includes information on general characteristics of NNSs, policy context, goals, objectives, strategies, interventions, implementation, monitoring and evaluation, resources, as well as sectors and stakeholders' roles, policy involvement, and collaboration mechanisms (17). In 2021, WHO and UNICEF released an update to infant and young child feeding (IYCF) practices assessment (28). As a result, new indicators of unhealthy food and beverage consumption were added to this review under the Infant and young child nutrition section of Table 1, (28). Nutrition indicators from ASEAN Guidelines are low birthweight, stunting, wasting, childhood overweight and obesity, iron deficiency anemia, Vitamin A deficiency, exclusive breastfeeding, timely introduction of complementary foods, minimum meal frequency, minimum dietary diversity, and minimum acceptable diet (11). The previous NNS review included nutrition indicators for infants but not for women (29). Due to the high malnutrition burden, this review includes three new nutrition indicators: minimum dietary diversity, minimum meal frequency, and minimum acceptable diet (Table 1) to assess feeding practices for infants and women across ASEAN countries.

2.3 Information extraction, management, and analysis

We extracted information from the NNSs and ASEAN Guidelines using an extraction form adapted from our previous study (17). Initially, one researcher reviewed the NNSs and ASEAN Guidelines, and a second researcher conducted a cross-check for accuracy. The findings were then shared with a government representative in Vietnam, staff in Cambodia, and an implementing partner from Save the Children in Laos for verification and input. We provided descriptive findings in tables to allow the comparisons (1) within a country with the older NNS, (2) among other countries, and (3) against regional and global standards. We have also collected information to discuss recent major changes in the NNS of the selected countries and to identify gaps concerning regional and global recommendations.

3 Results

Cambodia, Laos, and Vietnam have adopted NNSs as comprehensive national frameworks to improve maternal, infant, and young child nutrition. The most recent NNSs for Cambodia, Laos, and Vietnam were released in 2019, 2021, and 2022, respectively (Table 2). Cambodia and Laos' NNSs were approved in the same year the policy was effective, while Vietnam's NNS policy was approved 1 year later (Table 2). The structure of the three NNSs conformed to the framework established by the ICN in 1992 and provided a well-defined description of the country's context during policy formulation (Supplementary Table S1).

Compared with the previous NNS, the recent NNS included new policy objectives, specifically: (1) to improve diet (Laos), (2) to improve micronutrient status (Cambodia), (3) to prevent and control overweight, obesity, or other chronic diseases (Cambodia), (4) to improve knowledge and practices regarding nutrition in the general population (Laos), (5) to strengthen the national or local health system and workforce (Cambodia), and (6) to reduce inequities or barriers in access to care (Vietnam) (Supplementary Table S1). We listed interventions relating to women at reproductive age, during pregnancy, and the perinatal period (Table 3). Cambodia, Laos, and

TABLE 1 Nutrition indicators included in national nutrition strategies, by country[a].

	GNTs 2025	SDGs 2030	ASEAN Guidelines	Cambodia		Laos		Vietnam	
			2022	2014–2018	2019–2023	2016–2020	2021–2025	2011–2020	2021–2030
Infant and young child nutrition									
Low birthweight	√		√			√	√	√	√
Stunting	√	√	√	√	√	√	√	√	√
Wasting	√	√	√	√	√	√	√		√
Underweight				√	√	√	√	√	
Childhood overweight and obesity	√	√	√		√	√		√	√
Iron deficiency anemia			√	√	√	√	√	√	√
Vitamin A deficiency			√	√				√	√
Iodine deficiency disorders						√		√	√
Early initiation of breastfeeding				√		√			√
Exclusive breastfeeding	√		√	√	√	√	√	√	√
Continued breastfeeding at 1 and 2 years				√					
Timely introduction of complementary foods			√			√			
Minimum meal frequency			√			√			
Minimum dietary diversity			√			√		√	
Minimum acceptable diet Sweet beverage consumption Unhealthy food consumption			√	√	√	√			√
Nutrition status of women of reproductive age									
Iron deficiency anemia	√			√	√	√	√	√	√
Chronic energy deficiency (BMI < 18.5 kg/m²)				√				√	
Overweight and obesity				√	√			√	√
Minimum dietary diversity									

[a]GNTs, World Health Assembly's Global Nutrition Targets; SDGs, United Nations' Sustainable Development Goals.

Vietnam aligned with the regional ASEAN Guidelines on dietary counseling in recent NNSs. Maternal micronutrient supplementation was included in all three countries' previous and recent NNSs (Table 3). Interventions related to breastfeeding promotion during pregnancy were included in the ASEAN Guidelines and Laos and Vietnam's NNSs, while Cambodia's NNS discussed breastfeeding promotion and support but did not specify the timing, e.g., during pregnancy or at birth (Table 3).

In comparison with the previous NNS, the following interventions were dropped: dietary counseling, keeping physically active, or tracking weight gain during pregnancy (three countries), maternal micronutrient supplementation (Cambodia, Laos, and Vietnam), deworming during pregnancy (Laos and Vietnam), breastfeeding support at birth (Cambodia and Laos), and family planning (Laos) (Table 3). Balanced energy-protein supplements during pregnancy were dropped in the three countries' NNSs. Although Cambodia's NNS briefly shared progress on nutrition-related interventions for women of reproductive age and Laos mentioned the importance of nutrition education for adolescent girls, the three countries' updated NNSs primarily focused on direct interventions to improve nutrition for young children and women during pregnancy, rather than adolescents and women at reproductive age and in the perinatal period (19, 20).

Regarding interventions for neonates, infants, and young children, improved complementary feeding, school feeding program interventions, and deworming were included in all three NNSs, with the three countries also aligning on regional ASEAN recommendations for improved complementary feeding (Table 3). Interventions dropped in recent NNSs in this category included zinc supplementation in Cambodia and Laos (excluded in both the past and recent NNSs in Vietnam) (Table 3). Iron and Vitamin A supplementation was included in Laos and Vietnam but dropped for Cambodia (Table 3). Treatment of moderate/severe acute malnutrition was mentioned in the NNSs of Cambodia and Vietnam, but not Laos (Table 3). Both Laos and Vietnam dropped infectious disease prevention and management intervention, while this was a new intervention picked up by Cambodia (Table 3). Interventions related nutrition and HIV were dropped in all three countries in the recent versions (Table 3).

Interventions for food, food safety, and food security aligned with the ASEAN Guidelines and were included in all three countries' recent

TABLE 2 Characteristics of national nutrition strategies reviewed, by country[a].

	Date of Approval	Material policy instrument	Governing resources			
			Information, knowledge	Authority	Treasury	Organizational structure
Cambodia						
National Strategy for Food Security and Nutrition 2014–2018	Apr. 2014	√	√	√	√	√
National Strategy for Food Security and Nutrition 2019–2023	Nov. 2019	√	√	√	√	√
Laos						
National Nutrition Strategy to 2025 and Plan of Action 2016–2020	Dec. 2015	√	√	√	√	√
National Plan of Action on Nutrition 2021–2025	Oct. 2021	√	√	√	√	√
Vietnam						
National Nutrition Strategy for 2011–2020, with a vision toward 2030 NPAN Vietnam toward 2015	Feb. 2012	√	√	√	√	√
National Nutrition Strategy for 2021–2030, with a vision toward 2045 and NPAN Vietnam toward 2025	Jan. 2022	√	√	√	√	√

[a]Categories of policy instrument: material (to result in changes in actual); symbolic (to articulate aspirations for social betterment).
Governing resources: information or knowledge (to educate or change behavior of policy targets); authority (to regulate); treasury (to specify the availability and its use of financial resources); organization structure (to stipulate tasks to be done by relevant sectors or stakeholders).

and previous NNSs (Table 3). For example, these interventions are dietary diversification; safe water, sanitation, or hygienic practices; and food security, food market, and trade (Table 3). Subsidies for agricultural production, land use, or reform were not included as recommended interventions in the ASEAN Guidelines (Table 3). Some interventions were less consistent across all three countries, e.g., food fortification interventions (Cambodia and Vietnam), nutrition in emergencies (Laos and Vietnam), food safety (Cambodia and Vietnam), and social safety nets (Cambodia) (Table 3). Interventions for disease prevention and control were less consistent with ASEAN guidelines and all three countries' NNSs. Dropped interventions were nutrition and HIV (all three NNSs) and hypertension, diabetes, or cardiovascular diseases (Cambodia and Laos) (Table 3). Newly added interventions not presented in previous NNSs included a reduction of alcohol consumption or tobacco usage (Laos) and a reduction of sugar and fat-added foods, sweetened beverages, or salt consumption (all three countries) (Table 3).

Cross-cutting strategies in all three NNSs included national health campaigns, mass communication, agriculture or food system strengthening, interventions for vulnerable groups, and social or community mobilization (Table 3). Interventions included in some NNSs were interpersonal communication (Vietnam), and health system strengthening (Cambodia and Laos) (Table 3).

Supportive policies and legislation interventions, specifically food fortification regulations and food safety, were in all three NNSs while others, such as health insurance to cover nutrition-related services, were only in Vietnam's recent NNS and the ASEAN Guidelines. Policies and legislation on the marketing of breastmilk substitutes were included in ASEAN guidelines and the recent NNSs of the three countries (Table 3). Maternity leave and workplace lactation support as a part of maternity protection are only listed in Cambodia and Vietnam's recent NNSs and ASEAN Guidelines (Table 3). Policy objectives related to non-communicable diseases were included in two NNSs (Cambodia and Vietnam) (Supplementary Table S1). All three NNSs included indicators relating to MIYCN listed in the GNTs. Infant and young child nutrition indicators varied but included: low birth weight (Laos), stunting (all three countries), wasting (all three countries), underweight (Cambodia and Laos), childhood overweight and obesity (Cambodia and Vietnam), iron deficiency anemia (Cambodia and Laos), Vitamin A deficiency (Vietnam), and iodine deficiency disorders (all three countries). While some indicators for breastfeeding practices were in recent NNSs such as early initiation of breastfeeding (Vietnam) and exclusive breastfeeding (all three countries), indicators such as continued breastfeeding at 1 and 2 years were not included (Table 1).

Some nutrition indicators present in previous NNSs were dropped in recent NNSs, resulting in the recent NNSs' failure to align with regional ASEAN Guidelines. These indicators include the timely introduction of complementary foods (Laos), minimum dietary diversity (Laos and Vietnam), and minimum acceptable diet (Laos).

Recent NNSs include indicators related to the nutrition status of women of reproductive age, including iron deficiency anemia (all three countries) and overweight or obesity (Cambodia and Vietnam) (Table 1). However, chronic energy deficiency ($BMI < 18.5 kg/m^2$), which was previously included in Cambodia and Vietnam's NNSs, was no longer mentioned in any of the three countries' newest NNSs (Table 1).

As indicated in Table 4, each NNS delineated the roles, responsibilities, collaborative mechanisms, and execution framework, specifying whether the strategy operates within a focal sector, involves multiple sectors, or engages various stakeholders. The roles of

TABLE 3 Interventions included in national nutrition strategies, by country.

	Effect[a]	ASEAN Guidelines	Cambodia		Laos		Vietnam	
		2022	2014–2018	2019–2023	2016–2020	2021–2025	2011–2020	2021–2030
Women at reproductive age during pregnancy and at childbirth								
Dietary counseling, keeping physically active, or tracking weight gain during pregnancy	3	√	√	√		√	√	√
Balanced energy-protein supplementation for pregnant women	1[b]		√		√		√	
Maternal micronutrient supplementation during pregnancy (including iron folate, calcium, multiple micronutrients, or iodine)	1/ 1[b]		√	√	√	√	√	√
Deworming in pregnancy	1[b]				√		√	
Deliveries supported by skilled attendant	NR							
Breastfeeding promotion during pregnancy (including individual and group counseling)	1	√				√	√	√
Breastfeeding support at birth (including essential newborn care and the Baby-Friendly Hospital Initiative)	1[b] / 2	√	√		√			
Women's empowerment, the prevention of domestic violence or gender-based violence	1[b] / NR	√	√	√	√	√		
Family-planning interventions to promote birth-spacing	2				√			
Neonates, infants, and young children								
Breastfeeding promotion (individual and group counseling; including exclusive breastfeeding under 6 months, and prolonged breastfeeding at 1 and 2 years)	1	√	√	√	√	√	√	√
Improved complementary feeding (including timely introduction of complementary foods, dietary diversity, and meal frequency)	1	√	√	√	√	√	√	√
Zinc supplementation (including those for diarrheal children)	1	√	√		√			
Iron supplementation	1[b]	√	√		√	√	√	√
Vitamin A supplementation	1	√	√		√	√	√	√
Deworming	1[b]		√	√	√	√	√	√
Feeding for sick children (including diarrhea and respiratory infection)	NR	√			√		√	
Treatment of moderate / severe acute malnutrition	1	√	√	√	√		√	√
Infectious diseases prevention and management (e.g., diarrhea, acute respiratory infection, malaria)	1/ 1[b]	√		√	√		√	
School feeding programs	3		√	√	√	√	√	√
Food, food safety and food security								
Universal salt iodization	1	√	√	√	√		√	√
Food fortification (including Vitamin A, iron)	1[b]	√	√	√	√		√	√
Dietary diversification strategies, small animal husbandry, or home gardening	2	√	√	√	√	√	√	√
Safe water, sanitation, or hygienic practices	1	√	√	√	√	√	√	√

(Continued)

TABLE 3 (Continued)

	Effect[a]	ASEAN Guidelines	Cambodia		Laos		Vietnam	
		2022	2014–2018	2019–2023	2016–2020	2021–2025	2011–2020	2021–2030
Food safety, quality control, the prevention of food-borne diseases, or food labelling	NR	√	√	√	√		√	√
Food security, food market, and trade	1[b] /NR	√	√	√	√	√	√	√
Nutrition in emergencies	1[b]	√	√		√	√	√	√
Social safety nets, cash transfers, microcredit programs, food-for-work programs, or generalized food subsidies	1[b] /NR	√	√	√				
Agricultural production subsidies, land use, or reform	1[b] /NR		√	√	√		√	
Nutrition care for disease prevention and treatment								
Nutrition and HIV	1/ 1[b]	√	√		√		√	
Hypertension, diabetes, or cardiovascular diseases	NR		√		√		√	√
Increased physical activities	NR	√					√	√
Reduction of alcohol consumption or tobacco usage	1					√		
Reduction of sugar and fat-added foods, sweetened beverages, or salt consumption	NR	√		√		√		√
Cross-cutting strategies								
Mass communication	3	√	√	√		√	√	√
Interpersonal communication	1	√	√		√		√	√
Nutritional or health campaigns	3	√	√	√	√	√	√	√
Health system strengthening	NR	√	√	√	√	√	√	
Agriculture or food system strengthening	1	√	√	√	√	√	√	√
Specific strategies for vulnerable groups	1/ 1[b]	√	√	√	√	√	√	√
Integrated program monitoring and evaluation	1[b]	√	√	√	√	√	√	
Social or community mobilization	NR	√		√	√	√	√	√
Supportive policies and legislations								
Strengthen legislations on food fortification	NR	√	d	√	d	√	d	√
Strengthen legislations on food safety	NR		√		d		√	
Strengthen policies and commitments relating to food and nutrition; or incorporating nutrition goals into relevant laws, regulations, policies, and plans.	NR	√	√	√	√	√	√	√
Strengthen legislations on marketing of breastmilk substitutes	NR	√	√	√	√	√		√
Health insurance to cover nutrition, curative care for young children, or nutrition preventative care	NR	√						√
Strengthen legislations on maternity leave or workplace lactation support	NR	√	√	√			√	√

[a]Intervention effectiveness on maternal and child nutrition: (1) sufficient evidence; (2) insufficient or variable evidence; and (3) little or no evidence; NR, not reviewed (21, 23, 30).
[b]Interventions effective in specific context. d, under development.

governmental stakeholders, both at the national and sub-national levels, were assessed based on their contributions in terms of financial resources, provision of technical support, and implementation (Supplementary Table S2). Typically, the concept of technical support encompassed the involvement of international organizations, donors, the private sector, and academic or research institutions (Supplementary Table S2). Each NNS presented this information uniquely, with variations in the level of detail. Within the content of each NNS, Cambodia, Laos, and Vietnam all dedicated specific sections to elucidate the sectors or stakeholders involved.

TABLE 4 Sectors and stakeholders involved in national nutrition strategies, by country.

	Cambodia		Laos		Vietnam	
	2014–2018	2019–2023	2016–2020	2021–2025	2011–2020	2021–2030
Sectors involved						
Health and Nutrition	√	√	√	√	√	√
Agriculture	√	√	√	√	√	√
Food industry	√	√	√			√
Education		√	√	√	√	√
Culture, Information, Communication		√	√	√	√	√
Science, Technology, Environment		√	√	√		√
Labor, Social affairs	√	√	√	√	√	√
Finance		√	√	√		√
Internal and external trade		√	√	√		√
Planning, Investment		√	√	√	√	√
Stakeholders involved[a]						
National level (including Government, Parliament, and Ministries)	√	√	√	√	√	√
Sub-national levels (including provincial, city, district, and sub-district local authorities in various sector such as civil, health, nutrition, education agriculture)	√	√	√	√	√	√
Civil society organizations, or unions[b]	√	√	√	√	√	√
International organizations, or donors[c]	√	√	√	√	√	√
Private sector	√	√		√		√
Academic or research institutions	√	√		√	√	√
Contains section dedicated to sector and stakeholder involvement	√	√	√	√	√	√
Clearly describes the roles and responsibilities of sectors and stakeholders	√	√	√	√	√	√
Collaboration mechanism indicated	√	√	√	√	√	√

[a]Data allow for specific contributions such as technical support, financial support, or implementation are included in Appendix 2.
[b]Civil society organizations and unions include unions (Trade, Women, Farmers, and Youth), societies (Veterans, Teachers, Elderly), and religious, villages and tribe leaders.
[c]International Organizations, donors include UNICEF, WHO, FAO, World Bank, other development bank (e.g., ADB), governments of other countries (e.g., USAIDS, Australian Aid, UK Aid), Foundations (e.g., Bill & Melinda Gates Foundation), research foundation, and international non-Governmental Organizations (NGOs), and In-country donors.

4 Discussion

4.1 Alignment with global and regional standards

For over 25 years, NNSs have played a pivotal role in enhancing nutrition planning, implementation, monitoring, and evaluation, contributing to improved nutrition and health outcomes globally (13, 22). The structures and contents of recent NNSs in Cambodia, Laos, and Vietnam aligned with the 1992 ICN (13), which facilitated information capture and application (13, 20, 22). However, recent NNS are not comprehensive enough to meet global standards (i.e., 2025 GNTs and 2030 SDGs) or ASEAN regional standards despite increased efforts made since the previous NNS review (17). To meet regional standards and address these gaps as nutrition changes in the region from food system globalization, urbanization, and economic growth (11), countries must take steps to standardize process nutrition indicators, promote recommended interventions, and monitor progress toward meeting target indicators (19, 20).

4.2 Dynamic changes in the content of NNSs

While the recent NNSs of Laos, Vietnam, and Cambodia include plans to combat malnutrition, they exhibit a notable absence of comprehensive details regarding context, objectives, interventions, indicators, strategies, and coordination mechanisms when compared to their previous NNS documents (20). We compared the most recent NNSs to the previous versions to analyze and explain differences and trends in measuring malnutrition. We identified several noteworthy trends in these three countries. First, some interventions and indicators present in previous NNSs have been omitted in the most recent strategies, including balanced energy-protein supplementation for pregnant women (all three NNSs), zinc supplementation (Cambodia and Vietnam), iron supplementation (Cambodia), universal salt iodization (Laos), and chronic energy deficiency (Vietnam) (Tables 1, 3). Laos' NNS acknowledged the inclusion of a smaller set of 22 indicators and 36 interventions compared to the previous NNS and attributed the change in indicators from the previous NNS as a response to prioritization in areas such as climate change, gender equality, and nutrition in disasters and emergencies (19, 20). One possible reason was the onset of the COVID-19 pandemic, which emerged in 2020. As a result of the COVID-19 pandemic, Laos' recent NNS mentions the disruption of nutrition-related services while Cambodia's "Roadmap for Food Systems for Sustainable Development" highlights the need to strengthen existing systems (e.g., health, economic, agricultural, and food) to better prepare for future events like the COVID-19 pandemic (19, 20). NNS priorities may have shifted due to key decision-making events and meetings held online because of COVID-19 restrictions and may have led to the exclusion of individuals who advocate for and shape countries' food systems and contribute to plans' development and adoption. Cambodia's "Roadmap for Food Systems for Sustainable Development" mentions that the roadmap was developed at the height of the COVID-19 pandemic, and the lack of critical voices and transition to online events occurred because of COVID-19 restrictions (19).

Another potential reason for the reduction in the number of indicators and interventions between previous and recent NNSs is significant progress made on previous indicators and interventions, resulting in a focus on other priorities. For example, iodine was no longer an indicator for Laos' recent NNS due to improvements in household consumption of iodized salt and children's iodine levels (18). In Vietnam, there was a 10 years difference since the last NNS release. During this time, it is likely that the NNS's recent strategy reflected the changing country context regarding a shift in focus to nutrition policies and school nutrition. In Vietnam, chronic energy deficiency (a body mass index of less than 18.5 kg/m^2) became rare and thus excluded from the recent NNS. Cambodia's NNS may not fully reflect the change in the landscape due to reliance on outdated data (19) from the most recent nationally representative nutrition survey at the time of publication: the 2014 Cambodia Demographic and Health Survey (CDHS). The most recent CDHS was released after the NNS was released (19). Indicators and targets listed in the three NNS were mostly nutrition indicators. Table 1 includes a list of the six GNTs (27). The only GNTs tracked by all three countries were iron deficiency anemia for women of reproductive age and stunting for children under 5 years. The three countries did not align on the other four GNTs, thus limiting the utility of NNSs to track the region's contribution and progress toward meeting all six targets by 2025.

Another possible reason for the reduction of indicators in the most recent NNSs is a lack of reliable and available data in areas ranging from interventions and implementation to monitoring and evaluation. For example, Laos revised its nutrition measures and indicators after discovering that the agriculture sector was not able to track these indicators (20). Despite Cambodia NNS shifting focus toward breastfeeding to address the decline in breastfeeding rates over the past few years, there is limited data on the effectiveness and manner in which breastfeeding-related interventions are implemented (19). Data is limited even for areas on which all three countries align, such as dietary diversification strategies, small animal husbandry, or home gardening and safe water, sanitation, or hygienic practices (8).

All three countries' NNSs lacked information on interventions for women during the preconception period or for adolescents (other than during pregnancy for women at reproductive age), except for Vietnam with the indicator on anemia among 10–14-year-old girls (18–20). This major gap has been highlighted previously in this region and globally, citing a lack of data on the diets of these groups (8, 14, 16, 31). These populations should be a focus for both nutrition and non-nutrition interventions to ensure that women of reproductive age are physically and psychologically ready for pregnancy, thus improving the quality of pregnancy, reducing complications, and improving birth outcomes (7). The lack of data prevents countries from learning, adapting, and applying best practices toward global and regional contexts, and places additional constraints on areas such as decision- and policymaking, coordination, and implementation.

These results underscore the necessity to boost capacity, provide support to governments at various levels to reallocate policy and resources toward evidence-based interventions and programs, and actively implement, monitor, and evaluate multisectoral interventions to address the complex challenge of the triple burden of malnutrition during health emergencies.

These results underscore the need to boost capacity, provide support to governments at various levels to reallocate resources toward evidence-based interventions and programs, and actively implement, monitor, and evaluate multisectoral interventions to tackle the triple burden of malnutrition amid health emergencies (7, 8, 11).

4.3 Delays in release date remain a key challenge of NNS

While NNSs are useful in setting goals and measuring national progress on a wide range of nutrition indicators, they also have some limitations. First, for the three countries, there was an approximate one-year delay in the approval compared to the duration of the policy and there was no improvement in terms of the timing compared with the previous policy reviews (17). This means there is at least a one-year gap in the direction and resources for NNS implementation. Evaluating the achievement of a previous NNS and planning for a new one requires progress and impact data from the national survey, surveillance, and monitoring data. Member states should maximize available data from international sources such as UNICEF, WHO, WB, and Global Nutrition Reports to inform the progress. In addition, countries should promote a robust, streamlined, reliable electronic monitoring system for inputs, outputs, outcomes, and impacts to facilitate the planning.

Second, identifying and adopting new interventions or indicators during the drafting or implementation process is challenging. This, combined with the lack of data and insufficient human resource capacity in many ASEAN countries, hinders the effective implementation of nutrition interventions (16). Since countries are unable to use their impact study to inform these interventions, using global and regional evidence can be a good approach to inform interventions and indicators. However, there is also a gap in time between the release of the global guidelines and evidence and the inclusion into NNS. Policymakers would need to wait until the next round of NNS to include new interventions and indicators recommended by global guidelines. The late release of NNS is affected by a lack of evidence, consensus, or champions (32, 33).

Successful planning and implementation of an NNS requires the involvement of different stakeholders and sectors and an understanding of nutrition and health status, priorities, and policies between countries (13, 22). In Cambodia, Laos, and Vietnam, NNSs require further collaboration between sectors and countries involved with addressing malnutrition to ensure cohesion and comparability among NNS frameworks and address the triple burden of malnutrition (11). However, similar to the findings from the Global Nutrition Policy Report (14), we observed that not all NNSs explicitly outlined sector and stakeholder involvement or financial commitments. This omission can hinder governments' ability to hold stakeholders accountable for their contributions to achieving GNTs. Consequently, the responsibility for nutrition programs tends to fall primarily on the nutrition and health sectors (14), which may prevent the country or region from applying a comprehensive systems approach to promote nutrition and health status effectively, efficiently, and sustainably (7, 14). These study findings may also support ongoing efforts within ASEAN to establish a regional surveillance system among member states.

4.4 Study strengths

To the best of our knowledge, we are among the few researchers who have conducted a review of recent NNSs in lower- and middle-income countries, comparing them with recent global and regional recommendations and standards. We evaluated changes compared to previous NNSs. Our study employed standardized methods, including the use of a questionnaire, an information extraction form, and a rigorous review and validation process. These methods have been successfully applied in our previous study, which was peer-reviewed and published.

4.5 Study limitations

There are some limitations to our study including only Cambodia, Laos, and Vietnam because of the research team's access to national stakeholders for identifying, collecting, translating NNS documents, and interpreting and validating the study findings. Nevertheless, our approaches and tools could be applied by other researchers for similar research in different settings. Our findings are primarily focused on comparing national policies with regional and international standards, rather than directly comparing countries. However, the detailed information is available in the data tables.

Finally, we were unable to provide information on intervention implementation or results, as these topics fall beyond the scope of our study. It is important to note that our focus lies on policy analysis rather than evaluating the effectiveness of policies or their implementation. Additionally, we could only provide certain assumptions about the reasons behind the findings, such as the presence or absence of specific indicators or interventions. Further studies would be necessary to delve deeper into these aspects.

5 Conclusion

The NNSs of Cambodia, Laos, and Vietnam exhibit structural and content similarities, with a focus on promoting breastfeeding and enhancing complementary feeding. Despite certain alignments, there are some variations among countries and between NNS with international and regional standards. Factors such as COVID-19, shifting priorities, and data availability drove indicator adjustments in NNSs. To enhance coordination and policy efficacy, updating nutrition strategy data for cross-country comparisons and knowledge exchange is vital. Addressing NNS gaps through enhanced capacity, coordination, and governance ensures alignment with regional standards and amplifies the focus on MIYCN. This approach guarantees a successful and sustainable approach across the region.

Author contributions

TN: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. PH: Data curation, Validation, Writing – review & editing. PZ: Conceptualization, Data curation, Formal analysis, Investigation, Validation, Writing – review & editing. MW: Conceptualization, Validation, Writing – review & editing. JC: Conceptualization, Validation, Writing – review & editing. SC: Data curation, Validation, Writing – review & editing. RM: Conceptualization, Funding acquisition, Resources, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1277804/full#supplementary-material

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Risk–benefit assessment of foods and its role to inform policy decisions: outcome of an international workshop

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Policy decisions in public health require consideration and evaluation of trade-offs for which transparency and science-based evidence is needed. Improvement of decision-support tools is essential to help guide food policy decisions that promote healthy diets and meet the challenges of food systems without compromising food security, food safety, and sovereignty. Risk–benefit assessment of foods (RBA) is an established methodological approach designed to inform policy decisions within the area of nutrition and food safety. Despite methodological developments, translation of RBA findings into policies is still limited. In this context, a stakeholder workshop held in May 2023 gathered RBA experts and food regulators from Europe to identify the challenges, obstacles and opportunities in using evidence generated through RBAs to inform food policy decisions. A structured process was implemented to collect their views through online surveys, breakout groups, and plenary discussions. As a secondary objective, food regulators' views on other approaches for holistic risk assessment fit for food systems analysis were also explored. This paper summarizes the main findings of the workshop and discusses policy implications and future perspectives to improve the area of RBA and its role in food policymaking.

KEYWORDS

risk–benefit assessment, food policy, decision-making, health impact assessment, holistic approaches

1 Introduction

Governance targeting healthy and safe diets has been a central part of international strategies to reduce the burden of communicable and noncommunicable diseases (1, 2). As dietary habits are still among the leading behavioral risks factors contributing to global mortality, strengthening food policies and public health actions related to dietary choices remains crucial to reduce the burden of disease of populations (3, 4). Since these public health policies need to be prioritized to tackle the most important risk factors, while ensuring that food safety risks are not introduced, there is an increasing need for decision-support tools that are able to evaluate the health impact of diets and food systems considering both nutrition and food safety (5, 6).

Risk–benefit assessment (RBA) of foods is a decision-support tool that estimates the public health impact of foods and diets by evaluating both beneficial and adverse health effects in different exposure (e.g., often consumption) scenarios (3, 7). The evidence generated in RBAs aims to support priority-setting and formulation of policies that are coherently aligned across several disciplines (i.e., nutrition, toxicology, and microbiology) (8, 9). RBA builds on the risk assessment framework by mirroring its four steps (i.e., hazard identification, hazard characterization, exposure assessment and risk characterization) in a parallel assessment for beneficial effects (10, 11).

RBA and its methodologies have evolved over the past decades (3, 5, 7). Several case-studies and activities for capacity building for RBAs have been conducted within many research projects financed by the European Union (EU) (7–10, 12, 13). These case studies predominantly assessed the health impacts of scenarios of consumption of specific foods (e.g., fish and seafood; nuts; rice) (14–16); of food substitutions (e.g., meat for fish; meat for pulses) (17–19) including substitution scenarios with novel foods (20); or individual food components (e.g., iodine; folic acid) (21, 22). These studies have also led to an increased interest in RBA by the scientific community, and a growing body of evidence in risk–benefit relations of different foods and dietary patterns in populations across the EU. Furthermore, RBAs have been adopted by several food authorities including the European Food Safety Authority (EFSA), which recently updated their guidance on human health RBA, firstly published in 2010 (23–25). Despite this broad interest, these activities have not been accompanied by timely translation of knowledge into policies. Thus, there is a need for unraveling the potential of RBAs and increasing its visibility among regulatory bodies to ensure a wider application in policy making settings. If links between RBAs, risk–benefit management decisions, and communication of dietary recommendations are strengthened, more transparency and effective public health actions related to dietary choices could potentially be achieved (5, 26). This paper contributes to the limited literature that discusses the role of RBA and the gaps hindering its practical applications into policy decisions related to foods.

The HOLiFOOD project, a four-year research project (2022–2026) funded by the European Commission under the Horizon Europe Program and aiming to introduce a holistic approach for tackling food systems risks in a changing global environment (27), gathered a group of RBA experts and food regulators for an international workshop. The main objective of the workshop was to identify the challenges, obstacles, and opportunities in using evidence generated through RBAs to inform food policy decisions in the European context. Since RBAs could be an adaptable tool for food system analysis and useful to inform potential impacts of dietary shifts caused by different drivers such as sustainability and climate change, stakeholders´ views on the broader applications of RBAs were also briefly investigated. Hence, secondary objectives of the workshop were: (i) to investigate to which extent food regulators were aware or previously used output from RBA to support regulatory tasks related to public health in food safety and nutrition; and (ii) to explore food regulators' views on other approaches for holistic assessment, defined as the integrated assessment of health and sustainability impacts of food systems. This paper summarizes the main findings of the workshop, contributing with the yet emergent and novel debate on the implications and future perspectives of RBA for an enhanced role in food policy.

2 Methods

2.1 Workshop structure

The stakeholder workshop "Health Risk–Benefit Assessments: from Science to decision-making" was held online in May 2023, with a cohort of participants consisting of risk–benefit assessors, managers, and communicators. A structured process was implemented to gather the views of experts in RBA, experts in risk (and benefit) communication, and food policymakers through online surveys, group and plenary discussions.

An initial pool of participants was created based on the networks of the HOLiFOOD consortium members and by searches of relevant food authorities across different EU Member States. The individual people contacted were free to redirect or expand the invitation of the workshop with their coworkers if they wished so. Participation in the workshop was voluntary and followed the EU General Data Protection Regulation (GDPR) enforced in the HOLiFOOD project. The approach applied to engage with participants was structured in four steps: anonymous voluntary surveys (prior and during the workshop); an introductory keynote presentation; breakout groups with guided discussion points; and a final moderated plenary discussion.

2.2 Pre-workshop and in-workshop surveys

Invitations to participate in the pre-workshop survey were sent out to the invitees that confirmed interest and availability to attend the meeting approximately 1 month prior to the event. The pre-workshop survey which was supported by the SurveyXact platform,[1] served to tailor the workshop content and query the invited participants about any potential discussion points that were expected to be covered during the meeting, besides collecting information on the participants' background, expertise, and level of knowledge of RBA. During the workshop, the collaborative online tool Mentimeter[2] was applied to collect and display to the group the participants' background, level of knowledge, and experience on RBA, as well as to address the secondary objectives of the workshop by collecting their views on the need for RBA approaches that consider non-health dimensions in RBA. The tool was used prior to the breakout groups and at the end of the workshop. The audience's response was displayed to all participants and served as feedback and prompt to start discussions. The questionnaires are available in the Supplementary material.

2.3 Break-out groups and plenary discussions

During the discussion sessions, participants were invited to reflect on previous experiences on RBA application or usage of

1 https://rambollxact.com
2 www.mentimeter.com/

results and the information presented by the keynote speaker, and to contribute to moderated discussions on the following topics:

> *Theme 1*: Challenges of using RBAs to inform food-related policy decisions (e.g., could challenges be related to the structural organization of authorities?).
>
> *Theme 2*: Opportunities and needs concerning RBAs (e.g., could challenges be related to the reliability of the RBA methods?).
>
> *Theme 3*: Communication of RBAs (e.g., could challenges be related to how the results are communicated?).

The selected themes were associated with one or more components of the risk–benefit analysis paradigm (Figure 1), as proposed by Nauta et al. (8). Participants were divided into three groups. The workshop's facilitators ensured that each group had a similar number of participants with diverse backgrounds, and that all breakout groups discussed the three themes. During the breakout session, participants were invited to express their views at will. The information collected during the workshop was captured by three different rapporteurs and video recording.

In plenary, rapporteurs of each breakout group summarized the key discussion points, followed by the moderated discussion at plenum. After the information was extracted for analysis and cross-checked, the video recording was deleted.

3 Results

In total, 17 anonymous volunteers participated in the pre-workshop survey. Respondents suggested a variety of topics to be addressed in the workshop, ranging from questions on data requirements for RBA and methodological considerations to possible expansion of RBA approaches beyond health concerns (Table 1). All proposed topics were included as discussion points in the workshop. Due to time constraints, the suggested topics that were not specific to the health dimension were only addressed more broadly during the session on holistic approaches.

About half of the invitees confirmed both interest and availability to contribute to the workshop (initial pool of participants were approximately 50 people). In total, the stakeholder workshop gathered 37 participants from 19 institutions across 13 countries (see Appendix). The initial level of familiarity with RBA varied. Most of the participants had prior knowledge of RBAs, as self-stated in the surveys (familiar with RBAs, $n = 10$; some general knowledge on RBAs, $n = 7$; limited to no RBA knowledge, $n = 6$; preferred not to answer, $n = 14$).

During the workshop, either in plenary or in the breakout groups, participants shared examples of relevant RBA cases conducted in their country (e.g., on fish consumption or to inform recommendations on consumption of nuts), and exchanged lessons learned in their countries when communicating findings or using outputs from RBAs to support regulatory tasks. Additionally, discussion points brought up by participants and covering the themes previously introduced are presented below. A summary of main actions addressing the

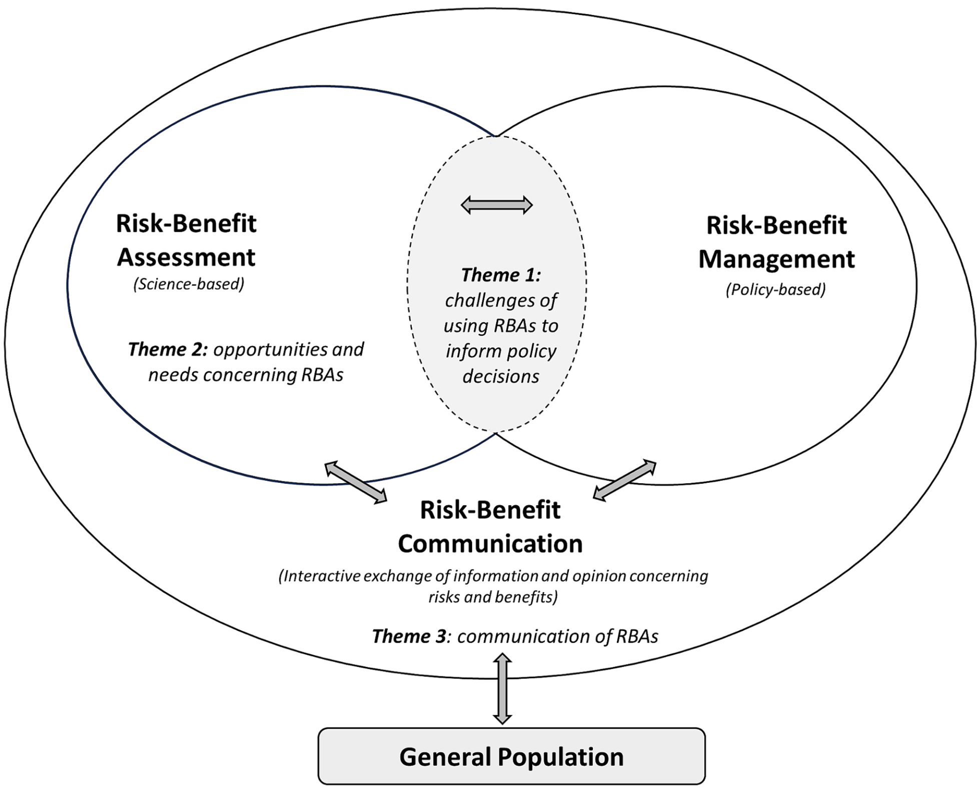

FIGURE 1
The risk–benefit analysis paradigm and the discussions' themes of the workshop. Adapted from Nauta et al., licensed under CC BY 4.0 (8).

TABLE 1 Discussion points related to risk–benefit assessment (RBA) of foods suggested by participants in the pre-workshop survey.

Discussion points suggested by respondents
• What is the type of data needed and minimum requirements?
• How to compare different risks or benefits, and in which scale or metric?
• Uncertainties in RBA
• Selection of health components
• Real-life examples of how risk–benefit studies have managed to reach policymakers
• With exception of fish and seafood products, for which other food categories would RBA be useful
• Systematic approaches to handle uncertainties in RBAs
• Shortcoming of the RBA models
• Ways to communicate the results of RBAs to the public
• Is performing RBAs the responsibility of risk assessors or risk managers?
• How to quantify and rank risks when different health outcomes (chronic and acute) are considered together
• Could RBAs be more informative to risk managers if it was not exclusively centered on human health?
• Have more comprehensive RBAs (addressing multiple contaminants in foods)
• RBAs and socio-economics issues

challenges, needs, and opportunities identified in the workshop and clustered by the authors are presented in Figure 2.

3.1 Challenges of using RBAs to inform food-related policy decisions

This theme identified and discussed challenges of using RBAs to inform food-related policy decisions. Participants recognized that, in countries across the EU, food safety and nutrition are traditionally separated domains, which is also reflected in the structural organization of food authorities. Consequently, it was argued that this division between nutrition and food safety departments may determine the type of questions posed by policymakers to risk (and benefit) assessors, and thus impact on the type of evidence being generated. It was highlighted that this "dissociation" of decision-making problems may lead to processes, priorities, and evidence being used to inform food policy decisions to result in separate actions within each of these fields. Therefore, requests for evidence formulated "in silos" was identified as one possible obstacle to addressing problems in a multidisciplinary approach as well as to promoting multisectoral actions across food safety, nutrition, and potentially sustainability. In this context, strengthening the communication between risk–benefit assessor and manager, alongside with multidisciplinary collaboration at risk management level could be considered as important elements for improving the formulation of decision-making problems.

In terms of collaboration between food safety and nutrition departments for RBAs, both successful and challenging examples at national level were reported. In one of the examples, disentangling interests to communicate outputs that translates both risks and benefits in an equal manner was reported as difficult, especially if external stakeholders were involved.

For the subtheme on holistic approaches, participants highlighted the need for future assessments to appropriately account for sustainability factors. Although RBAs could serve as a stepping stone for developing methods to assess the multi-dimensional impacts of foods by taking a food systems approach, several challenges linked to holistic approaches were discussed. For example, including other dimensions beyond health in RBAs might make the assessment resemble a decision-making process, as opposed to a process that provides evidence for decision-making. This can be problematic as the roles between risk assessors and managers will no longer be clearly defined. Furthermore, integrating other dimensions such as economic and environmental factors may increase the complexity and resources, including data, needed for the assessment. This could also increase the uncertainty introduced in the results and complicate the communication of outputs. Concerns in relation to the potential loss of information and transparency when dimensions are integrated were also expressed. Policy makers should be able to discern and navigate through the results of assessments from the micro (i.e., each dimension) and macro (i.e., integrated dimensions) perspective. In summary, it was suggested to run individual (i.e., single dimension) assessments before integration into one metric or output.

Lastly, an important challenge hindering the adoption of RBAs at a larger scale and internationally is that many countries still have neither the data nor the capacity needed to carry out RBAs. Hence, a clear actionable point highlighted was to continue supporting initiatives to build capacity within RBAs, as well as mapping country-specific data gaps and making data accessible.

3.2 Opportunities and needs concerning RBAs

This theme aimed at identifying ways to overcome obstacles related to the acceptability of RBA methods. Participants identified a variety of methodological, communication and awareness-raising needs to enhance the use of RBA outputs for regulatory decisions. They also acknowledged opportunities to address some of these needs. Opportunities and needs are summarized and presented in Table 2.

Discussion in this theme emphasized that the selection of health components to be included in the model should be guided by objective criteria and a structured review of available scientific evidence and evaluation of its strength. However, time and resources do not always allow for a systematic review of the evidence, which may lead to biased choices in the selection of evidence and data used in the RBA. Furthermore, the lack of data to characterize risks and/or benefits may lead to incomplete assessments, an issue to which traditional health risk assessment is also subjected. Some participants noted that integrating risks and benefits in a balanced way is also challenging because risks, in comparison to benefits, are continuously evolving, with new contaminants often being discovered and assessed.

Finally, the expansion of RBA across countries and operationalization of RBA at global scale was discussed. Nevertheless, it can be argued that an RBA focused on a specific region or country is often more informative due to national and regional differences in, e.g., dietary habits, nutrient intakes, and contamination levels. Data reflecting variability in these factors could also lead to lower consumer trust if different RBAs on the same food yield divergent advice. As in risk assessment, this can be justified by the fact that RBA case studies are highly dependent on the data used and the populational context.

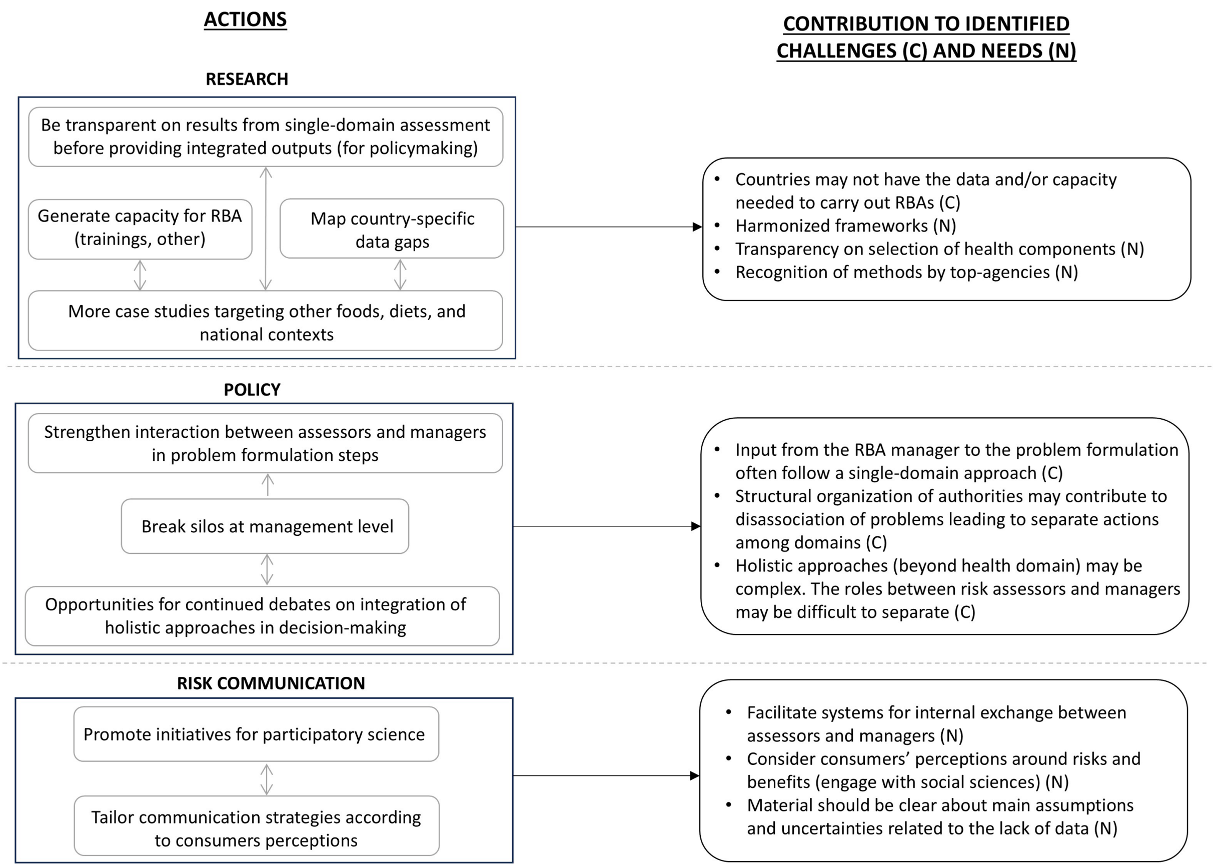

FIGURE 2
Summary of suggested actions to increase the adoption of risk–benefit assessment (RBA) for food-related policies and contributions of the identified challenges and needs following the findings of the international stakeholder workshop.

3.3 Communicating RBAs

Communicating both risk and benefits to citizens is important to ensure that dietary recommendations and trade-offs linked to dietary choices can be better understood. It was emphasized that the communication materials targeted to consumers should be clear about the fact that people are always protected by regulatory food safety frameworks. Some participants stressed that although food safety is never to be compromised, it is also relevant to demonstrate to consumers that some risks may be acceptable trade-offs for benefits. In addition, it was identified that to improve communication of RBA outputs, the communication materials and tools used to target policy-maker need to be different from those targeting citizens. Particularly for citizens, risk–benefit communication can have significant gains if investing in dialogs with the public, especially in understanding consumers´ perceptions around risks and benefits. To achieve this, expertise in social sciences is essential to help formulate appropriate communication strategies targeting consumers. Moreover, whether the target is citizens or food regulators, communication of RBA needs to include the assumptions and uncertainties of the approach, in addition to the main findings.

4 Discussion

To date, most of the publications on RBA have focused on the developments and future directions of the methodological framework, including articles reporting results of case-studies. Some authors have reviewed the different types of RBA studies (28–31), showing that most published case-studies have predominantly been conducted in the European context. Yet, to the best of our knowledge, no publication has tackled the bottlenecks in the practical application of the RBA findings to inform food-related policies. As the interaction and communication between risk–benefit assessors and regulators is of the utmost importance, the workshop outcome is regarded as a valuable contribution to the further development and implementation of RBA.

During the workshop, participants identified a variety of obstacles to using RBA outputs to inform regulatory decisions. These current obstacles explain the still limited translation of RBA findings into food-related policies and need to be addressed to ensure that decision maker can use this type of evidence that integrates knowledge from the multiple disciplines relevant to food systems. The workshop highlighted challenges, needs, and opportunities for RBAs that may be translated into tangible actions to further advance in this field. Although the online stakeholder workshop was short (less than half day program), the inputs reflected the diversity in background and geography of the participants and are helpful to guide current processes and next actions within RBAs.

Despite several methodological achievements, harmonization of RBA frameworks and simplified approaches are needed. Many of the RBAs carried out to date focused on fish and fish products

TABLE 2 Summary of opportunities and needs for risk–benefit assessment (RBA) development identified by participants of the stakeholder workshop.

Needs	Opportunities
• Simplified RBA approaches, which should be presented as a less complex, resource-demanding and time-consuming calculations.	
• Harmonized frameworks as assessments considering different beneficial and adverse effects while responding to similar risk–benefit questions might generate different advice.	• Development of more RBA case-studies through research projects. Development of harmonized frameworks and methodologies for RBA that can be applied by national research institutions.
• Transparency in communication of approaches, data used, model assumptions, and intermediate and final outputs of RBAs. Consumer trust might be diminished if advice from different assessments differ, and if transparent documentation and explanations are not provided.	
• Objective and transparent framework on how the components to be included in the assessments are selected to ensure reproducibility.	
• Harmonized processes to weigh the strength of available scientific evidence used to inform RBA and select data based on established criteria.	• Accumulated experiences within RBA can support guidelines and ensure communication of methods, results and underlying uncertainties targeted at different stakeholders (scientists, risk managers, citizens, other stakeholders).
• Increased number of case studies, tackling different foods, food components and diets, in different populations and countries.	• Promote training activities to increase capacity for RBA within national and international institutions. Engagement with stakeholders at national and international levels can increase the interest of risk managers to formulate risk–benefit questions and allocate resources for RBAs.
• Enhanced recognition of the utility and relevance of RBA by top agencies (e.g., WHO, FAO, etc.).	• Seek more engagement and active contribution of international agencies where RBA activities have been already introduced (WHO/FAO, EFSA) for the development and applications of RBA case studies (25, 49).

(28–30). Thus, expanding the body of evidence with more case studies that target other foods or diets is important to further demonstrate the applicability of RBA. The experience from additional case studies could be beneficial to tackle obstacles that are interlinked as identified in the workshop (Figure 2). For example, it will help demonstrate the flexibility of the methods, contribute to the identification of data gaps, increase capacity building, provide further inputs for discussions that aim at harmonizing frameworks at international level, and explore ways to improve risk–benefit communication strategies.

A recent study from Boué and colleagues proposed a harmonized strategy to select health outcomes to be included in RBAs (32), resulting in a higher transparency of the selection process. This strategy is based on extensive literature searches, where a long list of components is created, contemplating in equal importance components relevant in nutrition, microbiology, and toxicology domains. This framework is divided into two steps for identifying, evaluating the strength of evidence, and selecting health outcomes based on defined criteria. This approach implies that if a health component is relevant for the RBA but is not included due to limited evidence, it is recommended that data gaps are communicated (32). Similar systematic approaches could be a starting point to enhance transparency on the selection of health components, a need for improvement in RBAs as identified in the workshop. A downside of this approach is that reviewing the literature can be time-consuming, and it is not always possible to conduct a systematic review prior to starting an RBA. This approach may also not be robust enough to capture emergent risks if potential new hazards are not identified in the literature review step or if not part of the risk–benefit question commissioned.

Nonetheless, if reporting on the scoping process of an RBA becomes a common practice among publications, actions to tackle previously identified data gaps could likely be facilitated.

Beside RBA, there are other methods to rank risks of food-related hazards that are also useful to inform food policy decisions (33). For example, based on an FAO guidance on informed decision-making considering multiple factors (34), a study adopted a Multi-Criteria Decision Analysis (MCDA) framework to rank risks from ready-to-eat dishes based on their nutritional, chemical and microbiological hazards (35). Even if the discussion of other methods is not in the scope of this paper, we emphasize the importance of understanding the strengths and limitations of RBAs as well as the type of questions RBAs can help informing so that methods chosen to inform a decision-making problem are fit-for-purpose.

Cross-departmental collaboration at risk–benefit assessor and management level were important elements discussed in the workshop and ways to strengthen partnerships are to be explored. As defining the decision-problem is the first step in health assessments, facilitating inclusion of both food safety and nutritional entities at regulatory level could facilitate the generation and applicability of integrated evidence. Better formulation of decision-making problems could trigger further developments and innovation in current working approaches. This could guide policies that are needed to handle multifaced problems.

Findings of the workshop also give insights for improvement of communication strategies for RBAs. In addition to being transparent on assumptions and uncertainties surrounding the data (or lack of it), participants pointed out the importance of involving social sciences in the development of communication strategies for RBAs. Promoting spaces for exchange and close dialog among researchers, food regulators and citizens is essential as it may help both in early assessment stages (e.g., to set up relevant and well-defined scope for cases studies), and in knowledge translation approaches for research dissemination. A recent review demonstrated the importance of an individual's values and beliefs when purchasing foods (36). For example, in the European market, it was observed that consumers tend to give more importance to chemical risks (e.g., pesticides) than naturally occurring risks (36). The authors also demonstrated that risk acceptability in the population might differ based on the food item, and that understanding consumers´ perceptions on risks and benefits could be a way to tailor and improve communication materials of RBA findings targeted to citizens (36, 37). Furthermore, exploration of appropriated communication channels in relation to media and technological evolution should also be considered (38).

Several recent studies have quantified the negative environmental impact of diets and extensive efforts have been put to ensure that food policies and dietary recommendations are aligned to promote sustainable food systems (39–45). In this context, discussing holistic approaches that can assess the impact of diets and food systems beyond the health domain is extremely relevant (46–48). Due to the multidisciplinary character of the RBAs, participants' views on expanding RBAs to become part of a broader food system analysis were briefly explored in the workshop, as previously proposed in the literature (5).

Moving toward holistic approaches would amplify some of the challenges related to data availability and the integration of different sources of data, increasing the uncertainty in the results and adding complexity in interpreting and communicating outputs. It is important to highlight that holistic approaches do not substitute the value and inputs provided by single domain or dimension assessment but rather inform different types of research questions and decision-making problems. Moreover, holistic approaches could improve transparency about the integration of different lines of evidence and application of outputs in public health policy decisions. Nevertheless, some contributions suggest that the integration of dimensions that involves value-based judgments should be rather conducted by risk–benefit managers.

Given that RBA is a multidisciplinary method, the workshop methodology allowed for more than one member per organization, especially if participants had different fields of expertise and worked in different organizational units. Although the breakout groups were designed to split stakeholders with similar scientific or organizational background, the authors acknowledge this as a main limitation, as the outcomes of the workshop could be subject to potential bias due to the selection and composition of the cohort of participants.

The input from stakeholders and outputs of the workshop demonstrates the need for the RBA community to continue an open dialog and exchange with food regulators for a more thorough discussion on the points raised in this theme. Future opportunities for exchange on RBA translation into policy settings should focus on expanding the topics presented in this work, engaging as well with a larger panel from scientists and regulators from other continents.

5 Conclusion

Stakeholders identified a wide range of needs, opportunities, and challenges to increase the use of RBA to inform food policy decisions. Despite diverse views, RBAs were unanimously acknowledged as a useful tool to generate dietary recommendations, including tailored advice to vulnerable groups of the population, and as a more transparent approach for consumers to understand potential trade-offs among certain dietary choices. While finding single solutions and reaching group consensus to the several obstacles identified were not in the scope of the workshop, main actions to enhance the role of RBA in policymaking as suggested by participants included: (i) developing harmonized approaches, strengthening capacity, and improving communication on RBA outputs, underlying limitations, and uncertainties; and (ii) working toward breaking silos between different disciplines, stakeholders, and risk–benefit assessors and managers.

Data availability statement

The raw data supporting the conclusions of this article is available upon request to the authors.

Author contributions

CDMM: Conceptualization, Visualization, Writing – original draft. J-MM: Supervision, Writing – review & editing. MP: Conceptualization, Supervision, Writing – review & editing. STT: Conceptualization, Supervision, Writing – review & editing. SMP: Conceptualization, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2024.1458531/full#supplementary-material

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Appendix

List of organizations contributing to the workshop.

Organization	Number of participants
ANSES—French Agency for Food, Environmental and Occupational Health & Safety	1
ASAE—Portuguese Economic and Food Safety Authority	1
BfR—German Federal Institute for Risk Assessment	7
DTU—Technical University of Denmark*	7
EC—European Commission (DG SANTE)	1
EFET—Hellenic Food Authority	2
EFSA—European Food Safety Authority	1
FAO—Food and Agricultural Organization of the United Nations	2
FCNAUP—Faculty of Nutrition and Food Sciences from University of Porto	2
FVST—Danish Veterinary and Food Administration	1
Hungarian Ministry of Agriculture	1
INRAE—French National Research Institute for Agriculture, Food and Environment*	1
NVWA—Netherlands Food and Consumer Product Safety Authority	1
Norwegian Food Safety Authority	1
SLV—Swedish Food Agency	2
The Dutch Ministry of Health, Welfare and Sport	1
UVMB—University of Veterinary Medicine Budapest*	1
UNEW—Newcastle University*	2
WHO—World Health Organization	2
*Workshop organizers and/or HOLiFOOD partners	

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A global analysis of portion size recommendations in food-based dietary guidelines

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Objective: Since large food portion sizes (PS) lead to overconsumption, our objective was to review PS recommendations for commonly consumed food groups reported in Food-Based Dietary Guidelines (FBDGs) globally and to assess variation in PS across countries and regions.

Methods: Consumer-oriented FBDGs from the Food and Agriculture Organization (FAO) online repository were used to evaluate dietary recommendations, PS and number of portions for common food groups. Guidelines were classified for each group as qualitative, quantitative, or missing. A standardized approach was applied to convert PS recommendations given as household measures, cup equivalents, pieces and other measures into grams for cross comparison. Variation of recommended PS of common food groups within and across regions was examined.

Results: Among 96 FBDGs, variations were found both across and within regions. At a regional level, the highest median PS recommendations were seen in Europe for Meat, Fish and Pulses, in the Near East for Dairy products, and in Africa for most grain-based foods. Recommendations for Fruits and Vegetables showed the highest consistency across FBDGs worldwide, whereas guidance on Meat, fish & eggs and Cooked cereals/grains showed discrepancies in the classification of foods into categories, as well as in the number of portions per day.

Discussion: While some variation in PS recommendations across countries can be expected due to cultural and regional dietary practices, inconsistent definitions to refer to a portion and varied derivation methods may further produce discrepancies. Harmonizing development methods for FBDG could help establish more consistent reference portion sizes and therefore provide clearer guidance to consumers.

KEYWORDS

food-based dietary guidelines, portion size, dietary recommendations, dietary habits, food groups, healthy diet

1 Introduction

Public health bodies regard food-based dietary guidelines (FBDGs) to be a critical tool to promote healthy dietary habits and reduce the incidence of non-communicable diseases (NCDs). As such, FBDGs have been adopted by around 100 countries globally (1). FBDGs aim to translate the latest scientific evidence into practical food-based guidance for consumers, and therefore they should provide recommendations on both the types and amounts of foods and beverages that should be consumed to meet nutrient requirements, maintain a healthy weight, and prevent chronic diseases (2, 3). Their development typically involves multiple regional stakeholders and considers cultural, social, and economic factors that may affect food choices (4–6). Central to the guidance on the type and amounts of food and beverages to consume is the concept and use of portion sizes (PS). A "portion" is generally referred to as the amount of food that an individual is recommended to consume on one eating occasion (7, 8). PS can be described in grams, as food unit (e.g., one apple, one slice of bread), or with reference to common household measures, such as cup, spoon, plate or others (9). Alongside PS information within FBDGs, a recommended number of portions per day for each food group is often given.

Furthermore, consumers are routinely exposed to a diversity of messages concerning amounts of foods to consume, particularly in countries with labeled serving sizes (SS). While often used interchangeably with PS, SS are reference amounts for consumption, usually provided in grams or standard measures by manufacturers on packaged food products (10, 11). Within each food group, multiple servings can be consumed at one setting in a "portion". PS can in fact be multiples of a single SS recommendation (e.g., one portion of pasta might contain 2–3 servings of the 8–10 recommended servings to be consumed a day). Although referring to different concepts, consumers often interpret labeled SS as a recommended serving for dietary guidelines rather than as typical consumption units (11). The lack of clarity between PS and SS can therefore result in a misinterpretation of dietary recommendations for consumers (11–14). In Europe for example, despite numerous age-appropriate dietary recommendations, a lack of consistent PS recommendations has been recently highlighted (9, 15).

The focus of this paper will be on PS, as used within FBDGs. PS are considered an important factor influencing food intakes and several studies have highlighted their impact on nutrient and health outcomes (16, 17). As PS for many foods have reputedly increased over the past decades, their increase, alongside other changes in food intake and lifestyle, has been linked to the global rise in obesity rates (12, 18–20). Indeed, overweight and obesity result from an imbalance between energy intake and energy expenditure (21, 22), and exposure to larger PS has been directly shown to lead to increased energy intake (known as the portion-size effect) (23, 24). A systematic review of 72 studies found that larger PS were associated with higher energy intake, increased body weight, and a higher risk of obesity (25). In 2014, Zlatevska et al. found that for certain foods, doubling the PS served led to a 35% increase in consumption (10). Adequate and consistent PS guidance could therefore play a crucial role in weight management (18, 19, 26), and the creation of harmonized standard portions for main food groups is considered relevant to improve information to consumers (27).

FBDGs, which include guidance on both the type and amount of foods (2), represent an opportunity to provide suitable PS guidance to populations. The introduction of regional (e.g., the Nordic Nutrition Recommendations (28)) and more recently global guidelines (e.g., the Planetary Health Diet (29)), underscore the ongoing efforts to establish consistent nutritional standards across geographies. However, these guidelines mostly focus on dietary patterns and total intakes per day, not on recommended portions of specific foods. While noted by several in the scientific community as being an important opportunity in providing cohesive nutritional recommendations, harmonization of PS recommendations is yet to be addressed (30).

Current literature shows variation in the PS recommendations provided by FBDGs within regions. A recent review of food PS in European FBDGs found heterogeneity in the attention given to PS recommendations, as well as a notable variation in the gram amount recommended for many staple food items (27). At a global level, little is known about recommended amounts of specific foods in FBDGs, as most studies to date have been limited to certain countries (4) or examined other aspects of the FBDGs, such as sustainability (31). The objective of the present study is to review PS recommendations for the most commonly consumed food groups in dietary guidelines globally and to assess variation across global regions. This work will form a basis for understanding commonalities and discrepancies in the ways that PS are derived and used by public health bodies in FBDGs worldwide.

2 Materials and methods

2.1 Documents screening

The Food and Agriculture Organization (FAO) online repository of FBDGs (1) was accessed between July 1st, 2023 and July 12th, 2024 to obtain a list of countries with published FBDGs. All countries listed on the FAO repository were considered for inclusion in the study. An additional web search was also systematically conducted to capture the latest/most updated versions of each country's FBDGs, as well as additional background documents in the gray literature, using the following keywords: "[country] food-based dietary guidelines AND [scientific report OR scientific development]." All documents related to the listed FBDGs were accessed and downloaded for consideration, regardless of language. Google Translate was used to read documents written in any other language than English, French or Spanish.

The most recent version of all relevant documents was reviewed. For each country considered in this analysis, guidelines and recommendations aimed at the general healthy adult population were considered. The analyses were restricted to adult FBDGs only, therefore recommendations for infants, children, teenagers, elderly, pregnant and breastfeeding women were excluded. With respect to data extraction, a hierarchical process was employed. Consumer-targeted information was considered, rather than materials intended for healthcare professionals (HCPs) or scientific background documents, as this review aimed to evaluate the messages directly communicated to consumers. When multiple documents were available for consumers, the most comprehensive one was used for data extraction and cross-checked against any additional documents.

2.2 Data extraction and analysis

For each FBDG the following information was considered. First, we categorized the recommendations relating to food intake as either quantitative, qualitative, or absent. Quantitative recommendations consisted of a portion or serving size (e.g., "a medium fruit," "120 grams" or "2 apricots, 2–4 pineapple slices, 1 good handful of small fruits", …), number of servings per day (e.g., "eat dairy 3 times a day") or a total amount to consume per day or per week (e.g., "eat a handful of nuts each day," "eat 400 g of vegetables per day"). Qualitative recommendations referred to unquantifiable messages (e.g., "eat a variety of fruits," "reduce red meat consumption"). If both qualitative and quantitative messages were given for a same food group, the recommendation was considered quantitative. If at least one food within a particular food group was mentioned, this food group was considered having a recommendation. For each food group, information on the portion size(s) for each food listed, and how many portions of this food were recommended to be consumed, either daily or weekly as appropriate, were collected. Specific details on this process for each food group are provided below.

Nine commonly consumed food groups were considered in our analysis, namely Fresh fruits, Vegetables, Grains, roots & tubers, Dairy, Meat, fish & eggs, Pulses, Nuts & seeds, Fats & oils, and Sugar & sweets. When a number of portions was given as minimum or maximum per day, that value was recorded (e.g., "at least 5 fruits and vegetables per day"). When given per week, recommendations on the number of servings were divided by 7 to obtain a daily value. When different recommendations were provided for specific population groups (e.g., for men and women separately), the detailed information was used, and the average was reported. In the case of a recommended value grouping more than one food category (e.g., fruits/vegetables, meat/fish/pulses), the number of servings was divided and split proportionally to the number of categories.

To determine the portion size of each of the food groups considered, a standardized approach was applied, where all PS recommendations (e.g., household measures, cup equivalents, pieces and other measures) were converted to grams. When information was provided as gram amounts at an overall food group level no conversion was necessary. If different examples of foods were given within a food group, the average recommended portion (g) of the individual food values was calculated for the food group. In the case of PS recommendations given in other units (e.g., cup, food item, and tablespoon) these were converted to a gram equivalent using two sources: the Food Portion Sizes version 3 book (32) and the USDA's Food and Nutrient Database for Dietary Studies (FNDDS) 2017–2018 (33). When both sources provided a gram equivalent for the food, an average was computed. When only one had an equivalent, then its value was used. A visual aid tool (34) was used to convert recommendations provided in other common units (e.g., hand, palm, and plate). When none of these resources provided an equivalent and it was not possible to calculate a conversion, no value was included. However, it is important to note that this was uncommon and only affected 15 foods, which are detailed in Supplementary Table S3. If the document contained recommendations for several daily energy levels, the values corresponding to a medium activity level were considered. When a range of values was provided instead of a single amount, the mid-point of the range was reported.

In addition to the above, specific rules were applied for each food groups, as detailed below:

Fresh fruits: fruit juices, dry fruits, and coconut water were excluded from the PS calculations, to enhance consistency. For the PS recommendation "a medium fruit", the average of the following medium fruits was applied: banana, apple, pear, peach, orange, mandarin. For the PS "1 cup of fruit" (or multiple thereof), the average of the value for 1 cup of the 10 most recommended fruits was applied (apple, banana, orange, watermelon, pineapple, grapes, mango, pear, papaya, plum).

Vegetables: 3 subcategories were considered: Vegetables (unspecified), Vegetables (excluding green/leafy) and Green/leafy vegetables. To account for variability in the way that vegetables can be eaten, if unspecified, the calculations considered an average of the raw and cooked weight of vegetables (when applicable). For the PS "1 cup of vegetables" or multiples thereof, the average of the value for 1 cup of the 10 most recommended vegetables from FBDGs was applied (tomato, carrot, lettuce, cucumber, cauliflower, pepper, cabbage, pumpkin, okra, and green/leafy vegetables). When two specific recommendations were provided for "Vegetables (excluding green/leafy)" and "Green/leafy vegetables", the average of values for spinach, cabbage, broccoli and lettuce were considered in the green/leafy subcategory and excluded from the other one. While potatoes and other starchy roots were associated with vegetables in some FBDGs for the number of portions per day, they were excluded from the PS calculations for this food group and were considered as a subgroup of the Grains, roots & tubers food group instead.

Dairy: analysis of PS recommendations was performed for Milk & plant-based dairy alternatives, Yogurt & fermented dairy, and Cheese. 1 ml of milk was converted to 1 g of milk. To convert milligrams of yogurt into grams, the density 1.080 was used as a factor (32). Plant-based dairy alternatives were included in the same category as dairy milk, as they were most often considered within this group in the FBDGs. Kefir, and other local fermented dairy products were classified together with yogurts. Curd was classified in the cheese category. Other dairy-based products (e.g., custard) were excluded from the calculations.

Grains, roots & tubers: PS recommendations were split into the following subcategories: Bread, Cooked cereals/grains, Potatoes/starchy fruits & vegetables, and Ready-to-eat (RTE) breakfast cereals/muesli. Values for cereals were considered as cooked unless specified raw. Where a value for raw cereals was provided, this was converted to a cooked value using an average of the conversion factors for rice, pasta and noodles (2.0), as found in the USDA Food Buying Guide for Child Nutrition Programs (35).

Meat, fish & eggs: for the PS analysis, the following subcategories were considered: Meat, Fish & shellfish, and Eggs. When unspecified, 1 medium egg was considered to weigh 50 g. All meats (e.g., beef, pork, chicken, goat etc.) were grouped into a single category. Similarly, fish and shellfish which were also classified together ("Fish & shellfish" category).

Pulses: similarly to cereals, PS recommendations provided were considered cooked by default. No value to convert pulses was available in the USDA Food Buying Guide for Child Nutrition Programs (36), so we used the average of the values observed in the FBDGs which provided both raw and cooked values: 2.5, based on Afghanistan (2.5), Austria (2.1), Germany (1.8), Malta (2.0), Portugal (3.2), Spain (3.1), Turkey (2.6). When a recommendation of "1 glass" of pulses was given, it was converted in the same way as 1 cup. Soy products (e.g., tofu) were excluded from this category. Although they were initially reported in a separate category, only 9 FBDGs provided a PS for them, therefore the results are not included in this paper.

Nuts & seeds: this category included all types of tree nuts, ground nuts, and seeds. PS analysis excluded peanut butter and other similar pastes, olives, avocado, and lotus seeds. However, it is worth noting that these products were sometimes associated with Nuts & seeds on food pyramids and therefore are included in the recommended number of portions per day.

Fats & oils: includes oils, butter, and in some FBDGs other products as mentioned above in the nuts and seeds section.

Sugar & sweets: includes sugar, honey, jam/jelly, sweet snacks (candies, biscuits/cakes, etc …), chocolate.

The categories Fats & oils and Sugar & sweets were considered for the presence of quantitative/qualitative/no recommendation and number of portions per day, however, due to the low number of amount recommendations, they were excluded from the PS analysis.

All data were extracted manually, and stored on Microsoft Excel (Microsoft Office, V.2401). For each FBDG, portions were converted into gram amounts for each food, and food group. Quality checks were conducted by FS (the lead author) and PS values were reviewed by all team members. Outliers were identified and values were discussed within the research team. Three values were excluded from the calculation, as they were deemed implausible from a dietary intake perspective (e.g., in the Mexican FBDG, the recommendation for vegetables included a "1.5 raw cabbage" which when converted to a gram amount represented a PS of 1,050 g (700 g per cabbage x 1.5)). Data was extracted individually for each country, and summary for global regions was obtained by determining medians, standard error of mean (SEM) and minimum and maximum value for each food group by FAO global regions.

3 Results

3.1 Countries and regions

FBDGs from a total of $n = 100$ countries were listed on the FAO repository at the time of data collection (July 2023 to July 2024). Of the 100, three FBDGs were excluded from the analysis as some documents could not be accessed at the time of data extraction (Iran, Nepal, United Arab Emirates). One other country (Cambodia) was excluded, as only recommendations for children were available. Therefore $n = 96$ countries were included in the analysis: $n = 2$ in North America, $n = 11$ in Africa, $n = 34$ in Europe, $n = 16$ in Asia, $n = 29$ in Latin America and the Caribbean (LAC), and $n = 4$ in the Near East. The list of the included FBDG for each region, as well as the access link to their material, can be found in Supplementary Table S1.

3.2 Type of recommendations provided within FBDGs

Table 1 provides the frequency of quantitative or qualitative intake recommendations, or lack thereof, for food groups considered within this analysis. Globally, Fruits, Vegetables, and Meat, fish & eggs were the food groups for which quantitative recommendations were most commonly provided (Table 1). Fewer guidelines provided quantitative intake recommendations for the food groups Nuts & seeds, Fats & oils, and Sugar & sweets. North America and LAC were the regions with the lowest proportion of quantitative portion size guidance. As an example, within the LAC region for the food group Grains, roots & tubers, 48% of FBDGs provided quantitative messages, which corresponds to 15 countries not mentioning specific amounts (Table 1). With respect to Sugar & sweets, only a few countries provided quantitative recommendations, with 54 FBDGs providing some qualitative guidance, generally to limit consumption. Since the Canadian FBDG document provided qualitative guidance only, analyses of quantitative recommendations for this region are represented exclusively by the American FBDGs.

3.3 Number of portions per day

Supplementary Table S2 displays the recommended number of portions per day for each food group, at a global level (global median) and per global region. Fourteen consumer FBDGs did not include any recommendation for the number of portions to be consumed per day (Bahamas, Brazil, Canada, Dominica, Ecuador, Grenada, Guyana, Kenya, Namibia, Nigeria, Saint Lucia, Sierra Leone, Thailand, and Viet Nam) and 7 provided portion recommendations per day for only one food group (China, North Macedonia, Panama, Peru, South Africa, Sweden, Uruguay). In many instances, food categories were grouped into a unique recommendation. The most observed combinations were Fresh fruits/Vegetables (23 FBDGs, of which 1 combined Fresh fruits/Vegetables/Legumes) and Meat, fish & eggs/any other group (23 FBDGs, of which Meat, fish & eggs/Dairy: 6 FBDGs; Meat, fish & eggs/Pulses/Nuts & seeds: 7 FBDGs; Meat, fish & eggs/Pulses: 7 FBDGs, and Meat, fish & eggs/Dairy/Pulses/Nuts & seeds: 1 FBDG). Other observed combinations included Pulses/Nuts & seeds (5 FBDGs) and Grains, roots & tubers/Pulses (4 FBDGs). As seen in Table 2, the range of the number of daily recommended portions is wider for some food groups than for others. The lowest variation was observed for Fresh fruits and for Vegetables, with median recommended numbers of portions per day spanning from 2 to 3 for Fresh fruits, with a coefficient of variation (CV) of 0.2, and range from 2.3 to 4.1 for Vegetables, with a CV of 0.3. The number of recommended portions for Meat, fish & eggs was low in countries which only specified an amount for Fish (Supplementary Table S2). The highest CVs were found for Pulses and Sugar & sweets, Pulses and Nuts & seeds (0.8). The highest recommended number of daily portions was found for Grains, roots & tubers, with a global median of 6 portions. African FBDGs had the lowest recommended number of daily portions per day for most food groups and showed a median recommendation below the global median for all of them.

3.4 Portion size recommendations for the main food groups, considered by FAO global region

3.4.1 Fresh fruits and Vegetables

Recommended portion sizes (PS) for Fresh fruits and Vegetables, grouped by FAO region, are presented as global averages in Table 3. Supplementary Table S3 presents these results detailed for each specific country considered within this analysis. Across global regions,

TABLE 1 Mean percentage of quantitative[1] and qualitative recommendations for each food group provided in consumer FBDGs, by FAO region.

Region	n FBDGs	Fresh fruits			Vegetables			Grains, roots & tubers			Dairy			Meat, fish & eggs			Pulses			Nuts & seeds			Fats & oils			Sugar & sweets		
		QN	QL	NM	QN	QL	NM	QN	QL	NM	QN	QL	NM	QN	QL	NM	QN	QL	NM	QN	QL	NM	QN	QL	NM	QN	QL	NM
North America	2	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0	50	50	0
Africa	11	73	27	0	64	36	0	82	18	0	73	18	9	73	27	0	73	27	0	64	18	18	64	27	9	45	36	18
Europe	34	94	6	0	94	6	0	85	15	0	85	15	0	91	9	0	68	29	3	68	24	9	50	47	3	21	62	15
Asia and the Pacific	16	94	6	0	94	6	0	88	13	0	88	6	6	94	6	0	88	6	6	63	13	25	63	25	13	44	38	19
LAC[2]	29	66	34	0	66	34	0	48	52	0	59	41	0	66	34	0	59	41	0	28	62	10	41	59	0	34	66	0
Near East	14	100	0	0	100	0	0	100	0	0	75	25	0	100	0	0	100	0	0	100	0	0	0	100	0	25	75	0
Total	96	82	18	0	81	19	0	74	26	0	75	23	2	81	19	0	70	28	2	55	32	13	49	47	4	32	56	10

[1]A message on either the number of servings per day, total recommended per day, or portion size were considered as quantitative intake recommendations. [2]Latin America and the Caribbean. *n*, number of included food-based dietary guidelines; QN, quantitative recommendation; QL, qualitative recommendation; NM, not mentioned.

the median recommendation for Fresh fruits remained relatively consistent, all ranging between 120 g in Europe and 139 g in the Near East, except for North America (154 g). Important variation could be observed within regions, with maximum values being 2 to 3 times higher than the minimums in Europe and LAC. The lowest values were observed in Indonesia (50 g), Republic of Moldova (68 g), Barbados (77 g). Regarding the Vegetables categories, $n = 39$ countries provided an unspecified PS recommendation. Other countries provided different recommendations for Green/leafy vegetables ($n = 26$) and Vegetables excluding green/leafy ($n = 27$). For example, all FBDGs in the Near East region recommended specific PS for Green/leafy and non-green/leafy vegetables. When PS for the unspecified vegetables were calculated, they ranged from 50 g in the Netherlands to 204 g in Argentina. Values were found to be most consistent in Asia and the Pacific, with a minimum value of 75 g (Australia) close to the maximum of 102 g (Afghanistan). Despite some regional variations, the medians were consistent across regions and spanned from 80 g in Africa to 100 g in Europe, Asia and the Pacific, and LAC. A larger variation was observed in the recommended PS for the vegetable category which included Green/leafy vegetables only. Regarding the category excluding green/leafy vegetables, Asia and the Pacific and Africa showed the lowest regional medians (82 and 87 g, respectively) and Europe and the Middle East the highest (119 g). Values were particularly spread around the median in Africa (SEM = 20.2 g) and a 115 g gap existed between the highest and the lowest recommended PS (respectively 140 g in Sierra Leone and 25 g in Ethiopia). PS values for Green/leafy vegetables were in all regions lower than those for non-green/leafy vegetables and for unspecified vegetables. The global median PS for this category was 70 g. In each region, the set of recommended PS was noticeably spread around the median in each region, as shown in Table 3 by high SEM values, particularly in Asia and the Pacific and in Africa.

3.4.2 Grains, roots & tubers

The recommended PS for the Grains, roots & tubers food group are presented in Table 4, which shows a global median for this category of 90 g. Disparities in median recommendations were observed for Cooked cereals/grains, with variations in minimum and maximum amounts spanning from 30 g to 247 g, respectively in the Netherlands and in the Philippines. The lower values were often presented alongside a high number of recommended portions per day, ranging from 9 to 15 (Table 2). This may imply a recommended consumption of more than one serving per meal, however this is not specified. Within regions, recommendations were less consistent in Africa and in Asia and the Pacific, as per the high SEM values. African countries lacked specific recommendations for RTE breakfast cereals/muesli yet provided the highest PS recommendations for Bread and Cooked cereals/grains (142 g and 79 g, respectively). In contrast, the Near East FBDGs showed notably lower bread recommendations compared to other regions (median of 27 g versus 42 g globally), albeit with a recommended number of servings exceeding six per day, resulting in effectively doubling or tripling the actual portion size per eating occasion. The United States recommended a portion of 28 g. No country in Africa provided a recommendation for (RTE) breakfast cereals/muesli. The highest value (60 g) was observed in Germany. The lowest value was provided in the LAC region, with a PS of 18 g recommended in Costa Rica, and the lowest median (22.5 g) was observed in this region as well. With two recommendations of 36 and

TABLE 2 Median number of recommended portions per day for major food groups, by FAO region.

Region	Fresh fruits	Vegetables	Grains, roots & tubers	Dairy	Meat, fish & eggs	Pulses	Nuts & seeds	Fats & oils	Sugar & sweets
North America	2.00	2.28	6.00	3.00	4.86	0.21	0.71	-	-
Africa	2.25	2.75	4.75	1.50	0.85	0.90	1.00	1.00	0.75
Europe	2.50	3.00	7.00	2.50	1.29	0.50	1.00	2.00	1.00
Asia and the Pacific	2.00	3.25	6.00	2.00	2.50	0.95	0.60	5.00	3.75
LAC[1]	2.50	3.00	7.00	3.00	2.01	1.50	1.50	3.75	3.50
Near East	3.00	4.00	7.00	2.00	1.4	1.30	1.30	-	-
Global median	2.50	3.00	6.50	2.50	1.43	1.00	1.00	2.00	2.00
CV[2]	0.24	0.29	0.47	0.37	0.71	0.78	0.76	0.64	0.77

[1]Latin America and the Caribbean. [2]CV = Coefficient of variation.

TABLE 3 Portion size recommendations in grams for Fresh fruits and Vegetables in FBDGs, by FAO region.

		North America	Africa	Europe	Asia and the Pacific	LAC[1]	Middle East	All
Fresh fruits (g)[3]	*n* FBDGs	1	7	28	9	17	4	66
	Median	153.5	130.6	119.5	124.0	134.5	138.7	127.6
	SEM[2]	–	7.5	5.2	10.8	4.8	11.9	3.1
	min	–	100.0	66.7	50.0	76.8	106.5	50.0
	max	–	162.5	162.0	150.0	150.0	157.6	162.5
Vegetables – unspecified (g)[4]	n FBDGs	0	3	21	5	10	0	39
	median	–	80.0	100.0	100.0	99.6	–	100.0
	SEM	–	27.5	8.8	5.1	11.8	–	5.7
	min	–	71.0	50.0	75.0	70.0	–	50.0
	max	–	157.7	200.0	102.2	204.0	–	204.0
Vegetables – excluding green/ leafy (g)	n FBDGs	1	5	6	5	6	4	27
	median	128.3	86.7	118.8	81.6	100.4	119.4	100.4
	SEM	–	20.2	19.7	16.9	10.4	17.2	7.4
	min	–	25.0	75.6	46.3	91.3	81.6	25.0
	max	–	140.0	200.0	150.0	158.3	158.3	200.0
Vegetables – green/ leafy (g)	n FBDGs	1	5	7	5	4	4	26
	median	54.0	50.0	80.0	47.3	86.8	73.8	70.0
	SEM	-	24.6	16.4	16.7	31.3	10.4	8.6
	min	-	35.0	36.3	29.0	58.5	54.0	29.0
	max	-	164.4	164.0	125.0	199.1	94.5	199.1

[1]Latin America and the Caribbean. [2]Standard error of the mean. [3]Fresh fruits: excludes juices, coconut water, dry fruits (prunes, raisins, …). [4]Vegetables: unspecified: includes all types of vegetables; excl. Green leafy: when a different recommendation was given for general vegetables and green leafy vegetables – this category excludes green leafy vegetables; green leafy vegetables: includes any green leafy vegetable as provided, or an average of the values for spinach, cabbage, lettuce and broccoli, if the types of green leafy vegetables were not specified.

43 g (in Oman and Lebanon, respectively), the Near East showed the largest median for RTE breakfast cereal recommendations. Finally, Table 4 displays the recommended PS for Potatoes/starchy fruits & vegetables. For this category, regional median values ranged from 100 g in Asia and the Pacific, to 140 g in Africa, with despite notable differences in minimum recommendations (50 g in Asia and the Pacific and 117.5 g in Africa). The median PS recommendation in Europe was almost as high as the African value (138 g), and the maximum amount recommended was also observed in this region (250 g in Germany).

3.4.3 Dairy products

As seen in Table 5, the PS recommendations for Milk/plant-based dairy alternatives were consistent throughout the world, with 3 regions showing a similar median recommendation of 222–222.5 g (Africa, Europe, LAC). The more notable variation was observed in Asia, where

TABLE 4 Portion size recommendations in grams for Grains, roots & tubers in FBDGs, by FAO region.

		North America	Africa	Europe	Asia and the Pacific	LAC[1]	Middle East	All
Cooked cereals/grains (rice, pasta, noodles…)[3] (g)	*n* FBDGs	1	4	21	9	10	3	48
	median	74.5	142.3	85.0	97.5	90.0	78.2	88.0
	SEM[2]	–	25.3	11.3	21.8	7.8	2.7	7.0
	min	–	79.0	35.0	30.0	74.5	77.5	30.0
	max	–	202.5	240.0	246.5	150.0	86.0	246.5
Bread (g)	n FBDGs	1	6	20	7	11	3	48
	median	28.4	78.8	47.8	50.0	39.6	26.9	41.1
	SEM	–	24.2	4.7	21.1	3.1	3.4	5.2
	min	–	37.0	20.6	29.2	36.5	26.5	20.6
	max	–	173.3	100.0	158.8	67.0	36.9	173.3
Ready-to-eat breakfast cereals/ muesli (g)	n FBDGs	1	0	11	3	2	2	19
	median	28.4	–	30.0	30.0	22.5	39.5	30.0
	SEM	–	–	4.3	4.7	4.5	3.5	2.7
	min	–	–	18.0	21.3	18.0	36.0	18.0
	max	–	–	60.0	37.5	27.0	43.0	60.0
Potatoes/ starchy fruits & vegetables (g)	n FBDGs	0	3	17	7	12	0	39
	median	–	140.0	138.0	100.0	115.0	–	137.5
	SEM	–	11.0	13.8	17.0	12.3	–	8.4
	min	–	117.5	80.0	50.0	60.8	–	50.0
	max	–	155.5	250.0	180.0	200.0	–	250.0

[1]Latin America and the Caribbean. [2]Standard error of the mean. [3]Values for cereals were considered as cooked unless specified raw. Where a value for raw cereals was provided, this was converted to a cooked value using an average of the conversion factors for rice, pasta and noodles (2.0), as found in the USDA food buying guide for child nutrition programs.

both the minimum and maximum values were found (100 g in India and 313 g in Malaysia, respectively). Overall, most values ranged between 200 and 250 g for the Milk PS, with 44 out of 53 FBDGs providing a recommendation within this range. However, recommended PS for Cheese showed considerable variation across countries, particularly in Europe and in Asia and the Pacific, where the values ranged from 17 to 152 g and from 15 to 100 g, respectively. The lowest values (<20 g) were found in Sri Lanka (15 g), Jamaica (16 g), and Belize, Costa Rica, and Iceland (17 g). On the contrary, values ≥100 g were observed in Albania, Austria, Republic of Moldova, and India. As seen in Table 5, the Near East and Europe showed the highest regional medians, while lower median PS recommendations were found in Southern regions (LAC and Africa). The global median was 39 g. Medians were highest for all dairy categories in the Near East and North American FBDGs, in comparison to other regions, with a higher variation for Yogurts and fermented dairy (245 g versus a global median of 182 g). Just like for Milk, the lowest median for this category was observed in Asia and the Pacific with a value of 124 g. The recommendations varied widely among African FBDGs with a SEM value of 53 g and a maximum PS recommendation observed in Ethiopia being almost 3 times larger than the minimum observed in Benin and Gabon (respectively 350 g and 125 g).

3.4.4 Meat, fish & eggs and Pulses

Table 6 groups PS recommendations for major Meat, Fish & shellfish, Eggs, and Pulses found in FBDGs. Europe had notably higher recommendations for Meat, Fish & shellfish, and Pulses, encompassing all major protein sources except Eggs, which generally provided recommendations of 1 egg per portion. Indeed, only 10 out of 43 countries recommended more than 1 egg per portion (with values ranging from 80 to 125 g). The range of recommended PS values was particularly wide in Europe for Meat (from 27.5 g in Portugal to 135 g in Greece) and Fish & shellfish (from 27.5 in Portugal to 200 g in Romania). The highest PS recommendation for Meat was that of the Greek FBDGs, at 135 g. In regard to Fish & shellfish, maximum amounts were given in the Republic of Moldova and Romania (200 g). In regard to Fish & shellfish, maximum amounts were given in the Republic of Moldova and Romania (200 g). Conversely, Near East FBDGs suggested low recommendations for Meat intake, with PS for Meat of 30 g in Lebanon and Oman. The Asia and the Pacific region emphasized high PS values for Pulses with a regional maximum recommendation of 240 g in Malaysia, despite a few countries providing a low recommendation (30 g in Bangladesh and India). The lowest regional median for this group was observed in North America and in the Latin American FBDGs (46 and 80 g, respectively) as well as the recommendations for Fish & shellfish (28 and 38 g, respectively). As mentioned in section 3.3, there were inconsistencies in how food groups were categorized within this group, with Meat, fish & eggs sometimes being treated individually, while other times being grouped under broader categories such as “animal foods”. Also, the units and frequency differed for many protein-rich foods. These inconsistencies made it challenging to discern a consistent approach to grouping foods across recommendations.

TABLE 5 Portion size recommendations in grams for Dairy in FBDGs, by FAO region.

		North America	Africa	Europe	Asia and the Pacific	LAC[1]	Middle East	All
Milk and Plant-based milk alternates (g)	n FBDGs	1	4	25	10	11	3	54
	median	244.0	222.5	222.0	200.0	222.0	244.0	222.0
	SEM[2]	–	13.8	7.0	21.2	10.4	1.3	5.7
	min	–	200.0	125.0	100.0	122.0	240.0	100.0
	max	–	250.0	250.0	312.5	244.0	244.0	312.5
Yogurt & fermented dairy (g)	n FBDGs	1	4	21	6	11	3	46
	median	245.0	162.5	170.0	124.0	188.5	245.0	181.8
	SEM	–	53.0	9.1	19.3	17.3	4.3	8.2
	min	–	125.0	125.0	100.0	56.7	232.0	56.7
	max	–	350.0	259.2	202.5	245.0	245.0	350.0
Cheese (g)	n FBDGs	1	4	25	6	13	3	52
	median	49.6	27.5	50.0	40.0	30.0	52.5	39.0
	SEM	–	6.6	6.9	13.8	5.6	4.3	4.1
	min	–	20.0	16.7	15.0	15.6	45.0	15.0
	max	–	50.0	151.7	100.0	75.0	60.0	151.7

[1]Latin America and the Caribbean. [2]Standard error of the mean.

3.4.5 Nuts & seeds

The PS recommendations for Nuts & seeds varied across regions, with median values spanning from 13 to 30 grams (in LAC and Asia and the Pacific, respectively), as seen in Table 7. LAC, North America and the Near East generally had lower recommendations compared to Asia, where values tended to be notably higher. The two observed recommendations in the Middle East were 15 g (Lebanon, Oman). In LAC, most recommended PS were close to the median (within a 5 g above or below) with the exception of Argentina which provided a PS recommendation of 27 g. Notably high PS recommendations could be observed in Benin (50 g) and in Greece (40 g), with Africa and Europe showing the widest range of values, spanning, respectively, from 5 to 50 g and 11 to 40 g. Values were particularly inconsistent in Africa, as shown by a SEM of 6.4 g.

4 Discussion

This research aimed to examine portion size recommendations across food-based dietary guidelines (FBDGs) globally looking specifically at the provision of and variability within portion size recommendations. A total of 96 FBDGs were considered therefore to our knowledge, this paper represents the first global comparative analysis of food group portion size recommendations. This work highlights both variations and consistencies in recommended portion sizes, within and across food groups at a regional and global level.

Not all guidelines provided quantitative intake recommendations, with differences being particularly evident within specific food groups and across global regions. Apart from the North American region which was represented by only 2 countries, LAC provided the least quantitative recommendations within their FBDGs, whereas Europe provided the most quantitative recommendations. In all regions, Grains, roots & tubers was the food group with the highest number of recommended daily portions to be consumed, which is in line with other studies which highlighted grains as the food group representing the highest relative amount of food to be eaten (37). With respect to food groups with recommended PS, Fresh fruits & Vegetables were among the food groups with PS most often recommended. These findings are in accordance with previous studies, where messages encouraging consumption of fruits and vegetables were reported to be the most frequent in FBDGs worldwide (38). PS recommendations within these food groups were also the most consistent across the guidelines considered (3). On the contrary, the food group Sugar & sweets had the fewest quantitative recommendations and were more often mentioned alongside qualitative guidance, generally encouraging to limit or reduce their consumption. This is in line with existing recommendations from the WHO whereby a restrictive recommendation of less than 10% of dietary energy from sugar intake is given (39). Therefore, stakeholders developing FBDGs may have used the approach of recommending only limited amounts and infrequent consumption to be more relevant from a public health perspective than providing an actual amount for such a food group. Moreover, strategies to address sugar intakes have more recently focused on other approaches than FBDG recommendations, such as provision of personalized nutrition advice (40) or reformulation strategies (41–44). Furthermore, our work found that some FBDGs provided total amounts per day or number of portions per day, but not specific recommendations on a PS for some food groups. For example, the Vietnamese FBDGs provided monthly amounts to consume but gave no information on recommended daily food intakes.

The work presented here also identified disparities in the way food groups are defined, as well as the way that foods are classified into food groups. While commonalities existed (e.g., the frequent combination of Fruits and Vegetables, as a single food group, observed in many regions), discrepancies were equally notable, particularly regarding

TABLE 6 Portion size recommendations in grams for Meat, fish & eggs and Pulses in FBDGs, by FAO region.

		North America	Africa	Europe	Asia and the Pacific	LAC[1]	Middle East	All
Meat[3] (g)	n FBDGs	1	6	20	9	14	3	53
	median	28.4	77.7	92.5	72.5	66.7	30.0	75.0
	SEM[2]	–	2.1	6.5	7.0	5.5	15.0	3.6
	min	–	69.8	27.5	30.0	30.0	30.0	27.5
	max	–	85.0	135.0	82.0	98.0	75.0	135.0
Fish & shellfish[3] (g)	n FBDGs	1	6	23	9	9	3	51
	median	28.4	98.1	120.0	70.6	38.1	75.0	90.0
	SEM	–	18.7	9.9	11.4	8.1	18.0	6.8
	min	–	58.3	27.5	30.0	30.0	30.0	27.5
	max	–	190.0	200.0	132.4	90.0	90.0	200.0
Eggs[4] (g)	n FBDGs	1	6	18	8	12	2	47
	median	50.0	65.0	52.5	50.0	50.0	50.0	50.0
	SEM	–	9.4	6.5	10.7	0.3	0.0	3.4
	min	–	50.0	50.0	50.0	47.0	50.0	47.0
	max	–	100.0	125.0	120.0	50.0	50.0	125.0
Pulses[5] (g)	n FBDGs	1	7	20	9	13	3	53
	median	45.8	95.0	127.5	100.0	80.3	90.7	92.5
	SEM	–	7.9	13.9	24.5	8.6	15.1	7.6
	min	–	75.0	46.0	30.0	46.0	46.0	30.0
	max	–	132.0	250.0	240.0	125.0	91.9	250.0

[1]Latin America and the Caribbean. [2]Standard error of the mean. [3]Values can be either cooked or raw, depending on the FBDGs. Most of the times no precision was provided as to raw or cooked. [4]Eggs: 1 medium egg was considered to weigh 50 g. [5]Pulses: values were considered cooked, except for when "dry" seemed to refer to raw rather than to opposite of fresh pulses (Switzerland), or when the value provided was deemed irrational to be cooked as very low (Estonia). In these cases they were converted to cooked using factor 2.5. Excludes soy products such as tofu, tempeh, etc.

TABLE 7 Portion size recommendations in grams for Nuts & seeds in FBDGs, by FAO region.

		North America	Africa	Europe	Asia and the Pacific	LAC[1]	Middle East	All
Nuts & seeds[2] (g)	*n* FBDGs	1	6	13	6	7	2	35
	median	14.2	20.8	25.0	30.0	13.3	15.0	23.5
	SEM[3]	–	6.4	2.4	3.6	2.3	0.0	1.8
	min	–	5.0	11.3	15.0	8.0	15.0	5.0
	max	–	50.0	40.0	35.7	27.0	15.0	50.0

[1]Latin America and the Caribbean. [2]Excludes peanut butter, olives, avocado, lotus seeds (which were sometimes included in this food group in FBDGs). [3]Standard error of the mean.

protein sources and animal foods. For example, in Latin American FBDGs, dairy products were often considered "animal foods" and recommended together with other sources of protein, such as meat, fish (e.g., in Venezuela, Saint Vincent and the Grenadines, or Grenada) whereas in other global regions, notably Europe and North America, dairy products were more commonly kept apart from other animal-based foods. The lack of consistency in defining food groups is a well-known issue in nutrition research, and initiatives have been taken to address coding of food data to bring uniformity, and comparability of datasets including use of FoodEx2 coding in EFSA Food Consumption Database (45) and other similar strategies (46, 47). This was also the focus of the work conducted within the FNS-Cloud project, which developed innovations and support for to address food and nutrition data federation across Europe (48). However, such work is mostly dedicated to data collection in the context of nutritional surveys (49) rather than for the development of nutritional recommendations. The learnings or the approaches taken in such projects may not have been considered within the context of FBDG to date.

While one can consider variation in a negative manner, it is important to understand the reason for variation, and embrace the fact that variation is both natural and needed. One plausible explanation for the variations observed could be the influence of cultural eating habits across different global regions (38, 50) as well the availability and access to specific foods, which will result in both different food groups and/or foods within these groups. This aligns with findings from Carruba et al. who examined recommended PS in European FBDGs and found an influence of cultural attitudes toward foods, which manifested in country/regional differences (27). Local knowledge of dietary and culinary habits is known to be essential for the development and use of FBDGs (2) and is therefore naturally reflected in the variation observed. For example, the large PS recommendations observed in Africa for subgroups Cooked cereals/grains, Bread and Potatoes/starchy fruits & vegetables can be explained by the general high share of carbohydrates in the regional diet, which represents about 70% of the daily energy supply (51). On the other hand, the high consumption of meat in Europe (52) seems to be leading public health bodies to recommend limiting its intake (53) and increase that of fish instead, as shown by the larger recommended PS of fish in many European FBDGs. To reduce the variability in our analysis, some specific foods were excluded from the calculations (e.g., coconut water excluded from Fresh fruits, or corn-based products excluded from Cooked cereals/grains). It is however important to note that in certain countries, these foods may be an important part of the diet. While the aim of this paper was to evaluate the commonalities and differences in FBDGs and provide an overview of the observed variations, currently ongoing research is further analyzing these variations to determine whether regional differences are significant. This will enable allow a deeper understanding of how local habits shape dietary guidelines.

When considering food groups and foods within food groups, the variation within the Meat, fish & eggs group is worth noting. Meat, fish & eggs were commonly combined into a "Protein group", occasionally along with other foods with a high protein content such as Pulses or Nuts & seeds. With the emergence of sustainable dietary concerns (29, 54), as well as scientific evidence associating red and processed meat consumption with NCDs (55, 56), public health bodies are encouraging consumption of more plant-based foods. The importance of providing specific recommendations for meat and non-meat protein sources has been addressed in several recently developed European FBDGs (e.g., Denmark, 2021; France, 2019; Spain, 2022). However, it is difficult to understand if such messages are driven by nutritional or sustainability concerns, or both (3). In this analysis, the countries who introduced sustainability concerns did not necessarily recommend low PS for meat. In Europe for example, the Italian and the Dutch FBDGs extensively mentioned sustainability, however both provided recommended PS for Meat of 100 g, which is greater than the global median. However, the advised frequency of consumption in these documents was low. This highlights the importance of considering both the recommended PS and the number of portions per day or per week when assessing the sustainability of a diet. A review of plant-based diets and substitutions for animal-based foods in FBDGs recently highlighted an overall lack of recommendations for alternatives to meat and animal milk (31). The need for a reform of FBDGs, through the sustainability lens, has been stressed by Springmann et al., who pointed out the need for more specific recommendations including suggested minimum values for plant-based foods such as whole grains, nuts, and legumes, and stricter limits for red and processed meat and dairy (57). While no particular trend was identified between the year of publication of the guidelines and the combination of different sources of protein as food groups in our study, the recent issue of regional and global guideline documents which are mainly based on environmental aspects demonstrates the efforts to promote a shift of dietary habits toward sustainable consumption (28, 29).

The consideration of different baseline daily energy levels for the diet needs to be considered when comparing or considering variation across recommended portion sizes. While most FBDGs specified recommended intakes relevant to a 2000–2,200 kcal diet, variation was noted both within and across global regions. For example, the baseline energy level in the Zambian FBDG was 2,100 kcal, and that of the Ethiopian FBDGs was 2,700 kcal, representing a 25% difference across these 2 FBDGs within the same region. On the other hand, the energy level used in the Malaysian guidelines was 1800 kcal. Such variation does however not seem to affect the PS recommendation for each food group equally: in the case of Malaysia, the recommended PS are comparable for Fresh fruits and Meat, but vary widely for other foods such as Fish or Pulses. While some FBDGs explain how their recommended amounts help individuals meet energy and nutrient requirements (e.g., Malaysia, United States), others do not elaborate on whether their recommended values ensure that all calorie and nutrient needs are met (Hungary, Qatar). Future work could therefore focus on the standardization of the recommended PS to compare computed values based on a similar calorie requirement.

Variation in the recommended PS can also be linked to the method of derivation of the FBDGs. As mentioned above, guidelines exist to guide stakeholders in the development and implementation of the FBDGs and recommend following a stepwise approach to identify critical nutrients for the country population and select foods that are sources of these nutrients (2). This can be achieved in different ways, according to the resources available in each country. While some FBDGs are uniquely based on scientific consensus and daily energy requirements of the population (e.g., Philippines, Paraguay, Georgia, Kenya), others were derived through analysis of national consumption data and/or a diet modeling approach (Germany, Sri Lanka, Oman, United States). For European countries, EFSA has specifically emphasized the importance of modeling the effectiveness of FBDGs, which involves the use of nutrient intake data (58). In a 2018 review, Blake and colleagues highlighted that inconsistencies and deficiencies existed in the methods to review the evidence when developing FBDGs (59). However, this study only included 32 countries, and further research is still needed to fully understand the extent of these methodological gaps among FBDGs worldwide.

Addressing the terminology used with regards to PS is important. The terms "portion" or "serving", which are often used interchangeably, even among the scientific community and HCPs, can be confusing for consumers, who are often exposed to SS on packaged foods, and then PS within FBDGs. In countries without regulations, SS are manufacturer's suggestions and do not necessarily reflect recommendations from national guidelines. Further confusing the issue is that there is no distinction between the words "servings" and "portions" in many languages, so the labels would in fact reflect a portion (e.g., porzione (Italian), porcija (Lithuanian), porciones (Spanish), etc.). In FBDGs, lower PS values for Cooked cereals/grains or for Meat, fish & eggs were typically associated with higher recommended numbers of servings per day (for example in the Netherlands or in India). In these cases, the term "portion" was considered as including more than one serving, meaning the PS recommendation per meal was higher (e.g., the Indian FBDG recommend a 30 g PS for cooked grains, and 9 to 12 servings per day, meaning that 2 to 3 servings may be consumed within one meal, and the PS could therefore reach 90 g). This lack of consistency in the terminology used to provide PS recommendations is of concern and should be addressed to ensure an efficient delivery of the guidance to populations (13).

Discrepancies also exist between the guidelines provided for consumers and those produced for HCPs, and other experts. While emphasis was put on consumer-facing material, the different ways in which messages were included in FBDGs could lead to different interpretations of the recommended PS. Additionally, the variation which was detected between "theoretical" guidelines stemming from general scientific consensus and the actual translated recommendations provided to consumers often reflects a discordance on the approaches taken to disseminate nutrition messages (60). A characteristic example of this is the recommendation for Fresh fruits and Vegetables. Populations, particularly in Europe, are often advised to eat 5 fruits and vegetables a day (61). This originated from an arbitrary split of the WHO recommendation to consume at least 400 g per day, which were found to be beneficial for human health, into 5 portions of 80 grams (62). In practice, our calculations demonstrated the median PS recommendation for Fresh fruits was found much higher, for all studied regions, with the global median being of 126 g. Stakeholders in charge of developing FBDGs should ensure all messaging formats provide a consistent message to the consumer. Moreover, the inherent vagueness of certain messages may result in subjectivity of the interpretation (e.g., "a small fish", "a medium plate") and inevitably relies on social and cultural interpretations. Even when providing more detail, recommendations may be understood in different ways: fruits with or without the pit, rice or pasta raw or cooked, nuts with or without the shell. These limitations in the context of a scientific review highlight the potential difficulty for populations to efficiently translate the messages they are exposed to into adequate consumption patterns. The creation of consistent reference PS in line with dietary needs has already been indicated previously (27).

The FAO/WHO guidelines stipulate that behavioral and social sciences should be taken into account to enhance effectiveness of messages (2). The lack of harmonization in the way that PS recommendations are generally provided demonstrates that issues remain in considering the most practical way to provide dietary recommendations. Attention should be given to providing gram amounts for all foods as a reference, alongside the display of equivalent common household measures as visual / graphic messages are better understood by consumers. The WHO also notes that "consumers think in terms of foods rather than of nutrients" (2). The inclusion of reference PS within FBDGs therefore needs to be considered urgently as they provide practical guidance for consumers on the foods they should eat (27). Messages need to be communicated efficiently for populations to heed the FBDGs. Indeed, studies have shown that adherence to FBDGs is relatively low, with almost 40% of populations not complying with the recommendations, both in low and in high-income countries (63). Efforts are therefore needed to harmonize and strengthen FBDG messages in order to increase population awareness and use of FBDG PS recommendations (50, 64, 65).

This paper offers a global analysis of FBDGs, examining several food groups using a standardized approach to compare recommendations across major food categories and subcategories. However, some limitations are worth noting: the translations of some documents may have introduced interpretative bias, and the selection of a single document from multiple FBDG documents in some countries could affect comprehensiveness, as discrepancies in values across documents existed, which required certain assumptions to be made.

In conclusion, our findings highlighted regional commonalities and disparities in intake recommendations within FBDGs. Disparities were revealed particularly in the provision of quantitative intake guidance. Variability was also observed in how food groups were categorized, influenced by cultural and regional dietary practices. The inconsistent terminology and varied derivation methods further complicate the interpretation of these guidelines and the identification of the key drivers of their variation. Future work should assess whether PS significantly differ across regions. Harmonized efforts are needed for the creation of updated clearer, practical PS guidance for consumers, to enhance adherence to FBDGs.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

FS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. ALE: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. TNM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. ERG: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing.

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Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2024.1476771/full#supplementary-material

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Comprehensive global review and methodological framework for developing food atlases

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Introduction: An atlas is a trustworthy resource created from precise data collection that serves as a guide for communities. A food atlas is a useful tool for analyzing dietary data. There is a growing need for a food atlas that is part of the nation's strategy to help the health sector with specific nutritional or dietary assessments of individual consumption and overall wellbeing. Although researchers previously attempted to create a food atlas on a national level, the process of data collection was not well defined.

Methods: This study provides an overview of global food atlases that can be used to develop a procedure manual to guide experts in creating a dependable food atlas.

Results: To date, 27 countries have developed food atlases for various reasons. After examining these countries' experiences, six important steps in the procedure manual that should be considered when developing a food atlas were identified: choosing the most consumed food, using traditional cooking utensils, determining portion sizes, capturing photographs of the food, validating the food atlas, and publishing the food atlas.

Discussion: This procedure manual can be used as a guide until a validation study is conducted.

KEYWORDS

food atlas, atlas, global food, review, food consumption

1 Introduction

A food atlas is a visual guide that illustrates common foods or dishes from a population's national or regional diet, along with typical serving sizes (1). The purpose of a food atlas is to accurately determine portion sizes, which are crucial for understanding the nutritional value of food. Several food atlases have been developed, each with a specific focus. For instance, Greece created its first food atlas in 1992, featuring 170 different foods (2). The Northern Italy atlas, developed in 2005, includes the highest number of foods, totaling 434 items (3). Conversely, some countries may not have a food atlas owing to several reasons. One possible reason is limited financial and technical resources. Additionally, in some developing countries, the absence of infrastructure and trained personnel capable of collecting, analyzing, and maintaining data on food consumption patterns may pose challenges. Cultural and regional diversity in dietary practices further complicates efforts to standardize portion sizes and food descriptions. Moreover, the lack of interdisciplinary collaboration among nutritionists, public health experts, and other professionals hinders the development of accurate and culturally specific food atlases (4).

Various types of atlases exist, each with its own objective. Atlases may focus on nutrition, agriculture, specific diseases, age groups, and public health policies or nutrition interventions (5, 6). The most well-known type of atlas is the food atlas, which features various photographs of dishes. For example, the United Kingdom (UK) food atlas was created to assess children's nutritional consumption (6), whereas Ecuador's food atlas was designed for adults (7). Additionally, atlases created for specific diseases, such as dysphagia, have been used as valuable tools by healthcare professionals to educate patients and caregivers about the required texture-modified food and thickened fluid (5). Moreover, several existing food atlases have profoundly impacted public health policies and nutrition interventions by supplying critical data on food availability, consumption trends, and dietary diversity, which facilitate evidence-based policymaking. For example, the Food Atlas for the USA has been instrumental in identifying food deserts and devising targeted strategies to enhance access to nutritious foods, thereby influencing local and national policies aimed at mitigating diet-related health issues (4). Likewise, food atlases in developing countries have uncovered nutritional deficiencies and directed efforts to improve food security through agricultural and health-related programs (4).

In food atlases, data are typically collected from sources such as Food Frequency Questionnaires (FFQs), surveys, 24-h recalls, restaurant menus, household surveys or home visits, recipe books, and other sources (8–11). In most countries, 24-h Dietary Recall and FFQs are used to estimate food intake; however, these methods are often inaccurate because they rely on the respondents' short-term memories and the interviewer's prior experience. To determine the portion size of a dish, weighing the food before and after consumption is considered the most accurate measurement method. However, this approach is not suitable for dietary surveys involving many people because it is time-consuming and has a significant respondent load. Visual aids, such as plastic food replicas (food models) and photographs, may help to reduce errors made while estimating food portions during dietary recall. The accuracy of food-portion measurements in dietary recalls can be improved by using pictures.

Furthermore, a previous study found that two-dimensional images could accurately describe food portions in a manner comparable to three-dimensional food models. Many people and nations have investigated the reliability of using food images to estimate portion sizes. Their findings confirm the value of using food images to estimate serving size. Adopting precise food portion sizes suited to the local context is crucial for nutritional assessments because eating patterns differ between nations (12). Additionally, food is grouped into different categories in the atlas; for example, the food group is based on the most consumed food by society (e.g., how food is collected in Lebanon) and shows varied portion sizes to help estimate consumption, as well as inform consumers about the nutritional value and portion sizes (10).

At the national level, the Saudi food atlas was established in 2018 by the University Center at the College of Medicine at King Saud University owing to the need to consider one of the most critical health problems both globally and in the Kingdom of Saudi Arabia (SA): obesity (13). The General Authority for Statistics announced a bulletin of indicators of health determinants in SA for the year 2023 on its official website; the results of the bulletin stated that the prevalence of obesity among the adult population of SA reached 23.7%. This percentage was similar between males and females, whereas the percentage of those with ideal weight was significantly higher among females (39.6%) than males (29.5%). Among children aged <15 years, the prevalences of obesity and underweight were 7.3 and 41%, respectively. SA exhibits one of the highest prevalence rates of overweight and obesity among all age groups and children; thus, considering that the population is at significant risk for increased rates of noncommunicable disease mortality, these prevalences have also increased rapidly over the past few decades (14).

Food atlases serve various purposes, including health and nutrition; using effective tools, food atlases serve as a valuable resource for researchers conducting surveys. They also provide accurate information for implementing nutritional interventions. Although some researchers attempted to develop a food atlas at the national level, the methods used to collect information were unclear, and it is considered necessary to obtain a comprehensive understanding of the global food atlas and replicate the general steps taken to develop a national food atlas that reflects individual consumption patterns. This global assessment compiles general food atlases created for healthy adults worldwide to assist future researchers, sectors, and organizations in updating or developing food atlases.

1.1 Objective and scope

The objective of this study was to provide a descriptive global review of food atlases (the main reasons for creating and using food atlases, photography, portion size, number of food items, and how consumption information was collected for all food atlases around the world) that covers all adult food atlases published between 1992 and 2020. Additionally, this study aimed at establishing a procedural manual or criteria to support the development of national food atlases.

2 Materials and methods

This narrative review was conducted by collecting published scientific literature on food atlases from PubMed and Google databases in August 2021. The PubMed database was used to extract studies using keywords related to food and world atlases. A total of 682 studies were extracted from PubMed, 15 of which were included in the review after the data were screened according to predefined inclusion and exclusion criteria. The inclusion criteria for the review were studies related to food atlases (including topics such as the most famous food, photos, information about multiple portion sizes, and use of appropriate cutlery), and those including healthy adults (aged ≥18 years, both sexes). Moreover, to incorporate a food atlas from each country, the "Google" search engine was used to ensure that all countries were included. Generally, both methods were used to search for the food atlases in countries worldwide.

The literature was included if it was specifically focused on food atlases, while studies that centered on other types of atlases, such as those related to economic complexity, human anatomy, or heart disease, were excluded from consideration. The extracted data (scientific literature) summarizes the countries with a food atlas; 27 countries were identified (10 from Asia, 8 from Europe, 5 from Africa, 3 from America, and 1 from Australia). A scoring system was

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TABLE 1 Scoring system for the inclusion and exclusion of countries' food atlases.

#	Country	Most popular food	Photo	Multiple portion size	Clear photo	Use representative cutlery	Healthy	Adult (≥18 years)	Male	Female	Score	Result
	Number of points	1	1	1	1	1	1	1	1	1	Total	
1.	UK	1	1	1	1	1	1	1	1	1	9	Ö
2.	UK (18 months–16 years)	1	1	1	1	1	1	0	1	1	8	X
3.	Germany (meat atlas)	0	0	0	0	0	0	0	0	0	0	X
4.	Northern Italy	1	1	1	1	1	1	1	1	1	9	Ö
5.	Holland	0	0	0	0	0	0	0	0	0	0	X
6.	Greece	1	1	1	1	1	1	1	1	1	9	Ö
7.	Spain	0	0	0	0	0	1	1	1	1	4	X
8.	Balkans	1	1	1	1	1	1	1	1	1	9	Ö
9.	USA	0	0	0	0	0	0	0	0	0	0	X
10.	USA (seafood atlas)	1	1	1	1	0	1	1	1	1	8	X
11.	Ecuador	0	1	1	1	1	1	1	1	1	8	X
12.	Argentina	0	0	1	0	0	1	1	1	1	5	X
13.	Arab states and Gulf countries (dates atlas)	0	0	0	0	0	1	1	1	1	4	X
14.	Saudi Arabia	1	1	1	1	1	1	1	1	1	9	Ö
15.	United Arab Emirates (Abu Dhabi)	1	1	1	1	1	1	1	1	1	9	Ö
16.	Lebanon	1	1	1	1	1	1	1	1	1	9	Ö
17.	Egypt	0	0	0	0	0	0	0	0	0	0	X
18.	Tunisia	0	1	1	1	1	1	1	1	1	8	X
19.	India	1	1	1	1	1	1	1	1	1	9	Ö
20.	Sri Lanka	1	1	1	1	1	1	1	1	1	9	Ö
21.	China	1	1	1	1	1	1	1	1	1	9	Ö
22.	Malaysian	1	1	1	1	1	1	1	1	1	9	Ö
23.	Nepal	1	1	1	1	1	1	1	1	1	9	Ö
24.	Kenya	1	1	1	1	1	1	0	1	1	8	X
25.	West Africa	0	0	0	0	0	0	0	0	0	0	X
26.	Eastern Cape province	0	1	1	1	1	1	0	1	1	7	X
27.	Australia	0	1	1	1	1	1	1	1	1	8	X

Ö, included; X, excluded; UK, United Kingdom; USA, United States of America.

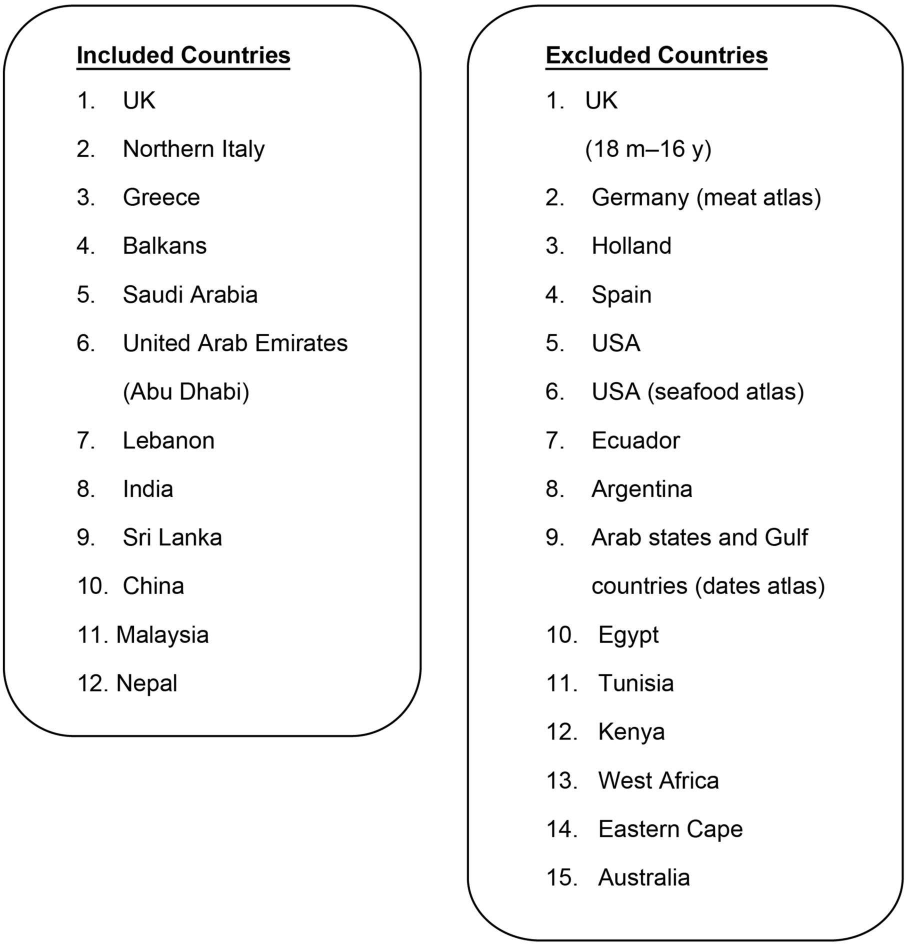

FIGURE 1
Included and excluded countries with food atlases. UK, United Kingdom; USA, United States of America.

developed to simplify decisions regarding the inclusion and exclusion of countries: nine domains (most popular food, photo, multiple portion size, clear photo, use representative cutlery healthy, adult (≥18 years), male, and female) were specified based on those included in the majority of food atlases; each of these nine domains was assigned one point; a score of 1 or 0 was given to each domain; if the total score was not equal to nine, the food atlas was excluded because each domain had to be represented in the food atlas framework included in this review (Table 1). Twelve and fifteen countries were included and excluded, respectively (Figure 1).

3 Results

3.1 Overall description of a food atlas

A food atlas is an effective tool that relies on precise food consumption data to guide national and international health and nutrition policies (15). It comprises a collection of images depicting different amounts of food that has been widely studied and recognized as a valuable resource in dietary data collection, as well as for improving the accuracy of food quantification during dietary records and interviews. The accuracy of dietary assessments is enhanced by allowing users to select images from the food atlas that best represent the actual or typical size of the food portions they consume (16–18).

Most food atlases follow similar guidelines, including the photographic development standards, types of food items, number of portion sizes for each food item, and common household utensils and cutlery used as reference measurements. However, the content of food atlases varies depending on the country and its objectives. For example, Greece developed a food atlas to help assess the dietary intake in its population, whereas the UK used it to evaluate the quantity of food consumed by its population. The United States of America (USA) developed an atlas to understand the factors that influence food selection; Australia aimed to differentiate portion sizes through images; China sought to provide a visual reference to improve the accuracy of dietary surveys; Sri Lanka aimed to identify food portion sizes and varieties; and Southern Nepal used it to create and approve a photographic guide for dietary evaluation (19, 20). Food atlases are valuable tools in various countries for different purposes, and their use is expected to continue to grow in the future.

Many countries have adopted ideas from food atlases created in other nations, which vary based on factors such as the target audience, population, and gender. For instance, the Kenyan food atlas focuses on adolescents aged 9–14 years, while the Eastern Cape Province food atlas is designed for children aged ≤24 months. The UK Young

TABLE 2 Timeline and number of food items of food atlases worldwide by country.

Year	Country (number of food items)
1992	Greece (170)
1994	UK (76)
2000	Argentina (118)
2005	Northern Italy (434)
2010	Australia (200)
2011	USA (N/A)
2012	Lebanon (212)
2013	India (247)
2014	UAE (Abu Dhabi) (83)
	Nepal (40)
	Germany (N/A)
2015	Holland (N/A)
2016	USA (seafood) (2)
	Eastern Cape province (N/A)
	Tunisia (N/A)
2017	Sri Lanka (125)
	UK (18 months–16 years) (104)
2018	Kenya (173)
	Balkans (135)
	Ecuador (68)
	Arab states and Gulf countries (60)
	West Africa (N/A)
	Saudi Arabia (231)
2019	Egypt (72)
	Spain (N/A)
2020	Malaysia (393)
	China (303)

UK, United Kingdom; USA, United States of America.

Person's food atlas is a collection of photographs used to evaluate the dietary intakes of children aged 18 months to 16 years. Food atlases can be created for specific health-related reasons and are considered reliable tools for medical professionals. For example, it could be challenging to explain a food atlas for treating dysphagia—a condition that requires texture-modified foods and thickened liquids—to patients and their caregivers. Additionally, some food atlases have been developed for particular types of food, such as the USA sea-food atlas, which measures seafood intake and its safety; the Gulf countries' and Egyptian date atlases, which provide information on dates farmed in the Gulf Region; and the German Meat atlas, that supports climate justice and food sovereignty, and raises awareness of the environmental challenges posed by industrial meat production. These atlases present new information and facts and establish connections among various vital issues (10, 20, 21).

A photographic food atlas is a collection of images depicting different portions of various dishes that helps to estimate portion sizes. Various countries have created food atlases that represent the most consumed foods in society. The first food atlas was developed in Greece in 1992 and included approximately 170 food items. Food atlases have continued to develop worldwide until 2020. Table 2 provides a timeline of the countries that have developed food atlases, and the number of items included in these atlases.

Most food atlases included 10 significant criteria that were determined after a review of global food atlases. As shown in Table 3, most countries agreed to meet most of the criteria: 96.3% of countries focused on food regarding the type of atlas, 74% of countries included multiple portion sizes in the atlas, and 70.4% included representative photos. The atlas target group was the public aged ≥18 years. By contrast, 11% of the food atlases focused on a target group or specific age group and represented specific food items, such as meat and dates.

3.2 Food items

The number of food items included in an atlas is not fixed; each country determines the number based on its needs or the information collected. The number of food items in each food atlas can vary for various reasons, such as determining commonly consumed foods based on the traditional diet of the community or selecting popular meals and dishes based on previous studies on food consumption in the region (1). For instance, Northern Italy had the highest number of food items ($n = 434$), followed by Malaysia ($n = 393$) and China ($n = 303$) (3, 18, 21). By contrast, Nepal had the lowest number of food items ($n = 40$), followed by the UK ($n = 104$) and the United Arab Emirates (UAE) ($n = 115$) (5, 19, 22). However, SA did not specify the number of food items included, while Egypt only collected 72 food items owing to the specialization of dates. Ecuador had difficulties estimating the nutrients in sauces and only collected 68 food items, while Nepal collected 40 food items due to the incorporation of more than one food item while eating; data were collected during only one meal. Half of the reviewed countries—including the UK (18 months–16 years), Balkans, Greece, Argentina, Lebanon, and Sri Lanka—averaged 138 food items (1, 2, 6, 10, 11, 23).

3.3 Collection methods

Different countries have various strategies to obtain information on the most consumed foods for inclusion in a food atlas. According to the data in Table 4, most countries used dietary or nutritional surveys, followed by FFQs, 24-h dietary recalls, and food recipe books (1, 8, 10, 11).

Other countries collected food consumption data using means such as FFQs, 24-h dietary recalls, pilot studies, food-related databases, cookbooks, and restaurant menus. For instance, the UK food atlas for children relied on the dietary and nutritional surveys of children aged 1.5–4.5 years, young people aged 4–18 years, and a pilot study, resulting in a total of 104 food items. Similarly, the food atlas of Australia includes food items from the "Diet Advice" website database, which were individually assessed to determine the number of foods requiring portion images for the accurate reporting of dietary intake (24).

The photographic food atlas of Kenyan adolescents in Nairobi County uses data from a variety of families with low-to-middle income backgrounds to represent the foods most consumed by

TABLE 3 General food atlas criteria.

Criteria	Country	Number of country (*N* = 27)	%
Foods in the atlas represent the most consumed foods in the population	UK/UK (18 months–16 years)/Northern Italy/Greece/Balkans/USA/Ecuador/SA/UAE/Lebanon/India/Sri Lanka/China/Malaysia/Nepal/Kenya	15	55.6%
The atlas includes representative photos	UK/UK (18 months–16 years)/Northern Italy/Greece/Balkans/USA/Ecuador/SA/UAE/Lebanon/Tunisia/India/Sri Lanka/China/Malaysia/Nepal/Kenya/Eastern Cape province/Australia	19	70.4%
There are details regarding photography of the food in the atlas	UK/Northern Italy/Greece/Balkans/USA/Ecuador/SA/UAE/Lebanon/Tunisia/India/Sri Lanka/China/Malaysia/Nepal/Kenya/Eastern Cape province/Australia	18	66.7%
The atlas includes multiple portion sizes	UK/UK (18 months–16 years)/Northern Italy/Greece/Balkans/USA/Ecuador/Argentina/SA/UAE/Lebanon/Tunisia/India/Sri Lanka/China/Malaysia/Nepal/Kenya/Eastern Cape province/Australia	20	74%
The target group of the atlas is the public (adults aged ≥18 years)	UK/Northern Italy/Greece/Spain/Balkans/USA/Ecuador/Argentina/Arab states and Gulf countries (dates atlas)/SA/UAE/Lebanon/Tunisia/India/Sri Lanka/China/Malaysia/Nepal/Australia	19	70.4%
The target group of the atlas is a specific age group	UK (18 months–16 years)/Kenya/Eastern Cape	3	11%
The atlas is for food	UK/UK (18 months–16 years)/Germany (meat atlas)/Northern Italy/Holland/Greece/Spain/Balkans/USA/USA (seafood atlas)/Ecuador/Argentina/Arab states and Gulf countries (dates atlas)/SA/UAE/Lebanon/Tunisia/India/Sri Lanka/China/Malaysia/Nepal/Kenya/West Africa/Eastern Cape province/Australia	26	96.3%
The atlas is for items other than food	Egypt	1	3.7%
The atlas represents the most consumed foods by the society	UK/UK (18 months–16 years)/Northern Italy/Greece/Balkans/USA/Ecuador/SA/UAE/Lebanon/India/Sri Lanka/China/Malaysia/Nepal/Kenya	15	55.6%
The atlas represents specific food items, such as meat, dates, etc.	Germany (meat atlas)/USA (seafood)/Arab states and Gulf countries (dates atlas)	3	11%

UAE, United Arab Emirates; UK, United Kingdom; USA, United States of America.

TABLE 4 Methods of identifying the most consumed food in countries worldwide.

Methods for included countries	Countries	Number of frequencies
Food frequency questionnaire	Greece/Argentina	2
The dietary or nutritional survey	UK/Balkans/Sri Lanka/Malaysia	4
24-hour dietary recall	Lebanon/Nepal	2
Data from previous studies	UAE	1
Food and nutrition websites	India	1
Questionnaire	SA	1
Recipe books	Northern Italy/India	2
Restaurant menu	Northern Italy	1
Referring to previous food atlas	Malaysia	1
Not determined	China	1

Kenyan adolescents (25). By contrast, the Seafood Atlas of the USA was based on pilot studies demonstrating that tilapia filets and white shrimp were suitable for producing generic fish and shrimp photographs (21). In Sri Lanka, various methods have been used to gather information on food consumption, including data from a nutritional survey and the development of an FFQ for Sri Lankan adults.

In Sri Lanka, the urban population's increased consumption of Western foods has led to their inclusion in the food atlas, with an input from several nutritional experts who believe that they might be essential for future use (11). For the Balkan region, the food atlas selection was based on prior food consumption surveys. Traditional cookbooks and restaurant menus were consulted to include additional dishes that reflect the local dietary patterns and cultural competency (1). In the UAE, the most consumed foods were determined using previous food consumption data, food atlases, and food composition tables, as well as data collected from Gulf Cooperation Council countries and the Middle East. This includes traditional UAE and Middle Eastern foods, which are characterized by distinct ingredient compositions (26). The Tunisian food atlas relies on epidemiological studies published between 1996 and 2005 to assess a wide range of food items and portions (27).

Different countries have employed various methods to select foods for the atlas based on their capabilities. For instance, Malaysia referred to previous food atlases, related documents, current national food consumption data, and researchers' observations of readily available market foods (22); India searched food and nutrition websites; and Northern Italy sought assistance from Italian diet recipe books, restaurants, cafeteria menus, and the most consumed dishes (3). In the UAE, data were extracted from previous studies, SA used a questionnaire, and China has yet to determine an exact method of collection (12, 26, 28).

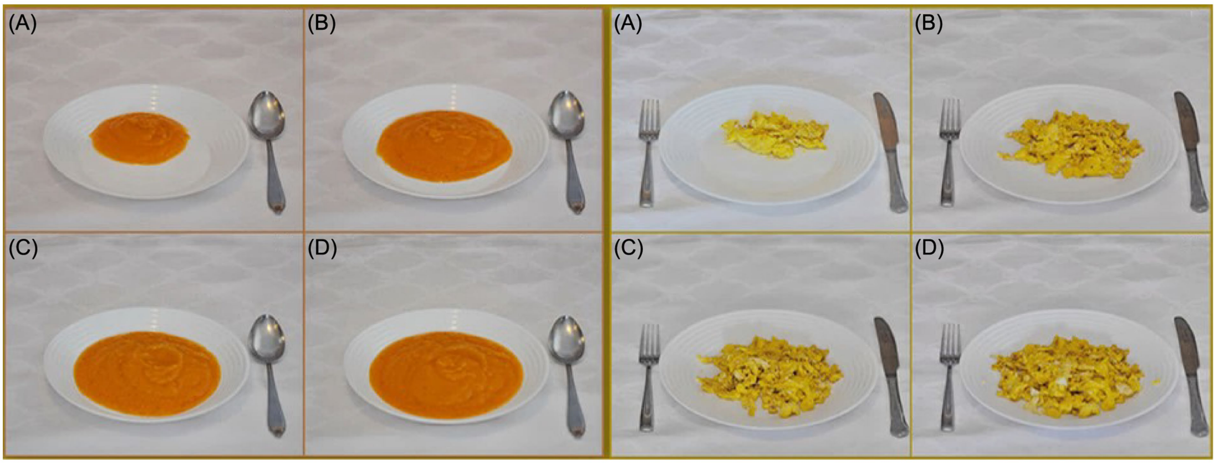

FIGURE 2
Utensils in the Balkan Region food atlas [Photo series of carrot soup (Left **(A—D)**)] and scrambled eggs [right **(A—D)**].

3.4 Utensils, photography, and portion sizes in food atlases

The selection of traditional and commonly used utensils that represent a community's eating habits and behaviors plays a critical role in determining consumption and enhancing the accuracy of using the food atlas as an assessment tool. The most used utensils—such as plates, bowls, and cups in countries like the UK, UAE, Italy, Greece, Balkan, Lebanon, Tunisia, Sri Lanka, and Australia—are standard white utensils used to present mostly consumed food items (Figure 2).

By contrast, the utensils used in the Ecuadorian atlas are light brown plates with six sets of white measuring cups to represent their culture, whereas Malaysia used a plain baby-blue plate to represent food items (Figure 3).

Furthermore, countries such as China choose utensils based on the color, shape, and amount of food; thus, plates of different colors and sizes were selected (Figure 4).

Generally, the variations in the utensils selected in a food atlas can be attributed to the traditional and cultural differences in the eating habits and behaviors in each country. To help assess and estimate the actual amount or portion of food consumed by users of the food atlas, most of the reviewed food atlases place spoons, forks, and knives next to the plates. For instance, the US food atlas places a piece of toast and garnished lemon wedge on the same seafood ceramic plate as a reference object (Figure 5).

The quality of the photographs is crucial for determining the appropriate portion size to represent the quantity of food consumed, and clear information about the cameras and tools used to photograph the food is necessary. In the Balkan food atlas, a professional photographer was hired to capture photographs of food portions under standard lighting conditions on a white background (1). The same conditions were applied in all photographs, the weight of the food portion was marked on the photograph, and images were presented in color to make them appear realistic. Different methods have been used to determine the portion sizes of food items in food atlases. In Greece, a questionnaire was administered to participants to report their usual portion sizes, and the 5th and 95th percentiles of the reported intake were selected to correspond to the quantities presented in the first and last pictures in each photo series of the atlas. Equal increments on a log scale were used to estimate the amount presented in the intermediate images (2). In Australia, the "Food Works" nutrition analysis software was used to determine the average size of portion sizes to portray a graduated increase in portion size (24). In the UAE, the weights for each portion size were obtained directly from the UK food atlas, and a household survey of local families was conducted to provide the required data on the portion sizes of traditional foods not stated in the UK food atlas (26).

Most food atlases used a series of photographs with food of different weights and sizes to provide multiple choices for common or nutritionally essential food items, such as rice, to determine portion sizes (2, 6, 24, 26). By contrast, Lebanon and Tunisia only used three portions for each food item (10, 27); we assumed that the portion sizes consumed were representative (27). Conversely, China designed 4–10 grades of food portions based on food size, quantity, or a set number of portions within the range of the most consumed amount (19). Generally, the weights of food portions were directly measured using electronic scales to the nearest gram (or milliliter for liquids) (19). Estimating portion sizes has been a significant limitation of dietary studies in the past, since estimates can be less accurate than weighed portions (6, 21). However, printed photographs of foods have shown increased accuracy in food portion estimation compared with unassisted estimates (6, 21).

4 Discussion

Food atlases assist in determining and estimating nutritional intake and are used in nutritional surveys, assessments of patients, evaluations of food consumed by populations, assessments of dietary habits and behaviors of society, and their relationship to weight gain.

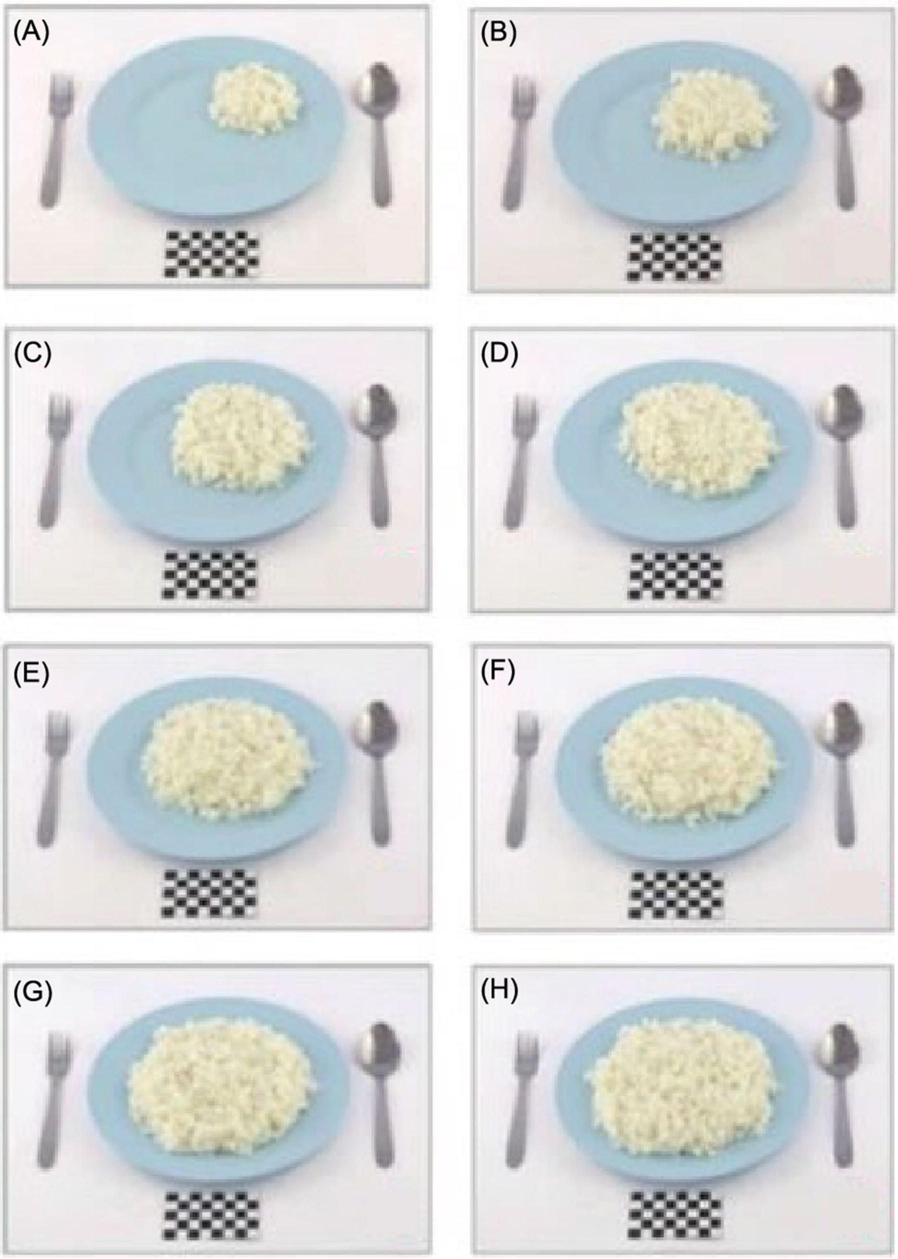

FIGURE 3
Utensils in the Malaysian food atlas [Photo series of rice **(A—H)**].

It also helps assess food consumption by age group and is used in FFQs.

In most countries, food atlases rely on national surveys and questionnaires to identify commonly consumed food items. However, some countries use a combination of methods to cover all types of consumed food items. Owing to differences in the methods used for identifying the most consumed foods in each country's food atlas, there is no consumption information methodology that can be considered the gold standard. The choice of a method depends on factors such as available resources, data, cost, time, and suitability for the developing team and population.

Food atlases contain photographs of food items describing traditional household utensils and portions. Ensuring the quality of food photographs thus requires consideration of all elements, such as lighting, camera, position, distance, angle, reference objects, and background. Many factors, including personal and food characteristics, affect the estimation of portion size by individuals and may lead to significant estimation errors. Therefore, determining the amount of food consumed by individuals remains a challenge in accurately estimating food portion sizes.

Despite these challenges, the development of a national food atlas offers several advantages. For instance, conducting studies to identify traditional dishes to be included in the atlas, such as in the Lebanese food atlas; and using accurate estimation and quantification for each food, along with color photos to attract participants, such as in the Sri Lankan food atlas (Figure 6).

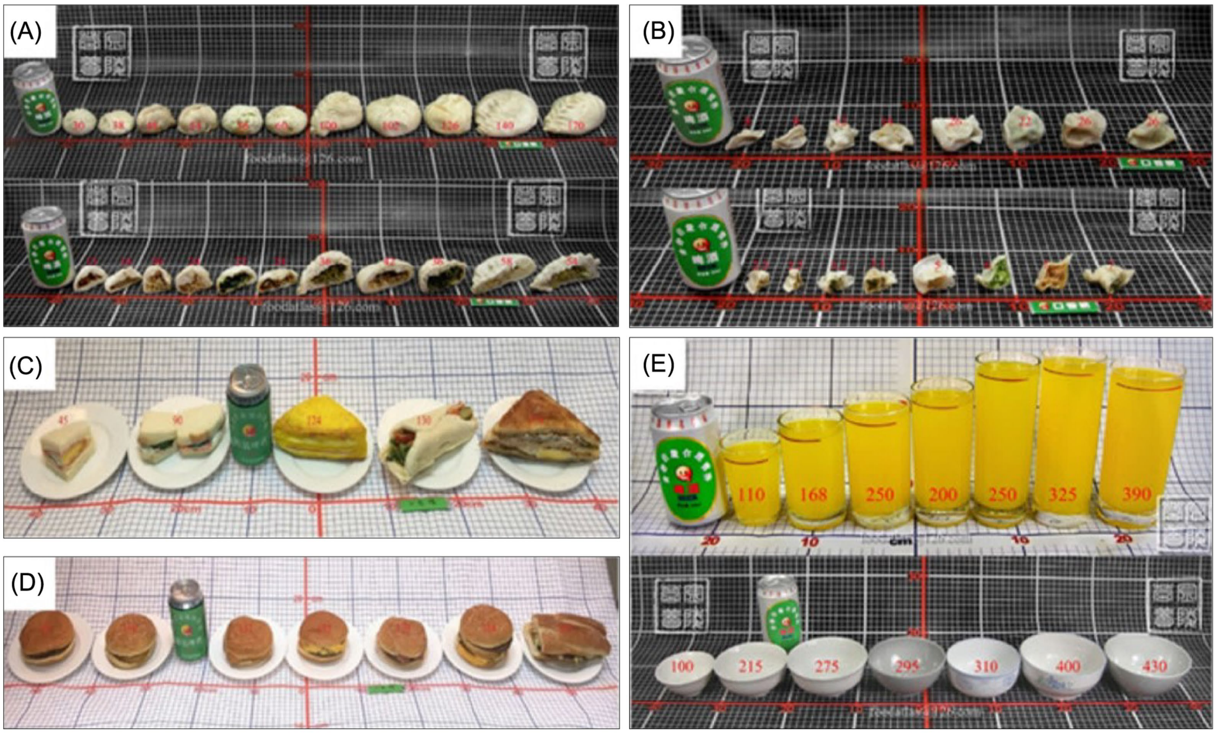

FIGURE 4
Utensils in the Chinese food atlas (Photos of Chinese and Western representative compound processed foods and tableware. **(A)** Steamed stuffed buns. **(B)** Dumplings. **(C)** Sandwiches. **(D)** Hamburgers. **(E)** Glasses (above) and bowls (below) of different sizes).

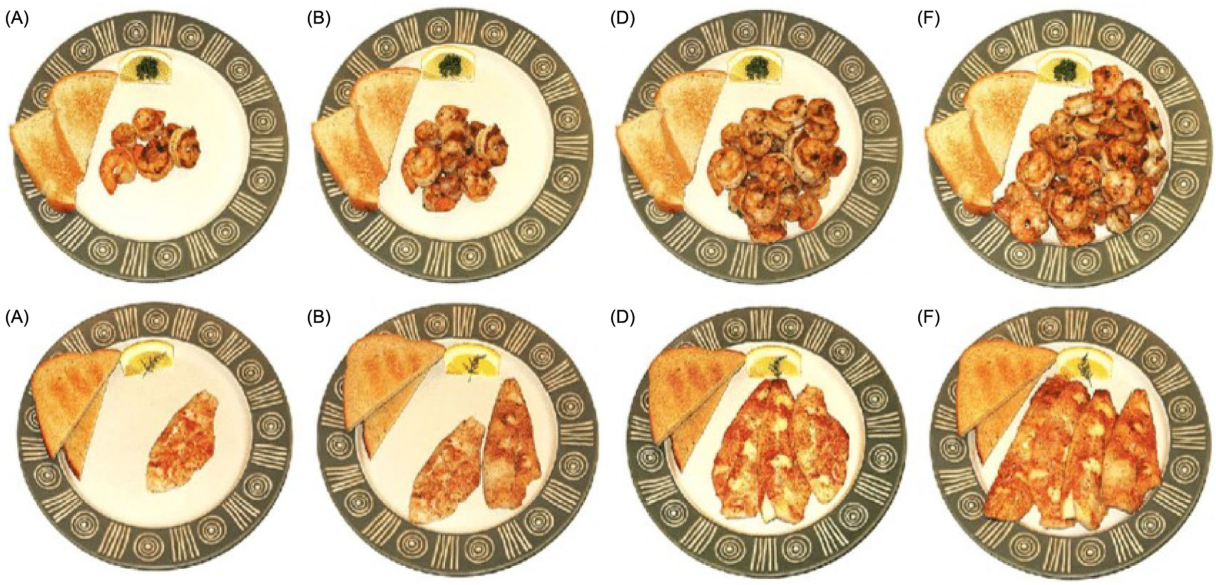

FIGURE 5
Utensils of the USA Seafood atlas [Photo series of shrimp and fish portion **(A—F)**].

4.1 Future steps in creating food atlases

Following a comprehensive review of food atlases globally, there has been a call for a scientifically unified guide to develop national food atlases. In response, a procedural manual was created to outline the steps required to create a food atlas that accurately reflects a community's food consumption. The manual was developed based on a thorough examination of relevant studies.

A steering committee was established to ensure the accuracy and scientific rigor of the food atlas. The committee—comprising experts

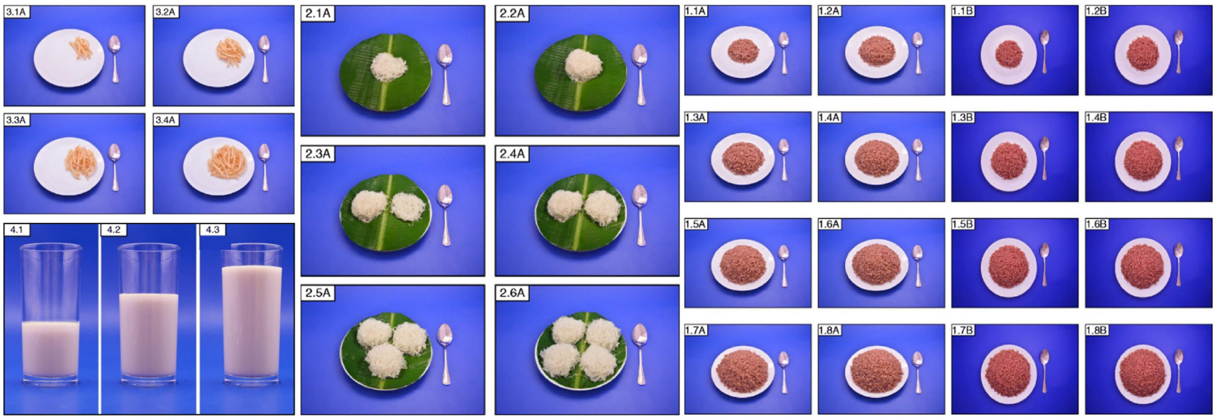

FIGURE 6
Photos in the Sri Lankan food atlas [Photo series of french fries (3.1A-3.4A)], milk (4.1-4.3), string hoppers (2.1A-2.6A), and cooked red rice (1.1A-1.8B).

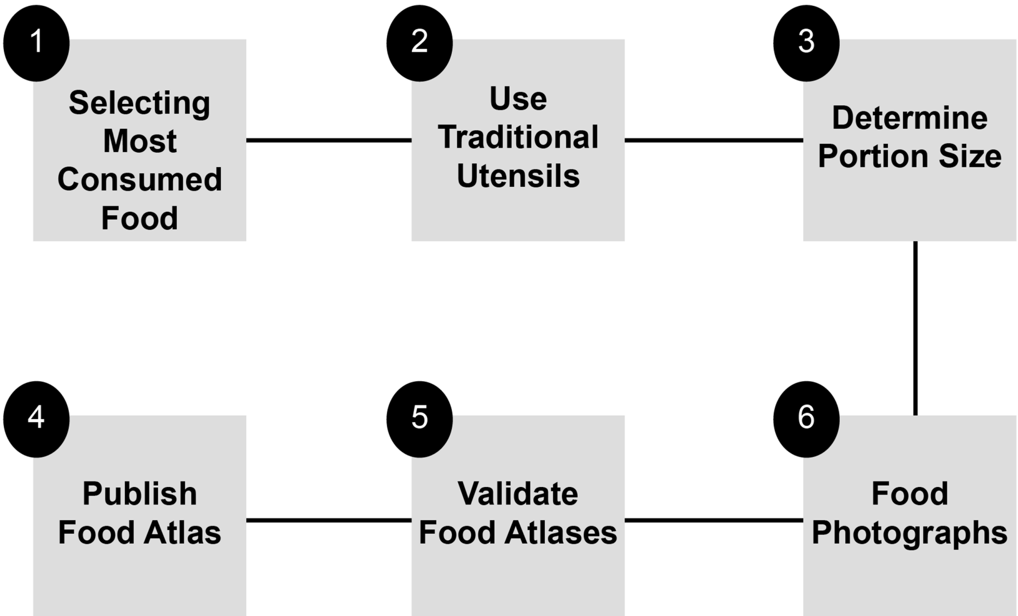

FIGURE 7
Process of developing a food atlas.

from various sectors (including government and private organizations) and possessing professional expertise in food, nutrition, education, psychology, public health, and other related fields—was responsible for providing scientific recommendations and conducting a thorough review of the food atlas outputs. The development of a food atlas involves six distinct stages (as illustrated in Figure 7).

First, selecting the most consumed food is a critical step in creating a food atlas. The foods chosen for the atlas should accurately represent a country's food consumption patterns. There are various methods for identifying typical foods in a specific region, and the choice of the most appropriate method should be based on the availability of data and resources (see Supplementary material for further details).

Second, selecting a representative utensil from a community. The public typically uses traditional utensils; thus, selecting a representative utensil plays an active role in the success of the food atlas. While determining traditional and commonly used utensils may require efforts, it will be helpful to improve the accuracy of the food atlas assessment (see further details in Supplementary material).

Third, portion size must be determined. The food portion size is determined based on the typical food intake of the population. Selecting the average portion size as a representative method for food consumed by individuals in the community is crucial (see Supplementary material for further details).

Fourth, photographs of the food are captured. Minimizing errors in portion size estimates is one of the most significant challenges in creating and photographing food atlases. These errors are influenced by the interaction between the format of the photograph series and the participants' skills in describing the portion size. The primary factors that are most likely to affect the interaction include the size of the images, portion sizes, interval, order of presentation, labels, background, color, and camera type. Although the protocols varied among different countries, the most common protocol was selected for the procedural manual (see Supplementary material for further details).

The fifth step is the process of validating food atlases, which is crucial because it confirms the accuracy and reliability of the atlas for use. Two methods were used to validate the atlas: visual estimation of the quantity of food, and recall information using the atlas (see Supplementary material for further details).

Finally, once validated, the food atlas is ready for publication. Technology plays an important role in ensuring success; thus, the atlas is published in multiple versions based on community preferences. Moreover, the availability of both digital and paper versions is essential for reaching people of all ages in society (see Supplementary material for further information).

The development of food atlases worldwide has identified certain disadvantages that must be avoided when creating a nationally representative food atlas. One of the disadvantages is the difficulty in determining the appropriate portion size and mixing different types of food; for example, the addition of cooked beans to white rice may affect dish density, leading to inaccurate portion-size estimation and photography. Additionally, variations in food recipes across different regions within the same country can result in differences in nutritional factors, such as calorie intake. Furthermore, limitations in the timing of food selection, such as only during lunchtime, can result in a lack of representation of dishes consumed at different times of the day. The use of the Scopus database for literature search presents another limitation, because it is crucial to extend the range of research metrics to encompass nearly twice the number of peer-reviewed publications. However, as a reputable source of information, the Scopus database is widely recognized for its extensive global data coverage.

Several potential strategies may address challenges related to food atlases, including accounting for regional variations and culturally sensitive portion sizes across different areas of Saudi Arabia. Additionally, emphasis should be placed on using consistent methodological approaches when determining appropriate portion sizes and recognizing variations in food recipes throughout the region. Collaboration across disciplines is also essential. By adopting these strategies, food atlases are expected to become more inclusive, accurate, and applicable to diverse cultural and methodological contexts.

5 Conclusion

Food atlases play a crucial role in promoting and optimizing nutrition and food-related aspects worldwide by providing a unified scientific method for their development. The aim of creating a food atlas is to establish an authoritative reference for the quantitative evaluation of food intake by community members, while reducing the likelihood of errors during the assessment process. This study emphasizes the importance of food atlases and provides a six-step procedure manual that can be used as a reference for their development. Further research is necessary to confirm the efficacy of the proposed manual, to streamline and standardize national initiatives. Moreover, given the widespread digital transformation currently occurring both globally and within individual countries, it is essential to conduct future studies that assess the feasibility of digitizing food atlases, thereby reducing the time required for their completion.

Author contributions

GF: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. RA: Formal analysis, Investigation, Methodology, Resources, Writing – original draft. LA: Formal analysis, Investigation, Methodology, Resources, Writing – original draft. SA: Formal analysis, Investigation, Resources, Writing – original draft. FA: Formal analysis, Investigation, Resources, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

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Comparing three summary indices to assess diet quality of Canadian children: a call for consensus

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Purpose: The Healthy Eating Index-Canada 2015 (HEI-C 2015), Diet Quality Index-International (DQI-I), and Healthy Eating Food Index 2019 (HEFI-2019) are commonly used to summarize the quality of Canadian diets. This paper sought to compare these three diet quality indices with respect to their ability to capture diets of different quality in Canadian children and to discriminate between population subgroups.

Methods: Data were collected in school-based surveys from grade 4–6 students (9–12 years old) in western Canada through 24-h dietary recall in 2016 (n = 336), 2018 (n = 454), and 2020/2021 (n = 909). Diet quality was assessed using HEI-C 2015, DQI-I and HEFI-2019. Agreement between the three indices was assessed using weighted Cohen's kappa. Univariate and multivariable linear regression models assessed diet quality according to student's sex, grade level, school material/social deprivation, and geographic region.

Results: HEFI-2019 scores had the widest range, while DQI-I had the smallest. Agreement was 0.55 between HEI-C 2015 and DQI-I, 0.38 between HEI-C 2015 and HEFI-2019, and 0.29 between DQI-I and HEFI-2019. Boys and students from materially deprived areas reported diets of lower quality, irrespective of the index. There were no differences in diet quality across grade levels and geographic region. Energy consumption was associated positively with DQI-I and negatively HEFI-2019 scores.

Conclusion: The three indices demonstrated fair to moderate agreement and varying ability to discriminate diet quality between different population subgroups of Canadian children. This study shows that the choice of a diet quality index affects the interpretation of results and practical considerations, yielding different conclusions with respect to the determinants of children's diet quality. Seeking consensus on which diet quality index to use for research, policy and/or practice would help support dietary research and policy development, and promote dietary guidelines implementation.

KEYWORDS

dietary assessment, diet quality index, children, healthy eating, epidemiology, public health

1 Introduction

The quality of the diets of Canadian children is often poor as they fail to meet the recommended intakes for fruit, vegetables, and sodium, with a significant portion of their energy intake coming from high-fat, sugary foods (1–3). It is well established that consuming diets of good quality is essential for growth and physical development, whereas emerging evidence points to their importance for mental health and well-being, as well as academic performance (4–6). Good quality diets have been associated with better health outcomes, including body weights, blood pressure, metabolic syndrome, mental health and academic performance (7–9). An accurate measure of diet quality is essential to study the importance of good diet quality and to assess the effectiveness of dietary interventions.

Several indices have been used to assess the quality of the whole diet of Canadian children (8, 10, 11). The most commonly used indices are the Diet Quality Index-International (DQI-I) (10, 12, 13), Healthy Eating Index-Canada 2015 (HEI-C 2015) (11, 14, 15), and the more recently developed Healthy Eating Index-2019 (HEFI-2019) (16). While all three indices aim to summarize the quality of the whole diet using established dietary recommendations, they consider different sets of criteria and scoring systems (17), hindering the interpretation of dietary guidelines to improve diet quality. It is not clear which index best captures diet quality of different population subgroups and should be used for research, policy and/or practice to help support dietary research and policy development, and promote dietary guidelines implementation. An optimal diet quality index should have a wide range of scores to distinguish between individuals who consume diets of different quality. Additionally, a diet quality index should be independent of diet quantity and be able to effectively differentiate between different population subgroupings (e.g., gender, age, socioeconomic status (SES), rural/urban residence) (18). Indeed, while some studies found little to no difference in diet quality between girls and boys (10, 19), government reports suggest that Canadian girls consume, on average, more vegetables and fruit and less sodium, compared with boys (2, 3). Moreover, younger children consume diets of higher quality than older children (19, 20), and children from families with higher SES have healthier dietary patterns, characterized by lower consumption of energy-dense foods and higher consumption of fruit, vegetables, and dairy products, compared with their peers from lower SES households (21–23). To our knowledge, no previous studies compared these three commonly used diet quality indices with respect to their ability to capture diets of different quality. This exploratory study sought to assess the agreement between HEI-C 2015, DQI-I, and HEFI-2019, and describe the ability of each index to discriminate the diet quality of Canadian children across population subgroups.

2 Methods

2.1 Procedures

Using a repeated cross-sectional design, grade 4–6 students from 25 APPLE Schools were surveyed in 2016, 2018, and 2020/2021. APPLE Schools is an innovative school-based health promotion program introduced in 2008 and currently delivered in 93 elementary schools located in socioeconomically disadvantaged communities across western Canada. The APPLE Schools program delivers health promotion activities targeting healthy eating, physical activity, and mental health and well-being, and benefits over 30,000 children annually (24, 25). Data collection took place in schools during regular class time. Students were provided with unique usernames and passwords to access the online survey portal on their Chromebooks. In 2016 and 2018, trained research assistants travelled to schools to oversee data collection in each classroom. In 2020, data collection procedures shifted to an online mode as per COVID-19 protocols, with trained research assistants connecting to each classroom through Zoom to prompt survey questions projected on the whiteboard. A total of 441 (66%), 473 (67%), and 973 (78%) students from 6, 7, and 12 schools completed the survey in 2016, 2018, and 2020/2021, respectively. Students provided assent, while their parents or guardians provided active-information passive-permission consent. The Health Research Ethics Board of the University of Alberta (Pro00061528) and the school boards that participated in the study approved all study procedures.

2.2 Measures

Students completed an interactive web-based 24-h dietary recall tool to derive diet quality (26). The tool has been previously validated in youth and prompts children to report all food and beverage items consumed the previous day, providing portion size images for each item and other cues to help students recall their intake. The tool was administered in springtime on Tuesdays, Wednesdays, Thursdays or Fridays, so that all collected dietary data pertained to the intake on springtime weekdays. Student responses were analyzed using nutrient databases (Canadian Nutrient File [CFN], Elizabeth Stewart Hands and Associates [ESHA], U.S. Department of Agriculture [USDA]) to yield daily intake data for 6 food groups (i.e., vegetables, fruits, grain products, meat and alternatives, milk and alternatives, and other), energy intake (i.e., total caloric intake, caloric intake from fat and saturated fats), 10 macronutrients and 23 micronutrients (26). To control for false reporting, students reporting implausible values of energy intake <500 or > 5000 kcal ($n = 91$ [2016], 17 [2018], 64 [2020/21]) were excluded from analysis (27).

Diet quality was assessed using three dietary indices.

2.2.1 Healthy Eating Index-Canada 2015

HEI was initially developed by the United States Department of Agriculture in 1995 (28–30). It is designed to reflect the recommendations outlined in the Dietary Guidelines for Americans and to promote healthy eating patterns by assessing two key categories of the diet: adequacy and moderation. HEI was adapted for use in Canada in 1995, 2005, 2010, and 2015 (31–35). In this study, HEI-C 2015 was calculated using the Canada's Food Guide 2007 recommendations for 9-13-year-old children (36). HEI scores range from 0 to 100, with higher scores indicating better diet quality.

2.2.2 Diet Quality Index-International

DQI-I is an international index developed in 2003 (37). It provides flexibility in regards to the components of a healthy diet included in the index calculation and hence enables comparison of dietary patterns across countries. By incorporating both foods and nutrients in diet quality evaluation, DQI-I takes into account the diversity of food consumption across different countries. DQI-I measures the four key categories of dietary intake: variety, adequacy, moderation, and overall balance. DQI-I scores range from 0 to 100, with higher scores indicating better diet quality.

2.2.3 Healthy Eating Food Index-2019

HEFI-2019 was developed by Health Canada in 2022 to assess adherence to the new Canada's Food Guide 2019 dietary recommendations among Canadians aged two years and older (16). HEFI-2019 assesses the intake of 10 specific dietary components, including five foods and four nutrients, with one component measuring the beverage intake. HEFI-2019 scores range from 0 to 80, with higher scores indicating better diet quality. To facilitate comparisons with DQI-I and HEI-C 2015, HEFI-2019 scores were multiplied by 1.25 to range from 0 to 100.

Supplementary Material details how each index is constructed. Full details are provided here (16, 28, 37).

2.2.4 Student- and school-level characteristics

Students reported their sex (girl vs. boy) and grade (4–6). Geographic region (rural vs. urban) and school material and social deprivation were derived from 2016 Canada Census data based on schools' postal codes (38, 39). Higher quintiles of material and social deprivation indices indicate higher deprivation. To ensure sufficient number of schools in each group of materially and socially deprived areas, quintiles 1–3 vs. 4–5 of the material deprivation index and quintiles 1–2 vs. 3–5 of the social deprivation index were combined.

2.3 Data analyses

The properties of each index were described using means, standard deviations (SD), minimum to maximum ranges, and coefficients of variation (CV). Simple linear regression was used to assess differences in diet quality indices measured at three time points. Percent agreement and weighted Cohen's kappa coefficients were used to assess the level of agreement between the three indices. Total scores were categorized into quartiles since no cut-off points for differentiating good vs. poor diet quality have been previously proposed for HEI-C 2015 and HEFI-2019. The weighted Cohen's kappa coefficients were calculated since more than two categories for each index were being compared (40). Quadratic weighting was used to account for the severity of disagreements (whereas unweighted kappa treats all disagreements equally). Next, it was assessed whether sex, grade level, energy intake, material and social deprivation quintiles, and geographic region are associated with each of the three indices, by adding these variables singularly and simultaneously to the univariate and multivariable linear regression models, respectively. The F tests, adjusted R-Squared, and root mean square deviation (RMSD) were used to assess the goodness of fit of the multivariable linear regression models. Students with missing values on sex and/or grade level were excluded ($n = 14$ [2016], 2 [2018], 0 [2020/21]). All statistical analyses were conducted using Stata 17.0 (College Station, TX). A p-value <0.05 was considered statistically significant.

3 Results

Data from 336 (2016), 454 (2018), and 909 (2020/21) students were available for analysis. Student and school characteristics are shown in Table 1. Over half (51.4%) were girls. About one-third were in grade 4, one-third in grade 5, and one-third in grade 6 (30.6, 37.1, 32.3%, respectively). Of 25 participating schools, 60.8% were located in urban areas. HEI-C 2015 and DQI-I had similar average scores and trends over time in each cross-sectional sample. Between 2016 and 2020/2021 HEI-C 2015 declined from 54.7 (SD = 13.9) to 49.5 (SD = 12.9), and DQI-I from 55.6 (SD = 9.7) to 53.2 (SD = 9.9). The HEFI-2019 scores were markedly lower than HEI-C 2015 and DQI-I in each cross-sectional sample and showed little variation over time: 45.0 (SD = 13.9) in 2016, 44.7 (SD = 13.1) in 2018, and 44.9 (SD = 13.6) in 2020/2021 (Table 1). Overall, the distribution of DQI-I scores had the lowest variability, ranging from 19.9 to 83.6 (CV = 18.1%), compared to HEI-C 2015 that ranged from 11.7 to 95.3 (CV = 25.8%) and HEFI-2019 from 8.6 to 90.1 (CV = 30.1%), with the latter having the widest range of scores.

Percent agreement and weighted kappa scores varied across the survey years but were statistically significant for all comparisons (Table 2). In a combined sample of students who participated in any of the survey cycles, percent agreement between HEI-C 2015 and DQI-I was 0.88 (95% Confidence Interval [CI]: 0.87, 0.89), between HEI-C 2015 and HEFI-2019 – 0.83 (95% CI: 0.82, 0.84), and between DQI-I and HEFI-2019 – 0.80 (95% CI: 0.79, 0.81). For this combined sample, weighted Cohen's kappa coefficient for agreement between HEI-C 2015 and DQI-I was 0.55 (95% CI: 0.52, 0.59), between HEI-C 2015 and HEFI-2019 0.38 (95% CI: 0.35, 0.42), and between DQI-I and HEFI-2019 0.29 (95% CI: 0.25, 0.33). These values of weighted Cohen's kappa coefficients translate into fair to moderate agreement (41).

Relative to girls, boys reported diets of lower quality, with the difference being particularly pronounced for DQI-I in both univariate ($\beta = -1.37$, 95% CI: −2.31, −0.43) and multivariable models ($\beta = -1.44$, 95% CI: −2.38, −0.50) (Table 3). There were no statistically significant differences in diet quality scores across grade levels regardless of the index used. Students attending schools in more vs. less materially deprived areas appeared to have worse diet quality irrespective of the index used, and these differences remained robust after adjusting for covariates (sex, grade level, energy intake, social deprivation, and geographic region). However, diet quality was higher in more vs. less socially deprived areas when using HEI-C 2015 ($\beta = 1.24$, 95% CI -0.09, 2.57) and DQI-I ($\beta = 1.03$, 95% CI: 0.05, 2.02) and after adjusting for covariates (sex, grade level, energy intake, material deprivation, and geographic region). Differences in diet quality according to geographic region were found for HEI-C 2015 but not for DQI-I and HEFI-2019. Finally, energy intake was positively associated with DQI-I ($\beta = 0.09$, 95% CI: 0.04, 0.14) and negatively associated with HEFI-2019 ($\beta = -0.19$, 95% CI: −0.25, −0.12).

4 Discussion

This study compared diet quality derived using three commonly used summary measures (HEI-C 2015, DQI-I, HEFI-2019) among grade 4–6 students from 25 elementary schools in western Canada. The three indices have different properties (e.g., dietary components assessed, range of values, coefficient of variation), with HEFI-2019 demonstrating the widest range of scores and DQI-I the narrowest variation in the scores. The three indices demonstrated fair to moderate agreement (41). The ability of the indices to discriminate the

TABLE 1 School and participant characteristics in 2016, 2018, and 2021.

Student characteristics	2016 (*n* = 336)	2018 (*n* = 454)	2021 (*n* = 909)	Total (*n* = 1699)
Sex, *n* (%)				
Girls	181 (53.9)	225 (49.6)	468 (51.5)	874 (51.4)
Boys	155 (46.1)	229 (50.4)	441 (48.5)	825 (48.6)
Grade, *n* (%)				
4	93 (27.7)	141 (31.1)	286 (31.5)	520 (30.6)
5	119 (35.4)	175 (38.6)	336 (37.0)	630 (37.1)
6	124 (36.9)	138 (30.4)	287 (31.6)	549 (32.3)
Diet quality index, mean (SD)				
HEI-C 2015	54.7 (13.9)	52.4 (12.9)	49.5 (12.9)	51.3 (13.2)[b]
DQI-I	55.6 (9.7)	55.0 (9.4)	53.2 (9.9)	54.1 (9.8)[b]
HEFI-2019[a]	45.0 (14.0)	44.7 (13.1)	45.0 (13.6)	44.9 (13.5)
Diet quality index, range (CV%)				
HEI-C 2015	19.3–93.4 (25.4)	14.6–95.3 (24.6)	11.7–89.3 (26.1)	11.7–95.3 (25.7)
DQI-I	28.0–80.8 (17.4)	26.1–80.6 (17.1)	19.9–83.9 (18.6)	19.9–83.9 (18.1)
HEFI-2019[a]	8.6-84.0 (31.1)	13.5–82.7 (29.3)	10.5–90.1 (30.2)	8.6–90.1 (30.1)

School characteristics	2016 (*n* = 6)	2018 (*n* = 7)	2021 (*n* = 12)	Total (*n* = 25)
Material deprivation quintile, *n* (%)				
1 (least deprived)	0 (0)	1 (14.3)	2 (16.7)	3 (12.0)
2	1 (16.7)	1 (14.3)	3 (25.0)	5 (20.0)
3	0 (0)	0 (0)	4 (33.3)	4 (16.0)
4	0 (0)	3 (42.9)	3 (25.0)	6 (24.0)
5 (most deprived)	5 (83.3)	2 (28.6)	0 (0)	7 (28.0)
Social deprivation quintile, *n* (%)				
1 (least deprived)	1 (16.7)	2 (28.6)	3 (25.0)	6 (24.0)
2	2 (33.3)	0 (0)	4 (33.3)	6 (24.0)
3	1 (16.7)	2 (28.6)	2 (16.7)	5 (20.0)
4	1 (16.7)	3 (42.9)	1 (8.3)	5 (20.0)
5 (most deprived)	1 (16.7)	0 (0)	2 (16.7)	3 (12.0)
Geographic region, *n* (%)				
Urban	0 (0)	0 (0)	3 (25.0)	3 (12.0)
Rural	6 (100)	7 (100)	9 (75.0)	22 (88.0)

CV, coefficient of variation; SD, standard deviation; HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019, Healthy Eating Food Index 2019.
[a]HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.
[b]*p*-value for trend from simple linear regression is < 0.0001.

quality of diets between different population subgroups of Canadian children varied, yielding different conclusions with respect to the determinants of children's diet quality. Also, higher energy consumption was associated with higher DQI-I and lower HEFI-2019 scores, with the strongest association for HEFI-2019.

This study revealed that, compared with the international index (DQI-I), the two Canadian indices (HEI-C 2015 and HEFI-2019) appear to have more variation in scores. In particular, the index that was developed specifically for Canadian diets (HEFI-2019) showed the widest variation in scores, suggesting it may better capture diets of lower and higher quality. No HEFI-19 scores have been previously reported specifically for children (16). It is therefore not possible to assess whether our scores align with the literature, albeit it is feasible the scores for all three indices may be lower in our sample derived from socioeconomically disadvantaged communities in western Canada. Fair agreement was found between HEI-C 2015 and HEFI-2019 and between DQI-I and HEFI-2019, while a moderate agreement was found between HEI-C 2015 and DQI-I. The latter finding is not surprising as both HEI-C 2015 and DQI-I use similar dietary components (adequacy, moderation) as opposed to HEFI-2019. The correlation between HEI-C 2015 and HEFI-2019 has been previously reported to be 0.79 (16), while in our sample it was as low as 0.6 (data not shown), which may be attributed to our use of a HEI-2015 version that was adapted for the Canadian population (28–30, 34). Finally, higher calorie intake was found to be associated with higher DQI-I but lower HEFI-2019 scores, with HEFI-2019 having the strongest

TABLE 2 Percent agreement and weighted Cohen's kappa coefficients (95% CI) for HEI-C 2015, DQI-I, and HEFI-2019.

		HEI-C 2015		DQI-I	
		Percent agreement (95% CI)	Cohen's kappa coefficient (95% CI)	Percent agreement (95% CI)	Cohen's kappa coefficient (95% CI)
2016	DQI-I	0.89 (0.88, 0.91)	0.62 (0.55, 0.69)	n/a	n/a
	HEFI-2019[a]	0.83 (0.81, 0.86)	0.42 (0.34, 0.49)	0.81 (0.78, 0.84)	0.33 (0.25, 0.41)
2018	DQI-I	0.88 (0.86, 0.89)	0.55 (0.49, 0.61)	n/a	n/a
	HEFI-2019[a]	0.82 (0.80, 0.84)	0.36 (0.30, 0.42)	0.79 (0.76, 0.81)	0.25 (0.18, 0.32)
2020/2021	DQI-I	0.87 (0.86, 0.89)	0.55 (0.50, 0.60)	n/a	n/a
	HEFI-2019[a]	0.83 (0.82, 0.85)	0.41 (0.36, 0.45)	0.80 (0.78, 0.82)	0.29 (0.24, 0.34)
Combined	DQI-I	0.88 (0.87, 0.89)	0.55 (0.52, 0.59)	n/a	n/a
	HEFI-2019[a]	0.83 (0.82, 0.84)	0.38 (0.35, 0.42)	0.80 (0.79, 0.81)	0.29 (0.25, 0.33)

CI, confidence interval; HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019, Healthy Eating Food Index 2019; n/a, not applicable. *p*-value for all kappa < 0.01.

[a]HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.

TABLE 3 Coefficients (95% CI)[a] of HEI-C 2015, DQI-I, and HEFI-2019[b] total scores for participant and school characteristics.

	HEI-C 2015		DQI-I		HEFI-2019[b]	
	Univariate (95% CI)	Multivariable (95% CI)	Univariate (95% CI)	Multivariable (95% CI)	Univariate (95% CI)	Multivariable (95% CI)
Sex (ref: girls)						
Boys	−0.81 (−2.09, 0.47)	−0.69 (−1.96, 0.58)	−1.37 (−2.31, −0.43)[c]	−1.44 (−2.38, −0.50)[c]	−0.84 (−2.14, 0.46)	−0.47 (−1.76, 0.82)
Grade (Ref: 4)						
5	−0.49 (−2.04, 1.07)	−0.22 (−1.78, 1.34)	0.50 (−0.65, 1.65)	0.52 (−0.63, 1.67)	−0.22 (−1.81, 1.36)	0.20 (−1.38, 1.79)
6	1.42 (−0.18, 3.03)	1.44 (−0.18, 3.05)	0.77 (−0.41, 1.96)	0.64 (−0.55, 1.83)	1.22 (−0.41, 2.86)	1.61 (−0.03, 3.25)
Energy intake (per 100 kcal)	0.07 (−0.006, 0.13)	0.04 (−0.03, 0.1)	0.10 (0.06, 0.15)[c]	0.09 (0.04, 0.14)[c]	−0.16 (−0.23, −0.10)[c]	−0.19 (−0.25, −0.12)[c]
Material deprivation (ref: lower)						
Higher	−3.22 (−4.65, −1.78)[c]	−3.05 (−4.52, −1.58)[c]	−1.18 (−2.25, −0.11)[c]	−0.87 (−1.96, 0.22)	−2.03 (−3.50, −0.56)	−2.54 (−4.03, −1.04)[c]
Social deprivation (ref: lower)						
Higher	1.41 (0.12, 2.70)[c]	1.24 (−0.09, 2.57)	1.20 (0.25, 2.15)[c]	1.03 (0.05, 2.02)[c]	−0.24 (−1.55, 1.08)	0.27 (−1.08, 1.62)
Geographic region (ref: urban)						
Rural	1.58 (0.30, 2.86)[c]	1.84 (0.54, 3.14)[c]	0.95 (0.007, 1.89)[c]	0.90 (−0.06, 1.86)	0.79 (−0.51, 2.09)	1.25 (−0.06, 2.57)
Goodness of fit						
F-statistic (*p*-value)		4.24 (<0.01)		6.11 (<0.01)		7.81 (<0.01)
R-squared		0.0172		0.0247		0.0313
Adjusted R-squared		0.0132		0.0207		0.0273
Root MSE		13.159		9.6819		13.331

CI, confidence interval; HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019; Healthy Eating Food Index 2019; Root MSE, root mean square deviation.

[a]From univariate and multivariable linear regression models with variables (sex, grade level, energy intake, material and social deprivation quintiles, and geographic region) added singularly and simultaneously to the models, respectively.

[b]HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.

[c]*p*-value < 0.05.

association with energy intake. Brassard et al. also reported the inverse relationship between energy intake and HEFI-2019 scores, proposing that it may be driven by two components which had the highest inverse correlation with energy intake: beverages and vegetables and fruit (16). HEI-C 2015 had no statistically significant association with energy intake in our study. Brassard et al. used the US HEI-2015 and also found no relationship with energy intake since each of its components is divided by total energy intake.

Consistent with government reports (2, 3), our results revealed that boys had worse diet quality than girls regardless of the index used, with DQI-I being the most robust at differentiating diet quality between girls vs. boys. The fact that, unlike HEI-C 2015 and HEFI-2019, DQI-I includes certain nutrients and dietary components (cholesterol, vitamin C, and macronutrient ratio) may have contributed to this finding. Our comparisons across grade levels revealed no statistically significant differences in diet quality regardless of the index used. This could be due to the narrow age range of children in our sample (9–12 years old), whereas previous studies in samples with a wider age range of children demonstrated statistically significant differences (1, 15, 19).

It has been previously demonstrated that children from lower SES families consume less fruit, vegetables and fibre, and more added sugar and energy drinks (42, 43). Our findings corroborate this evidence and show that regardless of the diet quality index used, students from more materially deprived neighbourhoods report worse diet quality, with HEI-C 2015 and HEFI-2019 better capturing these differences. Although diet quality appeared to be higher in more vs. less socially deprived areas, previous studies that reported on the association between social deprivation and diet yielded inconsistent findings (15, 44), possibly due to differences in diet quality indices used, covariates adjusted for, and characteristics of the study sample.

Except when using HEI-C 2015, no difference in diet quality was found between students residing in rural vs. urban areas. Similarly, Tugault et al. reported no significant differences in diet quality between rural vs. urban areas in a sample of 4,728 students 6–17 years old (15). While HEI-C 2015 was able to detect differences in diets between geographic regions, this could be due to smaller sample sizes and surveying participants from smaller geographic areas and no participants from metropolitan areas in our study.

To the best of our knowledge, this is the first study to compare established diet quality indices in a population-based sample of Canadian school-aged children. Data were collected through 24-h dietary recall with a sample size large enough to capture sufficient variation in diet quality across population subgroups. However, there are few limitations to consider. Collecting a single 24-h dietary recall on weekdays does not capture participants' usual dietary intake; yet collecting data from multiple 24-h dietary recalls and including weekend days is not feasible in school-based studies. The findings of the present study should therefore be interpreted as being based on a single 24-h recall rather than being based on a comparison of usual intake. Since participating schools are located in socioeconomically disadvantaged communities and have an active health promotion intervention in place, children's diets may differ from those of the general population. However, this does not affect the comparison of the three indices, the indices were able to capture variability in children's diets as well as variation across population subgroups. All data were self-reported which may be subject to social desirability and measurement bias.

In sum, this study shows that the choice of a diet quality index affects the interpretation of the results and practical considerations. Therefore, researchers, practitioners, and policymakers must seek consensus on which index to use and under which circumstances. Of the three indices examined, HEFI-2019 has been developed most recently specifically for Canadian diets. It reflects adherence to the dietary recommendation outlined in the latest Canada Food Guide and our current understanding of diet quality and how it should be measured. However, adjustments to HEFI-2019 may be needed to circumvent its dependency on diet quantity.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the raw data supporting the conclusions of this article will be made available by the authors, without undue reservation. Requests to access these datasets should be directed to katerina.maximova@utoronto.ca.

Ethics statement

The studies involving humans were approved by the Health Research Ethics Board of the University of Alberta (Pro00061528) and the school boards that participated in the study approved all study procedures. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

SP: Formal analysis, Investigation, Validation, Visualization, Writing – original draft, Writing – review & editing. PV: Conceptualization, Data curation, Funding acquisition, Methodology, Resources, Supervision, Writing – review & editing. JD: Formal analysis, Investigation, Methodology, Resources, Writing – review & editing. TT: Data curation, Investigation, Methodology, Writing – review & editing. KM: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Does the habitual dietary intake of adults in Bavaria, Germany, match dietary intake recommendations? Results of the 3rd Bavarian Food Consumption Survey

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Objective: Monitoring dietary habits is crucial for identifying shortcomings and delineating countermeasures. About 20 years after the last population-based surveys in Bavaria and Germany, dietary habits were assessed to describe the intake distributions and compare these with recommendations at food and nutrient level.

Methods: The 3rd Bavarian Food Consumption Survey (BVS III) was designed as a diet survey representative of adults in Bavaria; from 2021 to 2023, repeated 24-h diet recalls were collected by telephone using the software GloboDiet©. Food (sub-)group and nutrient intake data were modeled with the so-called NCI method, weighted for the deviation from the underlying population. Intake distributions in men and women were described as percentiles. These data were used to estimate the proportion of persons meeting dietary intake recommendations. In addition, food consumption data were compared with the results reported 20 years ago collected by the same methodology (2nd Bavarian Food Consumption Survey, BVS II).

Results: Using 24-h diet recalls of 550 male and 698 female participants, we estimated intake distributions for food (sub-)groups and nutrients. A major proportion of the adult population does not meet the food-based dietary guidelines; this refers to a series of food groups, including fruit and vegetables, legumes, nuts, cereal products, and especially whole grain products, as well as fresh and processed meat. Regarding selected essential nutrients, a considerable proportion of the population was at higher risk of insufficiency from iron (women), zinc (men), and folate (both men and women), as already described in previous studies.

Conclusion: A major proportion of the adult Bavarian population does not meet the current food-based dietary guidelines. Compared to BVS II data, favorable changes refer to lower consumption of total meat (especially processed meat) and soft drinks, and an increased intake of vegetables. The conclusions based on the intake of selected essential nutrients hardly changed over time. From a public health perspective, the still low intake of vegetables, fruit, nuts, cereal products, and particularly of whole grain products, and associated higher risks of insufficient supply of several vitamins and minerals call for action for improvement.

KEYWORDS

dietary intake, Bavaria, BVS III, NCI method, 24-h-recalls, nutrients, food (groups), food-based dietary guidelines (FBDGs)

1 Introduction

Since the 2nd Bavarian Food Consumption Survey (BVS II, 2002–2003) and the National Food Consumption Survey II (NVS II, 2005–2007) with four follow-up surveys in the National Nutrition Monitoring (NEMONIT), no population-based surveys in adults with a direct recording of dietary intake were conducted in Germany or any federal state of Germany. The 3rd Bavarian Food Consumption Survey (BVS III) aimed to close this gap for Bavaria and to provide current cross-sectional data on food consumption and nutrient intake of the adult population in Bavaria.

Food consumption survey methods are designed to estimate the dietary intake of a defined population. When the dietary intake distribution of a population is estimated based on a single-day measurement, the intake distribution contains between-person information while the within-person variation is not captured. This means that the variance of the usual group intake is inflated by day-to-day variation in individual intake. Repeated 24-h diet recalls (24HR) allow to account for this intra-individual variability. Several statistical methods were developed over the past decades to estimate usual intake distributions from repeated 24HR, taking into account intra-personal variation [e.g., (1–7)]. The approach developed at the National Cancer Institute NCI, commonly referred to as NCI method (6, 7), allows the inclusion of covariates when modeling intake distributions. The inclusion of a food frequency questionnaire (FFQ) as a covariate and thus combining two measurement instruments is of particular interest (8). Using the BVS II study data, we previously investigated the differences in food intake distributions by comparing the results of a weighted means approach and the NCI method (9). The estimation of valid intake distributions is a necessary precondition for evaluating the percentage of the population meeting intake recommendations.

In 2024, the German Society for Nutrition (DGE) published the results of a mathematical optimization model for deriving food-based recommendations (10, 11). So far, these values have not been evaluated using population-based intake data. Therefore, this study aimed at estimating the most valid food and nutrient intake distributions for the adult Bavarian population and describing the agreement with reference values.

2 Methods

2.1 Study population

The BVS III was planned as a representative study for the Bavarian population aged 18 to 75 years. In a two-stage random procedure (random selection of municipalities and random selection of subjects within these municipalities via the residents' registration offices), potential study participants were contacted. After removing quality-neutral non-participants, 1,503 men and women aged 18 to 75 years were surveyed, i.e., 26% of the persons in the gross sample.

2.2 Recruitment and data collection

The household visits took place in the time frame of October 2021 to November 2022, and the nutrition survey was conducted until January 2023. Thus, the entire study framework lay within the period of the SARS-CoV-2 pandemic.

During the face-to-face interview in the households, information on sociodemographic characteristics, diet-related behavior, including a short food frequency questionnaire (FFQ) covering approximately 30 foods and food groups, and on the health status of the participants was assessed. The short FFQ, based on the German version of the European Food Propensity Questionnaire (EFPQ), was included in the interview, and the results were used as covariates for the estimation of the distribution of habitual food and nutrient intakes, allowing for the combination of two measurement instruments (12) (see 3.5 Statistical Analysis). Additionally, participants completed self-administered questionnaires per tablet, e.g., on physical activity.

Dietary intake data were collected by 24HR during the 6 weeks following the home visit. Per subject, three 24HR should be completed on randomly selected days (two weekdays, one weekend day). To ensure standardized assessment, the software GloboDiet©, a further development of the EPIC-SOFT© software, which was used in the BVS II (13), was applied. The 24HR were conducted as computer-assisted telephone interviews (CATI) by trained interviewers. Subsequently, the data underwent intensive quality control. From 1,239 persons, one (n = 91), two (n = 165), or three (n = 983) 24HR were available and used for the statistical analysis.

All individual food items in the 24HR were assigned a code according to the German food composition database (Bundeslebensmittelschlüssel, BLS) (14), version 3.02. The foods were aggregated into main food groups and subgroups based on the hierarchical BLS coding system. In addition, the subgroups "fermented milk products", the main food group "alternative products" with its subgroups "milk alternatives" and "meat alternatives", as well as the main food group "whole grain products" were newly defined. Additionally, we defined the following food groups: "total meat" (sum of fresh meat and processed meat), "red meat" (fresh meat minus poultry), "fruit and vegetables" (sum of fruit and vegetables), and "cereal products" (sum of bread and bakery products, staple food, and whole grain products). Dairy consumption was converted into milk equivalents according to Breidenassel et al. (15).

2.3 Covariates

Self-reported body weight and height were used to calculate Body Mass Index (BMI; kg/m^2). BMI subgroups were established according to the WHO definition (16). Smoking was described as never, ex-, or current smokers. Habitual physical activity was assessed employing the validated EHIS-PAQ (17). Each person's physical activity level was described with one of the following categories: sedentary, low active, active, or very active (18).

Based on their information on their highest school and professional qualification according to the International Standard Classification of Education (ISCED), the participants were assigned the corresponding ISCED 97 level (19). According to the ISCED classification of the Federal Statistical Office and the German Microdata Lab, the assigned ISCED 97 levels were grouped into 3 educational levels (20): low educational group (levels 1 and 2), medium educational group (levels 3 and 4), and high educational group (levels 5 and 6).

The net equivalent income was calculated using information on net household income and household composition. For this purpose, the corresponding average value was first assigned to each income group queried (e.g., 1,250 euros for "1,000 to less than 1,500 euros"). Household size was weighted using the weighting factors of the modified Organization for Economic Co-operation and Development (OECD) scales (21). The first adult is weighted with a factor of 1.0, while the other household members aged 14 and over are weighted with a factor of 0.5, and all others with 0.3. The net equivalized income of the participants was calculated by dividing the net household income by the weighted household size. Classification into low, medium, and high income was carried out along the lines of risk of poverty and income wealth (22). A net equivalent income below 60% of the national median income is considered low, while net equivalent income above 200% of the national median income is considered high. The median national equivalized income in Germany in 2022, when most of the data collection in the BVS III took place, was 25,000 euros/year (23).

2.4 Description of weighting

To ensure representativeness for the Bavarian population, the nutritional data was weighted, based on the 2020 micro-census and intercensal population updates for Bavaria as a reference. The weighting was conducted to correct for the oversampling of the Augsburg study area and non-response, considering administrative district, political municipality size class, education level, gender, and age.

2.5 Statistical analysis

The descriptive analysis of characteristics of the study population was conducted separately for men and women. Results are given as arithmetic means and standard deviation or absolute and relative frequencies, as appropriate.

The NCI method (6, 7) was applied to estimate the distribution of habitual food and nutrient intakes separately for men and women. The NCI method is based on the idea that the usual intake can be understood as the probability of consumption multiplied by the amount consumed. The approach follows a two-step procedure by estimating the consumption probability of a food item by a logistic regression and the amount of consumption of a food item by a linear model separately. Both parts can be linked by allowing for a correlation of the person-specific effects included in the models. In both models, age, gender, BMI and education level were included as covariates. If available, FFQ information was also included as a covariate in the probability model. Additionally, a population-weighting variable was specified and for each 24HR, the information on whether it was recorded on a weekday or a weekend day was included. Intake estimates of daily consumed food items and nutrients were derived without fitting the probability model. For these calculations, the SAS macros MIXTRAN V2.1 and DISTRIB V2.1 provided by the National Cancer Institute (NCI) of the National Institute of Health (NIH) were used. In complex surveys, the application of balanced repeated replication (BRR) instead of bootstrap is recommended. As we focus on means and percentiles on the population level and not the standard error of estimates, we refrained from doing so.

Statistical analysis was performed using SAS software, version 9.4 of the SAS System for Windows (Copyright © 2002–2010 SAS Institute Inc.).

Habitual dietary intake estimates were compared with recommendations published by the DGE. To evaluate food group intake data, the newly released food-based dietary guidelines (FBDG), precisely the results of the "optimization model 2", were used (10, 11). Habitual vitamin and mineral intakes were compared with the most recent reference values published by the German Nutrition Society, except for retinol equivalents (24).

3 Results

3.1 Characteristics of the sample population

Results from the descriptive (not weighted) analysis are presented in Table 1. In the present study, 550 male (44%) and 689 female (56%) participants with a mean age of 48.6 and 49.2 years, respectively, were analyzed. The obesity prevalence was 21.6 and 15.1% in male and female participants, respectively. More than 62% of men had pre-obesity or obesity, while the corresponding figure in women was 43%. The proportion of current smokers was lower in women (14%) as compared to men (19%). About 31% of women and 22% of men followed a sedentary level of physical activity. The proportion of very active subjects was about twice as high in men as in women (31% versus 17%). About half of the participants had a high education and roughly 20% a low education; based on their self-reports, 14% were classified as having a high net equivalence income, while 26% (males) and 28% (females) were attributed to the low-income group.

3.2 Habitual food consumption

Data on food consumption in men and women are provided in Tables 2, 3, and in the Supplementary Tables S1, S2.

TABLE 1 Characteristics of male and female participants of the BVS III.

	Men (n = 550)		Women (n = 689)	
Age (years; mean, SD)	48.64	15.07	49.22	14.91
BMI (kg/m2; mean, SD)	26.95	4.49	25.19	5.22
Age groups (years)	*N*	Percent	*N*	Percent
18–34	120	21.82	141	20.46
35–49	149	27.09	202	29.32
50–64	190	34.55	225	32.66
65–75	91	16.55	121	17.56
BMI groups (kg/m2)	*N*	Percent	*N*	Percent
Underweight (<18.5)	3	0.55	21	3.05
Normal weight (18.5- < 25)	204	37.09	370	53.70
Pre-obesity (25- < 30)	224	40.73	194	28.16
Obesity (30+)	119	21.64	104	15.09
Physical activity level	*N*	Percent	*N*	Percent
Sedentary	119	21.64	214	31.06
Low active	127	23.09	204	29.61
Active	131	23.82	153	22.21
Very active	173	31.45	118	17.13
Smoking	*N*	Percent	*N*	Percent
Never	267	48.55	384	55.73
Previous	176	32.00	207	30.04
Current	107	19.45	98	14.22
Education	*N*	Percent	*N*	Percent
Low	120	21.82	143	20.75
Medium	135	24.55	218	31.64
High	295	53.64	328	47.61
Net equivalence income	*N*	Percent	*N*	Percent
Low	134	26.33	182	28.17
Medium	306	60.12	372	57.59
High	69	13.56	92	14.24
Missing	41		43	
Specific diet	*N*	Percent	*N*	Percent
Vegetarian	21	3.82	55	7.98
Vegan	8	1.45	13	1.89

SD, standard deviation.

The median (25th–75th percentile) consumption of fresh meat was 60.8 (44.9–77.1) g/day for men and 39.4 (27.6–53.2) g/day for women; additionally, 45.6 (27.6–66.4) g/day and 25.8 (14.4–41.2) g/day of processed meat were consumed, respectively. Arithmetic means were generally higher, indicating skewed distributions. The Bavarian diet is low in fish and seafood, with median consumption figures of 12.7 (6.8–23.0) g/day and 9.2 (4.8–9.2) g/day. Median egg consumption was about 15 g/day in both sexes. Women consumed more fermented milk products (yogurt, kefir) than men; when expressed in milk equivalents (MEq), men consumed 404 (276–561) g/day and women 429 (302–586) g MEq/day.

The median intake of meat and milk alternatives was low (1.2 and 1.8 g/day in males and females, respectively), i.e., half of the population consumed hardly any alternatives. 25% of the population (75th percentile) consumed at least 5.0 and 8.5 g/day, and 10% (90th percentile) consumed 31.2 and 43.5 g/day or more. Consumption of milk alternatives (about 80% of the alternatives) dominated over meat alternatives (about 20%).

Among fats and oils, butter and vegetable oils were the major contributors, while median margarine intake was very low (0.3 g/day). The median consumption of butter was highest with 7.3 (3.3–13.3) g/day in men and 5.7 (2.5–10.6) g/day in women. Median consumption

TABLE 2 Food group consumption distribution (g/day) in male participants (n = 550) of the BVS III, weighted for the deviation from the underlying population.

Food group, subgroup	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Total meat	110.2	47.0	31.8	47.1	77.2	110.6	142.0	170.9	188.3
Fresh meat	61.5	22.1	26.5	32.7	44.9	60.8	77.1	91.2	98.8
Red meat	40.5	9.5	25.8	28.6	33.7	40.0	46.6	53.1	56.9
Pork	18.4	10.3	6.0	7.5	10.8	16.2	23.6	32.3	38.6
Poultry	20.6	11.6	8.0	9.6	13.1	18.1	24.5	33.0	41.7
Processed meat	48.9	27.1	11.2	16.0	27.6	45.6	66.4	85.9	98.0
Sausages	41.9	25.1	8.0	11.7	21.2	38.5	59.3	77.4	86.9
Fish and seafood	18.0	17.2	2.5	3.7	6.8	12.7	23.0	38.7	51.5
Eggs	18.7	14.2	3.2	4.7	8.4	15.1	25.3	37.8	46.5
Dairy products	140.0	79.8	38.0	51.7	82.1	125.3	182.5	245.0	289.9
Milk equivalents	433.8	218.1	131.4	177.8	275.8	404.3	561.2	724.6	835.9
Milk	62.1	70.3	4.0	7.0	17.0	38.9	81.5	145.3	198.0
Fresh cheese, quark	10.8	18.1	0.2	0.4	1.2	4.1	12.2	28.5	43.5
Fermented dairy products (yogurt, kefir)	25.3	32.4	0.8	1.5	4.1	12.2	32.9	69.2	96.2
Cheese	33.5	17.3	9.9	13.1	20.4	31.0	43.9	57.2	65.4
Butter	9.4	8.1	0.7	1.3	3.3	7.3	13.3	20.5	25.5
Other fats and oils	10.8	5.4	4.0	4.9	6.9	9.8	13.6	18.0	21.1
Margarine	1.4	3.9	0.0	0.0	0.1	0.3	1.1	3.5	6.5
Vegetable oils	4.6	1.9	1.7	2.2	3.1	4.4	5.9	7.2	8.0
Cereal products	249.7	72.9	140.6	161.6	199.3	245.0	294.9	344.6	376.9
Bread and pastries (non-whole grain)	133.6	47.6	62.1	75.3	100.4	129.9	163.0	196.3	217.2
White bread, crisp bread, rolls	55.7	26.9	18.2	23.7	35.7	52.2	71.9	92.0	104.5
Other types of bread (brown bread, spelt bread)	27.2	22.8	3.2	5.1	10.4	21.1	37.3	57.3	72.1
Pastries	50.4	31.5	11.5	15.8	26.7	43.9	67.6	93.9	110.9
Pasta, rice, etc.	99.1	38.8	43.8	52.7	70.1	94.7	123.0	151.8	169.6
Rice	17.8	16.6	2.6	3.8	6.8	12.7	23.1	37.8	50.3
Pasta	66.1	26.1	29.0	34.9	46.6	62.9	82.4	101.6	113.3
Whole grain products	17.0	13.0	2.7	3.9	7.2	13.5	23.7	35.4	43.1
Muesli	2.4	5.8	0.0	0.0	0.1	0.4	1.7	6.0	11.5
Whole grain bread	13.9	13.1	1.4	2.1	4.4	9.6	19.3	32.4	41.2
Potatoes	64.8	29.6	23.1	29.2	42.5	61.2	83.3	105.3	119.5
Potatoes, fresh	60.6	29.8	20.2	26.0	38.2	56.1	78.3	101.6	116.8
Fruit and vegetables	230.1	126.3	65.9	87.9	136.0	208.2	301.4	398.3	466.4
Vegetables	144.4	58.4	58.5	74.0	102.7	138.6	180.4	222.5	248.3
Salad	18.4	11.8	4.5	6.1	9.7	15.7	24.2	34.3	41.1
Cruciferous vegetables	13.2	10.2	2.7	3.8	6.3	10.6	17.1	25.9	32.9
Sprouting vegetables	14.9	4.2	8.1	9.5	11.9	14.7	17.6	20.4	22.0
Fruiting vegetables	63.4	34.7	16.1	22.6	37.1	58.2	84.7	110.8	127.0
Root vegetables	12.8	6.2	5.0	6.0	8.3	11.6	15.9	20.8	24.4
Legumes	8.6	7.2	1.9	2.5	4.0	6.7	10.9	16.9	21.8
Fruit	86.1	74.7	5.1	9.7	27.2	67.4	124.9	189.2	232.4
Pip fruits	32.7	36.4	1.0	1.9	5.9	19.3	47.2	83.9	108.6
Stone fruits	6.5	17.6	0.0	0.1	0.2	0.9	4.1	15.3	31.3
Tropical fruits	27.9	38.9	0.5	1.0	3.5	12.7	36.9	75.0	106.2

(Continued)

TABLE 2 (Continued)

Food group, subgroup	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Citrus fruits	9.8	26.7	0.0	0.0	0.3	1.4	6.8	23.9	46.9
Nuts	7.1	10.2	0.3	0.6	1.3	3.3	8.4	18.4	27.0
Sweets	17.0	15.5	2.1	3.2	6.3	12.5	22.8	36.9	47.1
Chocolate and chocolate products	6.7	7.7	0.6	0.9	1.8	4.0	8.7	16.2	22.1
Ice cream	5.0	9.3	0.1	0.2	0.6	1.7	5.0	12.8	21.3
Desserts	13.2	4.4	6.5	7.8	10.4	13.0	15.5	19.1	21.5
Alternatives	12.1	33.0	0.1	0.1	0.4	1.2	5.0	31.2	79.3
Milk alternatives	10.5	33.8	0.0	0.0	0.1	0.3	2.0	19.6	75.2
Meat alternatives	2.2	6.7	0.0	0.1	0.1	0.4	1.2	4.1	10.0
Non-alcoholic beverages	1764.0	815.0	564.9	764.2	1168.8	1688.2	2280.1	2857.3	3231.6
Juices	33.3	66.0	0.4	0.9	3.1	10.5	33.5	85.6	142.1
Water	1511.4	860.7	172.1	384.5	875.3	1459.5	2072.7	2644.5	3014.5
Soft drinks	139.1	195.8	0.8	1.8	7.5	40.3	201.4	451.0	571.5
Coffee	285.8	234.7	7.3	21.2	97.4	246.8	414.0	598.6	731.3
Tea and other infusions	150.0	267.1	0.0	0.2	1.7	22.1	183.4	491.8	704.9
Tea	70.3	152.0	0.1	0.2	1.1	8.1	58.3	222.9	379.1
Other infusions	81.6	183.7	0.1	0.2	1.3	9.4	64.6	248.0	440.7
Alcoholic beverages	236.1	281.7	2.9	7.3	29.8	123.7	347.7	639.7	830.5
Beer	202.6	262.7	2.2	5.2	21.0	90.1	290.6	568.7	758.2
Wine, champagne	28.4	59.2	0.1	0.3	1.3	6.2	25.5	78.2	139.1

SD, standard deviation, P, percentile.

of vegetable oils amounted to 4.4 (3.1–5.9) g/day in men and 5.3 (3.8–6.9) g/day in women.

The median (25th–75th percentile) daily consumption of vegetables amounted to 138.6 (102.7–180.4) g/day for men and 165.4 (124.9–210.7) g/day for women. Also, daily fruit consumption was distinctly lower in men with 67.4 (27.2–124.9) g compared to women with 117.1 (61.7–185.7) g. The median daily consumption of potatoes amounted to 56 and 55 g in men and women, respectively. Median consumption of nuts was low with 3.3 g/day both in men and women. Median consumption of cereal products amounted to 245.0 g/day in men and 188.2 g/day in women. Major contributors were bread and pasta.

The dominating subgroup among non-alcoholic beverages was water (1.5 (0.9–2.1) l/day in men and 1.3 (0.8–1.3) l/day in women), followed by coffee (247 (97–414) ml/day in men and 273 (128–443) ml/day in women). Consumption of soft drinks was higher in men with 40.3 (7.5–201.4) ml/day compared to women with 13.5 (2.8–64.2) ml/day.

Men drank more alcoholic beverages, especially beer, than women. Median intake data for beer was 90.1 ml/d in men and 10.0 ml/d in women; for wine, median intake data were 6.2 ml/d in men and 11.4 ml/d in women. Mean values were distinctly higher indicating substantially skewed distributions.

The comparison of these intake data with the German food-based dietary guidelines (Table 4) shows that the recommendations on the consumption of plant-derived food, including fruit and vegetables, nuts, whole grain products, and vegetable oils were only met by a minor proportion of the population (<16%). Exceptions are only the food groups potatoes and legumes. On the contrary, red and processed meat, whose intakes exceed the FBDG for at least 88% of the population, are consumed in higher amounts than recommended. Median consumption of dairy products is slightly above the recommended amounts, with 47% of the men and 43% of the women consuming less than the corresponding FBDG.

Compared to the results of the BVS II, the median intake of vegetables increased, more distinctly in women than in men, but the median fruit intake remained stable in women and decreased in men (Table 5). A distinct difference was noted for processed meat consumption; men and women lowered their median intake by 40–48% compared to the amount reported 20 years ago. Also, the median intake of red meat slightly decreased. The same is true for fish and dairy products. Median poultry and egg consumption increased. Regarding beverages, a much higher median water consumption was noted, while beer (in men) and wine consumption (in men and women) decreased. In the case of skewed distributions and high intakes in less than 50% of the population, median values do not reflect changes in this subgroup.

3.3 Habitual consumption of energy and nutrients

The habitual consumption of energy and nutrients is shown in Table 6 (for males) and Table 7 (for females). The median (25th–75th percentile) daily energy intake was 1974 (1688–2,283) kcal/day in men

TABLE 3 Food group consumption distributions (g/day) in female participants (n = 689) of the BVS III, weighted for the deviation from the underlying population.

Food group, *subgroup*	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Total meat	71.9	39.2	13.4	21.4	41.0	69.6	98.7	124.6	140.2
Fresh meat	41.4	17.9	15.8	19.5	27.6	39.4	53.2	66.4	74.3
Red meat	25.0	7.1	14.9	16.6	19.9	24.1	29.1	34.3	37.8
Pork	10.5	6.7	3.2	3.9	5.8	8.8	13.4	19.3	23.6
Poultry	16.3	9.8	5.9	7.0	9.6	13.7	20.0	28.6	37.2
Processed meat	29.9	20.0	5.7	8.0	14.4	25.8	41.2	57.9	68.1
Sausages	22.6	16.8	3.5	5.0	9.4	18.0	32.0	47.2	55.7
Fish and seafood	13.3	12.9	1.8	2.6	4.8	9.2	17.3	28.8	38.5
Eggs	18.8	13.6	3.4	4.9	8.8	15.6	25.4	37.2	45.3
Dairy products	159.6	85.2	49.6	65.2	97.9	144.2	205.5	273.5	319.3
Milk equivalents	459.5	216.1	161.0	208.3	301.9	428.9	586.0	751.4	855.9
Milk	66.3	71.2	5.1	8.8	19.6	43.6	87.5	152.1	203.0
Fresh cheese, quark	14.4	22.0	0.3	0.6	1.9	6.3	17.6	37.6	55.1
Fermented dairy products (yogurt, kefir)	40.8	40.0	2.0	3.7	9.6	26.6	61.2	100.3	123.9
Cheese	31.9	15.7	10.1	13.2	20.1	29.7	41.5	53.3	60.6
Butter	7.4	6.5	0.5	1.0	2.5	5.7	10.6	16.3	20.3
Other fats and oils	10.1	5.1	3.7	4.5	6.4	9.1	12.8	16.9	19.8
Margarine	1.2	3.2	0.0	0.0	0.1	0.2	1.0	3.1	5.7
Vegetable oils	5.4	2.1	2.1	2.6	3.8	5.3	6.9	8.2	8.9
Cereal products	193.8	62.6	101.4	118.5	150.0	188.2	232.4	276.3	304.1
Bread and pastries (non-whole grain)	92.0	37.5	37.4	46.8	65.0	88.2	114.8	141.9	159.9
White bread, crisp bread, rolls	32.5	19.0	8.5	11.5	18.3	28.9	43.0	58.6	68.8
Other types of bread (brown bread, spelt bread)	18.8	16	2.2	3.4	6.9	14.3	26.0	40.2	50.2
Pastries	40.8	26.0	9.1	12.6	21.1	35.5	54.9	76.6	90.8
Pasta, rice, etc.	85.8	34.2	37.7	45.1	60.4	81.6	106.7	132.0	148.1
Rice	19.6	17.7	3.0	4.2	7.5	14.1	25.7	41.8	54.9
Pasta	47.1	20.1	19.9	24.0	32.2	44.1	58.9	74.3	84.5
Whole grain products	15.7	11.2	2.7	3.9	7.1	13.1	21.7	31.5	38.0
Muesli	3.5	7.5	0.0	0.0	0.2	0.7	2.9	9.4	17.6
Whole grain bread	12.3	10.8	1.3	2.0	4.1	9.0	17.4	27.6	34.2
Potatoes	58.6	27.0	20.8	26.3	37.9	55.3	75.9	95.6	107.8
Potatoes, fresh	55.0	27.2	18.3	23.4	34.2	51.0	71.7	92.4	105.6
Fruit and vegetables	309.4	154.3	103.2	132.9	196.7	285.7	395.1	517.2	600.1
Vegetables	171.0	64.6	75.4	92.4	124.9	165.4	210.7	256.4	286.4
Salad	17.3	11.2	4.2	5.7	9.1	14.8	22.9	32.3	38.9
Cruciferous vegetables	15.9	11.9	3.5	4.7	7.7	12.8	20.6	30.9	38.7
Sprouting vegetables	15.3	4.1	8.7	10.1	12.5	15.2	17.9	20.6	22.3
Fruiting vegetables	81.1	39.7	24.1	32.4	50.8	77.2	105.9	134.5	152.3
Root vegetables	15.4	7.4	6.2	7.5	10.2	13.9	19.2	25.1	29.3
Legumes	11.4	9.1	2.6	3.4	5.5	8.9	14.5	22.2	28.6
Fruit	133.1	92.6	15.4	27.8	61.7	117.1	185.7	260.0	308.9
Pip fruits	39.7	37.6	1.7	3.5	10.2	28.1	59.0	93.7	116.1
Stone fruits	9.2	18.5	0.1	0.1	0.4	1.9	8.3	26.4	46.4
Tropical fruits	38.9	46.0	1.2	2.3	7.1	22.2	54.1	98.6	131.3

(Continued)

TABLE 3 (Continued)

Food group, *subgroup*	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Citrus fruits	16.8	37.5	0.0	0.1	0.6	3.3	14.4	45.5	80.4
Nuts	7.0	9.8	0.3	0.5	1.2	3.3	8.6	18.0	26.2
Sweets	18.2	15.8	2.4	3.6	7.1	13.7	24.5	38.3	48.9
Chocolate and chocolate products	7.6	8.1	0.6	1.0	2.0	4.8	10.2	17.9	23.7
Ice cream	6.3	10.3	0.2	0.3	0.8	2.4	7.0	16.7	26.2
Desserts	13.0	3.9	7.4	8.3	10.0	12.9	15.2	17.5	20.2
Alternatives	13.3	29.1	0.1	0.2	0.5	1.8	8.5	43.5	78.2
Milk alternatives	11.1	29.5	0.0	0.0	0.1	0.4	3.5	35.4	74.5
Meat alternatives	3.2	8.3	0.0	0.1	0.2	0.6	2.1	7.6	16.1
Non-alcoholic beverages	1617.4	788.6	477.6	660.8	1033.4	1532.9	2108.4	2681.0	3034.2
Juices	29.1	58.8	0.3	0.7	2.3	8.5	28.5	76.9	128.2
Water	1401.3	795.9	200.6	398.2	806.1	1335.0	1919.1	2468.5	2818.3
Soft drinks	62.5	110.8	0.3	0.7	2.8	13.5	64.2	201.5	318.8
Coffee	311.5	237.7	14.0	35.8	127.7	273.4	443.4	623.3	757.6
Tea and other infusions	296.9	396.5	0.2	1.0	11.5	123.7	460.2	828.5	1084.8
Tea	106.7	212.1	0.1	0.3	1.8	14.6	103.2	349.7	537.5
Other infusions	190.2	303.7	0.4	1.2	7.3	53.1	253.6	569.3	805.2
Alcoholic beverages	92.7	143.9	0.5	1.3	6.0	30.2	116.8	274.6	396.7
Beer	50.0	101.2	0.2	0.5	2.0	10.0	46.4	145.4	252.0
Wine, champagne	40.2	70.3	0.3	0.6	2.5	11.4	44.0	116.3	185.7

SD, standard deviation, P, percentile.

TABLE 4 Median intake and proportion of male and female participants of the BVS III meeting the food-based dietary guidelines (scenario 2) of the German Nutrition Society (10, 11).

Food group	BVS III Median intake (g/day)		BVS III vs. scenario 2		FBDG (11) (g/day)
	Men	Women	% of men below FBDG value	% of women below FBDG value	Scenario 2
Vegetables	139	165	94	87	245
Fruit	67	117	98	93	300
Juices	11	9	85	87	61
Legumes	7	9	34	21	5
Nuts and seeds	3	3	84	84	13
Potatoes	61	55	18	23	37
Cereal products	245	188	74	90	309
Whole grain products	14	13	85	89	31
Vegetable oils	4	5	100	100	13
Red meat	40	24	<1	6	11
Poultry	18	14	70	82	23
Processed meat	46	26	7	12	9
Fish and seafood	13	9	65	76	18
Eggs	15	16	38	37	12
Dairy products	125	144	-	-	-
Milk equivalents	404	429	47	43	394
Fat spreads[#]	8	6	60	69	10

[#]Butter and margarine (BVS III).

TABLE 5 Median consumption of food groups in male and female participants of the BVS III compared to the BVS II.

Food group	BVS III (2021–23) (g/day)		BVS II (2002–03) (9) (g/day)	
	Men	Women	Men	Women
Vegetables	139	165	127	129
Fruit	67	117	80	116
Nuts	3	3	1	1
Potatoes	61	55	63	58
Cereal products	245	188	237	175
Vegetable oils	4	5	4	4
Margarine	0.3	0.2	1	1
Butter	7	6	10	8
Red meat	40	24	48	30
Poultry	18	14	15	12
Processed meat	46	26	87	43
Fish and seafood	13	9	18	14
Eggs	15	16	9	8
Dairy products	125	144	146	165
Water	1,460	1,335	613	768
Soft drinks	40	14	31	11
Beer	90	10	242	10
Wine	6	11	24	19

and 1588 (1338–1858) kcal/day in women. The median intake of saturated fatty acids and the sum of mono- and disaccharides were 35.6 g/day and 74.1 g/day in men, and 23.8 g/day and 51.1 g/day in women, respectively. Median dietary fiber intake in men and women was about 16 g/day, and men consumed twice the amount of ethanol than women (median intake of 15.7 g/day in men and 7.8 g/day in women).

When compared with the reference values of the DGE, the proportion of persons below these values is lowest for retinol equivalents, vitamin B2, niacin, and vitamin B12 (Table 8). A high proportion of the population not meeting the reference values was identified for folate, pantothenic acid, and vitamin B6, i.e., a substantial proportion of the population was at higher risk of insufficient supply of these nutrients. This also applies to the habitual intake of iodine, potassium, calcium, magnesium, zinc in men, and iron, especially in premenopausal women, for which up to 100% of the population did not meet the reference values.

4 Discussion

4.1 Summary of findings

In this population-based study, current data on the intake of food groups and nutrients are presented for men and women. The precise intake distribution was modeled using the NCI method. The results provided information on dietary changes over the past 20 years and their (dis-)agreement with food-based dietary guidelines as recently released in Germany. The most pronounced and favorable changes refer to a lower consumption of processed meat (including sausages) and beer (in men). Median intake of vegetables increased especially in women. However, in many aspects, the observed diet deviates substantially from the respective recommendations and guidelines, e.g., on fruit and vegetable intake. Unfavorably low intakes of whole grain products and fruit and vegetables on the one hand, and high intakes of red and processed meat on the other hand are still prevalent. Vitamin and mineral intake result from food selection and no improvement over the past shortcomings was observed.

4.2 Methodological aspects

In this population-based study, 26% of the eligible persons participated eventually. Notably, the prevailing SARS-CoV-2 pandemic was an important confounding factor. After the home visit, 1,239 persons completed 24HR. To account for biases from differential non-response, all analyses were weighted for the deviation from the underlying population.

Misreporting, especially underreporting, is a persistent problem in dietary assessment, leading to an underestimation of dietary intake (25). Obesity being a major determinant of the likelihood of underreporting (25), and the prevalence of obesity being comparable in both BVS II and BVS III, the extent of the problem of misreporting seems fairly stable. In addition, we used the same method for dietary assessment in both studies, i.e., telephone interviews conducted by trained interviewers using the same software, to ensure a highly comparable and standardized protocol.

TABLE 6 Energy and nutrient intake distributions (per day) in male participants (n = 550) of the BVS III, weighted for the deviation from the underlying population.

Nutrient	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Energy [kcal]	1997	438	1,321	1,452	1,688	1974	2,283	2,567	2,752
Energy [kJ]	8,362	1833	5,532	6,079	7,069	8,267	9,562	10,753	11,524
Protein [g]	76.8	16.6	51.3	56.1	65.0	75.7	87.5	98.6	105.8
Fat [g]	83.7	20.4	52.6	58.7	69.3	82.3	96.9	110.6	119.1
Saturated fatty acids [g]	36.2	9.6	21.6	24.4	29.4	35.6	42.5	48.9	53.1
Monounsaturated fatty acids [g]	28.7	7.0	18.0	20.1	23.7	28.2	33.2	38.0	40.9
Polyunsaturated fatty acids [g]	12.6	3.6	7.4	8.3	10.0	12.3	14.8	17.3	18.9
Omega-3 fatty acids [g]	1.8	0.6	1.0	1.1	1.4	1.7	2.2	2.7	3.0
Omega-6 fatty acids [g]	10.8	3.1	6.2	7.0	8.5	10.4	12.7	14.9	16.4
Carbohydrates [g]	202.5	54.7	119.8	135.2	163.3	198.4	237.4	274.6	299.0
Starch [g]	110.5	28.9	66.3	74.6	89.9	108.5	129.0	148.8	161.1
Total mono- and disaccharides [g]	79.2	35.5	30.8	38.3	53.3	74.1	99.7	126.1	144.7
Disaccharides [g]	46.7	21.6	17.9	22.2	31.0	43.4	58.9	75.5	86.7
Lactose [g]	6.8	4.4	1.7	2.3	3.7	5.9	8.9	12.5	15.3
Saccharose [g]	37.1	18.7	12.6	16.1	23.5	34.1	47.4	61.9	72.0
Monosaccharides [g]	31.9	16.8	10.6	13.5	19.7	28.9	40.8	54.1	63.7
Fructose [g]	17.0	9.3	5.3	6.9	10.2	15.3	21.9	29.3	34.6
Glucose [g]	14.4	7.7	4.8	6.1	8.9	13.0	18.4	24.6	29.0
Dietary fiber [g]	16.9	5.5	9.0	10.3	12.9	16.3	20.3	24.2	26.8
Water-insoluble fiber [g]	11.2	3.8	5.8	6.7	8.5	10.7	13.4	16.2	18.0
Water-soluble fiber [g]	5.5	1.8	3.0	3.4	4.2	5.3	6.6	7.9	8.7
Alcohol (ethanol) [g]	22.2	21.7	2.4	3.8	7.8	15.7	29.3	47.9	64.1
Sodium [g]	3.4	1.3	1.6	1.9	2.4	3.1	4.1	5.1	5.9
Chloride [g]	5.2	1.9	2.7	3.1	3.9	4.9	6.3	7.8	8.8
NaCl (salt) [g]	7.7	3.2	3.7	4.3	5.4	7.1	9.3	11.8	13.6
Potassium [g]	2.6	0.7	1.6	1.8	2.1	2.5	3.0	3.4	3.7
Calcium [mg]	835	236	498	555	666	809	976	1,146	1,260
Phosphorus [mg]	1,260	310	802	885	1,039	1,233	1,455	1,667	1808
Magnesium [mg]	315	85	192	214	254	306	367	426	466
Zinc [mg]	10.1	2.1	7.0	7.6	8.7	10.0	11.4	12.8	13.7
Iron [mg]	10.8	3.0	6.5	7.3	8.7	10.5	12.6	14.8	16.2
Iodide [µg]	84.2	26.6	48.1	53.9	65.1	80.4	99.2	119.0	132.8
Vitamin A: Retinol equivalents [mg]	1.03	0.40	0.51	0.59	0.74	0.97	1.25	1.56	1.78
Vitamin A: Beta-carotene [mg]	2.86	1.34	1.16	1.39	1.89	2.61	3.56	4.63	5.36
Vitamin A: Retinol [mg]	0.53	0.25	0.23	0.27	0.35	0.48	0.65	0.85	0.99
Vitamin D: Calciferole [µg]	2.43	0.88	1.24	1.42	1.80	2.30	2.91	3.59	4.04
Vitamin E: Alpha-tocopherol equivalents [mg]	11.5	4.2	5.8	6.7	8.5	11.0	14.0	17.0	19.1
Vitamin E: Alpha-tocopherol [mg]	10.8	3.9	5.5	6.3	8.0	10.3	13.1	15.9	17.9
Vitamin C, ascorbic acid [mg]	86.8	33.5	41.0	48.2	62.6	82.2	106.3	131.1	148.2
Vitamin B1, thiamine [mg]	1.20	0.38	0.69	0.77	0.93	1.15	1.42	1.70	1.89
Vitamin B2, riboflavin [mg]	1.31	0.41	0.74	0.84	1.02	1.26	1.56	1.85	2.05
Vitamin B6, pyridoxin [mg]	1.43	0.43	0.83	0.93	1.12	1.38	1.69	2.00	2.22
Niacin [mg]	17.9	5.9	9.7	11.1	13.7	17.1	21.3	25.6	28.6
Niacin equivalents [mg]	33.1	8.3	20.8	23.1	27.1	32.4	38.2	44.1	47.9
Pantothenic acid [mg]	3.98	1.38	2.10	2.40	2.98	3.78	4.76	5.79	6.51
Biotin [µg]	43.7	20.0	20.0	23.3	30.2	40.3	53.6	68.2	78.9
Total folate [µg]	207	66	115	130	160	199	246	294	326
Vitamin B12, cobalamin [µg]	5.26	1.75	2.82	3.24	4.00	5.03	6.26	7.58	8.48

SD, standard deviation, P, percentile.

TABLE 7 Energy and nutrient intake distributions (per day) in female participants (n = 689) of the BVS III, weighted for the deviation from the underlying population.

Nutrient	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Energy [kcal]	1,612	393	1,011	1,128	1,338	1,588	1858	2,132	2,303
Energy [kJ]	6,753	1,646	4,235	4,723	5,603	6,649	7,782	8,929	9,644
Protein [g]	60.0	14.5	38.1	42.4	49.7	59.0	69.0	79.0	85.8
Fat [g]	70.4	18.5	42.4	47.8	57.4	69.1	81.9	95.0	103.2
Saturated fatty acids [g]	30.0	8.7	16.9	19.4	23.8	29.3	35.4	41.6	45.5
Monounsaturated fatty acids [g]	23.8	6.3	14.4	16.1	19.3	23.3	27.7	32.1	35.0
Polyunsaturated fatty acids [g]	11.2	3.3	6.5	7.3	8.8	10.8	13.1	15.5	17.1
Omega-3 fatty acids [g]	1.6	0.6	0.8	1.0	1.2	1.5	1.9	2.4	2.7
Omega-6 fatty acids [g]	9.5	2.9	5.4	6.1	7.5	9.2	11.2	13.3	14.7
Carbohydrates [g]	165.2	49.3	92.0	105.5	130.3	160.8	195.6	230.8	253.1
Starch [g]	85.9	25.7	47.1	54.4	67.4	83.8	102.0	119.9	131.4
Total mono- and disaccharides [g]	76.6	35.2	29.0	36.4	51.1	71.4	96.2	123.9	142.1
Disaccharides [g]	44.7	21.3	16.6	20.8	29.3	41.2	56.1	73.2	84.5
Lactose [g]	7.6	4.7	2.0	2.7	4.3	6.6	9.9	13.8	16.7
Saccharose [g]	36.7	18.9	12.1	15.7	22.9	33.5	46.8	62.0	72.3
Monosaccharides [g]	32.6	17.3	10.7	13.7	20.0	29.3	41.4	55.7	65.5
Fructose [g]	17.7	9.8	5.5	7.1	10.6	15.8	22.6	30.6	36.3
Glucose [g]	14.5	7.8	4.8	6.1	8.8	13.0	18.4	24.9	29.3
Dietary fiber [g]	16.2	5.4	8.4	9.7	12.3	15.6	19.3	23.3	26.0
Water-insoluble fiber [g]	10.8	3.7	5.5	6.4	8.1	10.4	12.9	15.7	17.6
Water-soluble fiber [g]	5.1	1.7	2.7	3.1	3.9	4.9	6.0	7.3	8.1
Alcohol (ethanol) [g]	12.1	13.4	0.9	1.6	3.6	7.8	15.5	27.5	37.5
Sodium [g]	2.4	1.0	1.2	1.3	1.7	2.2	2.9	3.6	4.2
Chloride [g]	4.0	1.5	2.0	2.3	2.9	3.7	4.7	5.9	6.7
NaCl (salt) [g]	5.5	2.3	2.6	3.0	3.8	5.0	6.6	8.4	9.8
Potassium [g]	2.4	0.6	1.4	1.6	1.9	2.3	2.8	3.2	3.5
Calcium [mg]	788	227	464	521	625	762	922	1,087	1,202
Phosphorus [mg]	1,035	269	642	713	845	1,009	1,196	1,391	1,519
Magnesium [mg]	279	77	168	188	224	270	324	381	417
Zinc [mg]	8.3	1.8	5.5	6.1	7.0	8.2	9.4	10.7	11.5
Iron [mg]	9.6	2.7	5.7	6.4	7.6	9.3	11.1	13.2	14.5
Iodide [μg]	74.3	23.6	42.4	47.6	57.5	70.8	87.1	105.5	118.2
Vitamin A: Retinol equivalents [mg]	1.10	0.43	0.54	0.62	0.79	1.03	1.32	1.66	1.90
Vitamin A: Beta-carotene [mg]	3.46	1.59	1.43	1.73	2.32	3.17	4.28	5.52	6.48
Vitamin A: Retinol [mg]	0.50	0.24	0.21	0.25	0.34	0.45	0.61	0.81	0.95
Vitamin D: Calciferole [μg]	2.32	0.84	1.18	1.36	1.71	2.19	2.79	3.44	3.90
Vitamin E: Alpha-tocopherol equivalents [mg]	11.1	4.1	5.6	6.5	8.2	10.6	13.4	16.5	18.7
Vitamin E: Alpha-tocopherol [mg]	10.3	3.7	5.2	6.0	7.6	9.7	12.3	15.2	17.2
Vitamin C, ascorbic acid [mg]	99.1	37.3	47.9	56.1	72.4	94.0	120.0	149.0	168.1
Vitamin B1, thiamine [mg]	0.99	0.31	0.57	0.63	0.77	0.94	1.16	1.40	1.57
Vitamin B2, riboflavin [mg]	1.13	0.36	0.63	0.71	0.88	1.09	1.34	1.62	1.81

(Continued)

TABLE 7 (Continued)

Nutrient	Mean	SD	P5	P10	P25	P50	P75	P90	P95
Vitamin B6, pyridoxin [mg]	1.16	0.36	0.66	0.74	0.90	1.11	1.36	1.63	1.82
Niacin [mg]	13.9	4.8	7.3	8.4	10.5	13.2	16.5	20.2	22.7
Niacin equivalents [mg]	25.7	7.0	15.6	17.4	20.8	25.0	29.9	34.9	38.2
Pantothenic acid [mg]	3.58	1.26	1.88	2.15	2.68	3.39	4.27	5.25	5.93
Biotin [μg]	40.8	20.0	18.6	21.7	28.2	37.5	49.6	64.1	74.4
Total folate [μg]	197	64	108	122	151	189	233	281	314
Vitamin B12, cobalamin [μg]	3.92	1.41	2.01	2.31	2.91	3.71	4.70	5.77	6.54

SD, standard deviation, P, percentile.

TABLE 8 Median intake of selected vitamins and proportion of male and female participants of the BVS III not meeting the reference values of the German Nutrition Society (DGE).

Vitamin	Daily intake, BVS III (median)		% of participants below the reference value		Reference value (DGE[1])	
	Men	Women	Men	Women	Men	Women
Vitamin A, Retinol equivalents [mg]	0.97	1.03	25	11	0.75	0.65
Vitamin E, α-tocopherol equivalents [mg]	11.0	10.6	75	63	14	12
Vitamin B1 [mg]	1.15	0.94	55	57	1.2	1.0
Vitamin B2 [mg]	1.26	1.09	63	39	1.4	1.1
Vitamin B6 [mg]	1.38	1.11	69	78	1.6	1.4
Niacin equivalents [mg]	32.4	25.0	0	0	15	12
Pantothenic acid [mg]	3.78	3.39	79	87	5	5
Folate, total [μg]	199	189	91	93	300	300
Vitamin B12 [μg]	5.03	3.71	24	58	4	4
Vitamin C [mg]	82.2	94.0	77	51	110	95

[1]Reference values for 25–50-year-old men and women (34), except for retinol equivalents (24).

Due to the limited number of participants, the NCI method did not allow for the estimation of intake distributions for further subgroups, e.g., age groups. Another limitation of the NCI method is that it cannot identify non-consumers. Therefore, estimated population distributions do not enable the identification of the proportion of the population not consuming a certain food item.

4.3 Evaluation of habitual food consumption

The proportion of persons following a vegetarian or vegan diet in adult Bavarians increased over the past years (13); at the same time, people also followed the concept of a flexitarian diet, i.e., limiting the number of days with meat-based dishes. As the median meat consumption decreased, the observation of decreasing meat consumption is not driven by the group of vegetarians and vegans but rather reflects a broad change in eating behavior in the population.

Although the consumption of red meat and especially processed meat has decreased among men and women over the past 20 years (Table 5), current consumption levels reported here are on average higher than the recommended levels of the FBDG; in men, less than 1% met the FBDG for red meat, and 7% were in line with the FBDG for processed meat.

Median dairy product consumption decreased by about 20 g/day over the past decades (BVS II). When converted into milk equivalents (15), the intakes of 43% of men and 47% of women are below the FBDG.

The comparison of the consumption of foods of plant origin with the FBDG revealed significant deviations (Table 4). Adult men and women in Bavaria consumed far fewer vegetables and fruit in 2021–2023 than recommended, with 10% or less of men and women meeting the fruit and vegetable intake recommendations. To a similar extent, this also applies to the consumption of nuts and seeds, with more than 80% of the adult population eating fewer nuts and seeds than recommended. However, vegetable intake increased over the past 20 years, especially in women.

The median potato intake on the other hand exceeded the corresponding FBDG by almost 90%, while the consumption of cereal products was distinctly lower than recommended. Moreover, the FBDG for whole grain products were missed by far: 85% of all men and almost 90% of all women did not meet the recommendations. In the BVS II, similar amounts of potatoes were consumed on average (Table 5), and the consumption of cereal products increased slightly since then.

For the first time, the consumption of milk alternatives as well as meat alternatives is reported in the BVS III and indicates an increasing importance of milk alternatives in particular. These findings are supported by market data: In the past years, the consumption of alternatives for dairy and meat products has grown continuously, although the absolute contribution is still rather low, with dairy product alternatives making up 6.6% of the total dairy market in 2023 in Germany (26).

A positive development is the distinct decrease in the consumption of soft drinks, beer, and wine in the BVS III compared to 20 years ago, while at the same time, the median consumption of drinking water has almost doubled (Table 5).

Major observed dietary changes (compared to BVS II), especially the decreased meat consumption, were mirrored by data from food balance sheets (27).

4.4 Evaluation of habitual consumption of vitamins and minerals

The modeling of the nutrient intake distribution, correcting for intrapersonal variation, enables the evaluation of micronutrient intakes by identifying the proportion of the Bavarian population with an intake below or above reference values. We used the reference values of the German Nutrition Society (11) established to ensure that almost all persons of the population met their nutrient requirements when meeting these values. Accordingly, men and women not meeting these reference values have a higher risk of insufficient intake of the respective nutrients; for diagnosing nutrient deficiency, biochemical analyses of biomarkers in biospecimens are warranted. German reference data for average requirements in the population were not established but would represent the preferred concept for comparison.

The largest proportion of persons below reference values was observed for folate, exceeding 90% in both sexes and corresponding to previous findings in Germany (28). However, available biomarker data to evaluate the supply status of folate in the German population described the problem precisely (29). In addition, high proportions of individuals not meeting recommendations were also observed for pantothenic acid, vitamin E, and vitamin B6. For all three vitamins, lower risks of insufficiency were observed in previous studies in Germany (29, 30). The high proportion of men (more than 75%) not reaching the reference values for vitamin C (110 mg/d) was particularly surprising, which may be explained by the low median intake of vegetables and particularly of fruit in men (Table 4). The proportion of men and women below the DGE reference values for vitamins was lowest for niacin; also, for retinol equivalents and vitamin B12 (in men), low proportions were observed. We did not include vitamin D in this comparison because diet usually constitutes only a minor contribution to vitamin D supply (31). Overall, we did not observe distinct differences to former studies as summarized by Bechthold et al. (32, 33).

In terms of mineral intakes, low proportions of the population not meeting the DGE reference values were observed for phosphorus, sodium, and chloride (Table 9). It should be noted, however, that the intake of sodium and chloride cannot be precisely assessed using 24HD, since, e.g., adding salt (NaCl) at consumption is not recorded, resulting in an underestimation of the intake of these minerals. On the other hand, large parts of the population not meeting the reference values were observed for iodine, calcium, magnesium, zinc in men, and iron in women (both pre- and postmenopausal). To determine the actual iron supply status, established biomarker measurements would have to be performed. Similar observations concerning these minerals were made for Germany in the NVS II, yet to a lesser extent (30). Surprisingly, also the median potassium intake was 40% lower than the DGE reference value, resulting in 97 and 98% of men and women, respectively, not meeting the reference values. Possible reasons may include the inadequate consumption of potassium-rich foods, particularly fruit, vegetables, nuts, and cereal products (Table 4), as well as underreporting.

4.5 Strengths and weaknesses

We present here for the first time after two decades detailed information on the diet of adults in Bavaria, describing the population distribution of food groups and nutrients. Employing the same methodology as in the previous BVS II enables a direct comparison with the dietary habits then and – hence – the description of the dietary changes over the past 20 years. We also applied the same food composition database in both studies (BLS 3.02), allowing a direct comparison between these studies. However, this can also be interpreted as a shortcoming, as an updated food composition database would have captured changes in food composition over time and included current food items, allowing for a more precise coding and nutrient calculation.

The field phase of the study took place during the SARS-CoV-2 pandemic. Besides potential effects on the response rate, which we addressed by weighting all analyses to compensate for any discrepancies with the underlying population, the pandemic may also have influenced dietary habits during the field phase, e.g., regarding out-of-home food consumption, particularly in the context of communal catering, which was not or not always possible at the time.

5 Conclusion

The present data describe changes in the dietary habits of the Bavarian adult population since the previous Bavarian Food Consumption Survey (BVS II) in 2002–2003.

TABLE 9 Median intake of selected minerals and proportion of male and female participants of the BVS III not meeting the reference values of the German Nutrition Society (DGE).

Mineral	Daily intake, BVS III (median)		% of participants below the reference value		Reference value (DGE[1])	
	Men	Women	Men	Women	Men	Women
Sodium [mg]	3,142	2,200	2	16	1,500	1,500
Chloride [mg]	4,935	3,717	2	9	2,300	2,300
Potassium [mg]	2,508	2,325	97	98	4,000	4,000
Calcium [mg]	809	762	77	83	1,000	1,000
Magnesium [mg]	306	270	69	64	350	300
Phosphorus [mg]	1,233	1,009	0	2	550	550
Zinc [mg]	10.0	8.2	68	24	11*	7*
Iron [mg]	10.5	9.3	57	97 / 93[2]	11	16/14[2]
Iodide [μg]	80	71	99	100	200	200

[1]Reference values for 25–50-year-old men and women (34); [2]premenopausal/postmenopausal; *for a diet with low phytate intake.

The proportion of vegetarians and vegans has increased in the Bavarian population, and a flexitarian diet appears to become more prominent, resulting in a growing importance of meat alternatives and particularly milk alternatives in the daily diet, but also in a reduction in the consumption of red meat and especially processed meat. Other favorable changes compared to the BVS II include an increase in vegetable consumption, lower consumption of soft drinks, beer, and wine, as well as a concomitant increase in drinking water consumption.

However, a major proportion of the adult Bavarian population does not meet the current food-based dietary guidelines. Major deviations of the median intake from the FBDG of the DGE were observed for a wide range of important food groups, including fruit and vegetables, nuts and cereal products, particularly whole grain products. Accordingly, large proportions of the Bavarian population do not meet the DGE reference values for several essential nutrients, including folate, pantothenic acid, vitamin B6, iodine, calcium, and – previously not described – potassium.

The prevailing SARS-CoV-2 pandemic is likely to have affected the habitual diet. Subsequent surveys will have to examine the extent to which the situation has changed since the end of the pandemic.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics review board at the Medical Faculty of the Ludwig-Maximilians-University of Munich. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FR: Data curation, Writing – original draft, Writing – review & editing. NW: Data curation, Formal Analysis, Methodology, Writing – review & editing. SG: Data curation, Writing – review & editing. NO: Writing – review & editing. MS: Project administration, Writing – review & editing. CR: Project administration, Writing – review & editing, Funding acquisition. MK: Project administration, Writing – review & editing. KG: Conceptualization, Funding acquisition, Resources, Writing – review & editing. JL: Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2024.1537637/full#supplementary-material

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Application of the Healthy Eating Index in a multicultural population: introduction of Adaptive Component Scoring

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The United States, and many modern nations, represent assemblies of many cultural groups. Such groups are often influenced, sometimes profoundly, by the culinary traditions of their countries of origin, resulting in a diversity of cultural dietary patterns. Such patterns all derive key elements of nutritional quality from essential food groups—such as vegetables and fruits—but vary in their inclusion of "discretionary" food groups, such as dairy. The application of robust, validated, and standardized diet quality scoring is important in nutrition research, and in the food-as-medicine movement at large if what is being "managed" is to be measured. While robustly validated, the Healthy Eating Index is closely aligned with the *Dietary Guidelines for Americans*, and thus may not readily account for all multicultural dietary variations. Other diet quality metrics account for deviation from the prevailing American dietary pattern, but none does so in a way that expressly adapts to food components included or excluded so that "credit" for nutritional quality is appropriately assigned in all cases using a standard metric. In this context, we introduce and explain Adaptive Component Scoring as applied to the Healthy Eating Index in the service of advancing fair and universal diet quality scoring. Implications for nutrition research and food-as-medicine initiatives are briefly enumerated.

KEYWORDS

diet quality, dietary index, diet score, Healthy Eating Index, dietary patterns, multicultural diets, nutrition, food groups

Introduction

The Healthy Eating Index (HEI) (1) and the related Alternative Healthy Eating Index (2) are among the most widely used and robustly validated measures of overall diet quality in the United States. These measures have been correlated directly with all-cause mortality and total chronic disease risk in large cohorts (3). Overall diet quality measured accordingly is now recognized as the single leading predictor variable for premature death in the United States (4), and much of the world (5).

Despite these strengths, there are important limitations to the HEI. The metric is closely aligned with the Dietary Guidelines for Americans (6), and accordingly confers credit for food groups that prevail in the American diet, including dairy, meat, poultry, fish, seafood, and grains. Whereas meat, poultry, and fish are assigned to a "protein" category in the HEI scoring construct, for which legumes may substitute, the omission of dairy or grains from a dietary pattern reduces the total, achievable HEI score.

Of note, an array of traditional East and Southeast Asian diets—including one associated with a *Blue Zone* population (7, 8) omit dairy (9). While categorizable as an omission relative to the HEI construct, these diets in fact never included dairy historically, and only occasionally do so now as elements of the Western diet are globalized. The long-standing inclusion of dairy by select populations, and its exclusion by others, has resulted in marked, demographic variation in the prevalence of lactose tolerance (10). The native, mammalian condition is lactose intolerance after infancy/weaning, and persistence of lactose tolerance throughout the lifespan represents an adaptation by certain human populations (10, 11).

Along with select, traditional Asian diets, vegan diets also exclude dairy. The traditional Paleo diet excludes dairy, and in many applications excludes grains as well (12, 13). Other diet types, whether for disease management, food intolerance, or personal preference, may exclude select food groups such as meat, poultry, fish, dairy products, and/or grain products. While not all of this impact HEI scores, some of them do.

Across a vast expanse of relevant evidence, there is no indication that health outcomes, including the most definitive—vitality and longevity—are adversely affected by the exclusion of dairy when the overall balance of the diet is sound (14). This is certainly true of meat as well, and the same is likely true for the exclusion of grains, although less evidence and fewer real-world examples pertain here. High quality versions of select Asian diets, vegan diets, and potentially Paleo diets are reasonable contenders when dietary patterns "best" for health are under consideration (15–17).

The USA is a multicultural society with a wide range of dietary practices, many based on heritage (18, 19), and others based on alternative nutrition principles and emphasis (e.g., restricting total carbohydrate intake). While routinely applied in this context, the standard application of the HEI may be ill-suited to score diets fairly across this expanse of practices. To address this limitation, and generalize the utility of routine diet quality scoring with a common metric, we introduce a simple adaptation of the HEI.

Methods

To adapt the HEI to dietary patterns that exclude select food groups, an initial determination needed to be made about food groups that could reasonably be deemed "discretionary" in balanced, complete, and sustaining dietary patterns. The determination of "*discretionary*" *versus universal food components* was made by consensus of the authors, two registered dietitian nutritionists, and one physician expert in nutrition. That consensus was in turn predicated on: (1) work related to mapping the range of dietary patterns currently prevailing in the U.S.A., and to some extent other regions around the world (20); (2) the range of eating patterns represented in worldwide dietary guidelines (21) and clinical practice guidelines (22); (3) the range of dietary patterns saliently associated with longevity and health span (14, 15, 18, 23); and (4) the range of natively adapted human dietary practices (24). Across this breadth of considerations, fruits, vegetables, nuts and seeds were universal; meat, seafood, dairy, grains, and legumes were discretionary. Of note, the characterization of a given food group as discretionary depends partly on other elements in a given dietary pattern. As an example, legumes may be discretionary in a Paleolithic diet that includes meat, seafood, and/or fish, but would not be discretionary in a vegan diet excluding these alternative protein sources. Adaptations were made to the standard HEI scoring construct (1) as shown in Table 1.

TABLE 1 Scoring components: HEI-2020 vs. ACS.

Component	HEI[1] 2020 (maximum points)	ACS[2] (maximum points)
Adequacy		
Total fruits	5	5
Whole fruits	5	5
Total vegetables	5	5
Greens and beans	5	5
Whole grains	10	10 (optional)
Dairy[3]	10	10 (optional)
Total protein foods	5	5
Seafood and plant proteins	5	5
Fatty acids	10	10
Moderation		
Refined grains	10	10 (optional)
Sodium	10	10
Added sugars	10	10
Fatty acids	10	10

[1]Healthy Eating Index.
[2]Adaptive Component Scoring.
[3]Includes fortified soy beverages.

The approach to Adaptive Component Scoring was developed to adjust the HEI denominator based on the food groups available to contribute "credit" to the numerator. To create the adapted formula, terms and categories were established as shown in Table 2.

For any given diet, the adjusted scores may be established based on the *a priori* exclusion of discretionary components, e.g., Asian diets may exclude dairy; Paleo diets may exclude dairy, grains and legumes. See Figure 1 for the adapted formula.

Results

In practice, HEI scoring allows for full protein credit from a range of sources not excluded collectively from any balanced diet, namely: meat, poultry, fish and seafood, and plants (i.e., legumes). Thus, no diet identified required adjustment in this area. A number of diets defined by both cultural parameters and nutritional parameters require adjustment for dairy. See examples in Table 3. Select expressions of certain diets, notably Paleo and low-carb, require adjustment for grains. The maximum HEI score that can be achieved is 90 due to no credit for whole grains. See Table 3 for sample score adjustments.

When stratifying dietary patterns into 10 evenly spaced tiers (deciles) using the HEI-2020, application of Adaptive Component Scoring elevated the scores of the higher tiers for diets excluding dairy and/or grains (see Table 3). This enabled the formulation of an "optimal" diet quality tier for various East Asian diets, and high-fidelity versions of the Paleolithic diet, comparable to scores for dietary patterns with all food groups represented. Absent use of Adaptive Component Scoring, a range of cultural diets, some expressly associated with optimal health outcomes, could not achieve optimal HEI scores.

TABLE 2 Established terms and categories for ACS.

Term	Categories
Total components (foods and nutrients) in the HEI score	Whole fruits; total fruits; total proteins; seafood & plant protein; greens/beans & total vegetables; nutrient entries (i.e., sat fat; added sugar; sodium; fatty acid ratio [(PUFA+MUFA)/SFA]); dairy[1]; whole grains; refined grains; total protein
Universal (required) components in the adapted HEI score	whole fruits; total fruits; seafood & plant protein; greens/beans & total vegetables; nutrient entries (i.e., sat fat; added sugar; sodium; fatty acid ratio [(PUFA+MUFA)/SFA])
Discretionary (optional) components in the adapted HEI score	dairy[1]; whole grains; refined grains; (total protein—seafood & plant protein)

[1]Includes fortified soy beverages.

$$\mathbf{A_S = I_S*(T_S/IT_S)}$$

Where:

A_S = adjusted HEI score
I_S = HEI score for included components
T_S = total possible HEI score for all components
IT_S = total possible HEI score for included components

For example:

A given diet excludes select components and can achieve a maximal score of 80. An individual's diet within this pattern achieves a score of 60. The adjusted HEI score for this entry is:

$$A_S = I_S*(T_S/IT_S)$$
$$A_S = 60*(100/80)$$
$$A_S = 75$$

FIGURE 1
Formula for Adaptive Component Scoring.

Discussion

The quality of a given dietary pattern derives from the quality of health effects it imparts: disease prevention; health promotion; contributions to vitality and longevity. (N.B. Contributions to planetary health are of noteworthy importance, but beyond the scope of the current focus) Invoking such considerations, there is more than one way to achieve a "high quality" diet (15, 19, 25), and no one culture owns a monopoly on the formula. A universally applicable standard for high diet quality predicated on key health outcomes must allow for cultural variations, including the exclusion of a food group that has a traditional place in some cultures, but not others. Adaptive Component Scoring respects the fundamental construct of the Healthy Eating Index, while making this crucial accommodation for cultural variations.

Some food groups are clearly discretionary. There are entire human populations that have no long-standing tradition of dairying, for instance, in which lactose intolerance and the exclusion of dairy from the cultural diet both prevail. There are other populations with long exposure to dairy, and obvious adaptation to it as indicated by widespread lactose tolerance, courtesy of a genetic mutation (26). Of note, both of these groups are represented among the world's Blue Zones, famous for their healthy life span (25, 27). This salient example illustrates the potential to achieve the same high quality of overall dietary pattern with, and without, dairy. The simple adaptation of the HEI introduced here serves as a quantitative translation of that important principle.

While there are food groups that may be deemed "discretionary" based on modern science, evolutionary biology, and the range of cultural practices, there are clearly food groups that are not. While short-term adjustments might allow for the exclusion of vegetables, fruits, or legumes from the diet, there is no discernible signal across the expanse of evidence sources noted above that such patterns are conducive to optimal health outcomes across the human lifespan. Adaptive Component Scoring was thus directed at those components of an overall dietary pattern that both (a) actually do come and go across an expanse of cultural diversity and prevailing behavior; and (b) can reliably be associated with the same set of health outcomes, summarized as years in life (i.e., longevity), and life in years (i.e., vitality). In practice, this directs the adjustments preferentially to dairy and grains. There is no need to make adjustments for the exclusion of meat, poultry, fish, or seafood, not because these do not occur, but because the HEI already accounts for this by allowing for full credit from plant-derived protein sufficient in quantity and quality (17).

Unadjusted, the HEI can present challenges when applied to dietary patterns that exclude dairy (and/or fortified soy products, which also allow quality points in the HEI) or minimize grain consumption, even if those diets are otherwise nutrient-dense and aligned with health outcomes. While it offers a robust framework for

TABLE 3 A representative sampling of Healthy Eating Index 2020 scores, with and without Adaptive Component Scoring applied, for optimized versions (i.e., highest achievable HEI score) of select dietary patterns that exclude one or more discretionary food groups.

Dietary Pattern	Components	Excluded Food Groups	HEI-2020 score for optimized version, unadjusted (Top Tier)	HEI-2020 score for optimized version, Adaptive Component Scoring applied
Keto	Total Fruit, Whole Fruit, Total Protein Foods, Total Vegetables, Greens and Beans, Dairy, Seafood and Plant Proteins, Fatty Acids, Refined Grains, Sodium, Added Sugars, Saturated Fat	Whole Grains	74	85
Low-Carb	Total Fruit, Whole Fruit, Total Protein Foods, Total Vegetables, Greens and Beans, Dairy, Seafood and Plant Proteins, Fatty Acids, Refined Grains, Sodium, Added Sugars, Saturated Fat	Whole Grains	89	99
Paleo, with limited non-dairy	Total Fruit, Whole Fruit, Total Protein Foods, Total Vegetables, Greens and Beans, Dairy, Seafood and Plant Proteins, Fatty Acids, Refined Grains, Sodium, Added Sugars, Saturated Fat	Whole Grains	88	97
Paleo, without dairy or dairy alternatives	Total Fruit, Whole Fruit, Total Protein Foods, Total Vegetables, Greens and Beans, Seafood and Plant Proteins, Fatty Acids, Refined Grains, Sodium, Added Sugars, Saturated Fat	Dairy, Whole Grains	80	100
Vegan	Total Fruit, Whole Fruit, Total Protein Foods, Total Vegetables, Greens and Beans, Whole Grains, Seafood and Plant Proteins, Fatty Acids, Refined Grains, Sodium, Added Sugars, Saturated Fat	Dairy	90	100
Vietnamese	Total Fruit, Whole Fruit, Total Protein Foods, Total Vegetables, Greens and Beans, Whole Grains, Seafood and Plant Proteins, Fatty Acids, Refined Grains, Sodium, Added Sugars, Saturated Fat	Dairy	89	99

assessing diet quality, it may not fully account for dietary variations that limit these food groups, despite evidence that such diets can still promote optimal health and reduce disease risk. Several alternative scoring systems, including the Mediterranean Diet Score [MDS] (28), Alternative Healthy Eating Index [AHEI] (2), and Plant-Based Diet Index [PDI] (29), allow for reduced or absent intake of dairy or grains while still achieving high scores. These systems acknowledge that diets rich in vegetables, fruits, legumes, nuts, and healthy fats—without necessarily relying on grains or dairy—can still reduce the risk of chronic diseases such as cardiovascular disease and cancer (30, 31). However, each of these metrics is 'fixed' rather than adaptive in response to intrinsic dietary variation. The signature distinction of Adaptive Component Scoring is that it is, indeed, "adaptive," giving credit as it's due for those food components contributing to overall diet quality. As an example, whole grains are an important contributor to high-quality flexitarian diets, but may be omitted entirely from select expressions of a high-quality Paleolithic diet. Dairy is a signature element in the DASH diet, but is absent from the traditional Okinawan diet.

Other types of scoring systems, such as the Dietary Inflammatory Index [DII] (32) and NOVA classification [NOVA] (33), focus on the processing and inflammatory potential of foods rather than specific food groups, reflecting a more global, multi-cultural perspective. These approaches, too, are fixed, and not directly responsive to variation in the sources of key dietary inputs. This highlights the value of developing adaptive scoring methods that better accommodate diverse dietary patterns, including those that exclude or minimize dairy or grains, without compromising the ability to measure diet quality across various cultural and nutritional styles. Such flexibility can enhance inclusivity while maintaining the strengths of established tools like the HEI.

Attention to the diverse means of elevating overall dietary quality for a multicultural society is increasing, but has historically been limited (34). Among the important implications of this focus is the opportunity to standardize diet quality without standardizing diet type in intervention studies and food-as-medicine initiatives. The food-as-medicine movement (35) is directed to the level of population, and in particular, to population groups that are most food—and nutrition-insecure. Such groups are particularly multicultural. Familiarity is well established as a key driver of dietary preference, and adherence to prescribed diets predicated on a "one-size-fits-all" approach for a diverse population is known to be rate-limiting in their impacts; long-term adherence is a particular limitation (36).

An adaptation of the HEI for multicultural deployments offers the promise of innovations in nutrition research and service that could reduce attrition, enhance adherence, improve satisfaction, and generalize far more readily. In the food-as-medicine movement, efforts directed at the improvement of health outcomes by means of improved diet quality call for routine and standardized measurement of what is being managed. For diet quality assessment to be practiced fairly across such an expanse, it must be adapted to diverse, cultural patterns of dietary intake.

As an example of application of ACS under real-world conditions, our work involves both assessing current diet (habitual intake, rather than per-day intake), and providing guidance toward a personalized goal diet. The "improvement" in diet both intended, and achieved, is measured by change in HEI score—both for individuals, and the population. This, in turn, requires the attachment of HEI scores to goal diets. As our work involves culturally diverse populations, the personalization of goal diets also involves a multicultural array of dietary patterns. Empirically, we observed that optimized versions of select culturally diets, such as various Asian diets that omit dairy, garnered lower HEI scores than comparably, wholesome dietary patterns in other cultural lanes, inclusive of all food groups. We apply ACS when exclusion of a given HEI food group pertains because of high-fidelity adherence to a dietary type that omits that food group, generally at the higher levels (e.g., top 3 deciles) of the HEI scoring range. Application of ACS in this context serves as intended to "level the playing field," generating comparable quality (HEI) scores for multicultural goal diets satisfying comparable nutritional parameters, while varying slightly in the food groups from which such nutrients are derived. The application of ACS to current dietary intake, along with dietary goal-setting, correspondingly pertains when (a) measurement is of habitual, not per-day, intake; and (b) that same high-fidelity adherence to optimized (i.e., upper HEI deciles) has been achieved.

We note that the generation of HEI scores predicated on dietary intake assessment presupposes, and indeed requires, that the dietary intake assessment methods applied are reliable, valid, and pertain to habitual rather than episodic intake. The same constraints pertain to the application of ACS, for which the generation of HEI scores is prerequisite.

Objective measures of diet quality are useful at both the individual and population level in risk stratification (2); in translating risk into projected costs (37); and in gauging the progress achieved in any given clinical nutrition or food-as-medicine intervention (38). Diet quality, measured objectively, has been cited as the single leading predictor variable for total chronic disease risk and premature death in developed countries around the world (5), with notable attention to that association in the United States (39). Change in overall diet quality, using a standard measure, is a useful outcome measure in nutrition research (40). Finally, overall diet quality is an important parameter to consider for both individuals and populations when establishing dietary goals. The application of ACS expands the array of dietary patterns that can meet or achieve a given quality threshold, thus expanding opportunities to tailor nutrition prescriptions to culture and native preference and measure diet quality improvement in both individuals and populations across an expanse of cultural diversity.

The introduction of Adaptive Component Scoring is intended to advance such objectives. The utility of this innovation will best be tested and affirmed in just such context.

Data availability statement

The datasets presented in this article are not readily available because use of the ACS is intended for the public domain, and pertinent data sets are accessible via public access to the Health Eating Index 2020 scoring construct. Requests to access the datasets should be directed to Lauren Q. Rhee, lauren.rhee@jointangelo.com.

Author contributions

DK: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. LR: Data curation, Writing – review & editing. DA: Writing – review & editing.

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A comparison of development methods used to define portion sizes in food-based dietary guidelines around the world

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Introduction: Food-based dietary guidelines (FBDGs) are essential public health tools for delivering dietary recommendations, and generally include guidance on portion sizes. Despite existing guidelines on developing and implementing FBDGs, there is still no consensus on best practices for their formulation. This paper compares the methodologies used by public health organizations to create FBDGs and examines how both methodology and geographical location may influence recommended portion sizes.

Methods: Documents on FBDG development were obtained from the Food and Agriculture Organization online repository of FBDGs, either directly from consumer-facing FBDG or from corresponding scientific reports. Methodological details in FBDG development were extracted and categorized. Recommended portions in grams per day were extracted for 15 food categories to enable comparison across development methods and global regions.

Results: FBDGs from 96 countries were accessed and translated. Of these, n = 83 were based on consensus/review, n = 15 used data-based approaches, and n = 30 included other minor calculations. Thirty-nine FBDGs were derived from a combination of consensus/review and another method. Of the countries providing portion size information, only one did not report its methodological approach. Comparisons of median portions sizes of food groups across methodologies showed no significant differences. Analyses across regions revealed that portion recommendations were generally consistent, with significant differences found only for one food group, namely, Fish & shellfish, where portion size recommendations were significantly higher in Europe compared to those in Latin America and the Caribbean.

Discussion: Results indicate little variation in the recommendations for portion size across development methods, and for most food groups, across global regions. These findings suggest there is potential to harmonize portion size derivation in FBDGs at regional or global levels. However, further research is needed to assess whether harmonized guidance can apply to other aspects of FBDGs.

KEYWORDS

food-based dietary guidelines, portion size, dietary recommendations, linear programming, diet modeling, dietary intake

1 Introduction

According to the World Health Organization (WHO), unhealthy eating habits are a major risk factor for non-communicable diseases (NCDs) (1). In 2017, a systematic analysis showed that 11 million deaths and 255 million disability-adjusted life years (DALYs) were attributable to suboptimal diets (2). The current rise in obesity and outbreak of NCDs underscores the importance of dietary recommendations. As "consumers think in terms of foods rather than of nutrients" (3), various initiatives including food-based dietary guidelines (FBDGs) are used to provide nutritional information for consumers.

FBDGs, defined as "a set of healthy eating messages provided for a population" (4) represent a valuable tool in communicating dietary recommendations to populations. FBDGs aim to "improve food consumption patterns and nutritional status of individuals and populations" by promoting practical and culturally acceptable healthy diet and lifestyle habits (3). They also serve as a tool in national nutrition, health and agriculture policies. Initially introduced in the United States, they are now implemented in more than 100 countries worldwide (5). Common formats include food pyramids, which allow to visualize food groups and PS in a hierarchical manner, and food plates (e.g., "MyPlate" model in the United States), which divide a plate into sections to represent ideal proportions of different food groups (6). In addition, booklets, apps, and online resources provide detailed guidance on meal planning, portion control, and nutrient intake. Several public health authorities have published guidance on how to develop and monitor the impact of FBDGs. In 1998, the Food and Agriculture Organization of the United Nations (FAO) and the WHO published a technical report providing scientific considerations for the preparation of FBDGs (3), and the European Food Safety Authority (EFSA) released a scientific opinion on establishing FBDGs in 2010 (7). These include elements such as review of existing consumption patterns, defining the specific scope and problem for the region/country to focus the purpose, goals and targets of the guidelines, and the testing and optimisation of the developed guidelines (3, 5).

Whilst it is recognized that advice provided in FBDGs is informative, there remains no general consensus on the best practices for deriving and monitoring FBDGs. As understanding the food environment and food consumption patterns can be used to support changes in population and planetary health (8, 9), countries continue to develop or update their FBDGs to support public health targets (5). In a recent review, four commonly used components were identified for the development of FBDGs: evidence of diet-health interactions, nutrient supply, energy supply, and dietary habits. However, this report also highlighted the absence of major components such as population segmentation or the consideration of recommendations on environmental sustainability (10). In addition, Blake and colleagues looked at the quality of the evidence used to generate the guidelines and found deficiencies in the approaches used to both review the evidence and rate its quality (11). It is, however, crucial to ensure that food intake recommendations are tailored to address both global and local dietary challenges (12, 13).

FBDGs can include both qualitative and quantitative guidance. The latter, being the focus of this paper, includes the concept of portion size (PS) recommendations. PS and frequency of consumption are used to direct the overall amount of given food/food group consumers are recommended to consume. A "portion" typically refers to the suggested amount of food which an individual ingests at a single meal or eating occasion (14, 15). Frequency is the number of times the portion is recommended to be consumed in a typical day or week. Different approaches are used to derive reference PS. One approach is to base the guidance on amounts which are considered optimal for achieving desired health targets, but these can be difficult to reach in practice due to inequities in food security worldwide (16, 17). The other approach is to base portions on usual intakes, which are easier for people to understand and follow, but may not be desirable for health purposes (18), as median PS, especially for foods high in fat, salt and sugar, have increased significantly over the past decades (19–21). Usual intakes are determined using food intake data collected as part of national consumption surveys (22, 23). Impact of differing approaches used to derive PS, and their use in FBDGs has not been investigated to date. Recent studies have found similarities in the food groups recommended yet noted some discrepancies in the recommended amounts across differing FBDGs (24–26).

This research aims to review the methodologies used to develop quantitative dietary recommendations in FBDGs worldwide, with a particular focus on the use of food intake data. Our objective is to investigate the potential impact that different methodologies may have on the recommended intakes by comparing the distributions of recommended PS for each food group. A key aspect of this study is to determine the impact of the development method taking into account the local context across global regions.

2 Materials and methods

A comprehensive and systematic approach was taken to data collection and analysis, to ensure a clear and objective approach to the collection and handling of data within this study. Details of the methods applied, are outlined in full detail below.

2.1 Food-based dietary guidelines documents

The online FAO repository of FBDGs was accessed between 1 July 2023 and 12 July 2024 to obtain a list of countries with published FBDGs. All countries listed on the FAO repository were considered for inclusion in the study. An additional web search was conducted to capture latest/most updated versions of each country's FBDGs as well as additional background documents in the gray literature, using the following keywords: "[country] food-based dietary guidelines scientific report OR scientific development." All documents related to the listed FBDGs were accessed and screened. To read documents written in any language other than English, French or Spanish, Google Translate was applied to texts of relevant documents.

The most recent version of the FBDG documents was reviewed. For each country considered in this analysis, guidelines and recommendations aimed at the general healthy adult population were assessed. Since the analyses were restricted to adult FBDGs only, those recommendations specifically designed for infants, children, teenagers, elderly, pregnant and breastfeeding women were excluded. FBDGs were grouped by region, as presented on the FAO repository. Data, described below, was manually extracted and stored on Microsoft Excel (Microsoft Office, V.2401).

2.2 Categorization of FBDG development methods

The methodology used to derive quantitative recommendations was determined from the methods section of FBDGs or from their associated background or scientific report documents. The methods used were classified into three categories, as follows: 1. Scientific consensus / literature review based on groups of experts, review of published reports, or literature review of the knowledge or nutritional situation of the country, or on the associations between diet and health; 2. Minimal calculations based on different energy levels and/or certain anthropological constraints (e.g., sex differences); and 3. Data-based approaches using data modeling that included a combination of constraints for energy, nutrients, and foods or food groups applied to a suitable data set (e.g., linear programming). Upon review of the documentation, we noted that several countries applied more than one method (e.g., scientific consensus and data-based approach). Therefore, all methodological approaches used were captured, allowing multiple methods to be listed for each FBDG. For the purpose of this analysis, when more than one methodological approach was applied, i.e., consensus/review plus either calculations or data-based approaches, then the FBDG was classified according to the additional method, with the aim to compare the recommendations between FBDGs using consensus/review only and FBDGs using calculations and statistical approaches. When no information was provided regarding the development of the FBDG, it was classified as "Not specified." Some FBDGs reported following specific methodologies outlined in regional guidelines; in this case, the methodologies were more often detailed in these reports rather than in the national FBDGs, and the detailed information was collected from the referenced documents. When a data set was used, details pertaining to its composition, including cohort representativeness, data collection methodology, and other relevant characteristics, were obtained from external documentation sources. These included peer-reviewed articles or supplementary information provided by the original dataset creators.

2.3 Portion sizes

A standardized approach was applied to determine the PS of each food group included in our analyses. When PS was provided as gram amounts at an overall food group level, no conversion was necessary. If PS for different foods were given within a food group, the average recommended portion (g) of the individual food values was calculated. In the case of PS recommendations given in other units (e.g., cup, food item, tablespoon) these were converted to a gram equivalent using two sources: the Food Portion Sizes Book (version 3) (27) and the USDA's Food and Nutrient Database for Dietary Studies (FNDDS) 2017–2018 (28). When both sources provided a gram equivalent for the food, an average was computed. When only one had an equivalent, then its value was used. A visual aid tool (29) was used to convert recommendations provided in other units (e.g., hand, palm, plate). If the document contained recommendations for different daily energy levels based on physical activity, the values corresponding to a medium activity level were considered. When a range of values was provided instead of a single amount, the mid-point of the range was reported. In addition, specific rules were applied for each food groups, which are detailed in Supplementary Table 4.

For each FBDG, portions were manually converted into gram amounts for each food and food group. Quality checks were conducted by the lead author and PS values were reviewed by all team members. Outliers were identified and values were discussed within the research team. Three values were excluded from the calculation, as they were deemed implausible from a dietary intake perspective (e.g., in the Mexican FBDG, the recommendation for vegetables included a "1.5 raw cabbage" which when converted to a gram amount represented a PS of 1,050 g (700 g per cabbage × 1.5). Values for global regions were obtained by calculating medians and the interquartile ranges (IQR) or each food group.

Data for the following food groups was extracted from the FBDGs as described above: Fresh fruits; Vegetables (unspecified); Vegetables (excluding green/leafy); Vegetables (green/leafy only); Cooked cereals/grains; Bread; Potatoes, starchy fruits and vegetables; Milk / plant-based alternatives; Yogurts and fermented dairy; Cheese; Meat; Fish & shellfish; Eggs; Pulses; Nuts & seeds.

2.4 Comparative analyses

Kruskal–Wallis tests were applied to compare the distributions of recommended PS of food groups across regions and across methodological approaches (30). Wilcoxon Rank-Sum tests (31) were applied to compare the distributions between data-based approaches and other approaches combined. For both tests, *p*-values were adjusted for False Discovery Rate (FDR) using Benjamini-Hochberg procedure (32). Post-hoc analyses were performed when the *p*-value was below 0.05, consisting of a Dunn-s test with Bonferroni correction for multiple testing (33). Comparisons were performed across regions, across development methods and between data-based approaches and other methods, specifically to examine the potential impact of using survey data. Analyses were performed on RStudio version 4.2.2.

3 Results

3.1 Included food-based dietary guidelines

At the time of data extraction, 100 countries were listed on FAO repository of FBDGs. Of these, three FBDGs were excluded as the documentation needed was not accessible online (Iran, Nepal, United Arab Emirates). A fourth FBDG was also excluded, because its recommendations targeted only children (Cambodia). Therefore $n = 96$ countries were included in the analysis: $n = 2$ in North America, $n = 11$ in Africa, $n = 34$ in Europe, $n = 16$ in Asia, $n = 29$ in Latin America and the Caribbean (LAC), and $n = 4$ in the Near East. Supplementary Table 1 lists the FBDGs included from each region, the access link to their consumer material from which PS were extracted, as well as the access link to the material reporting the development methodology when it was provided on a separate document.

3.2 Methodological approaches applied to derive food intake guidance in FBDGs

Table 1 summarizes the methodologies used to determine dietary recommendations in FBDGs, by FAO region. The specific approach used by each country are provided in Supplementary Table 2. The majority of countries ($n = 83$) mentioned either the formation of a group of experts, a review of the nutritional status of the population, or an evaluation of the associations between diet and health in their guidelines. Of these, $n = 39$ additionally conducted calculations, either minimal or data based. Overall, about a third ($n = 30$) of the 96 FBDGs analyzed included minimal calculations. However, relatively few countries included data-based approaches in their dietary guidelines, with only $n = 15$ of them describing a programming method. Seven out of 96 countries did not specify the method used. Among these, six did not include any PS recommendations (see Supplementary Table 2). The remaining country, Slovenia, provided PS recommendations but did not report the methodological approach used to develop them ("Not specified"). As a result, Slovenia was excluded from the statistical comparisons across methods.

For the countries who reported using a data-based approach, Table 2 provides the main characteristics of the dietary data and variables used within the analysis for the derivation of recommended intakes. While different titles were used to describe the process (e.g., "programming," "optimisation," "modeling"), data-based approaches generally involved applying a set of diverse food group and nutrient constraints to meet dietary needs. These procedures often utilize dietary intake data and consider local eating habits to ensure that the recommendations align with typical consumption patterns. However, when considering the data reported to be used only $n = 8$ FBDGs mention using a nationally representative dataset as an input in their model (Australia, Denmark, France, Germany, the Netherlands, Oman, United Kingdom, United States). All reported datasets used were national food consumption surveys, except for Oman where the data used was a household expenditure and income survey. FBDGs for Estonia, Finland, Iceland, Latvia, Norway and Sweden were adapted from the Nordic Nutrition Recommendations (34), and Dominica, Grenada, Saint Lucia and Saint Vincent and the Grenadines were developed after the FAO Manual from the English-speaking Caribbean (35).

3.3 Comparison of portion size recommendations across regions and methods

Not all countries included PS recommendations in their FBDGs, with $n = 26$ countries not providing PS recommendations for any of the 15 food categories examined. Thus, the PS comparisons within the work presented here were based on FBDGs from 70 countries organized into six global regions (Table 3). A comparison of recommended PS across the six global regions is presented in Table 3, with a global median included for reference. Significant variation was observed for Bread, Meat, and Fish & shellfish, as indicated by *p*-values below 0.05. However, after adjusting for FDR, only the PS recommendations for Fish & shellfish remained significantly different across regions ($p = 0.02$). Specifically, Europe had higher recommended PS for Fish & shellfish compared to Latin America & the Caribbean (LAC), with a Bonferroni corrected *p*-value of 0.005.

Table 4 provides the comparison of PS recommendations in FBDGs across the three different methodological approaches considered. While unadjusted *p*-values showed statistically significant differences for the Meat, Fish & shellfish and Pulses food groups, none remained significant after adjusting for FDR. Therefore, this analysis did not identify any association between the approach used in a FBDG and its respective recommended PS.

Figure 1 illustrates the comparison of PS recommendations in FBDGs when methodological approaches were grouped by data-based approaches versus those that used other methods (Consensus/review and Minor calculations), for selected food groups. The full data for all 15 food groups and Wilcoxon Rank-Sum test can be found in Supplementary Table 3. No significant differences were observed between the PS recommendations derived via data-based approaches and those derived via other methods.

TABLE 1 Methodological approaches applied to determine dietary recommendations in FBDGs by FAO region.

Region	*n* FBDGs	Methodological approaches applied[1]			
		Literature/evidence review, scientific consensus	Minimal calculations	Data-based approaches	Not specified
North America	2	2	0	1	0
Africa	11	9	2	4	1
Europe	34	31	9	5	2
Asia and the Pacific	16	15	6	3	1
Latin America and the Caribbean	29	22	12	1	3
Near East	4	4	1	1	0
Global	96	83	30	15	7

[1]Each FBDG may be based on more than one method.

4 Discussion

This study identified three primary methodological approaches that were used to develop portions sizes within FBDGs in several countries around the world: consensus/literature review, minor calculations, and data-driven approach. We sought to characterize these to examine the impact of the methodologies and geographical regions on recommended PS of key food groups. Our analysis showed that many FBDGs were based solely on existing scientific evidence in the development of their FBDG either by conducting literature reviews or forming expert opinions. Only n = 15 relied on the use of data, of which even fewer completed detailed dietary modeling using relevant national food consumptions surveys. When we considered the impact on PS, we found the region rather than methodological approach had a greater influence.

While comparisons across methods were considered within this paper, it is important to remember that each approach has merit and is selected based on available data, resources and specific context being considered. Each has its own strengths and weaknesses. For example, it is well known that consensus approaches can draw on a collective knowledge of experts in any given field, allowing for the inclusion of insights that may not be explicitly detailed in existing literature (36, 37). This is also the case for addressing challenges such as planning and developing nutrition guidance (38, 39). However, caution in the use of this approach is also warranted. In their analysis of 32 FBDGs, Blake et al. (11) reported that most countries relied on a consensus-based approach to formulate their recommendations, which is similar to the findings presented here. However, they noted that this approach was often applied without grading the strength of such recommendations, and very few countries conducted a formal systematic review (11, 40). In the present study, we focused on the impact of using a data modeling approach versus not, and combined methodologies reported as consensus and review, and also found that the majority of FBDGs used this approach. Looking at this in more detail, only a very small number of countries conducted a systematic review, relying mostly on scientific consensus of informed experts. This approach has been open to criticism in more recent years, due to potential bias and conflicts of interest (41, 42). This aspect was not examined in the current study but is worthy of further investigation.

Differing from previous studies, our work specifically examined the use of data in the development of guidelines. Fewer than half of the FBDGs combined consensus or review with other approaches, which varied from minor calculations to complex dietary modeling. A blended approach aims to ensure that guidelines are based on high-quality evidence, while remaining practical and applicable for the target population (10). For instance, guidelines from the US Dietary Guidelines Advisory Committee (DGAC) utilized both consensus from experts and data-driven insights, creating a comprehensive framework that encompasses various viewpoints and research findings. Other examples for the use of combined methods are Germany (scientific consensus/review and data-based approaches) and Cuba (scientific consensus/review and minor calculations).

A key finding from this work is that there are currently limited data-driven FBDGs, and there is a need to increase the availability and use of data in the development of such recommendations. Supporting and informing future developments of FBDGs, several European funded initiatives, such as Plan'EAT (43) and FEAST (44), are developing harmonized strategies for FBDG development, incorporating sustainability as a core element. We have also more recently seen regional collaborations, such as the Nordic Nutrition Recommendations (NNR) or the EAT Lancet diet, which demonstrate the potential of unified frameworks that can be adapted locally. Additionally, platforms that facilitate data sharing such as EFSA and WHO GIFT, will play a crucial role in supporting these efforts by providing local data for contextualisation of regional collaboration or unified frameworks (45), thus promoting consistency in public health practices across regions.

A major challenge in deriving FBDGs from typical intakes is the scarcity of high-quality food consumption data, especially nationally representative food consumption surveys (46, 47). We found that only 8 of the 96 included FBDGs used such surveys. Many countries have limited datasets available, as they require substantial resources to collect and analyze (48). Furthermore, the scope, size and detail of the existing datasets can vary significantly, not always representing the broader population accurately, or its dietary habits throughout the year, addressing seasonal variation. In the FBDGs of Ethiopia and Sri Lanka for example, the analyses were based on a 24-h recall limited to one day, from which

TABLE 2 Characteristics of the dietary data used for the derivation of recommended intakes in FBDGs.

Development method	Country	Survey/data used	Years of data collection	Food intake assessment method	Nationally representative (yes/no)	References
Linear programming	Benin	Different cross-sectional surveys	2005–2006	2 to 3 days 24-h recall	No	(77)
	United Kingdom	National Diet and Nutrition Survey (NDNS)	2008–2011	3 days 24-h recall	Yes	(78)
Diet modeling	Ethiopia	Cross-sectional National Food Consumption Survey (NFCS/EFCS)	2011	1 day 24-h recall	No	(79, 80)
	Zambia	US and West African food composition tables for nutrient analysis, Zambia's food consumption data	NS	n/a	No	(81)
	Ghana	Different surveys	NS	n/a	No	(82)
	Sri Lanka	Survey conducted by Wayamba university: sample of rural, urban and estate populations	2015–2017	1 day 24-h recall	No	(83)
Food pattern modeling	United States	National Health and Nutrition Examination Survey (NHANES)	2013–2016	2 days 24-h recall	Yes	(84)
	Oman	Omani household expenditure and income survey (OHEIS)	1999–2000	n/a	Yes	(85, 86)
Food modeling	Australia	National Nutrition Survey (NNS)	1995	1 day 24-h recall	Yes	(87)
Model calculations	Denmark	Danish National Survey of Diet and Physical Activity (DANSDA)	2011–2013	7 days food diary	Yes	(88)
Optimisation	France	Etude Individuelle Nationale des Consommations Alimentaires (INCA2)	2005–2007	7 days food diary	Yes	(89, 90)
	Netherlands	Dutch National Food Consumption Survey (VCP)	2007–2010	2 days 24-h recall	Yes	(91–93)
	Germany	German National Nutrition Survey II (NVS II)	2005–2007	2 days 24-h recall	Yes	(94)
Not named (mentions "model")	Thailand	Sample of 20 households, and five sets of secondary data from the Institute of Nutrition, Mahidol University-INMU (unpublished data)	NS	n/a	No	(95, 96)
Not named	Costa Rica	Latin American Study of Nutrition and Health (ELANS), and home measurements and food composition database	2015	2 days 24-h recall	Yes	(97)

NS, not specified; n/a, not applicable.

usual intakes cannot be precisely derived (49). In fact, lack of broad applicability of the data used was noted in the Ethiopian documents, where the authors reported that intakes might have been significantly influenced by the seasonality of the survey. Access to food consumption data is also not equal across global regions (50). The lack of dietary data, particularly in low and middle-income countries, is a widely known issue that has been reported previously (51–53). In this context, public health measures are needed to support countries in overcoming their difficulties to assess the nutritional status of their population (48, 54). Efforts to harmonize food data across Europe and beyond, such as those led by the EFSA (55) and initiatives like the Food Nutrition Security (FNS) Cloud (56), could improve the accessibility of these tools, and subsequent data collection and availability. Enhanced data

TABLE 3 Distribution of portion size recommendations in FBDGs, per region.

Food	Statistic	Global	Africa	Asia and the Pacific	Europe	Latin America and the Caribbean	Near East	North America	p[1]	Adj p[2]	*Post hoc* analysis adj p[3]
Fresh fruits	*N*	66	7	9	28	17	4	1			
	Median	127.6	130.6	124.0	119.5	134.5	138.7	153.5	0.490	0.628	n/a[5]
	IQR[4]	41.2	19.0	34.2	50.0	16.3	33.0	0.0			
Vegetables–unspecified	*N*	39	3.0	5.0	21.0	10.0	0.0	0.0			
	Median	100.0	80.0	100.0	100.0	99.6	n/a	n/a	0.503	0.628	n/a
	IQR	30.4	43.3	0.4	40.0	11.6	n/a	n/a			
Vegetables–excl. green/leafy	*N*	27	5	5	6	6	4	1			
	Median	100.4	86.7	81.6	118.8	100.4	119.4	128.3	0.511	0.628	n/a
	IQR	56.9	50.7	11.3	62.3	17.8	45.6	0.0			
Vegetables—green/leafy	*N*	26	5.0	5.0	7.0	4.0	4.0	1.0			
	Median	70.0	50.0	47.3	80.0	86.8	73.8	54.0	0.708	0.708	n/a
	IQR	46.6	63.3	20.0	38.1	46.8	33.0	0.0			
Cooked cereals/grains (rice, pasta, . . .)	*N*	49	4	10	21	10	3	1			
	Median	90.0	142.3	98.8	85.0	90.0	78.2	74.5	0.544	0.628	n/a
	IQR	58.8	40.4	59.6	65.5	24.3	4.3	0.0			
Bread	*N*	48	6	7	20	11	3	1			
	Median	41.1	78.8	50.0	47.8	39.6	26.9	28.4	0.032	0.160	n/a
	IQR	23.7	93.0	71.0	23.0	10.0	5.2	0.0			
Potatoes, starchy fruits and vegetables	*N*	39	3	7	17	12	0	0			
	Median	137.5	140.0	100.0	138.0	115.0	n/a	n/a	0.115	0.215	n/a
	IQR	60.3	19.0	55.9	80.3	58.3	n/a	n/a			

(Continued)

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TABLE 3 (Continued)

Food	Statistic	Global	Africa	Asia and the Pacific	Europe	Latin America and the Caribbean	Near East	North America	p[1]	Adj p[2]	*Post hoc* analysis adj p[3]
Milk / plant-based alternatives	*N*	54	4	10	25	11	3	1			
	Median	222.0	222.5	200.0	222.0	222.0	244.0	244.0	0.657	0.704	n/a
	IQR	44.0	46.3	103.9	50.0	32.5	2.0	0.0			
Yogurts and fermented dairy	*N*	46	4	6	21	11	3	1			
	Median	181.8	162.5	124.0	170.0	188.5	245.0	245.0	0.081	0.203	n/a
	IQR	86.0	112.5	77.0	65.0	58.3	6.5	0.0			
Cheese	*N*	52	4	6	25	13	3	1			
	Median	39.0	27.5	40.0	50.0	30.0	52.5	49.6	0.368	0.614	n/a
	IQR	39.7	11.3	44.6	47.5	2.5	7.5	0.0			
Meat	*N*	53	6	9	20	14	3	1			
	Median	75.0	77.7	72.5	92.5	66.7	30.0	28.4	0.015	0.115	n/a
	IQR	40.0	3.9	33.3	29.9	28.4	22.5	0.0			
Fish & shellfish	*N*	51	6	9	23	9	3	1			
	Median	90.0	98.1	70.6	120.0[a]	38.1[a]	75.0	28.4	0.001	0.021	0.005[a]
	IQR	75.8	31.1	55.0	50.0	42.9	30.0	0.0			
Eggs	*N*	47	6	8	18	12	2	1			
	Median	50.0	65.0	50.0	52.5	50.0	50.0	50.0	0.053	0.183	n/a
	IQR	9.0	38.3	23.3	40.0	0.0	0.0	0.0			
Pulses	*N*	53	7	9	20	13	3	1			
	Median	92.5	95.0	100.0	127.5	80.3	90.7	45.8	0.115	0.215	n/a
	IQR	70.0	27.9	105.0	95.0	64.4	23.0	0.0			
Nuts & seeds	*N*	35	6	6	13	7	2	1			
	Median	23.5	20.8	30.0	25.0	13.3	15.0	14.2	0.068	0.183	n/a
	IQR	15.0	13.5	11.3	5.0	4.7	0.0	0.0			

[1]*p*-value for Kruskal–Wallis test. [2]Adjusted *p*-value for Kruskal–Wallis test (adjustment for False Discovery Rate—Benjamini Hochberg). [3]Adjusted *p*-value for Dunn's test adjusted with Bonferroni correction–run if adjusted *p*-value for KW test was below significance level of 0.05. [4]Interquartile range. [5]Not applicable. [a]Indicates significant difference between groups, from *post-hoc* analysis (corresponding $p = 0.005$).

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TABLE 4 Distribution of portion size recommendations in FBDGs, per development method.

Food	Statistic	Global	Consensus/ review only	Data-based	Minor calculations	p[1]	Adj p[2]	*Post hoc* analysis adj p[3]
Fresh fruits	*N*	65	26	14	25			
	Median	125.6	125.1	122.3	130.5	0.637	0.735	n/a[5]
	IQR[4]	40.6	37.9	46.3	35.0			
Vegetables–unspecified	*N*	39	16	8	15			
	Median	100.0	100.0	80.0	100.0	0.063	0.236	n/a
	IQR	30.4	52.3	19.5	17.7			
Vegetables–excl. green/leafy	*N*	26	9	6	11			
	Median	98.6	96.8	105.6	100.4	0.987	0.987	n/a
	IQR	53.2	24.3	44.5	62.7			
Vegetables—green/ leafy	*N*	25	10	6	9			
	Median	75.0	83.3	52.0	80.0	0.282	0.704	n/a
	IQR	44.5	40.1	6.0	29.5			
Cooked cereals grains (rice, pasta, . . .)	*N*	48	16	9	23			
	Median	90.0	95.0	78.2	90.0	0.540	0.735	n/a
	IQR	59.3	65.2	61.5	42.0			
Bread	*N*	47	16	10	21			n/a
	Median	42.3	37.0	41.9	50.0	0.523	0.735	0.735
	IQR	24.4	15.2	35.5	25.5			
Potatoes, starchy fruits and vegetables	*N*	38	13	6	19			
	Median	136.3	138.0	137.8	125.0	0.686	0.735	n/a
	IQR	62.6	81.7	28.6	64.2			
Milk / plant-based alternatives	*N*	53	19	11	23			
	Median	222.0	222.0	244.0	205.0	0.338	0.725	n/a
	IQR	44.0	47.0	47.5	67.0			
Yogurts and fermented dairy	*N*	45	15	10	20			
	Median	188.5	188.5	200.0	169.3	0.504	0.735	n/a
	IQR	88.0	41.5	113.8	82.1			
Cheese	*N*	51	19	12	20			
	Median	38.0	41.3	27.5	35.0	0.137	0.412	n/a
	IQR	39.3	40.5	29.7	40.3			
Meat	*N*	52	19	11	22			
	Median	75.0	82.0	75.0	64.6	0.019	0.168	n/a
	IQR	41.3	23.8	30.7	39.3			
Fish & shellfish	*N*	50	19	12	19			
	Median	90.0	115.0	100.0	48.3	0.022	0.182	n/a
	IQR	77.9	71.8	42.6	56.9			
Eggs	*N*	46	13	11	22			
	Median	50.0	50.0	50.0	50.0	0.439	0.735	n/a
	IQR	9.5	0.0	35.5	5.0			

(Continued)

TABLE 4 (Continued)

Food	Statistic	Global	Consensus/ review only	Data-based	Minor calculations	p[1]	Adj p[2]	*Post hoc* analysis adj p[3]
Pulses	*N*	52	18	11	23			
	Median	92.3	122.5	92.0	80.0	0.049	0.236	n/a
	IQR	66.3	88.6	24.2	73.9			
Nuts & seeds	*N*	35	10	10	15			
	Median	23.5	25.9	20.8	17.3	0.667	0.735	n/a
	IQR	15.0	10.6	10.0	14.4			

[1]*p*-value for Kruskal–Wallis test. [2]Adjusted *p*-value for Kruskal–Wallis test (adjustment for False Discovery Rate—Benjamini Hochberg). [3]Adjusted *p*-value for Dunn's test adjusted with Bonferroni correction–run if adjusted *p*-value for KW test was below significance level of 0.05. [4]Interquartile range. [5]Not applicable.

standardization would help streamline the process of developing and updating these guidelines across regions (57, 58). While the FAO and WHO advocate for a review of food consumption patterns as one of the steps in developing FBDGs, they note that different types of data that can be utilized, offering different options depending on the local data availability (3).

Whilst we recognize that incorporating data in developing policies and public health tools such as FBDGs is valuable, the use of dietary intake data comes with certain limitations which should also be considered. Diet modeling is a flexible and robust approach to translate nutrient recommendations into realistic food choices, but it is very sensitive to the quality of the data used, which can be varied and influenced by the survey duration (number of days on which the estimates are based) (48), the data collection methodology used (e.g., food frequency questionnaire, dietary record) (59) and under-reporting, which occurs across all self-reported food intake data (60, 61).

Regardless of the approach used in the FBDG development process, our study did not reveal significant differences in recommended PS. Nevertheless, certain methodological limitations could affect these findings. For example, some specific details from the FBDG documents were possibly lost in translation. Additionally, relying on two specific data resources for converting recommended food amounts to grams, when needed, may have introduced some bias in PS estimation. However, the use of these documents, and any assumptions made are clearly articulated in the current work. It is also important to highlight that this observation was based on an analysis where only 15 out of 96 of the sources employed data-based approaches, which may limit the generalizability of the findings. As more nutritional surveys are initiated (45, 46), the use of data-driven methods is likely to increase, potentially strengthening the evidence base for future FBDGs. Consequently, the findings of this study may need to be revisited as the availability of data grows, alongside the adoption of novel statistical approaches involving metabolomics, machine learning, meal pattern analysis, and others (62–65). Furthermore, along with the lack of differences seen across methods, comparisons across global regions revealed no significant differences in the recommended PS, except for Fish & shellfish, between European and Latin American FBDGs. A possible reason for the significantly lower PS recommendation for Fish & shellfish in Latin America and the Caribbean compared to that in Europe could be the alignment of guidance to local dietary habits or broader and more complex issues such as cost, and availability. Indeed, other studies have shown that fish consumption is low in Latin American countries, with lower socio-economic groups consuming notably less of this food category (66).

While the overall consistency across regions might reflect a certain degree of consensus, the wide range of observed PS values suggests that underlying drivers could influence these recommendations in ways not fully captured in the present analysis. The work presented here focused specifically on PS, which may not have varied, but other facets may have, such as the consideration of sustainability or affordability of the diet, which are mentioned in many guidelines (12). Indeed, food consumption relies on many factors including ethnography, agronomic context, and economics (67–69). As these fall beyond the scope of our analysis and were not addressed in this paper, further investigation is necessary to ensure that no critical factors have been overlooked in identifying potential additional sources of variation. In particular, the incorporation of sustainability messages in FBDGs may increasingly influence recommended amounts. For instance, by recommending small PS of meat, certain countries (e.g., Germany, Costa Rica) already encourage healthy eating while advancing environmental goals.

Moreover, the consistency of PS values identified in the current analysis does demonstrate the potential of extending guidelines to a regional or even a global level. At the European scale for example, the authors of a recent analysis of PS recommendations in European FBDGs concluded that defining standardized portions could promote healthy eating programmes common to many countries, while respecting local dietary habits, and would also facilitate the communication of nutritional information by referring to quantities of a food product actually consumed, rather than to 100 g or ml (25). Additionally, Yamoah et al. (70) looked at trends in PS consumption across 24 world countries and concluded that standardization of strategies for food portions are relevant. A common concept could in fact serve as a framework for the creation of national FBDGs and could be adapted to specific local conditions by suggesting locally relevant food choices within the common food groups (10). As noted, some dietary guidelines are taking this approach, being developed at a regional level, including Nordic Nutrition Recommendations (71), which suggests that such consensus does lend itself to broad over-arching recommendations within regions.

To our knowledge, this study is the first to examine the extent to which data are used to derive recommendations within FBDG,

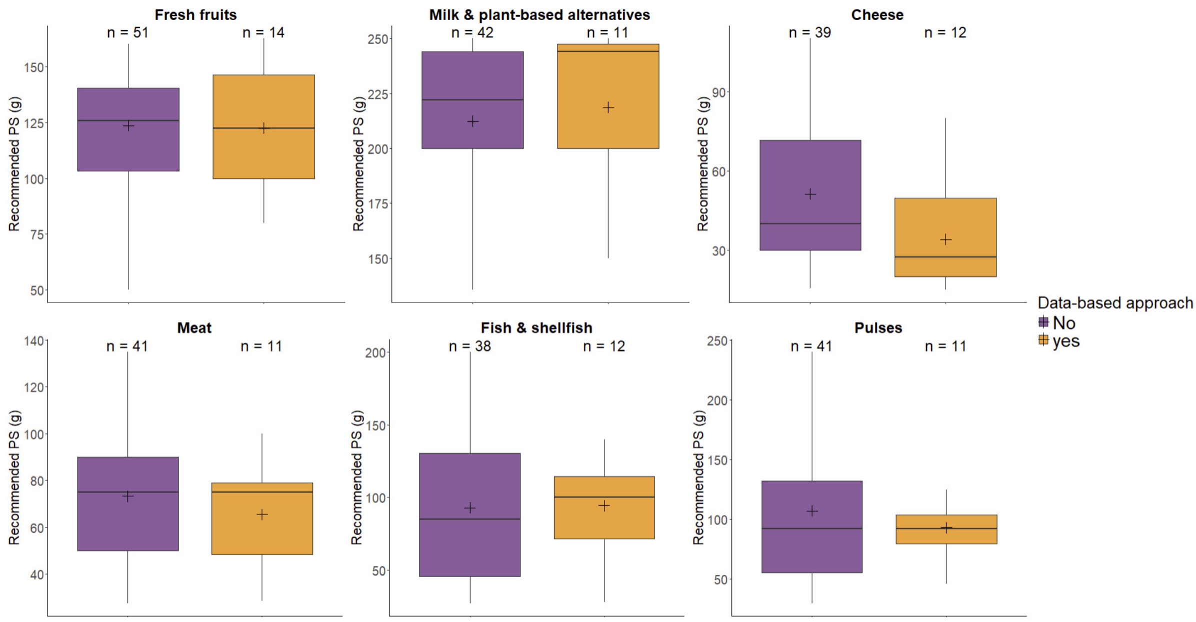

FIGURE 1
Distribution of PS recommendations in FBDGs, data-based versus other methodological approaches.

and to compare recommended PS across potential key drivers of variation (i.e., global regions and development methods). FBDGs are often created using different sources and types of information. How these data sources/types are categorized are subjective, and the categorization used in this paper (consensus/ review and data-based approaches) may omit the fact that consensus opinions can be based on a certain knowledge of data which was not specifically listed. Furthermore, while the statistical analysis did not report differences in recommended PS across methods and across regions for most studied food groups, the large IQRs observed suggest variations in the guidance provided to consumers, which may lead to different nutritional outcomes. For example, the global IQR for portions of Pulses was of 70 g across regions, and that of Fresh fruits was 41 g. Such ranges can, respectively, correspond to differences of 17 g of proteins for a portion of lentils and 24 mg of vitamin C for a portion of orange (72), therefore considerably impacting nutrient intakes.

Coordinated approaches in the development of PS, associated with FBDG recommendations, would assist regional and national groups in developing PS recommendations in a systematic manner, avoiding duplication of effort, and reducing development costs (10). Harmonizing PS recommendations could facilitate the development of FBDGs, ensuring consistency across countries and ultimately contributing to improved public health outcomes globally. To achieve this, understanding whether various recommended portions within the observed ranges derived through different methodologies result in varying levels of adherence is crucial. Indeed, recent research has shown that many individuals are falling short of their national recommendations, particularly for fruits, vegetables, and starchy foods, but overconsume discretionary foods (73, 74). Modifying PS recommendations within FBDGs could therefore have limited impact, as several barriers to PS control have been identified. These include social and psychological factors, and childhood habits which may be difficult to overcome (75). Population approaches to reduce PS would indeed require a change in the food environment in order to have a significant impact on populations' intakes (76), therefore the dietary habits of the target populations need to be considered when deriving recommended amounts (10). While this study focused on methods to develop FBDGs, investigating procedures to monitor their effectiveness and people's adherence to established recommendations could also inform effective strategies for future updates.

While the development of FBDGs is led by policymakers, it may also be pertinent to consider some consultation with other stakeholders including academic researchers, consumers, public health bodies, as well as other stakeholders. This wide and encompassing approach could ensure mutual involvement in adopting healthy and appropriate PS where relevant. Establishing healthy and contextually appropriate PS is a key step in guiding, informing, and supporting consumer choices effectively.

In conclusion, data-based approaches can enhance literature reviews/scientific consensus to strengthen the rationale and assess the potential impact on dietary intakes from FBDG recommendations. In addition, policy makers should aim to harmonize PS derivation methods globally, reaching a balance between optimal and usual intakes (18). Such a concept is possible but requires investment in development and implementation; this could serve as a starting point for the derivation of the national FBDGs and be adapted to the specific local circumstances (10).

Data availability statement

The original contributions presented in this study are included in this article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

FS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review and editing. ALE: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review and editing. TNM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review and editing. ERG: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review and editing.

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Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Supplementary material

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Dietary intake among youth adhering to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets in Sweden

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Objective: To assess the intakes of food groups, energy, and macronutrients among youth in Sweden who adhere to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets. Further, to evaluate youth's adherence to the food-based dietary guidelines (FBDG).

Design: In this cross-sectional study, dietary intake data was obtained through repeated non-consecutive 24-h dietary recalls (24HDR) and a dietary screener assessing consumption frequency of food groups. Usual daily intakes were estimated using the Multiple Source Method (MSM), and for usual intakes of food groups the 24HDR intake data was combined with consumption frequency.

Setting: Gothenburg, Sweden, December 2022–January 2024.

Participants: In total 235 youth (78% female, mean age 22 $\pm$ 2 years), consisting of 60 vegans, 59 lacto-ovo-vegetarians, 55 pescatarians, and 61 omnivores.

Results: For usual intakes (median value), both g/d and g/MJ, all plant-based dietary groups had higher intakes of legumes and plant-based meat analogs compared to omnivores (for all, $p < 0.001$), and vegans and lacto-ovo-vegetarians had higher intakes of plant-based dairy substitutes (vs. pescatarians and omnivores, $p < 0.001$). Moreover, vegans had higher intakes of refined grain products (vs. pescatarians, $p = 0.012$), nuts/seeds (vs. pescatarians and omnivores, $p = 0.002$), and vegetable oil (vs. omnivores, $p = 0.014$). Omnivores had higher intakes of fried/premade potato dishes (vs. lacto-ovo-vegetarians and vegans, $p < 0.001$), and lower intakes of plain potatoes (vs. lacto-ovo-vegetarians and pescatarians, $p < 0.001$). Overall intakes of 'sweets and snack foods' did not differ between dietary groups. Omnivores had higher usual intakes of energy compared to lacto-ovo-vegetarians and pescatarians (10 vs. 9 MJ/d, $p = 0.016$). Most macronutrient recommendations were met across groups, except for carbohydrates (below for omnivores), fiber (below for omnivores and pescatarians), and saturated fatty acids (exceeded by all except vegans). For the FBDG for whole grains, omnivores (23%) had a higher adherence vs. vegans (2%) and lacto-ovo-vegetarians (3%), $p < 0.001$. No difference was found between dietary groups for adherence to the FBDG's for fruits, berries, and vegetables (10%), nuts (24%), and vegetable oil (4%).

Conclusion: Swedish youth, regardless of dietary practice, need to increase intakes of fruits, berries, vegetables, nuts, and whole grains, and limit consumption of discretionary foods to better align with food and nutrition recommendations.

KEYWORDS

plant-based, macronutrient intake, food group intake, food-based dietary guideline, youth

1 Introduction

Unhealthy dietary habits, characterized by high quantities of red and processed meat and limited plant-based foods (i.e., fruits, vegetables, and whole grains), are one of the top modifiable risk factors contributing to poor health and the global burden of disease (1). Simultaneously, these habits are major contributors to environmental destruction (2, 3). Evidence demonstrates that a global transition toward a diet mostly or entirely composed of plant-based foods is part of the solution to reduce both diet-related non-communicable disease (2, 4, 5) and negative environmental impact from dietary intake (2, 3, 6). With regards to this, for long-term health, the Nordic Nutrition Recommendations 2023 (NNR2023) recommend intakes of ≥500 g/d fruits, berries, and vegetables (F&V), ≥90 g/d whole grains, 20–30 g/d nuts, 25 g/d vegetable oil, ≥350 g/d low-fat milk and dairy products, and 300–450 g/week of fish, including 200 g/week from oily fish as well as limited intake of free sugars, salt, and alcohol (7). NNR2023 also state that legumes should constitute a significant part of the diet and intakes of red meat should be below 350 g/week, whereof processed meat should be limited (7).

In recent years, the interest in plant-based diets such as vegan, lacto-ovo-vegetarian, pescatarian and flexitarian has increased in westernized countries (8). In Nordic countries, an estimated 3–8% of young people, based on national dietary surveys, adhere to lacto-ovo-vegetarian or vegan diets in Sweden (17–18 years) (9), Finland (16–18 years) (10), and Norway (18–29 years) (11). As youth (12) are in a stage of life with increased autonomy over their own dietary choices, and most often choose to adopt plant-based diets for reasons other than health (13, 14) including ethical, environmental, financial, or food preferences, the dietary intake is likely to be heterogenous, which could potentially influence diet quality. The overall evidence among adults and children/adolescents indicates that plant-based diets can provide nutritional benefits such as higher dietary fiber and lower saturated fatty acids (SFA) but may also increase the risk of inadequate intakes of some key micronutrients, whereof vitamin B_{12}, vitamin D, calcium, iron, zinc, iodine, and selenium (15–18). However, these nutritional outcomes depend on the types and quantities of foods consumed, supplement use, and bioavailability in foods.

Studies on the dietary intake among youth eating plant-based compared to omnivorous diets are limited, and in Sweden it was last assessed in the late 1990's (19). Given the increased supply of convenient and nutritionally diverse plant-based foods (20–23) up-dated knowledge is required on the dietary intake among current youth eating plant-based diets. Therefore, our objective was to assess the intakes of food groups, energy, and macronutrients among youth in Sweden who adhere to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets. Further, to evaluate the adherence to the FBDG's by NNR2023 among youth with different dietary practices.

Abbreviations: BMI, Body Mass Index; EI, Energy Intake; FBDG's, Food Based Dietary Guidelines; F&V, Fruits, Berries and Vegetables; g/d, Gram per day; g/MJ, Gram per Megajoule; MJ, Megajoule; MSM, Multiple Source Method; NNR2023, Nordic Nutrition Recommendations 2023; PAL, Physical Activity Level; SFA, Saturated Fatty Acids; 24HDR, 24-Hour Dietary Recall.

2 Materials and methods

2.1 Recruitment and study eligibility

Between December 2022 and January 2024, healthy 16 to 24 year olds living in Gothenburg, Sweden, or nearby municipalities were recruited by convenience and snowball sampling. Various recruitment methods were employed. Posters about the study were placed in high-schools, universities, libraries, cafes, training centers, gyms, and outside poster boards. Information about the study was shared via newsletters, e-mail lists, and social media platforms. Paid advertisements were utilized on Instagram and Facebook, targeting 18–24 year olds. Physical recruitment occurred at high schools, a public science festival, as well as sports and sustainability events for students.

To be eligible for participation, the youth had to 'be between the age of 16–24 years', 'be healthy with no chronic or acute disease', 'have adhered to their current dietary practice (vegan, lacto-ovo-vegetarian, pescatarian, or omnivore) for a minimum of 6 months and have no intention to alter their current dietary practice', 'not be pregnant, lactating, or have children', 'comprehend Swedish', and 'agree to physically visit the research facility in Gothenburg for participation'.

2.2 Sample size

A priori, sample size was calculated (24) for the primary outcome, energy intake (EI), using data from the Swedish national food consumption survey among youths aged 17–18 years, across sexes (25). To detect a difference of 2.1 MJ between groups with a power of 80%, 42 people are needed in each dietary group, and therefore to account for dropouts we aimed to recruit 60 youth per dietary group.

2.3 Study design

All participants visited the research facility at the University of Gothenburg once to partake in the research project named *VeggiSkills-Sweden,* which used a cross-sectional mixed-methods design. During the visit, anthropometrics were measured, blood and urine samples were collected, and an interview-administered 24-h dietary recall (24HDR) was completed. In addition, during the visit participants were asked to fill in a 255-item web-based questionnaire which assessed dietary habits in the past 6 months [i.e., dietary practice, animal-sourced foods included in the diet, mealtime frequency, supplement use, and consumption frequency of food groups using a revised dietary screener (26)], food literacy competencies (general nutrition knowledge, critical nutrition literacy, food skills), food choice motives, health and lifestyle habits (i.e., tobacco use, frequency of physical activity) and sociodemographic information (e.g., parental education level). In this paper, data about dietary intake, anthropometrics, health and lifestyle habits, and sociodemographic information are presented.

2.4 Categorization into dietary groups and exclusion of participants

Participants were asked to self-identify their current dietary practice in the web-based questionnaire. To categorize participants into dietary groups their self-identified dietary practice was cross-checked with their responses to a question in the web-based questionnaire which assessed animal-sourced foods included in their diet in the previous 6 months. Participants filled in the questions, "How often have you included 'milk and/or dairy products', 'eggs and/or foods containing eggs', 'fish, seafood, and/or fish products', 'poultry and/or poultry products', 'red meat and/or red meat products', in your diet in the past six months?." If they self-identified a vegan dietary practice and selected 'never' to all the options, they were categorized into the vegan dietary group (27). If they self-identified an 'ovo-vegetarian', 'lacto-vegetarian', or 'lacto-ovo-vegetarian' dietary practice and reported consumption of milk and/or dairy products and/or eggs, but no fish/seafood or meat (all types) they were categorized into the lacto-ovo-vegetarian dietary group (27). If they self-identified a pescatarian dietary practice and reported consuming fish, seafood and/or fish products, but no intake of meat (all types) they were categorized into the pescatarian dietary group, regardless of intake of eggs and milk/dairy products (27). If they self-identified an omnivorous dietary practice and reported consuming any type of meat and other animal-sourced foods, they were categorized into the omnivorous dietary group (27). When examining the 24HDR dietary intake data, we found one deviation from the dietary group categorization, in which one participant categorized as lacto-ovo-vegetarian reported fish consumption once. This information was additionally cross-checked with their responses to the dietary screener assessing food group consumption in the past 6 months, and no inconsistency with the dietary practice was observed; thus, the participant was not re-categorized.

A total of 244 youths were recruited. Nine participants were excluded, whereof seven due to dietary practice ineligibility [six self-identified a flexitarian diet with limited intake of all animal-sourced foods (27) and one self-identified a pescatarian diet but contradicted this in the dietary screener reporting consuming meat], and two participants who only completed one out of four 24HDR's.

2.5 Anthropometric measurements

At the research facility, weight was measured to the closest 0.1 kg while in light clothing and no shoes on using a Beurer 180BF digital scale (Beurer GmbH, Germany), and height was measured to the closest 1 mm by a wall-mounted stadiometer (Hyssna M, Sweden). Body mass index (BMI) was calculated, body weight (kg)/height (m^2).

2.6 Assessment of dietary intake, 24-h dietary recalls

Dietary intake data was obtained through four non-consecutive web-based 24HDR's (maximum of two were from a weekend). The first 24HDR was completed at the research facility as an interview following the Multiple Pass Method (28). Participants were asked to recall their complete dietary intake (including supplements) from the previous day. Probing questions were asked about time and place of food intake, and intake of commonly forgotten foods (e.g., beverages, condiments, sweets, snacks). Simultaneous to the interview, the interviewer entered the intake into a web-based dietary assessment program, Nutrition Data (Nutrition Data Sweden AB, Sweden). The program was connected to the Swedish Food Composition database (version 2023 06 13, Swedish National Food Agency) which consisted of 2,300 foods. Additionally, some items had been nutritionally calculated using brand product information. Following the visit, participants were asked to complete three self-administered 24HDR on different non-consecutive days in the web-based dietary assessment program. They received unannounced messages (text and email) asking them to complete a 24HDR. They received a maximum of three reminders per recall. Participants completed all their recalls within 7 weeks.

In the web-based program portion sizes could be reported in household measurements (teaspoon, tablespoon, deciliter), predefined quantities (e.g., slice, piece) or in weight (gram). Participants were provided a portion guide booklet developed by the Swedish National Food Agency [published 2010, Uppsala, Sweden (29)] and instructed to use it to estimate portions. The booklet contained 24 food photo series (e.g., cooked spaghetti, bolognese, rice, cereal etc.), each with 5–6 portion sizes per food. The original booklet did not contain photos for some commonly eaten snack foods. Therefore, prior to this study commencing, portion size photos were created, using a standardized method (30), for seven foods (nuts and dried fruit, candy, potato chips, popcorn, ice-cream, chopped tomatoes, and chopped carrots). The photos were added to the booklet, resulting in portion size photos for 31 different foods.

In the web-based program, participants were instructed to report separate food items ('spaghetti', 'bolognese') instead of composite meals ('spaghetti with bolognese'). Additionally, recipes with specified ingredients and quantities could be entered into the program by the participants. If specific items could not be found in the program, participants were instructed to select nutritionally similar replacement foods (e.g., new plant-based soy meat analog could be replaced with a similar soy-based meat analog available in the program), or they could describe the item in an open notes section. All items specified in the open notes section were reviewed by the first author and subsequently entered into the recall. Either a nutritionally similar replacement food from the database was selected, or the nutritional information of the specific food item was obtained from the brand and thereafter entered into the program (e.g., organic plant-based dairy substitutes).

In this study, free sugars was defined according to the World Health Organizations definition (31), i.e., sugars from all foods which contain added sugars, as well as sugars which are naturally present in honey, syrups, fruit juice, and fruit juice concentrate. Content of sugars in foods was automatically calculated using the Swedish Food Composition database.

2.7 Consumption frequency of food groups

To assess the consumption frequency of food groups, in the web-based questionnaire participants were asked to fill in a dietary screener which assessed how often they had consumed 30 different food groups in the past 6 months. The 10 predefined frequencies ranged from 'never/rarely' to '6+ times per day', see Supplementary Table 1. In this study, the original dietary screener, 'MyFoodMonth 1.1' (26), which was designed to capture intake frequencies for some key food groups consumed in Norway, and to reflect intakes of some nutrients (i.e., calcium, iodine), was translated from Norwegian to Swedish. Additionally, the questionnaire was revised to reflect food groups commonly consumed in Sweden and among individuals with plant-based diets. Thus, resulting in 30 food groups instead of 33 which the original dietary screener consists of.

3 Data processing and statistical analyses

3.1 Categorization of food groups

Food and drink items reported in the 24HDR were categorized into overall food categories based on nutritional similarity ('fruits, berries, and vegetables', 'cereals and grains') or function of the foods ('plant-based meat analogs', 'sauces, dressings, and mayonnaise'). Subsequently, to distinguish between foods with differing nutritional characteristics within some of the overall food categories (e.g., 'refined grain products' and 'whole grain products') food groups were formed. Whole grain products were categorized as having >50% whole grains (dry weight) (32), which was determined by using the Swedish Food Composition database or brand product information. Description of foods included in each overall food category and food group is available as Supplementary Table 2.

For composite meals reported (e.g., 'cheese hamburger', 'pizza') more than 95% were disaggregated into separate foods (e.g., 'burger bun', 'beef burger', 'tomatoes') by the first author. This was done by using standardized ingredients and proportions available from the Swedish Food Composition database, whereof quantities were adapted to the portion reported. For brand specific composite meals reported (e.g., a frozen pasta meal), a standard and representative recipe was developed by using the product ingredient list and proportion of ingredients as to meet the nutritional information of the food. Some composite meals reported could not be disaggregated and were therefore grouped into the food category 'composite foods' (e.g., 'spring rolls', 'dumplings'). This food category constituted <2% of the total mean EI per dietary group and was not included in the analyses of usual intakes of food groups.

3.2 Evaluation of misreporting of dietary intake

Misreporting of EI was evaluated for each participant using Goldberg cut-offs (33). Average reported EI (crude data) below, within, and above the cut-offs based on the participants physical activity level (PAL) was defined as under-, acceptable-, and over-reported, respectively. Basal metabolic rate was calculated for each participant using Henrys equations (34). Data is presented for descriptive purposes and in this study no participants were excluded based on misreporting.

3.2.1 Assessment and categorization of physical activity level

The participants PAL (35) was assigned using questionnaire data which assessed the self-reported frequency of exercise per week in the last 6 months. Category of PAL was assigned as follows; PAL 1.4 = less than 1 times/week of moderate intensity; PAL 1.55 = 1–2 times/week of moderate intensity; PAL 1.7 = 3–4 times/week of moderate intensity; PAL 1.8 = 5–6 times/week of moderate intensity; PAL 2.0 = ≥6 times/week of moderate intensity and 1–2 times/week of vigorous intensity.

3.3 Estimation of usual dietary intakes

Usual individual dietary intakes were estimated for food groups, energy, macronutrients, whole grain, and salt using the Multiple Source Method (MSM) (36). The MSM is a two-part regression model which uses short-term dietary intake data, in the present study from the 24HDR's, to account for within-and between person variation in intakes and as a result usual individual daily intake can be estimated. The statistical analyses were run using the web-based program (MSM analysis version 19Nov2009).[1] First, the probability of consumption on a random day was estimated using a logistic regression, followed by estimation of the quantity consumed on a consumption day using a linear regression. Subsequently, the probability of consumption and quantity consumed on a consumption day are multiplied, resulting in an estimate of individual usual daily intake of the nutrient or food group. The statistical method has been described in detail elsewhere (37, 38). For the estimates of usual intake of food groups, consumption frequency, which was obtained from the dietary screener, was added as a covariate to the MSM-regression models. This improves the probability estimates. The consumption frequency from the dietary screener was converted to daily intakes. For example, if a participant reported consuming a food group once a week, the frequency was converted to 0.14 times/day, and if they reported consuming a food group 2–3 times a day the frequency was converted to 2.5 times/day etc. The dietary screener did not assess consumption frequency for all the specific food groups categorized in this study, for example vegetable and seed oil, refined grain products, and eggs. Therefore, consumption frequency was only added as a covariate in the MSM-models for 21 of the food groups.

Sensitivity analyses were run for food group intake, with adjustment for age and sex as covariates into the MSM-models. The covariates were selected based on theory. Furthermore, to account for differences in usual intakes of food groups relative to EI, the energy-density of food group intake was calculated for each individual, i.e., grams per megajoule (g/MJ) (39).

1 https://msm.dife.de/tps/en

3.4 Adherence to the FBDG's by NNR2023

To evaluate adherence to the FBDG's the estimated usual intakes were compared to the quantitative FBDG's by NNR2023 (7). To evaluate adherence to the FBDG of low-fat milk and dairy products, intakes of milk and yoghurt (≤1.5% fat) and low-fat dairy products (including cheese [≤17% fat] which had been converted to milk equivalents using a yield factor of 10) were included. Whole grain intake was automatically calculated using the Swedish Food Composition database or by brand product information.

3.5 Statistical analyses for comparison of dietary intakes between dietary groups

For categorical variables, differences between dietary groups were assessed using crosstabulation with Chi-Square or Fischer's Exact test. Variables were assessed for normal distribution by visual inspection of histograms and Q-Q plots and the Shapiro Wilks test. For normally distributed continuous variables (age and BMI) the parametric One-Way ANOVA was used to test for differences between dietary groups. Dietary intake variables were mostly right skewed therefore the non-parametric Kruskal-Wallis One-Way ANOVA was used to test for differences between dietary groups. For all tests, the Bonferroni *post-hoc* test was applied to correct for multiple analysis, and statistical significance was accepted as two-sided adjusted *p*-value of <0.05. All dietary intake results are expressed as median value with 25th and 75th percentile, and number and percentage (%) for adherence to the FBDG's. To allow for comparability with other studies, usual dietary intakes of food groups (g/d and g/MJ), energy, macronutrients, whole grain, and salt are presented with mean ± SD values in Supplementary material. Statistical analyses were performed using IBM SPSS version 29 (IBM Corp., Armonk, NY, United States).

4 Results

4.1 Participant characteristics

Participant characteristics are presented in Table 1. The total sample ($n = 235$) consisted of 60 vegans, 59 lacto-ovo-vegetarians, 55 pescatarians, and 61 omnivores. Of the total sample, 78% were female, mean age of 22 ± 2 years, and mean BMI of 23 ± 3 kg/m^2, with no difference between dietary groups. Omnivores had the highest proportion (52%) with a PAL corresponding to a vigorous physical activity level (≥1.8) which differed from vegans (25%) and lacto-ovo-vegetarians (22%), $p < 0.001$. All four 24HDR's were completed by 99% of the sample, and no difference was observed between dietary groups for percentage of recall days completed from a weekday or weekend (Table 1). Of the reported average EI in the 24HDR's, 7% of the total sample's average intakes were categorized as under-reported and none as over-reported, and it did not differ between dietary groups (Table 1).

4.2 Food group intake among youth adhering to plant-based or omnivorous diets

Usual daily intakes of food groups (g/d and g/MJ) are presented as median value with 25th and 75th percentiles in Tables 2, 3.

4.2.1 Plant-based foods

For overall usual intakes of F&V (310 g/d, not including F&V juice), potatoes (50 g/d), and whole grain products (43 g/d), there were no differences between dietary groups. All plant-based dietary groups had higher usual intakes of legumes and plant-based meat analogs compared to omnivores, with vegans having the highest intakes. Furthermore, usual intakes of plant-based dairy substitutes were significantly higher among vegans (184 g/d) and lacto-ovo-vegetarians (116 g/d) compared to pescatarians and omnivores (33 and 20 g/d, $p < 0.001$). Moreover, vegans had higher usual intakes of refined grain products compared to pescatarians (221 vs. 177 g/d, $p = 0.007$), higher intakes of nuts and seeds compared to pescatarians and omnivores (13 vs. 8 and 4 g/d, $p = 0.002$), and higher intakes of vegetable oil compared to omnivores (8 vs. 5 g/d, $p = 0.014$). Lacto-ovo-vegetarians (38 g/d) and pescatarians (23 g/d) had higher usual intakes of potatoes (plain) compared to omnivores (0 g/d, $p < 0.001$), while omnivores (28 g/d) had higher intakes of 'fried potatoes and potato dishes' compared to vegans and lacto-ovo-vegetarians (9 and 0 g/d, $p < 0.001$; Table 2).

For intakes of plant-based foods based on energy-density (g/MJ), the findings remained mostly consistent with the absolute intakes (g/d). However, we found significant differences between dietary groups for intakes (g/MJ) of fruit juice (higher among lacto-ovo-vegetarians vs. omnivores), refined grain products (higher among vegans vs. both pescatarians and omnivores), and vegetable oil (higher among both vegans and lacto-ovo-vegetarians vs. omnivores; Table 3).

4.2.2 Animal-sourced foods

No difference was found in usual intakes of dairy products and eggs, for either absolute intake (g/d) or intake based on energy-density (g/MJ), among consuming groups of dairy products and eggs (all dietary groups except vegans; Tables 2, 3). For fish and seafood, no difference was found in usual intakes (g/d and g/MJ) between pescatarians and omnivores. The omnivores had a usual intake of 141 g/d red meat and poultry (all types).

4.2.3 Sweets and snack foods and beverages

For overall usual intakes of 'sweets and snack foods' (72 g/d) and sugar sweetened beverages (51 g/d) no differences were found between dietary groups (Table 2). However, differences were found in the usual intakes of specific food groups of 'sweets and snack foods'. For 'candy and chocolate products' vegans had the lowest intakes compared to all other dietary groups (vegans 7 g/d, lacto-ovo-vegetarians 15 g/d, pescatarians 16 g/d, omnivores 23 g/d, $p < 0.001$). For 'cakes, baked goods, and sweet snack bars' vegans (40 g/d) had higher intakes compared to lacto-ovo-vegetarians (23 g/d) and omnivores (27 g/d; both, $p < 0.001$), while pescatarians

TABLE 1 Participant characteristics of youth aged 16 to 24 years in Sweden adhering to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets (*n* = 235).

	Total sample (*n* = 235)		Vegan (*n* = 60)		Lacto-ovo-vegetarian (*n* = 59)		Pescatarian (*n* = 55)		Omnivore (*n* = 61)		
Participant characteristics	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*-value
Age (years)*	22	2	22	2	22	2	21	2	21	2	0.05
BMI (kg/m^2)*	23	3	22	3	22	2	22	3	23	3	0.07
	N	%	N	%	N	%	N	%	N	%	
Sex											0.11
Female†	183	78	45	75	49	83	47	86	42	69	
Male†	52	22	15	25	10	17	8	14	19	31	
Use of tobacco products‡											
Snuff use†	66	28	14	23	19	32	17	31	16	26	0.68
Cigarette use†,‖	40	17	11	19	12	20	9	17	8	13	0.74
Physical activity level											**0.01**
Low activity, PAL 1.4†,¶	14	6	8	13	4	7	1	2	1	2	
Moderate activity, PAL 1.55–1.7†,¶	144	61	37	62	42[a]	71	37	67	28[b]	46	
Vigorous activity, PAL 1.8–2.0†,¶	77	33	15[a]	25	13[a]	22	17	31	32[b]	52	
Parental educational level											
Mother, ≥3 years university education†	158	67	35	58	41	69	39	71	43	70	0.42
Father, ≥3 years university education†	120	51	29	48	29	49	34	62	28	46	0.33
Misreporting of intake in the 24HDR's§											0.39
Under reported intake†	17	7	2	3	5	8	4	7	6	10	
Acceptable reported intake†	218	93	58	97	54	91	51	93	55	90	
Food intake day											0.85
Weekday (Mon-Thur)†	621	66	163	68	156	66	145	67	157	64	
24HDR, completed											
Recall day 1†	235	100	60	100	59	100	55	100	61	100	n/a
Recall day 2†	235	100	60	100	59	100	55	100	61	100	n/a
Recall day 3†,**	234	99.6	60	100	59	100	54	98.2	61	100	0.23
Recall day 4†,**	232	98.7	59	98.3	58	98.3	54	98.2	61	100	0.71

SD, Standard deviation. BMI, Body mass index. PAL, Physical activity level. 24HDR, 24-h dietary recall. *Test for difference between groups using one-way ANOVA with Bonferroni *post-hoc* test. †Test for difference was assessed by cross-tabulation using Pearson Chi-Square test or Fischer's Exact Test, the percentage is shown within group. Unlike letters ([a,b]) in the same row indicate between which dietary groups there is a difference. ‡Snuff user and cigarette user were categorized as 'never' or 'rarely/sometimes/daily' according to their responses in the web-based questionnaire assessing snuff/cigarette use the past six months. ‖Missing values for smoking (*n* = 4). ¶PAL1.4 = <1 times/week of moderate intensity; PAL 1.55 = 1–2 times/week of moderate intensity; PAL 1.7 = 3–4 times/week of moderate intensity; PAL 1.8 = 5–6 times/week of moderate intensity; PAL 2.0 = ≥6 times/week of moderate intensity and 1–2 times/week of vigorous intensity. §Misreporting was evaluated based on average energy intake using Goldberg cut-offs (see methods for detailed description), and none had energy intakes categorized as over-reported. **Values are given with one decimal place for meaningful values. Significance level was accepted as two-sided, adjusted, *p*-value of < 0.05 for all tests, and bolded *p*-values indicate significant difference between groups.

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TABLE 2 Absolute (g/d) usual daily intakes of food groups (median and 25th, 75th percentile) among youth aged 16 to 24 years in Sweden adhering to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets (*n* = 235).

Food group	Total sample (*n* = 235)		Vegan (*n* = 60)		Lacto-ovo-vegetarian (*n* = 59)		Pescatarian (*n* = 55)		Omnivore (*n* = 61)		
Absolute usual daily intake, g/d	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	*p*-value*
Plant-based foods											
Vegetables, root vegetables, and mushrooms (all types)[†]	211	153, 259	218	164, 264	215	153, 268	184	144, 247	212	150, 256	0.47
Fruits and berries[‡]	102	55, 175	116	37, 200	109	61, 168	91	52, 158	98	55, 175	0.77
Fruit and vegetable juice	8	1, 46	8	2, 52	22	6, 62	7	1, 21	6	0, 36	0.05
Potatoes, plain	22	8, 47	23	13, 41	38[a]	10, 70	23[a]	13, 44	0[b]	0, 48	**<0.001**
Fried potatoes and potato dishes[§]	23	0, 40	9[a]	0, 34	0[a]	0, 35	28	0, 43	28[b]	18, 50	**<0.001**
Whole grain products[¶]	43	19, 74	41	24, 59	41	17, 67	50	18, 81	57	20, 99	0.13
Refined grain products	191	148, 253	221[a]	170, 280	200	135, 258	177[b]	148, 209	183	148, 242	**0.012**
Legumes	33	15, 59	83[a]	60, 120	36[b]	21, 53	32[b]	27, 38	10[c]	6, 14	**<0.001**
Nuts and seeds[‖]	9	2, 20	13[a]	7, 24	10	3, 19	8[b]	1, 17	4[b]	1, 19	**0.002**
Vegetable and seed oils	7	4, 12	8[a]	5, 15	9	4, 12	8	4, 12	5[b]	3, 10	**0.016**
Plant-based meat analogs	52	19, 95	106[a]	82, 143	72[b]	44, 107	40[c]	23, 61	0[d]	0, 0	**<0.001**
Plant-based dairy substitutes	95	15, 171	184[a]	144, 279	116[b]	36, 171	33[c]	4, 106	20[c]	1, 82	**<0.001**
Animal-sourced foods											
Red meat and poultry (all types, including processed)	0	0, 79	0[a]	0, 0	0[a]	0, 0	0[a]	0, 0	141[b]	114, 175	**<0.001**
Fish, seafood, and fish products (all types)	0	0, 21	0[a]	0, 0	0[a]	0, 0	27[b]	6, 50	17[b]	5, 41	**<0.001**
Egg (all types)	0	0, 32	0[a]	0, 0	0[b]	0, 38	25[b]	0, 42	27[b]	0, 38	**<0.001**
Milk and dairy products[††]	144	0, 262	0[a]	0, 0	166[b]	91, 255	213[b]	142, 283	219[b]	135, 402	**<0.001**
Butter and margarine[§]	9	5, 13	8	3, 12	8	4, 14	10	6, 16	8	5, 12	0.20
Sweets and snack foods and beverages											
Candy and chocolate products[§]	14	6, 27	7[a]	2, 18	15[b]	8, 22	16[b]	9, 32	23[b]	6, 34	**<0.001**
Cakes, baked goods, sweet snack bars[§]	31	16, 46	40[a,c]	27, 48	23[b]	11, 35	35[c]	11, 49	27[b,c]	17, 41	**<0.001**
Ice-cream and cream-based puddings[§]	3	0, 22	0[a]	0, 16	8[b]	6, 23	3[a, b]	2, 20	0[a,c]	0, 23	**<0.001**
Salted snacks[§]	11	5, 19	12	7, 21	11	4, 20	10	0, 16	11	4, 23	0.19
Sugar sweetened beverages	51	9, 97	20	6, 120	22	9, 128	71	37, 97	46	0, 73	0.09
Alcoholic beverages	59	18, 150	46	17, 131	117[a]	0, 208	73	19, 129	33[b]	21, 118	**0.02**

g/d, gram per day. Usual intakes were calculated by the Multiple Source Method using repeated 24-h dietary recalls (between 2–4 days) and consumption frequency as a covariate (except for the food groups vegetable and seed oils, refined grains, and eggs since consumption frequency was not assessed). *For all variables, Kruskal-Wallis One-Way ANOVA was used test for differences between the dietary groups with Bonferroni *post-hoc* test to adjust for multiple comparisons. Bolded *p*-values indicate significant difference between the groups in the *post-hoc* test and unlike letters ([a,b,c,d]) in the same row indicate between which groups there is a difference. [†]Includes processed vegetable products and excludes potatoes and legumes. [‡]Includes fresh, frozen, canned, and dried fruit/berries, and excludes fruit juices (separate group) and fruit/berry jams, marmalades, and compotes. [§]Includes vegan alternatives. [¶]Whole grain products are defined as having > 50% (dry weight) whole grains (32). [‖]Includes salted nuts/seeds. [††]Includes cheese and cheese products and excludes dairy ice-cream (ice-cream and cream-based pudding group) and butter (butter and margarine group). For details of foods included in each food group, refer to Supplementary Table 2. *p*-value of < 0.05 (two-sided) was accepted as statistically significant.

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TABLE 3 **Energy-density (g/MJ) of usual daily intakes of food groups (median and 25th, 75th percentile) among youth aged 16 to 24 years in Sweden adhering to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets (*n* = 235).**

Food group	Total sample (*n* = 235)		Vegan (*n* = 60)		Lacto-ovo-vegetarian (*n* = 59)		Pescatarian (*n* = 55)		Omnivore (*n* = 61)		
Energy-density of usual daily intakes, g/MJ	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	*p*-value*
Plant-based foods											
Vegetables, root vegetables, and mushrooms (all types)[†]	22	17, 28	23	19, 29	22	17, 29	22	17, 28	20	17, 28	0.28
Fruits and berries[‡]	11	6, 18	13	3, 22	12	6, 17	10	6, 17	10	6, 18	0.67
Fruit and vegetable juice	1	0, 5	1	0, 5	2[a]	1, 6	1	0, 2	1[b]	0, 3	**0.04**
Potatoes, plain	3	1, 5	3	1, 4	4[a]	1, 7	3[a]	2, 5	0[b]	0, 5	**<0.001**
Fried potatoes and potato dishes[§]	2	0, 5	1[a]	0, 4	0[a]	0, 4	3	0, 5	3[b]	2, 5	**<0.001**
Whole grain products[¶]	5	2, 8	5	3, 7	4	1, 8	6	2, 10	6	2, 9	0.23
Refined grain products	21	17, 26	24[a]	18, 29	21	17, 27	20[b]	16, 22	20[b]	14, 24	**0.004**
Legumes	4	1, 6	9[a]	6, 12	4[b]	3, 6	4[b]	3, 5	1[c]	1, 1	**<0.001**
Nuts and seeds[‖]	1	0, 2	1[a]	1, 3	1	0, 2	1[b]	0, 2	0[b]	0, 2	**0.002**
Vegetable and seed oils	1	0, 1	1[a]	1, 2	1[a]	1, 1	1	0, 1	1[b]	0, 1	**0.001**
Plant-based meat analogs	6	2, 10	12[a]	9, 15	8[b]	5, 12	4[c]	3, 6	0[d]	0, 0	**<0.001**
Plant-based dairy substitutes	10	2, 19	20[a]	13, 34	12[b]	4, 21	4[c]	0, 12	2[c]	0, 8	**<0.001**
Animal-sourced foods											
Red meat and poultry (all types, including processed)	0	0, 8	0[a]	0, 0	0[a]	0, 0	0[a]	0, 0	16[b]	11, 18	**<0.001**
Fish, seafood, and fish products (all types)	0	0, 2	0[a]	0, 0	0[a]	0, 0	3[b]	1, 6	1[b]	0, 5	**<0.001**
Egg (all types)	0	0, 3	0[a]	0, 0	0[b]	0, 4	3[b]	0, 4	3[b]	0, 4	**<0.001**
Milk and dairy products[††]	15	0, 27	0[a]	0, 0	20[b]	11, 26	23[b]	15, 33	23[b]	14, 39	**<0.001**
Butter and margarine[§]	1	1, 1	1	0, 1	1	1, 1	1	1, 2	1	1, 1	0.06
Sweets and snack foods and beverages											
Candy and chocolate products[§]	2	1, 3	1[a]	0, 2	2[b]	1, 3	2[b]	1, 3	2[b]	1, 4	**<0.001**
Cakes, baked goods, sweet snack bars[§]	3	2, 5	4[a]	3, 6	3[b]	1, 4	4	2, 5	3[b]	2, 4	**<0.001**
Ice-cream and cream-based puddings[§]	0	0, 2	0[a]	0, 2	1[b]	1, 2	0[a,b]	0, 2	0[c]	0, 2	**<0.001**
Salted snacks[§]	1	1, 2	1	1, 2	1	0, 2	1	0, 2	1	0, 2	0.32
Sugar sweetened beverages	5	1, 11	2	1, 12	2	1, 13	8[a]	5, 11	5[b]	0, 7	**0.034**
Alcoholic beverages	6	2, 16	5	2, 13	12[a]	0, 23	9	2, 17	4[b]	2, 11	**0.009**

g/MJ, gram per megajoule. Usual daily intakes were calculated by the Multiple Source Method using repeated 24-h dietary recalls (between 2–4 days) and consumption frequency as a covariate (except for the food groups vegetable and seed oils, refined grains, and eggs since consumption frequency was not assessed). *For all variables, Kruskal-Wallis One-Way ANOVA was used to test for differences between dietary groups with Bonferroni *post-hoc* test to adjust for multiple comparisons. Bolded *p*-values indicate significant difference between the groups in the *post-hoc* test and unlike letters ([a,b,c]) in the same row indicate between which groups there is a difference. [†]Includes processed vegetable products and excludes potatoes and legumes. [‡]Includes fresh, frozen, canned, and dried fruit/berries, and excludes fruit juices (separate group) and fruit/berry jams, marmalades, and compotes. [§]Includes vegan alternatives. [¶]Whole grain products are defined as having > 50% (dry weight) whole grains (32). [‖]Includes salted nuts/seeds. [††]Includes cheese and cheese products and excludes dairy ice-cream (ice-cream and cream-based pudding group) and butter (butter and margarine group). For details of foods included in each food group, refer to Supplementary Table 2. *p*-value of < 0.05 (two-sided) was accepted as statistically significant.

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(35 g/d) had higher intakes compared to lacto-ovo-vegetarians ($p = 0.03$). For 'ice-cream and cream-based puddings' lacto-ovo-vegetarians (8 g/d) had higher intakes compared to vegans and omnivores (both, 0 g/d), and pescatarians (3 g/d) had higher intakes compared to omnivores ($p < 0.001$). For alcoholic beverages, lacto-ovo-vegetarians had higher usual intakes compared to omnivores (117 vs. 33 g/d, $p = 0.02$).

For intakes based on energy-density (g/MJ), the findings remained mostly consistent with the absolute intakes (g/d) except for 'cakes, baked goods, and sweet snack bars', which no longer differed between pescatarians and lacto-ovo-vegetarians. However, for usual intakes of sugar sweetened beverages based on energy-density, pescatarians had higher intakes compared to omnivores ($p = 0.022$; Table 3).

4.2.4 Sensitivity analyses for food group intake, adjustment for age and sex

In the sensitivity analyses performed in the MSM, adjusting food group intakes (g/d) for age and sex, the findings remained consistent with the unadjusted values, except for intakes of nuts and seeds, which no longer significantly differed between vegans and pescatarians (12 vs. 7 g/d, $p = 0.05$).

4.3 Energy and macronutrient intake among youth adhering to plant-based or omnivorous diets

Usual daily intakes of energy and macronutrients are presented as median value with 25th and 75th percentiles in Table 4. Omnivores had the highest usual EI (10 MJ/d) which differed from lacto-ovo-vegetarians and pescatarians (for both, 9 MJ/d, $p = 0.016$).

For intakes of macronutrients based on percentage of energy (E%), omnivores had usual intakes of carbohydrates (including fiber) marginally below recommendations (44E%), and the intake was significantly lower compared to vegans (51E%) and lacto-ovo-vegetarians (47E%), $p < 0.001$. Further, all plant-based dietary groups had higher usual intakes of fiber (g/MJ) compared to omnivores, $p < 0.001$. However, both pescatarians (2.8 MJ/d) and omnivores (2.6 g/MJ) did not meet the recommendation for fiber according to energy density, ≥3 g/MJ. All dietary groups had usual intakes of free sugars (6E%) in line with the recommendation of <10E%. All dietary groups had usual intakes of protein and total fat within NNR2023 recommendations. Omnivores had higher usual intakes of protein (16E%) compared to all the plant-based dietary groups (vegans 12E%, lacto-ovo-vegetarians 12E%, pescatarians 14E%, $p < 0.001$). Vegans had the lowest usual intake of total fat (36E%), differing from both pescatarians and omnivores (40E% and 39E%, $p < 0.001$). All dietary groups except vegans (8E%) exceeded the recommendation of <10E% SFA (lacto-ovo-vegetarians 12E%, pescatarians 13E%, omnivores 14E%, $p < 0.001$). Moreover, all dietary groups had E% from monounsaturated and polyunsaturated fatty acids within recommendations, although all plant-based dietary groups had higher E% from polyunsaturated fatty acids compared to omnivores ($p < 0.001$). Omnivores had significantly higher usual intakes of salt (from foods only) compared to pescatarians (8 vs. 7 g/d, $p = 0.004$). Although, all dietary groups had usual intakes of salt that exceeded the recommendation of 6 g/d.

4.4 Adherence to the food-based dietary guidelines

The number and percentage of participants with usual intakes that meet the FBDG's from the NNR2023 is presented in Table 5.

Among the total sample, 10% met the FBDG of ≥500 g/d of F&V, 24% met the FBDG of ≥20 g/d nuts (including salted nuts), 4% met the FBDG of ≥25 g/d vegetable oil, and 19% met the FBDG of <6 g salt, with no significant difference between dietary groups. Vegans had the highest and lacto-ovo-vegetarians the lowest adherence to the FBDG for F&V (13% vs. 5%) and highest among vegans and lowest among omnivores for vegetable oil (8% vs. 2%), while vegans had the highest and pescatarians the lowest adherence to the FBDG for nuts (33% vs. 18%). For whole grains, 10% of the total sample met the FBDG of ≥90 g/d, with significantly higher adherence among omnivores (23%) compared to vegans and lacto-ovo-vegetarians (2 and 3%, $p < 0.001$).

Of the consuming dietary groups (excluding vegans), no difference was found for adherence to the FBDG of ≥350 g/d of low-fat milk and dairy products. Less than a third of pescatarians (29%) and omnivores (25%) had usual intakes which met the FBDG of 300–450 g/week of fish (total), with no difference between the two dietary groups. However, pescatarians had a higher adherence to the FBDG of ≥200 g/week of oily fish compared to omnivores (27% vs. 8%, $p < 0.001$). For red meat (including processed), 21% of the omnivores had intakes that met the FBDG of <350 g/week.

5 Discussion

5.1 Key findings of dietary intake among youth adhering to plant-based or omnivorous diets

In this study of 16 to 24 year olds in Sweden, youth adhering to plant-based diets had higher usual intakes of legumes and plant-based meat analogs compared to omnivores, with highest intakes among vegans. Additionally, vegans and lacto-ovo-vegetarians consumed more plant-based dairy substitutes compared to pescatarians and omnivores. Furthermore, differences were found for usual intakes (g/d and g/MJ) of refined grain products, nuts and seeds, and vegetable oil (highest among vegans), plain potatoes (highest among lacto-ovo-vegetarians), fried potatoes and potato dishes (highest among omnivores), and for food groups within the category of 'sweets and snack foods'. Intakes of fruits and berries, vegetables, whole grain products, and overall intakes of 'sweets and snack foods' did not differ between the dietary groups. These findings remained mostly consistent when adjusted for sex and age. Most of the NNR2023 macronutrient recommendations were met across dietary groups, except for carbohydrates (below for omnivores), fiber (below for omnivores and pescatarians), and SFA (exceeded for lacto-ovo-vegetarians, pescatarians, and omnivores). We found no difference between the dietary groups for adherence to the FBDG's for F&V, nuts, vegetable oil, salt, low-fat dairy (excluding vegans), and total fish (excluding vegans and lacto-ovo-vegetarians). Although, omnivores had a significantly higher adherence to the FBDG for whole grains compared to vegans and lacto-ovo-vegetarians, and pescatarians had a higher adherence to the FBDG for oily fish compared to omnivores. Nevertheless, the

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TABLE 4 Usual daily intake of energy, macronutrients, whole grain and salt (median and 25th, 75th percentile) among youth aged 16 to 24 year olds in Sweden adhering to vegan, lacto-ovo-vegetarian, pescatarian or omnivorous diets (*n* = 235).

		Total sample (*n* = 235)		Vegan (*n* = 60)		Lacto-ovo-vegetarian (*n* = 59)		Pescatarian (*n* = 55)		Omnivore (*n* = 61)		
Usual daily intake	Recommended daily intake*	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	Median	25th, 75th	*p*-value†
Energy, MJ/d	9.4 MJ (Female), 11.8 MJ (Male)*	9	8, 10	9	8, 10	9[a]	8, 11	9[a]	8, 10	10[b]	9, 11	**0.016**
Protein, g/d		74	61, 92	65[a]	52, 81	66[a]	58, 87	76[a]	63, 83	95[b]	75, 115	**<0.001**
Protein, g/kg‡	≥0.83 g/kg§	1.1	0.9, 1.4	1.1[a]	0.9, 1.3	1.1[a]	0.9, 1.3	1.1[a]	1.0, 1.4	1.4[b]	1.1, 1.7	**<0.001**
Protein, E%	10–20 E%	13	12, 16	12[a]	11, 13	12[a,b]	12, 14	14[b]	12, 15	16[c]	14, 17	**<0.001**
Carbohydrates, g/d		240	207, 276	263[a]	226, 299	232[b]	200, 265	228[b]	197, 247	243	213, 271	**<0.001**
Carbohydrates, E%	45–60 E%	46	42, 51	51[a]	47, 54	47[b]	43, 52	45[b,c]	41, 48	44[c]	40, 47	**<0.001**
Dietary fiber, g/d	≥25 g/d (Female), ≥35 g/d (Male)	28	23, 35	35[a]	30, 39	28[b]	24, 33	24[b]	21, 31	25[b]	19, 31	**<0.001**
Dietary fiber, g/MJ‡	≥3 g/MJ	3.1	2.6, 3.7	3.7[a]	3.3, 4.2	3.2[b]	2.7, 3.7	2.8[b]	2.2, 3.4	2.6[c]	2.1, 2.8	**<0.001**
Total sugars, g/d		79	66, 91	80	65, 89	77	69, 88	76	67, 88	83	65, 97	0.57
Total sugars, E%		14	12, 16	14	12, 17	14	12, 16	14	13, 16	14	11, 16	0.80
Free sugars, g/d‖		37	30, 45	36	28, 49	38	33, 43	38	30, 45	37	26, 48	0.84
Free sugars, E%‖	<10 E%	6	5, 8	6	5, 8	6	5, 8	6	5, 8	6	4, 8	0.35
Fat, total, g/d		92	78, 109	88[a]	75, 100	88[a]	71, 112	91	77, 108	102[b]	90, 113	**0.002**
Fat, total, E%	25–40 E%	38	35, 41	36[a]	32, 39	38	35, 42	40[b]	35, 42	39[b]	37, 42	**<0.001**
SFA, g/d		29	22, 37	21[a]	17, 24	27[b]	21, 37	32[b,c]	26, 38	36[c]	31, 42	**<0.001**
SFA, E%	<10 E%	12	9, 14	8[a]	7, 10	12[b]	9, 14	13[b,c]	11, 15	14[c]	12, 16	**<0.001**
MUFA, g/d		38	33, 45	38	31, 45	36[a]	30, 43	37	32, 44	42[b]	36, 46	**0.017**
MUFA, E%	10–20 E%	16	14, 17	15	14, 18	16	14, 17	16	14, 17	16	15, 17	0.76
PUFA, g/d		17	14, 22	23[a]	19, 26	16[b]	14, 21	16[b]	13, 19	15[b]	13, 17	**<0.001**
PUFA, E%	5–10 E%	7	6, 8	9[a]	8, 10	7[b]	6, 8	7[b]	6, 8	6[c]	5, 7	**<0.001**
Whole grain, g/d¶	≥90 g/d	44	26, 66	45	33, 64	43	24, 60	44	20, 67	48	27, 82	0.38
Salt, g/d††	<6 g/d	7	6, 9	8	6, 9	7	6, 8	7[a]	6, 8	8[b]	7, 9	**0.004**

MJ/d, Megajoule/day. SFA, Saturated fatty acids. MUFA, Monounsaturated fatty acids. PUFA, Polyunsaturated fatty acids. Usual daily intakes were calculated by the Multiple Source Method using repeated 24-h dietary recalls (between 2–4 days). *Recommended dietary intake by NNR2023 for healthy 18–24 year olds, and recommended energy intake is based on a standard weight and physical activity level of 1.6. †For all variables, Kruskal-Wallis One-Way ANOVA was used to test for differences between dietary groups with Bonferroni *post-hoc* test to adjust for multiple comparisons. Bolded *p*-values indicate significant difference between the groups in the *post-hoc* test, and unlike letters ([a,b, c]) in the same row indicate between which groups there is a difference. ‡Values are given with one decimal place for meaningful values. §Recommended daily intake of protein in gram per kilogram body weight for adults ≥ 18 years, both sexes. ‖Free sugars was defined according to WHO's definition (31), i.e., sugars from all foods which contain added sugars, as well as sugars which are naturally present in honey, syrups, fruit juice and fruit juice concentrate. ¶Whole grain content in foods was automatically calculated using the Swedish Food Composition database or by brand product information. ††Salt from foods only (including salt in the cooking method, e.g., 'cooked pasta with salt'), and not including discretionary sources of salt reported in the 24HDR's. *p*-value of < 0.05 (two-sided) was accepted as statistically significant.

TABLE 5 Proportion of youth adhering to plant-based or omnivorous diets with usual intakes that meet the quantitative food-based dietary guidelines (FBDG) from the Nordic Nutrition Recommendations 2023 (NNR2023).

		Total sample (*n* = 235)		Vegan (*n* = 60)		Lacto-ovo-vegetarian (*n* = 59)		Pescatarian (*n* = 55)		Omnivore (*n* = 61)		
		% meeting recommendation*		% meeting recommendation		% meeting recommendation		% meeting recommendation		% meeting recommendation		
Food groups	FBDG by NNR2023	N	%	N	%	N	%	N	%	N	%	*p*-value[†]
Vegetables, fruits, and berries[*,‡]	500–800+ g/day	23	10	8	13	3	5	6	11	6	10	0.49
Whole grains[*,§]	≥90 g/day	24	10	1[a]	2	2[a]	3	7	13	14[b]	23	**<0.001**
Nuts[*,¶]	20–30 g/day	56	24	20	33	13	22	10	18	13	21	0.23
Vegetable oil*	≥25 g/day	10	4	5	8	2	3	2	4	1	2	0.20
Low-fat milk and dairy products[*,‖]	350–500 g/day	26	11	0[a]	0	4[a, b]	7	8[b]	15	14[b]	23	**<0.001**
Fish (lean and oily fish)*	300–450 g/week	31	13	0[a]	0	0[a]	0	16[b]	29	15[b]	25	**<0.001**
Whereof oily fish[*,††]	≥200 g/week	20	9	0[a]	0	0[a]	0	15[b]	27	5[a]	8	**<0.001**
Red meat (including processed)*	<350 g/week	187	80	60[a]	100	59[a]	100	55[a]	100	13[b]	21	**<0.001**
Salt (foods only)*	<6 g/day	45	19	11	18	13	22	15	27	6	10	0.11

*Adherence to the FBDG is based on individual usual intakes which were estimated by the Multiple Source Method using repeated 24-h dietary recalls (between 2–4 days) and consumption frequency (except for the food groups vegetable oil, low-fat milk and dairy, oily fish, and salt since consumption frequency was not assessed). Usual intakes were compared to the lower cut-off of the FBDG. [†]For all variables, to test for differences between dietary groups crosstabulation with Fischer's exact test was used. Bolded *p*-values indicate significant differences and unlike letters (a,b) in the same row indicate between which dietary groups there is a difference. [‡]Not including potatoes, legumes, fruit/vegetable juices, or fruit jams/compotes/soups. [§]Whole grain intake was calculated using the Swedish Food Composition database or by brand product information. [¶]Includes salted nuts. [‖]Includes intakes of low-fat milk (≤1.5%), yoghurt (≤1.5%) and dairy products (incl. Low-fat cheese [≤17% fat], which was converted to milk equivalents using a yield factor of 10). [††]At least 200 g of the recommended total fish intake should be from oily fish. *p*-value of < 0.05 (two-sided) was accepted as statistically significant.

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vast majority of the participants did not meet the NNR2023 FBDG's, regardless of dietary practice.

5.2 Intakes of plant-based food groups

To meet energy and nutritional requirements when adhering to a plant-based diet, animal-sourced foods need to be replaced with other food groups. In this study, all plant-based dietary groups consumed more legumes and plant-based meat analogs compared to omnivores. Moreover, vegans consumed more refined grain products, nuts/seeds, vegetable oil, and plant-based dairy substitutes compared to omnivores and/or pescatarians, indicating that these food groups replaced animal-sourced foods. Our findings are somewhat similar with previous studies on children/adolescents in Germany (14) and youth in Norway (40) which also observed higher average intakes (g/d or g/MJ) of nuts and seeds, legumes, and plant-based meat and dairy alternatives among vegans compared to omnivores. A previous study of youth in Sweden (from the late 1990's) also found that vegans consumed more nuts and seeds and legumes compared to omnivores of similar age (19, 41). However, we found no difference between the dietary groups for usual intakes of F&V which stands in contrast to the aforementioned studies on children/adolescents and youth adhering to plant-based or omnivorous diets, which observed higher average intakes (g/d or g/MJ) of fruits and berries and/or vegetables among vegans compared to omnivores (14, 19, 40, 41).

5.3 Replacement of animal-sourced foods among youth adhering to plant-based diets

5.3.1 Plant-based meat analogs and legumes

The NNR2023 state that legumes should constitute a significant part of the diet since they are a source of protein, complex carbohydrates, dietary fiber, folate, zinc, and iron, as well as being low in SFA and have a low environmental impact (7). There is no dietary recommendation for intakes of plant-based meat analogs from the NNR2023.

In our study vegans had usual intakes (g/d and g/MJ, median value) of plant-based meat analogs (106 g/d, 12 g/MJ) somewhat lower than the omnivores intakes of red meat and poultry (141 g/d, 16 g/MJ). However, vegans consumed eight times more legumes compared to omnivores (83 g/d vs. 10 g/d). Furthermore, lacto-ovo-vegetarians and pescatarians consumed four-to-seven times the intake of plant-based meat analogs and three-fold the intake of legumes compared to omnivores. Thus, our findings suggest that the youth in this study who adhered to plant-based diets replaced animal-sourced foods (i.e., red meat and poultry) with plant-based meat analogs, and to a lesser extent with legumes. However, the youth adhering to plant-based diets in our study had much lower intakes of legumes and vegetables compared to what was observed among vegans in the late 1990's who had average intakes of 255–352 g/d of legumes and 292–320 g/d of vegetables (median values) (42). In the late 1990's plant-based meat analogs were less common. The growing variety and availability of plant-based meat analogs in recent years (23), may lead to current youth favoring these products as a replacement for animal-sourced foods over legumes, whole grain products, and vegetables. Nevertheless, in our study, the higher intake of legumes and plant-based meat analogs, and the absence of red or processed meat among youth eating plant-based diets demonstrated better alignment with the food and macronutrient recommendations compared to omnivores of similar age.

Replacing red meat with plant-based meat analogs can lower the environmental impact from dietary intake (3). Furthermore, if fortified they can provide equal or greater quantities of micronutrients, and simultaneously provide a more favorable nutritional content of SFA and dietary fiber compared to red and processed meat (3). However, not all plant-based meat analogs are fortified, and protein content of these products varies, and additionally there are concerns over their high sodium content and limited bioavailability of iron and zinc (20, 21). Furthermore, while legumes are nutrient dense, they lack some essential micronutrients found predominantly in red meat, poultry, and fish, including vitamin B_{12}, vitamin D, iodine, and omega-3 fatty acids (43–45). Thus, youth eating plant-based diets, particularly vegan and lacto-ovo-vegetarian diets, need to plan their dietary intakes to ensure that they meet their requirements of micronutrients by other food sources or by use of appropriate supplementation.

5.3.2 Dairy products and plant-based dairy alternatives

To ensure sufficient intake of calcium, iodine, and vitamin B_{12}, NNR2023 recommend that fortified plant-based dairy products replace milk and dairy if intakes are less than 350 g/d (7). In this study, lacto-ovo-vegetarians (166 g/d, 20 g/MJ) and pescatarians (213 g/d, 23 g/MJ) had similar total dairy intakes to omnivores (219 g/d, 23 g/MJ), and few consumed low-fat dairy products which is recommended by NNR2023. Vegans reported intakes of plant-based dairy products (184 g/d, 20 g/MJ) somewhat similar to dairy intakes among omnivores, indicating that dairy is mostly replaced with plant-based alternatives. Also, in this study lacto-ovo-vegetarians appear to partially replace dairy products with plant-based dairy alternatives (116 g/d, 12 g/MJ).

Plant-based dairy substitutes have both nutritional benefits and shortcomings. They contain lower SFA (except for coconut-based products) and more fiber compared to milk and dairy products, although the protein and sugar content varies by product (22). A recent nutritional composition study of plant-based substitutes on the Swedish market showed that fortified plant-based substitutes of milk and yoghurt can provide similar micronutrient content as fortified dairy products (22). In Sweden, most plant-based milks are fortified with vitamin D, vitamin B_{12}, calcium, and vitamin B_2, and few are fortified with iodine (22). However, plant-based dairy alternatives for yoghurt, cheese, and cream are not as commonly fortified compared to milk alternatives. Furthermore, there are differences in fortification policies across Nordic countries which impact the nutritional equivalence of plant-based substitutes to dairy. The variation in fortification between products may negatively influence micronutrient intake if the plant-based diet is not well-planned and if dairy is replaced with unfortified plant-based dairy alternatives.

5.4 Intakes of sweets and snack foods

The NNR2023 recommend limited intakes of sweets and sugar sweetened foods/beverages as they contribute primarily to sugar, added fat, and energy, while providing minimal nutritional value (7). Dietary intakes of discretionary foods in the form of sweets and snack foods are relatively high among adults and young populations in Scandinavian countries (9, 46, 47), which was also observed in our study. Furthermore, we observed no difference between the dietary groups for overall usual intakes of 'sweets and snack foods' or absolute intakes (g/d) of sugar sweetened beverages. Although the types of sweets and snack foods consumed differed between the dietary groups. These results align with a similar study of youth in Norway who ate plant-based or omnivorous diets (n = 165, 16–24 years) (40). Our findings indicate that while youth adhering to plant-based diets increase their intakes of some plant-based foods compared to omnivores of similar age, their overall intakes of sweets and snack foods do not decrease. If sweets and snack foods displace healthy plant-based foods, it may present a challenge in meeting micronutrient recommendations from foods without exceeding energy requirements.

5.5 Intakes of energy, macronutrients and salt

We found that omnivores had higher usual EI (median value) compared to pescatarians and lacto-ovo-vegetarians. However, the omnivorous group had a higher percentage of males (though not significantly different), and a higher proportion reported vigorous physical activity, both of which are associated with greater energy needs.

Our results demonstrate that the usual intakes of protein (E%) and SFA (E%) decreased while the intakes of carbohydrates (E%) and fiber (g/MJ) increased between the dietary groups in parallel with the reduction of animal-sourced food groups included in the diet, and vegans were the only dietary group to have intakes of SFA within recommendations. These findings are in agreement with the overall findings of average mean intakes from previous cross-sectional studies of healthy children/adolescents (2–18 years, 30 studies) (16), Swedish youth (19) and adults (≥18 years, 141 studies) (18) adhering to vegan, lacto-ovo-vegetarian or omnivorous diets. Also, mostly in line with a similar study of youth in Norway eating plant-based (vegan, lacto-ovo-vegetarian, pescatarian, flexitarian) or omnivorous diets (40).

In our study, vegans had macronutrient intakes most aligned with the dietary recommendations. The omnivores had usual intakes of macronutrients least aligned with the dietary recommendations (i.e., SFA, carbohydrates, and fiber), which is partially explained by their lower intakes of plant-based foods (e.g., legumes) and higher intakes of animal-sources of protein (red meat and processed meat and high fat dairy products). All dietary groups had usual intakes (E%) of free sugars in line with the dietary recommendations (<10E%), which stands in contrast to the dietary intakes found among Swedish youth from the national food consumption survey (9.8-11E%) (48). A potential explanation for the lower intake of free sugars we found among the youth in the present study, is that their reported intakes of sugar sweetened beverages, a leading contributor to sugar intake, was half the amount compared to the reported intakes by Swedish youth in general (51 vs. 100 g/d, median value) (9, 48). Furthermore, intakes of free sugars may be slightly underestimated due to some foods in the food composition database being nutritionally calculated by brand product information, therefore the content of free sugars was not available. All dietary groups in this study exceeded the recommendation for salt, whereof only 19% of the youth had intakes of salt below 6 g/d. Intakes of salt are solely from foods and their preparation (e.g., 'pasta cooked with salt'), thus usual intakes are likely underestimated as discretionary salt was not included. Further research is needed to explore the main dietary sources of energy, salt, macro- and micronutrients in the youths' intakes, and identify strategies for promoting healthier dietary habits among youth.

5.6 Adherence to the FBDG's for F&V and whole grains

A low adherence to the FBDG's, particularly for F&V, whole grains, and nuts has been observed among both adolescents and adults in many European countries, including Sweden (9, 47, 49, 50). In this study, one in 10 had usual daily intakes of ≥500 g F&V and ≥90 g whole grains which is comparable to findings from the Swedish national food consumption surveys, where 10% of youth (17–18 years) and 17% of adults had daily intakes of F&V that met the FBDG, and ≤8% of youth and 12% of adults met the dietary recommendations for whole grains ((9, 25, 49). Vegans in this study had the highest proportion with usual intakes meeting the FBDG for F&V and nuts and seeds, as well as vegetable oil, indicating somewhat healthier food habits on individual level. Although, a previous study of young Swedish vegans (n = 30) from the late 1990's found that 70% (21 out of 30) of the vegans met the recommended daily intake of 500 g F&V (excluding potatoes) compared to 3% of omnivores (1 out of 30) of similar age (41). Thus, our findings indicate that current youth eating plant-based consume lower intakes of F&V compared to vegans in the late 1990's, likely as a result of the increased availability of different types of pre-made plant-based foods. Furthermore, in this study omnivores had a significantly higher adherence to the recommended intakes of whole grains compared to vegans and lacto-ovo-vegetarians, demonstrating that youth eating plant-based diets in this study consumed refined grain products more often than whole grain products. Whole grain products are more nutrient dense than refined grain products, and they provide some micronutrients which may be consumed in lower quantities when animal-sourced foods are excluded from the diet (including iron, zinc, selenium, and riboflavin (16, 17, 51)). Thus, replacing refined grain products with whole grain alternatives would support youth, particularly those eating plant-based, in meeting their requirements of micronutrients.

It might be expected that youth who adhere to plant-based diets increase their intakes of F&V as to meet nutritional requirements. However, factors including convenience, availability, price, and taste and sensory aspects are likely more influential in shaping youths' food choices and consumption of F&V as well whole grain products (52–54). Further, whether they possess food-related competencies, including skills, knowledge and behaviors which can facilitate them in making food choices aligned with the dietary guidelines, i.e., food literacy competencies (55, 56). A recent study in Norway observed a positive association between youth's food literacy (general nutrition knowledge and food skills) and diet quality, although the youth had food literacy levels categorized as moderate (57). As long-term low intakes of F&V and whole grains are associated with an increased risk for non-communicable diseases (cardiovascular disease, all-cause mortality, type-2 diabetes (58–60)), youth should be supported in increasing their intakes of these food groups and developing food literacy competencies necessary to consume healthy diets.

5.7 Strengths and limitations

To the best of our knowledge, this is the first study since the late 1990's to assess the dietary intakes of youth in Sweden eating plant-based diets compared to omnivorous diets. The strength of this study is the comparable number of participants with similar characteristics within each dietary group. Furthermore, there was a high compliance to the 24HDR dietary assessments and less than 10% of the average reported intakes in the 24HDR's were categorized as under-reported. Short-term dietary intake data may fail to capture foods consumed episodically and does not account for within-and between person variation. Thus, to account for this, usual daily intakes were estimated using the MSM which adjusts for variability in dietary intakes. Additionally, for food group intake, the short-term dietary intake data from the 24HDR's was used in combination with consumption frequency in the MSM, which improves the estimates of usual daily intakes, particularly for food groups consumed episodically (37, 38). While the small sample size may affect the reliability of usual intake estimates by the MSM, the results were largely consistent with those based on average intakes (data not shown), except for some food groups less commonly reported in the 24HDR's (e.g., 'ice-cream and cream based puddings' and 'fried potatoes and potato dishes'). This suggests that the potential limitation of the sample size did not impact our overall findings of dietary intakes, but the MSM improved intake estimates for episodically consumed foods. Nevertheless, this study has limitations to be considered. First is the cross-sectional design and the use of convenience sampling, which resulted in a study sample with mostly female participants which impacts the generalizability of our results. Although, females are over-represented among plant-based consumers in previous literature (14, 57, 61), thus the sample recruited may be representative of youth populations consuming plant-based diets. Furthermore, although we performed sensitivity analyses for intakes of food groups (g/d), adjusting for sex and age—which supported our overall findings, due to the similarity in participant characteristics, potential differences related to sex and age may not have been detectable. Lastly, given the study topic and the recruitment methods employed (convenience and snowball sampling), the potential that the youth who were recruited in this study were more "health conscious" than youth in general needs to be acknowledged.

6 Conclusion

In conclusion, youth adhering to vegan, lacto-ovo-vegetarian, and pescatarian diets consume higher intakes of legumes and plant-based meat analogs compared to omnivores, suggesting that these food groups replace meat in the diet. Additionally, the highest intakes of several plant-based foods (legumes, nuts and seeds, refined grain products, plant-based meat and dairy alternatives) was observed among vegans. However, very few of the youth in this study had usual intakes that meet the recommended dietary intakes of F&V, nuts, vegetable oil, and whole grains, regardless of eating a plant-based or omnivorous diet. Although intake of energy and macronutrients are mostly in line with recommendations, youth face a challenge to reduce intakes of discretionary foods and consume enough fruits, berries, vegetables, nuts, and whole grain products. Thus, youth need support to better align with food recommendations if their potential for long-term individual health as well as planetary health is to be secured.

Data availability statement

The datasets presented in this article are not readily available because of ongoing analysis. However, data can be made available on reasonable request. Requests to access the datasets should be directed to isabelle.mulkerrins@gu.se.

Ethics statement

This study involving humans was approved by the Swedish Ethical Review Authority (Dnr: 2022–04188-01). The study was conducted in accordance with the local legislation and institutional requirements. Written informed consent was obtained on study site from all subjects prior to their study participation. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants' legal guardians because people aged 15 and older can provide their own informed consent for study participation in Sweden. This study was conducted according to the guidelines laid down in the Declaration of Helsinki.

Author contributions

IM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. AM: Conceptualization, Writing – review & editing. SG-J: Conceptualization, Writing – review & editing. CM: Writing – review & editing. CL: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2025.1528252/full#supplementary-material

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The cost of healthy eating in two major cities in Ecuador: a comparative analysis

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Background/objectives: Healthy eating is essential to maintaining health and preventing disease. However, various economic and social factors make it difficult to access an adequate diet in many regions, especially in low-middle income countries (LMIC). In Ecuador, the economy underwent significant changes following the SARS-COV-2 pandemic, affecting food prices and, therefore, the population's ability to maintain a healthy diet. We want to showcase the costs of a healthy diet in Quito and Guayaquil by evaluating the price of food items sold to consumers in major supermarket chains/food suppliers.
Methods: A diet model was designed based on foods from the basic family basket (BFB) and standard nutritional recommendations. Prices were collected through visits to supermarkets and 3 types of diet were analysed: regular diet with BFB portions, regular diet with healthy portions, and our healthy diet model.
Results: The cost of a healthy diet is significantly higher than a regular diet; with the price of healthy eating in Ecuador, in 2023, being $184.66 per person per month, which represents 41% of the unified basic salary (or 3.2 times more expensive than the BFB), making it unaffordable for many families with scarce resources. In Quito and Guayaquil, the most expensive foods in a healthy diet were dairy products, eggs, and meat.
Conclusion: Healthy eating in the two major cities of Ecuador represents almost half of the basic monthly salary, making it inaccessible to most families with limited resources, and becoming a matter of public health. Our study highlights the need for public policies to improve access to healthy foods as well as local policies to incentivize direct trade of food items (i.e., directly from the producer to the final consumer).

KEYWORDS

healthy diet, regular diet, cost, affordability, Ecuador

1 Introduction

Healthy eating emerges as a fundamental pillar, from a medical perspective, to preserve health by providing substantial nutritional support and playing a crucial role in preventing multiple diseases throughout life. In the systematic analysis of dietary risk conducted by Afshin et al. (36) across 195 countries from 1990 to 2017, poor diets were estimated to be responsible for approximately 11 million deaths, primarily due to cardiovascular disease and cancer (36). The leading dietary risk factors included high sodium intake, low consumption of whole grains and insufficient fruit intake (36). Furthermore, in a large cohort study published by Shan et al. (1), greater adherence to a healthy eating pattern was significantly associated with a reduction in the risk of coronary heart disease and stroke by 10–20% over up to 32 years of follow-up [HR 0.80 (95% CI, 0.77–0.830)] (1). On the other hand, in the systematic review published in 2019 by Lassale et al. (2) it was found that an inversely proportional relationship exists between a healthy diet (especially the traditional Mediterranean diet) and depression. Furthermore, in the meta-analysis presented in 2017 by Kelly et al. with 15,285 patients from 7 studies, a statistically significant association was found between a healthy diet and decreased mortality in patients with chronic kidney disease (3).

Despite the clear and widely recognized importance of healthy eating, various obstacles, such as rapid urbanization, lifestyle changes, economic instability, and the recent SARS-COV-2 pandemic, have affected the population's ability to maintain an adequate diet; in particular, low-middle income countries (LMIC) (4, 5). In Ecuador, the average per capita caloric intake is 2,141 kilocalories per day, which corresponds to the minimum estimated threshold required to accomplish basic energy requirements. Nevertheless, this average masks significant disparities in both food distribution and nutritional quality, which are reflected in alarming public health indicators; for instance, the prevalence of chronic malnutrition among children stands at 25.3% (6). Additionally, according to the 2015 report by the Food and Agriculture Organization (FAO), 11% of Ecuadorians lacks adequate access to food. This situation is closely linked to structural factors such as poverty, which affects 25.8% of the population, and limited the accessibility to a healthy diet. These conditions contribute to ongoing food and nutrition insecurity in Ecuador (7).

Moreover, data from the National Health and Nutrition Survey (ENSANUT-ECU) in 2012 reveal critical deficiencies in dietary patterns. On average, Ecuadorians consume only half of the daily recommended intake of fruits. Similarly, protein consumption is low and does not meet daily needs. In contrast, the intake of carbohydrates and fats exceeds recommended levels. These nutritional gaps are more pronounced among households in the lowest quintile, underscoring the strong correlation between socioeconomic status and the fulfilment of daily dietary requirements (8).

On the other hand, the World Health Organization (WHO) notes that after years of global "stability," the world's percentage of people experiencing hunger increased dramatically in 2020 and continued to rise in 2021, reaching 9.8%; this reflects the negative impact of the pandemic on the global economy and people's quality of life (5). In the Latin American context, the Pan American Health Organization (PAHO) highlights that 22.5% of the population in the region does not have sufficient resources to access a healthy diet, with economic and social factors being the main determinants (4).

As for Ecuador, after the pandemic the economy experienced substantial transformations, including an increase in the Consumer Price Index (CPI) and a monthly inflation of 0.36%, directly affecting the costs of basic food items (9, 10); furthermore, Ecuador's annual inflation rate has experienced significant fluctuations: in 2021 this rate was 0.13%, followed by 3.47% during 2022 and 2.22% in 2023 (11). This economic impact might have limited the access to essential foods for a balanced diet for the population, generating the need for a comparative analysis between the costs of a healthy diet and the costs of a regular diet according to the basic family basket (BFB) established by the Ecuadorian government. Therefore, in this context, our research focuses on determining the real costs of a healthy diet in Ecuador, specifically in Quito and Guayaquil, to determine the accessibility for a family of two adults.

2 Materials and methods

We conducted a descriptive cross-sectional study by applying a healthy diet model that was designed based on foods reported from the Ecuadorian basic family basket (BFB) and by considering standard nutritional recommendations. The BFB was created by the Ecuadorian government and the National Institute of Statistics and Census (INEC) and is defined as a set of goods and services that are essential to meet the basic needs of a household composed of 4 members with 1.6 income earners, who earn the unified basic salary ($450 USD as of 2023). The foods and their respective categories included in the BFB are presented in Table 1 (12).

The representation of a healthy plate, according to food-based dietary guidelines of Ecuador (GABA, according to its acronym in English), is depicted in the shape of a wooden spoon, symbolizing the integration of essential foods for a balanced and culturally appropriate diet that promotes healthy eating habits. This spoon visually illustrates the 11 recommendations for a healthy diet and lifestyle (6). The spoon bowl is divided into four sections: the green section (approximately 50%) corresponds to fruits and vegetables such as bananas and tomatoes; the blue section (approximately 20%) emphasizes grains and cereals like rice and potatoes; the purple section (approximately 20%) represents protein sources like eggs and chicken; and the beige section (approximately 10%) depicts fat-rich foods like avocado (6). Additionally, the handle of the spoon emphasizes commensality, promoting Ecuadorian food production, as well as the importance of safe drinking water. The outer edge of the spoon promotes physical activity, including running and swimming. Besides, a separate circular area highlights foods that should be avoided, such as candies. Some of these characteristics of the spoon, along with the 11 recommendations, were considered in the development of our diet (6). In this regard, we created our healthy diet model based on the following standard nutritional recommendations: 2000 kcal per day divided into 55% carbohydrates, 20% protein and 25% fat (13, 14). The portion sizes in the diet were established from the WHO, other international agencies and food-based dietary guidelines of Ecuador (GABA) whose portions are shown in Table 2 (15–18).

With this data, a diet adjustment was made to fulfil 90 to 105% of the daily nutritional requirements for a complete month for two average adults consuming 2000 kcal per day each, considering that 1 gram of carbohydrate is equivalent to 4 kcal, 1 gram of protein is

TABLE 1 Comparison of basic family basket (BFB) and healthy diet models adjusted to fulfil 90–105% of the daily requirements: food items and portions for two people, for one month.

Category	BFB model (Characteristics of collected information)	Healthy model (Characteristics of collected information)	Monthly amount based in BFB portions for two people	Monthly amount of healthy portions for two people
Grains and derivatives	White rice	Brown rice	500 grams	2,240 grams
	White wheat tagliatelle (egg-free)	Whole wheat tagliatelle noodles	500 grams	1493.36 grams
	White loaf bread with crust	Whole wheat loaf bread with crust	500 grams	1493.36 grams
Meat	Meat with bone		500 grams	
	Meat without bone, brisket or steak cut	Beef loin cut	500 grams	1920 grams
	Chicken (different of skinless)	Skinless chicken breast	500 grams	3,840 grams
Fish and seafood	Fish (Albacore, tilapia, dorado and snook)	Corvina fish	500 grams	1,600 grams
	Canned tuna with oil	Canned tuna in water (sodium <10% of the daily value)	92 grams	1,600 grams
Edible fats and oils	Vegetable palm oil	Cold-pressed olive oil (dark glass bottle)	500 milliliters	480 grams
	Vegetable shortening (margarine)		250 grams	
Milk, dairy products and eggs	Chicken egg	Chicken egg	500 grams	3,080 grams
	Whole milk	Semi-skimmed milk	500 milliliters	21,000 millilitres
	Fresh cheese	Fresh cheese	500 grams	4,400 grams
Fruits	Avocado	Avocado	500 grams	1493.36 grams
	Lemon	Lemon	500 grams	1493.36 grams
	Orange	Orange	500 grams	1493.36 grams
	Banana	Banana	500 grams	1493.36 grams
	Naranjilla	Naranjilla	500 grams	1493.36 grams
	Plantain	Plantain	500 grams	1920 grams
Vegetables	Green peas	Fresh green peas	500 grams	1920 grams
	White onion	White onion	500 grams	1920 grams
	Red onion	Red onion	500 grams	1920 grams
	Corn	Corn	500 grams	1920 grams
	Beans	Fresh beans	500 grams	1920 grams
	Fava beans	Fresh fava beans	500 grams	1920 grams
	Tomatoes	Tomatoes	500 grams	1920 grams
Tubers and derivatives	Potatoes	Potatoes	500 grams	12,600 grams
	Yucca	Yucca	500 grams	12,600 grams
Legumes and derivatives	Lentils	Lentil	500 grams	8,960 grams
	Dry beans	Dry beans	500 grams	4,480 grams
	Peanuts		500 grams	
Coffee, tea and soft drinks	Sugar	White sugar	500 grams	2,400 grams
	Salt	Common salt	1,000 grams	280 grams
	Instant coffee	Artisanally ground coffee beans	500 grams	990 grams
	Gelatin powder	Unflavored gelatin powder (High in protein, low in sugar, and free of trans fats)	42.5	40 gr

equivalent to 4 kcal and 1 gram of fat is equivalent to 9 kcal. As part of the adjustments, we used raw versions of protein items and cooked versions of carbohydrate foods. For the diet adjustment, we based on "Ecuadorian Food Exchange List" of the dietary guidelines of Ecuador (6). The portions are shown in Table 1, along with the healthy version of each food chosen in our model.

Evidently, not all the products listed in the BFB could be considered as part of a healthy diet; therefore, we removed

TABLE 2 Portion guidelines and serving frequency for a healthy diet.

Food item	Recommended portion	Number of servings
Cereals	40 grams	2 servings/day
Chicken meat	120 grams	4 servings/week
Beef	120 grams	2 servings/week
Fish	100 grams	2 servings/week
Canned tuna	100 grams	2 servings/week
Fats and oils	5 grams	2 servings/day
Milk	250 milliliters	3 servings/day
Cheese	44 grams	2 servings/day
Eggs	55 grams	1 serving/day
Fruits	80 grams	2 servings/day
Vegetables	80 grams	3 servings/day
Tubers	150 grams	2 servings/day
Legumes	80 grams	3 servings/day
Sugar	15 grams/day	Not applicable
Salt	5 grams/ day	Not applicable
Coffee	80 grams	4 servings/day
Gelatine	240 mL	1 serving/week

margarine and soda drinks, similarly peanuts were removed because they exceeded the recommended daily fat percentage, and other products were exchanged for their healthier counterparts. Additionally, we also modified the BFB diet into a "healthy BFB diet," taking into consideration the average Ecuadorian diet and portions considered in the BFB but including healthy options of each food item based in evidence (Table 2) (19–26). Therefore, for our analysis, we created three types of diet: a regular diet according to BFB recommended portions, regular diet with healthy portions (healthy BFB), and our healthy diet model for two adults for one month; we also report the costs of alimentation according to INEC (open data published) adjusted for two people (https://www.ecuadorencifras.gob.ec/informacion-historica-ipc-canastas-2023/).

The lowest and highest prices of the regular and healthy versions of the aforementioned food items were collected during field visits to six supermarkets in both Guayaquil and Quito (the two most densely populated cities of Ecuador); each supermarket was identified by a letter in order to preserve anonymity. The sample included a mix of high-end, mid-range and low-end supermarket chains to obtain diverse data about prices in urban areas. Supermarkets B and D were classified as lower mid-range, supermarket F as low-end, C as mid-range, E as upper mid-range and supermarket A as high-end. It is important to consider that the classification of supermarkets by market tier refers to their general pricing strategy, target consumer base, and product variety.

To identify the cheapest and most expensive options of every food item, each data collector divided the product's price by its weight in grams to calculate the cost per gram. This approach ensured that differences in package sizes did not interfere with accurately determining the lowest and highest price of each product. We determined specific characteristics of the products to avoid significant price, as detailed in Table 1. The collector recorded both the minimum and maximum costs, along with their corresponding weights in grams. This process was carried out for every food item in each supermarket. The data was collected using the Kobo ToolBox software, after which the information was downloaded into an Excel spreadsheet for data handling and quality checks. For comparison with official data, we used the value of alimentation expenditure component of the BFB to September 2023 obtained from the website of the INEC.

We calculated the average cost of the healthy diet overall and for each city. We determined the monthly and daily cost of a healthy diet for one person. To assess affordability, we considered the premise that, according to previous studies, an affordable diet must represent an expense of less than 30% of the family's income (27). In this context, we calculated the ratios between the cost of the diets (healthy and regular) and the basic monthly salary of a person for September, 2023 in Ecuador. Additionally, we compared the monthly cost of the healthy diet for one person with income quintiles based on the latest published information.

3 Results

Our analysis of the data collected reveals an important gap between the affordability of a regular diet and a healthy diet in both Quito and Guayaquil.

Regarding the analysis of diets by supermarket, it is noted that, in all supermarkets, our healthy diet model was more expensive compared to the other diets. In addition, the cost of the regular diet with BFB portions is much lower than the other diets; when looking at the minimum cost analysis for this diet, supermarket F (low-end) offered the most economical option with $59.46, while supermarket A (high-end) was the most expensive with $72.51. In comparison, when looking at the maximum cost, supermarket C (mid-range) was the most economical and supermarket B (lower mid-range) was the most expensive with $75.66 and $126.56, respectively. On the other hand, for our healthy diet model, when looking into the minimum cost analysis, the most expensive option was supermarket A (high-end) with $348.22 and the most economical was F (low-end) with $264.81; while, in terms of maximum cost, the most expensive supermarket was A (high-end) with $476.46 and the most economical was supermarket E (upper mid-range) $366.56. The minimum and maximum costs for the three analysed diets per month for two adults, stratified by supermarket can be found in Figure 1.

In terms of the analysis by food category, Figures 2–4, report the prices overall, in Guayaquil, and in Quito, respectively. Each figure shows the price of a regular diet reported in the BFB by the INEC; the minimum and maximum cost of the regular diet with BFB portions; the minimum and maximum cost of the regular diet with healthy portions; and the minimum and maximum cost of our healthy diet model. All costs are based on diets for two adults for one month.

The most expensive category of the regular diet reported in the BFB by the INEC was "grains and derivatives" with an overall price of $28.29 ($24.80 for Guayaquil and $33.46 for Quito) followed by "meats" with $20.66 ($23.28 for Guayaquil and $21.26 for Quito) (Figures 2–4); "grains and derivatives" were more expensive in Quito (Figure 4), while "meats" were more expensive in Guayaquil (Figure 3). In contrast, when looking at our collected data from the supermarkets,

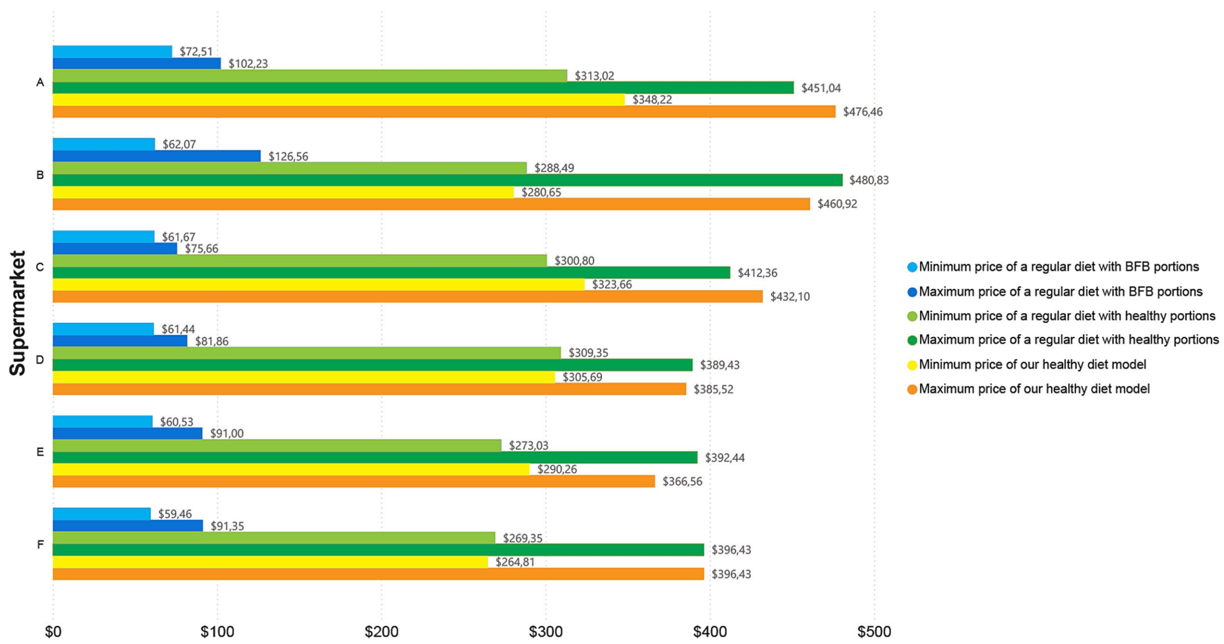

FIGURE 1
Overall price by supermarket, showcasing minimum and maximum cost of the three analysed diets per month for two adults.

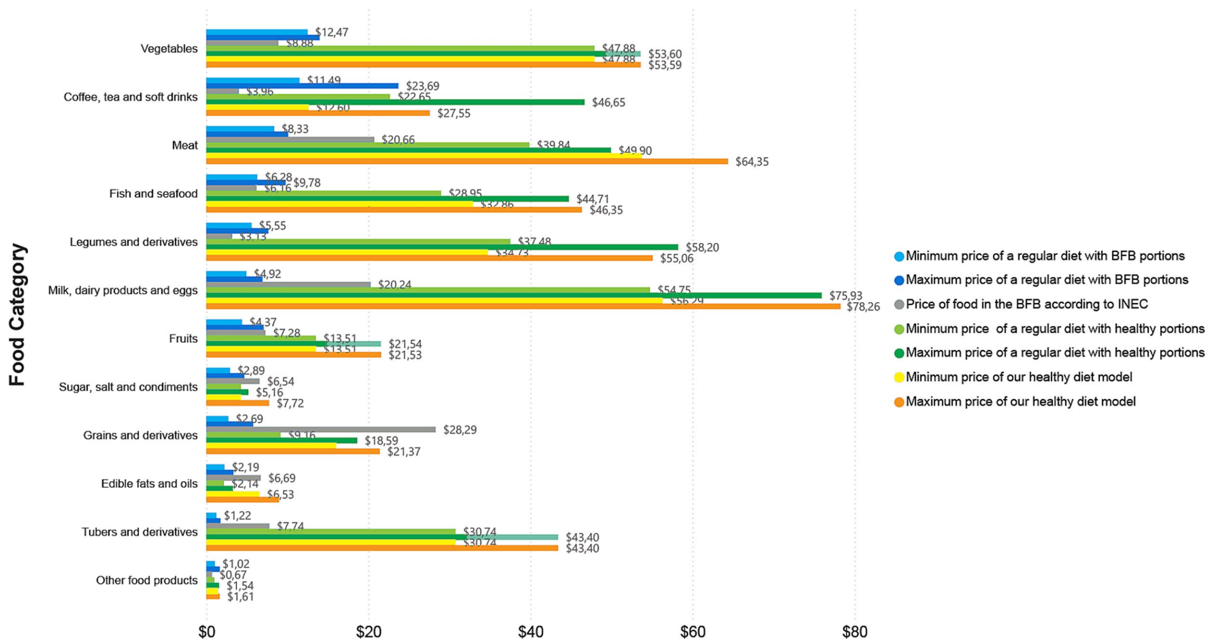

FIGURE 2
Overall price by food category, showcasing minimum and maximum cost of the three analysed diets per month for two adults.

we divided food prices into minimum and maximum cost; in the minimum cost (overall price) group of the regular diet with BFB portions, the most expensive food category was "vegetables" ($12.47) and "coffee, tea and non-alcoholic beverages" ($11.49) (Figure 2). The same categories were the most expensive when looking at the minimum and maximum cost of the regular diet with BFB portions both in Guayaquil and in Quito; in the latter, however, "coffee, tea and non-alcoholic beverages" were more expensive than "vegetables" (Figures 2,3).

When looking overall price at the regular diet with healthy portions at minimum cost, the most expensive categories were "milk, dairy products and eggs" with $54.75 followed by vegetables with $47.88 (Figure 2); the same occurred in Quito ($56.88 and $45.58, respectively), while in Guayaquil the most expensive was still "milk,

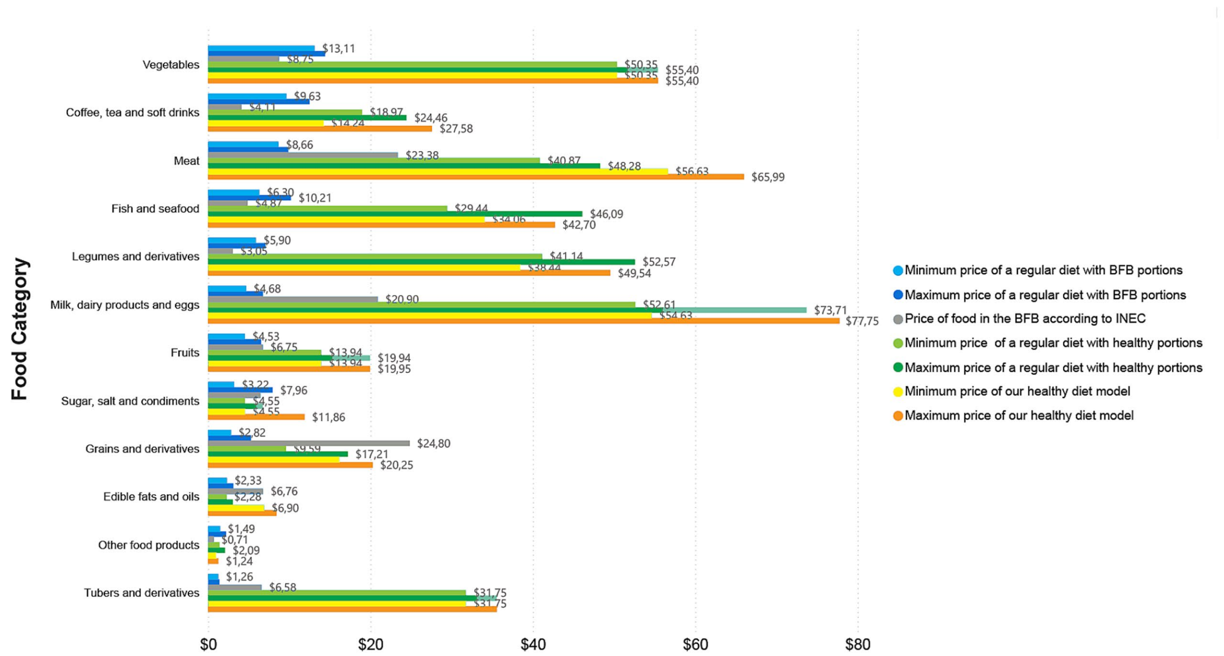

FIGURE 3
Price by food category in Guayaquil, showcasing minimum and maximum cost of the three analysed diets per month for two adults.

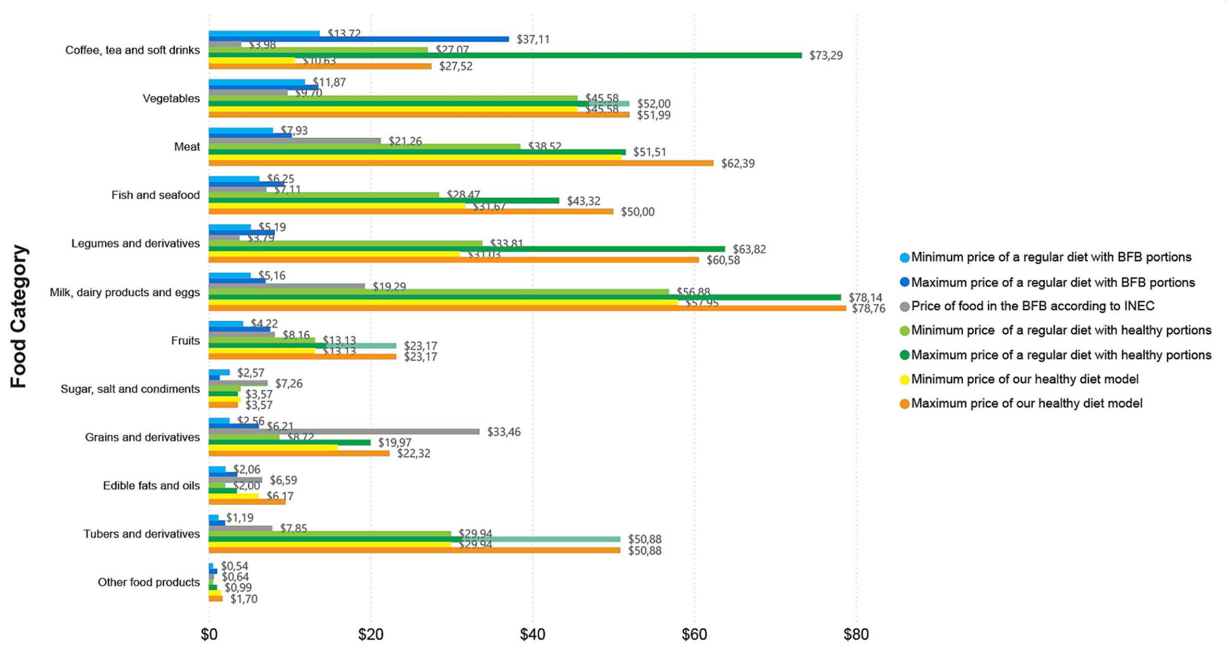

FIGURE 4
Price by food category in Quito, showcasing minimum and maximum cost of the three analysed diets per month for two adults.

dairy products and eggs" with $52.61, but followed by vegetables with $50.35 (Figures 2,3). The maximum cost for a regular diet with healthy portions kept the category "milk, dairy products and eggs" as the most expensive overall with $75.93, followed by "legumes and derivatives" with $58.20 (Figure 2); in Quito and in Guayaquil "milk, dairy products and eggs" were the most expensive with $78.14 and $73.71, respectively (Figures 2,3). In Guayaquil, "vegetables" took the second place with $55.40, while in Quito, "coffee, tea and non-alcoholic beverages" were the second most expensive with $73.29, (Figures 2,3).

On the other hand, when assessing our healthy diet model, a similar trend appeared, with "milk, dairy products and eggs" being the most expensive category (in both minimum and maximum cost) overall and for Quito (Figures 2,4); "meats" represented the second most expensive category (in both minimum and maximum cost) overall and in Quito, while being the most expensive (when looking at the minimum cost) and the second most expensive (when looking at maximum cost) in Guayaquil (Figure 3). Finally, in Guayaquil, the second most expensive category, in our minimum cost analysis was "milk, dairy products and eggs" with $54.63 and the first most expensive with $77.75 when looking at maximum cost (Figure 3).

In our comparison of diets, we noted that the sole category with a higher cost, as indicated in the BFB by the INEC, was "grains and derivatives." Its prices exceeded those of this category in both the regular diet with healthy portions and our healthy diet model. This trend was evident in both the overall analysis and in individual cities (Quito and Guayaquil). In the remaining categories, the cost of a regular diet with healthy portions or our healthy diet model consistently exceeded the prices recorded in the BFB by the INEC. Furthermore, "legumes and derivatives" constituted the sole category where the expense of a regular diet in healthy portions exceeded that of our healthy diet model; conversely, in all other categories, the cost of our healthy diet model surpassed that of the regular diet with healthy portions (Figures 2–4).

Regarding overall food expenses, when looking into individual food items required per month for two adults, in the regular diet with BFB portions at minimum cost, the priciest items were coffee ($11.40) and fish ($5.65), while at maximum cost, they were $23.43 and $8.83, respectively. In the regular diet with healthy portions, the most expensive items at minimum cost were cheese ($24.76) and coffee ($22.56), while at maximum cost were coffee ($46.39) and cheese ($37.20). In our healthy diet model, the priciest items were chicken at $27.63 and boneless beef at $26.12 (when looking at the minimum cost), whereas the most expensive items in the maximum cost analysis were cheese at $37.20 and fish at $32.74.

In general, the cost of the regular diet per month for two adults with the portions recommended in the BFB was lower than the other healthier diets, with the minimum cost being $63.26 and the maximum cost being $95.96; the same pattern can be seen when looking at each city (Figure 5). However, when analysing the same regular diet per month for two adults but in healthy portions, a significant increase is seen, with the minimum and maximum costs raising to $291.70 and $421.71, respectively. In turn, when comparing this latter diet with our healthy diet model, there is not much difference in terms of the maximum cost (regular diet with healthy portions: $421.71; healthy diet model: $428.99); but there is a difference of $18.27 when comparing the minimum cost (regular diet with healthy portions: $291.70; healthy diet: $309.97) (Figure 5). Interestingly, in Quito, the maximum cost of our healthy diet model was lower than the maximum cost of the regular diet in healthy portions ($442.18 and $463.94, respectively) with a difference of $21.76 (Figure 5). In contrast, in Guayaquil, the difference between our healthy diet model and the regular diet with healthy portions is greater, with the minimum cost of the regular diet with healthy portions being $295.65 and that of our healthy diet model being $321.37, that is, a difference of $25.72; while at the maximum cost the difference was $31.14 (Figure 5).

It should be noted that diets were more expensive in Quito than in Guayaquil, except in minimum cost analysis of our healthy diet model, which was $298.67 in Quito and $321.37 in Guayaquil (Figure 5). A healthy diet in Guayaquil costs on average $368.19 for two adults per month ($184.10 per person), while in Quito the average is $370.43 for two adults per month ($185.22 per person). Our overall analysis revealed that the cost of the proposed healthy diet model was $184.74 per person per month. In this sense, a healthy diet per month for two adults in Guayaquil is $240.23 more expensive than the budgeted amount reported in the BFB ($127.96, adjusted for two people), while in Quito an extra $230.09 is required to eat healthy (per month for two adults) on top of the reported $140.34in the BFB adjusted for two people.

Additionally, the average daily cost of a healthy diet per person in Guayaquil was $6.14 and in Quito it was $6.17. While the daily cost of alimentation stipulated by the BFB is $2.13 in Guayaquil and $3.83 in

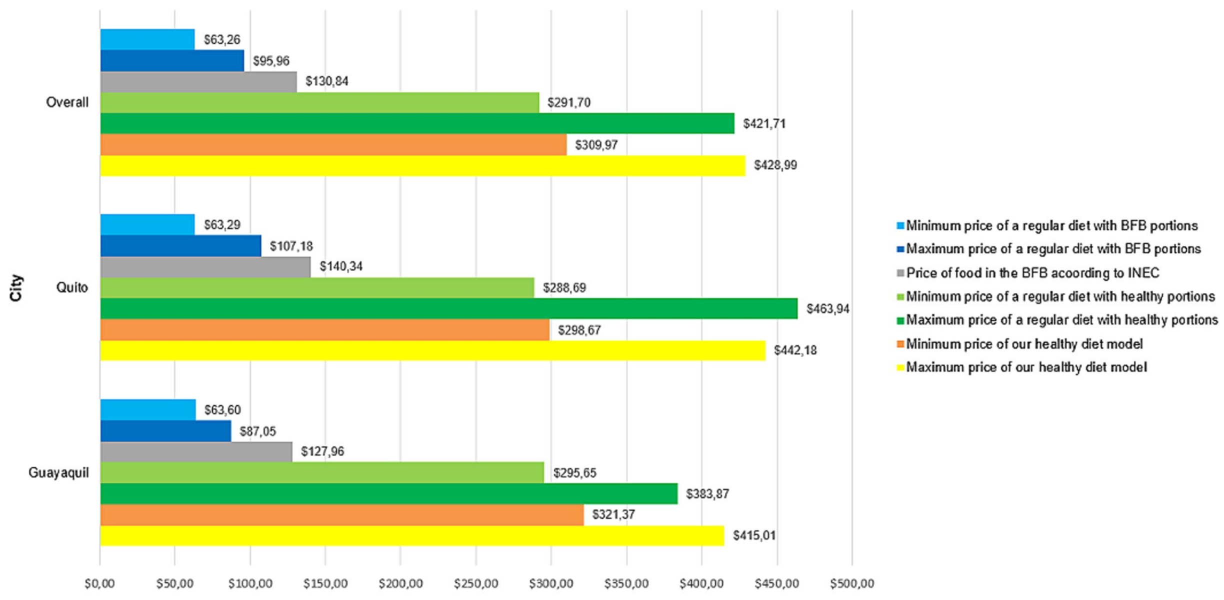

FIGURE 5
Total price, in general and by city, showcasing minimum and maximum cost of the three analysed diets for two adults.

Quito which represents $4.01 and $2.34 daily additional, respectively. Moreover, considering that the unified basic salary of Ecuador in 2023 was $450.00 (28), a person from Guayaquil or Quito would need to spend 41% of their wages to access a healthy diet; much more than the calculated 14.5% of the BFB. Even if we consider the average of the regular diet with healthy portions, an Ecuadorian worker would have to invest 39.63% of the unified basic salary to obtain it (Figure 5).

Finally, to incorporate the socioeconomic factor, we calculated the percentage of income required to afford a healthy diet according to income quintiles in Quito for the year 2022 (this information is not available for Ecuador as a whole or for 2023) (29). In this regard, a person in the first quintile (Q1) would need 378% of their income ($49) to afford a healthy diet; for the second quintile, that percentage would be 185.22% (based on an income of $100) and for the third quintile, 120.27% (income of $154) (29). Individuals in the fourth quintile (income: $244) would need to allocate 75.91% of their incomes, which also exceeds the range of affordability an affordable diet must represent less than 30% of the income (27). Consequently, only people in the fifth quintile (income: $658) can afford a healthy diet, spending 28.15% of their income (29).

4 Discussion

Our study determined that, in Ecuador, acquiring a healthy diet is more expensive than the reported regular diet in the Basic Family Basket (BFB) created by the Ecuadorian National Institute of Statistics and Census (INEC); it represents an investment of 41% of the unified basic salary of $450. The observed differences in cost of each diet are related to the nutritional quality ant the quantity of the food items required to meet nutritional requirements. In this regard, the healthy diet model includes higher-quality and less processed food, which generally have a higher price in our context. For instance, in the meat category, the healthy diet model includes skinless chicken and beef loin cuts, in line with international recommendations that promote lean protein intake and limit high-fat animal products. Another example is the used of semi-skimmed milk and cold-pressed olive oil in dark glass bottle in the healthy model to improve dietary quality; however, these items are more expensive than the refined and ultra-processed versions included in the BFB. Furthermore, the portion sizes in the healthy model are adjusted to align with the GABA guidelines and international recommendations, in order to provide a diet for two average adults with an energy requirement of 2000 kcal per day each one. This involves increasing the frequency or quantity of certain food categories. Although these changes offer nutritional benefits, they also contribute to increases cost of the healthy diet. On the other hand, our study reveals that only people in the highest income quintile can afford the healthy diet model. This highlights the economic challenges faced by average Ecuadorian households in accessing nutritionally adequate diets in a context of food insecurity and income inequality.

This is not the first report of the cost of healthy eating in the South American or Hispanic region. For instance, Verdugo et al. made a comparison between a healthy diet according to the Chilean food-based dietary guidelines and an unhealthy diet, using the minimum prices taken from a list established by the retail price regulatory agencies of their country in 2015; they determined that, a healthy diet was significantly more expensive than the unhealthy option ($p < 0.001$) even when corrected by caloric density (the unhealthy option had a lower cost per kilocalorie than the healthy option) (30). Similarly, Bouzas et al. (31) in their 6-year, parallel-group randomized clinical trial that included 6,838 Spanish adults with metabolic syndrome, found a directly proportional relationship between the quality of a diet (and its potential benefits) and its price; the higher the price, the greater the intake of healthy foods such as vegetables, whole grains and fruits, whereas the most economical diets were characterized by higher energy density foods (i.e., unhealthy food with higher kilocalories).

The cost of our healthy diet model in Ecuador for one person, as of September 2023, is $184.74 per month ($6.16 daily), this value is, approximately, two times higher than that published in June 2022 by the local newspaper "Primicias" that reported a value of $87.90 (32). This newspaper based its article on the report entitled "The State of Food Security and Nutrition in the World 2022" published by the Food and Agriculture Organization of the United Nations (FAO) (33); in this report, the calculated global daily cost of a healthy diet was $3.54, so that approximately 3.1 billion people, globally, cannot acquire an adequate diet due to this economic constrain (33). In addition, in Latin America and the Caribbean the cost was higher, at $3.89, being the region with the highest cost in acquiring a healthy diet (our calculated diet was $2.27 more expensive) (33). In comparison to this report, our study takes into account local variations in food prices across the two major cities in Ecuador, whereas the global report by FAO provides an average cost of healthy diets that may not accurately reflect the actual expenses faced by Ecuadorian households; furthermore, their report used purchasing power parity (PPP) dollars to compare the acquisition of goods between countries (33), which may not entirely represent the real expenditure in local currency (34, 35). The difference between this report and our study suggests that the cost of a healthy diet in Ecuador may have increased substantially in the past years, mirroring trends observed globally where the prices of nutritious foods have risen at a faster pace than those of less healthy options (36). This rapid increase in the price of healthy foods relative to less healthy alternatives exacerbates the already significant financial barriers faced by low-income populations in accessing a nutritious diet (37, 38). Regardless of the source, it is clear that accessing a nutritious, sustainable, and healthy diet represents a substantial economic burden for the average Ecuadorian employee (33, 35). It is essential to note that our study focused only on the prices of food items, without considering other associated costs such as preparation, storage, or transportation that could further increase the total expenditure required for a healthy diet.

Other studies have analysed the cost of healthy eating in a similar fashion as ours. For instance, Lee et al. conducted a study in Sydney and Canberra with data collected from November to December 2015; they divided the population into socioeconomic quintiles, with the first quintile being the families with the lowest income and fifth quintile being the families with the highest income. They reported that food was more expensive in Sydney compared to Canberra and that a regular diet was more expensive than a healthy one; also, families in the lowest quintile had greater difficulties in acquiring healthy food (27, 39). Another study done by Bracci et al. (40), in the same country, comparing the usual western diet, the diet based on dietary guidelines, and the Mediterranean diet between October and November 2022, determined that all the diets studied were affordable for the population considering that a typical person (single woman aged 30) earns

AUD$1,835 per week and that the costs of the analysed diets ranged from AUD$75–80 (40). The aforementioned studies showed that healthy eating is affordable in Australia, which is not surprising given that the median weekly earnings are AUD$1300 (AUD$5200 per month), and the minimum wage, as of 2024, is AUD$915.9 weekly (AUD$3663.6 per month) 8 times higher than the basic monthly salary for an Ecuadorian employee (USD$450) (41, 42). In contrast, Van et al. conducted a study in several regions of Vietnam, based on the Vietnamese healthy dietary guidelines and extracting prices from national and regional databases from 2016 to 2020 (43). They concluded that, although acquiring this diet has been more feasible over the years included in the analysis, the acquisition gap of the population in the lowest socioeconomic quintile has remained unsustainably high (on average 68.4% of this group cannot acquire a healthy diet) (43). Finally, Rao et al. in their systemic review analysing healthier foods and diets from 27 articles written in English and published until 2011, the difference between healthier and less healthier options was $1.49, denoting that, although the gap is smaller than in our article, the healthy diet remains more expensive than the usual one (36). In Ecuador, as of April 2023, the rate of unemployment was 4.2%; however, only 35.2% of those employed earn the same as or higher than the unified basic salary (UBS) ($450), 50.2% earn less than the UBS, and 10.4% are employed but receive no salary according to the INEC (44). Meaning that, in Ecuador, 64.8% of the population could not afford a healthy diet, as of April 2023.

The analysis by supermarkets highlights the significant influence the retail environment has on the affordability of a diet. The healthy diet model was the most expensive across all supermarkets, reinforcing the economic challenges associated with adopting an adequate diet in Ecuador. The supermarket classified as low-end offered the lowest prices across all diet types (in minimum price), making it more affordable for low-income populations. Nevertheless, even in this store, the cost of a healthy diet was substantially higher than the regular diets. On the other hand, regular diet with BFB portions was cheaper in the mid-range and low-end supermarket. This may reflect limited nutritional quality but greater affordability. Moreover, the high-end supermarket has the highest minimum cost for the healthy diet model, raising concerns about the affordability of healthier options.

4.1 Limitations

One of the limitations of this study is that it is a cross-sectional analysis, so the prices were only collected at a single point in time, which may not reflect variations throughout the year or over time. Additionally, the prices were obtained from major supermarket chains, which may not represent the full range of food prices available in the cities studied. Another limitation is that the study did not take into account factors that may influence food prices, such as seasonality, transportation costs, or local market dynamics. For instance, it may be necessary to include local markets, community fairs, or bulk-buying options, where prices could be considerably lower. In this regard, the study may have overestimated the actual cost of a healthy diet. Moreover, this study proposed a healthy diet model based on the nutritional requirements for two healthy adults, without considering specific diseases or conditions, or the dietary needs associated with each life stages such as childhood, adolescence and older adulthood. Consequently, these findings may not be generalizable to all Ecuadorian households. Future research should incorporate specific dietary requirements of families with children or relatives with special nutritional needs to provide a realistic understanding of the affordability of a healthy diet in Ecuador.

Finally, the dietary adjustment does not account for the fibre content of the foods used, due to the absence of this information in the "Ecuadorian Food Exchange List" from the Ecuadorian dietary guideline. In addition, no adjustments were made for yield and food waste between the purchase and consumption, especially for fruits and tubers. Nevertheless, for the determination of the nutritional contribution, raw versions of protein sources and cooked versions of carbohydrates sources were used. Even though this affects the weight of the food, it does not significantly influence the nutritional value of the food items.

5 Conclusion

Our study underscores the substantial discrepancy in the affordability of regular vs. healthy eating in Ecuador, especially in its principal cities, Quito and Guayaquil. The results indicate that nutritious diets are consistently pricier than conventional diets. The regular diet with quantities recommended by the Basic Family Basket (BFB), which does not provide sufficient nutrients to be considered healthy, is significantly more economical than both a healthier variant of the standard diet and our suggested healthy diet model. The examination of food categories indicates that the most expensive components of a balanced diet are generally milk, dairy products, and eggs, succeeded by meats and vegetables, with notable price discrepancies between Quito and Guayaquil. The study also revealed that the financial strain of obtaining a healthy diet is significant, necessitating almost 41% of the unified basic salary (UBS), much above the 14.5% projected for a standard diet by the BFB; considering that 64.8% of the population earn less than the UBS, healthy eating in Quito and Guayaquil is not feasible.

This economic limitation is not exclusive to Ecuador; analogous findings from other locations suggest that the expense of nutritious diets is a worldwide concern, particularly for low-income demographics. The elevated cost of healthy foods intensifies the difficulties faced by many Ecuadorians, especially considering the country's income inequalities. The study highlights the pressing necessity for governmental initiatives to enhance the accessibility and affordability of nutritious meals for all Ecuadorians, in light of these financial obstacles.

Furthermore, our findings highlight the pressing need for governmental action to reduce the affordability gap. First, subsidies or tax exemptions for essential healthy foods (such as dairy, lean proteins, and vegetables) could alleviate costs for consumers. Second, policies to strengthen local food systems and support direct trade between producers and consumers may reduce intermediaries and lower final prices. Third, integrating affordability targets into the existing Ecuadorian Food-Based Dietary Guidelines (GABA) would help align nutritional recommendations with socioeconomic realities. Finally, urban planning strategies, such as incentivising community markets and public procurement of local produce, could enhance accessibility of healthy foods for vulnerable groups. Finally, in terms of research, future studies should consider the environmental impact in the cost of different diets. Additionally, future investigations could explore the long-term health outcomes associated with both the regular and healthy models. It is also relevant to consider consumer behaviour and food preferences when adjusting the healthy diet, because these factors can influence its adoption. Integrating affordability and cultural acceptability into the healthy diet model is essential to address both undernutrition and the increasing prevalence of non-communicable diseases in low- and middle-income countries.

Data availability statement

The datasets for this article are not publicly available due to concerns regarding participant/patient anonymity. Requests to access the datasets should be directed to the corresponding author.

Ethics statement

The study was approved by the Biomedical Ethics and Research Committee of King Abdulaziz University, Jeddah, Saudi Arabia (reference number 220-22). All procedures were conducted in accordance with local legislation and institutional requirements. Written informed consent was obtained from all participants.

Author contributions

LG-P: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. LA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. GA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. DO: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. DA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. JG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. VH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. NP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. MT: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. CC: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. FR: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. CG: Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing – original draft, Writing – review & editing. JL-R: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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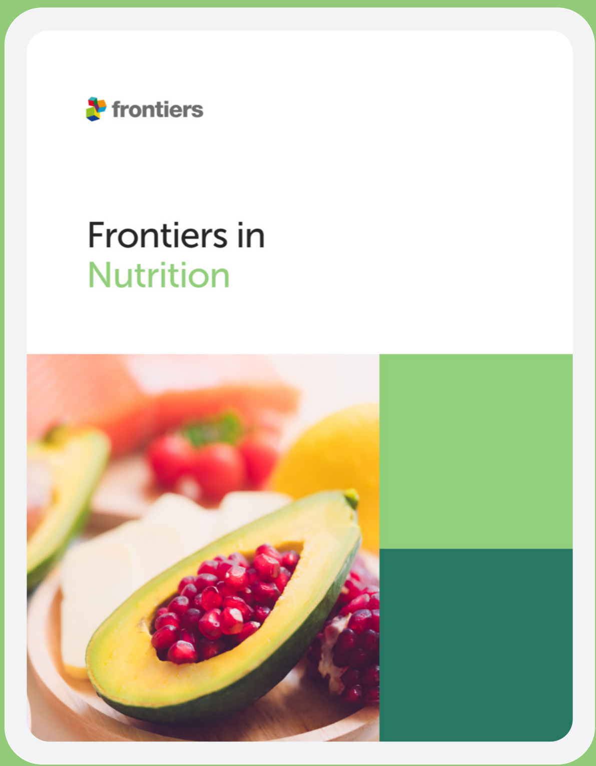

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