



How supportive is the global food supply of food-based dietary guidelines? A descriptive time series analysis of food supply alignment from 1961 to 2013

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ARTICLE INFO

Keywords:

Food supply
Dietary guidelines
Food environment
Global health
Structural
Determinants of health

ABSTRACT

Background: FAO/WHO have encouraged national governments to create food-based dietary guidelines (FBDGs) to support healthy diets. However, little is known about the extent to which food supply composition aligns with FBDGs, thereby structurally supporting or undermining population-level adherence. It is also unclear how this alignment has evolved over time. The aim of this study was to determine to what extent the global food supply aligns with FBDGs, and to examine historical trends.

Methods: Descriptive time series analysis of food supply alignment (FSA), 1961–2013. FSA was characterised as a ratio dividing country-level food supply data by FBDG across four food groups: fruit and vegetables (FV); sugar (SU); fish and seafood (FS); and red and processed meat (RP). FBDG data was collected from guidance produced by international bodies, and from countries with published FBDGs. The food supply was estimated using yearly FAOSTAT data. A population-weighted average of this ratio was created for all countries included in the analysis, and stratified by region and country income.

Findings: FBDGs from 89 countries were included. Of those, 80% had country guidelines for FV, 34% for SU, 44% for FS, and 21% for RP. FSA (1.0 = perfect alignment) based on global guidelines showed a higher supply than recommended for FV (1.2), SU (1.2) and RP (1.1). FSA based on country guidelines showed a lower supply than recommended for FV (0.9) and a higher supply than recommended for SU (2.3), RP (2.3) and FS (1.4). FSA also showed substantial differences in levels and trends across region and country income.

Interpretation: As of 2013, food supplies were not aligned with national and international FBDGs and misalignment persisted across five decades with substantial variation in trends based on geography and country income. The long running nature of these trends suggest that the transition toward sustainable and healthful food systems represent a significant global challenge. Additionally, acknowledging the degree of misalignment between macro-level structural factors, such as the composition of the food supply, in relation to national or global food policy aims may further aid efforts for population level adherence.

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<https://doi.org/10.1016/j.ssmph.2021.100866>

Received 31 March 2021; Received in revised form 3 June 2021; Accepted 4 July 2021

Available online 6 July 2021

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Key questions

What is already known?

- Poor diet makes a substantial contribution to the global burden of disease and to health inequalities.
- There is an increasing emphasis on tackling the structural determinants and aligning food systems with healthy and sustainable diets.
- National governments and international organisations publish food-based dietary guidelines, but little is known about whether the food supply structurally supports or undermines population-level adherence to these guidelines.

What are the new findings?

- The global food supply is in many cases misaligned with dietary guidelines from both national governments and international organisations.
- An overall increase in the global supply of food between 1961 and 2013 has led to greater alignment with dietary guidelines for fruit and vegetables, but less alignment for sugar and red and processed meat.
- The alignment of the food supply with dietary guidelines varied substantially between countries in different regions and income categories.

What do the new findings imply?

- The misalignment of the food supply with dietary guidelines presents a significant global challenge for efforts to improve the sustainability and healthfulness of food systems.
- This work highlights the long standing nature of this misalignment and the importance of considering macro-level structural factors such as the food supply in supporting population health policies.
- The metric of ‘food supply alignment’ presented here could be a useful tool for surveillance and policy evaluation.

Introduction

The need for food policy, systems, and environments that support health and sustainability.

Improving diets worldwide is a priority given the substantial contribution of poor diet to the global burden of disease. Many of the world’s populations over- or under-consume particular foods and nutrients relative to recommendations for a healthy diet (Murray et al., 2020). A higher quality diet is associated with a reduced risk of a variety of chronic diseases and a decreased risk of death (Sotos-Prieto et al., 2017).

In attempting to support individuals in eating more healthily, experts have placed growing emphasis on tackling the structural determinants of diet by improving food policies, systems, and environments. It is increasingly acknowledged that food selection and dietary behaviour is driven by a complex set of social and economic influences. As a result, poor diet and related health outcomes are socially and economically patterned, with the most deprived having, on average, the poorest quality diet (Darmon & Drewnowski, 2015; Siddiqui et al., 2020).

In particular, recent movements have increasingly considered the role of food access in determining dietary intake, and inequities in dietary intake and related health outcomes (Caspi et al., 2012). These inequities extend to food availability, which refers to the adequacy of the supply of healthy food. In the public health literature, food availability typically includes dimensions such as the neighbourhood food environment, meaning the presence or absence of different food outlets in a neighbourhood or the availability of products within food outlets (Caspi et al., 2012). Further upstream, the food supply, impacted by

trade and agricultural policy, as well as commercial actors and consumer demand, feeds into food availability at the retail level (Barlow et al., 2020; Hawkes, 2006).

In high-income countries, and increasingly in low- and middle-income countries, the over-abundance of cheap, energy-dense, nutrient-poor foods in the food supply is likely a contributor to low diet quality at the population level (Darmon & Drewnowski, 2015; Lawrence & Baker, 2019). In addition to being detrimental to health, many of these foods are also brought to market via unsustainable agricultural and production practices, which undermine environmental sustainability (Johnston et al., 2014).

Although the contemporary food system has had undeniable success in addressing undernutrition, with food insecurity at the global level declining over several decades, the modern supply of food raises concerns for both the burden of chronic disease and environmental sustainability (Food and Agriculture Organization of the United Nations, 2020). Moreover, the long-term increase in food security, defined by the FAO as being “when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”, recently stalled. The number of people affected by hunger is once again on the rise, in part because of food system shocks and stresses driven by climate change, while a *healthy* diet remains inaccessible for many (Food and Agriculture Organization of the United Nations, 2020).

Food-based dietary guidelines, disease prevention and environmental sustainability

The over-consumption of poor nutritional quality food in populations across the globe is a significant challenge, and an array of policies have been deployed to attempt to address it. The Food and Agriculture Organization and the World Health Organization (FAO/WHO) have advocated since 1998 that national governments create food-based dietary guidelines (FBDGs) as a means of improving dietary intake. FAO and WHO provide guidance to support countries in developing FBDGs, including emphasising the need for diet and nutrition surveillance as a building block for FBDG development (Joint/onsultatio, 1998), which not all countries currently undertake. In response to the need to improve health and prevent disease, some countries have developed FBDGs over the past decades, but many more countries (103 in 2019) still do not have FBDGs (Herforth et al., 2019).

More recently, there has been a move toward guidelines that support not only human health, but planetary health as well (Gonzalez Fischer & Garnett, 2016). Many governmental and non-governmental groups have increasingly advocated diets that provide ‘win-wins’, being both healthier and more environmentally sustainable, including suggestions to limit the amount of meat and fish consumed (Garnett, 2014). However, so far only a small number of countries have explicitly included sustainability as a component in their FBDGs (Ahmed et al., 2019; Gonzalez Fischer & Garnett, 2016). Further, while bringing consumption in line with current national FBDGs would lead to a reduction in greenhouse gas emissions, existing environmental targets would still fail to be met, suggesting that FBDGs in many countries do not go far enough in endorsing sustainable diets (Springmann et al., 2020).

From a food policy perspective, FBDGs serve several purposes. While they may have some impact on individual dietary behaviours, and are often communicated in user-friendly ways (for example through plates and pyramids illustrating the recommended diet), they also serve as a guide for governments and public health agencies. In some countries, they can form the legal requirements for government-provided institutional meals, including for example, school meals in the United States. In these contexts, FBDGs not only provide guidance for individual consumption, they also dictate the nutritional standards for millions of meals served daily. While FBDGs can provide a model, indicating what a healthy diet would look like for a nation’s population, there has been a call for other food policies to complement FBDGs and support better

adherence throughout the population (Gonzalez Fischer & Garnett, 2016). FBDGs need to be supported by buy-in from different government departments, as well as through coordinated policies such as regulations around public procurement, taxation, advertising, trade, and agriculture (Gonzalez Fischer & Garnett, 2016; Wijesinha-Bettoni et al., 2021). A recent survey of FBDG implementation around the world found that some countries with FBDGs did not have a strategy or plan around how they would be implemented or have a budget allocated for implementation, while a majority did not collect monitoring and evaluation data related to FBDGs (Wijesinha-Bettoni et al., 2021).

Despite the emphasis on developing FBDGs across the globe, there is little understanding of the extent to which country-level food supplies align with these guidelines. There is also little understanding of how food supply alignment may vary between countries with different characteristics. Food supply alignment reflects the extent to which the composition of the food supply structurally supports or undermines population-level compliance with FBDGs. An over-abundance of foods that are detrimental to health, such as sugar or red and processed meat, or an under-supply of health-promoting foods, such as fruit and vegetables, may both be problematic for population health. Further, an over-supply of all types of food may represent a tension with environmental sustainability, as all foods, to differing degrees, entail the use of natural resources in their production. An under-supply of health-promoting foods may be a structural driver of undernutrition, while an over-supply of foods may be a structural driver of food waste or overnutrition.

Understanding food supply alignment with FBDGs, how that alignment has evolved over time, and how it varies by income and geographic region can be a crucial tool for tracking progress on achieving dietary public health targets, identifying priority areas for action, and evaluating policies promoting healthy and sustainable diets.

With these goals in mind, the aim of this study was to determine to what extent the global food supply for selected food groups aligns with existing FBDGs at the global and country levels, and to examine the historical trend over a 52-year period to answer the following questions:

- What were the trends in food supply alignment with FBDGs from 1961 to 2013?
- How did the trends in food supply alignment vary by country income and geographic region?

Methods

Study design

We used a descriptive time series analysis to quantify the alignment between FBDGs and national food supplies from 1961 to 2013. The FBDGs included both those published by national governments and by leading world authorities on health.

Data sources

National food supply data and corrections

We collected food supply data from the FAO Food Balance Sheets, collated in the FAO Corporate Statistical Database (FAOSTAT), for the years 1961–2013 (Food and Agriculture Orga, 2020a). This timespan included all years for which data was available before FAO modified its methodology, making subsequent data less comparable to earlier years (Food and Agriculture Orga, 2021).

The FAO Food Balance Sheets represent a comprehensive picture of a country's food supply available for domestic use during a given year. These data are calculated by taking into account production, exports and imports, changes in food stocks (decrease or increase), and food waste and losses occurring between production and the household (i.e. losses occurring through storage, transportation, and processing; through use

for livestock feed; and through use for seed or non-dietary purposes). In addition, we included a correction for losses in weight during cooking and adjusted for non-edible food portions using estimates from the USDA's Food and Nutrient Database (Department of Agricu, 2018). We divided this estimated national food supply by population size estimates to derive per capita supply (g/person/day) of each food item (Food and Agriculture Orga, 2020b).

Where data was not available for a given country during all years in the analysis period, we sought a geographically-comparable alternative, supplementing data from overlapping territories in cases where borders had been redrawn. Where this was not possible, we excluded countries from the analysis (see Supplementary File 1 for details).

FAOSTAT data tables account for pre-consumer upstream food losses and waste occurring after harvest but before reaching the consumer. We did not account for downstream food waste at the consumer level in this analysis because the analysis is focused on the composition of the food supply as available to the consumer. Post-purchase waste is therefore not of central concern for these purposes.

Country food-based dietary guidelines and food groups

We identified countries with FBDGs using the FAO FBDG repository, which assembles information on FBDGs in countries around the world and is regularly updated (Food and Agriculture Orga, 2020c). We extracted a list of countries from the webpage in June 2020. Where the necessary information on the FBDGs for a country was not available on the repository, we conducted an online search to identify the food guide (Google search terms: country name + dietary guidelines/food guide; name in national language as listed on the FAO FBDG repository). Where guidelines were not available in a language spoken by the research team (English, French and Spanish), we used Google translate and the camera-based Google translate app to translate documents into English (Google. Google Translate, 2020; Google. Google Translate., 2020).

We included food groups based on health relevance, frequency of reference by dietary guidelines and alignment with food item categories in the FAO Food Balance Sheets. We standardised dietary guidelines to g/capita/day. Where a number of portions was recommended but portion size was not specified, we applied a portion size based on WHO guidance where available (e.g., 80g/portion for fruit and vegetables as suggested by WHO) (World Health Organization, 2003), or the median portion size specified by other regional or national guidance (112.5 g/portion for fish and seafood and 124 g/portion for red and processed meat, see Supplementary File 2, Table S2 and S3 respectively).

Where a proportion of energy from a specific food group was recommended and recommended daily energy intake was not stated, we assumed a recommended daily intake of 2300 kcal/day based on the Dietary Guidelines for Americans recommendation for a moderately active adult (Department of Agricu, 2020–2025). Where a volume of a food was specified, this was converted to mass using food-specific volume to mass equivalencies from the USDA's Food and Nutrient Database (Department of Agricu, 2018). Where a guideline was presented as a single value, this value was used. Where a guideline was presented as a target range, the midpoint was used. Where guidelines were different for different population sub-groups, we used the recommendation for moderately active adults, and the average for men and women. Where guidelines were provided for children specifically and not for adults, this guideline was excluded.

Where countries did not provide a guideline for one of the food groups that could be standardized to g/capita/day for the general or adult population, for example where there was no guideline for a food group or the guideline could not be quantified (e.g. "consume moderate amounts," or "increase or reduce intake"), or where guidelines were only made available for children, we excluded them from the analysis of that food group.

Global food-based dietary guidelines

We also identified recommendations from authoritative international sources for the food groups of interest in order to compare food supply to a global standard. These recommendations (hereafter global FBDG) were WHO's guidelines on fruit and vegetable intake (at least 400 g/day) (World Health Organization, 2003) and on free sugar intake (less than 10% of daily calorie intake, equivalent to 57.5g/day for an intake of 2300 kcal) (Department of Agricu, 2020–2025; Guideline: sugars intake, 2015), as well as the World Cancer Research Fund's guideline on red and processed meat intake (no more than 350–500 g/week, equivalent to a daily average of 53.6g/day), informed by their ongoing and systematic analysis of the evidence on behavioural risk factors, cancer risk and mortality (Limit red and processed m, 2018). No suitable global recommendation was identified for fish and seafood intake.

Country income and region

We grouped countries by income, using World Bank income groups (low, lower-middle, upper-middle and high) (World Bank. World Bank Co, 2020), which are based on gross per capita income estimates for each country. We also grouped them geographically, using World Bank regions (East Asia and Pacific; Europe and Central Asia; Latin America and the Caribbean; Middle East and North Africa; North America; South Asia; Sub-Saharan Africa) (World Health Organization, 2020). Due to the small number of low-income countries with FBDGs ($n = 2$), we combined low-income and lower middle-income countries.

Analysis

In order to determine the alignment between the food supply and dietary guidelines, we calculated a ratio with the food supply as the numerator and the dietary guideline (standardised to g/capita/day as described above) as the denominator. We created a ratio between

country-specific food supply and (1) country-specific dietary guidelines; and (2) global recommendations.

Using these ratios, we created a mean weighted by country population, and described this mean ratio for each food group for each year from 1961 to 2013. We repeated these analyses separately by country income group and geographic region. Dietary guidelines, income category and geographic region were held constant.

Patient and public involvement

There was no patient or public involvement in this analysis.

Results

Sample characteristics

A list of 93 countries (just under half of the world's countries) with FBDGs was extracted from the FAO FBDG repository. From this list, government documents detailing FBDGs were identified for 90 countries. For the three remaining countries, government documents could not be identified, but FBDG details were extracted from English-language academic articles (one review and one description of the process underlying FBDG development (Montagnese et al., 2019; Musaiger et al., 2012)). Of these countries, one was excluded from the analysis as guidelines were only published for school-aged children (Cambodia), and two further countries were excluded as FAOSTAT did not provide data about their food supply (Qatar and the Seychelles). Finally, for eight countries, FAOSTAT data was not present for all study years. Of these, seven were countries belonging to the former USSR or Yugoslavia, and data from the respective territory was attributed to each country prior to 1992. The final country (Oman) was excluded as no such substitution was possible.

Of the remaining 89 countries, 72 had published guidelines for fruit and vegetable intake that were valid for this analysis, 30 had published valid guidelines for sugar intake, 19 had published valid guidelines for

Table 1
Characteristics of countries included in sample relative to global FBDGs.

	Whole sample (n)	Median (IQR) food supply in 2013 (g/capita/day) ^{a,b}			Global FBDGs					
		Fruit and vegetables	Sugar	Red and processed meat	Intake guideline (g/capita/day)			Alignment in 2013 (supply/guideline) ^a		
					Fruit and vegetables	Sugar	Red and processed meat	Fruit and vegetables	Sugar	Red and processed meat
All	89	323 (290,797)	64 (20,101)	57 (3,94)	400	57.5	54	1.2	1.2	1.1
Income										
High	40	432 (363,454)	121 (88,169)	112 (90,118)				1.1	2.2	1.9
Upper middle	34	805 (289,846)	20 (20,96)	87 (41,92)				1.6	0.9	1.3
Lower	15	272 (259,284)	51 (30,59)	3 (2,11)				0.7	0.9	0.2
Region										
East Asia and Pacific	12	626 (320,756)	20 (20,43)	92 (54,94)				1.7	0.6	1.5
Europe and Central Asia	31	442 (370,535)	105 (87,121)	111 (88,128)				1.2	1.8	1.9
Latin America & the Caribbean	28	280 (270,309)	117 (116,133)	57 (50,78)				0.8	2.1	1.2
Middle East and North Africa	5	667 (602,731)	78 (77,79)	10 (10,10)				1.8	1.5	0.3
North America	2	437 (437,437)	151 (139,163)	101 (96,107)				1.1	3.0	2.1
South Asia	5	218 (180,256)	41 (30,53)	3 (2,3)				0.7	1.0	0.1
Sub-Saharan Africa	6	222 (204,229)	27 (24,38)	12 (12,19)				0.5	0.8	0.4

^a Weighted by country population.

^b Adjusted for losses in weight during cooking and adjusted for non-edible food portions using estimates from the USDA's Nutrient Data Base.

Table 2
Characteristics of countries included in sample relative to country-specific FBDGs.

	Countries with country-specific FBDGs (n)				Median (IQR) food supply in 2013 (g/capita/day) ^{a,b,c}				Country-specific FBDGs				Mean alignment in 2013 (supply/guideline) ^a			
	Fruit and vegetables	Sugar	Red and processed meat	Fish and seafood	Fruit and vegetables	Sugar	Red and processed meat	Fish and seafood	Median (IQR) intake guideline (g/capita/day) ^b				Fruit and vegetables	Sugar	Red and processed meat	Fish and seafood
									Fruit and vegetables	Sugar	Red and processed meat	Fish and seafood				
All	72	30	19	39	351 (291, 805)	48 (20, 63)	89 (77, 118)	80 (49, 81)	480 (400, 615)	25 (20, 26)	57 (48, 71)	54 (32, 56)	0.9	2.3	2.3	1.4
Income																
High	36	10	14	27	431 (360, 448)	148 (135, 161)	117 (90, 120)	49 (46, 54)	444 (400, 514)	58 (58, 58)	67 (17, 71)	32 (32, 34)	0.9	3.1	3.5	1.5
Upper middle	26	15	5	11	813 (312, 850)	20 (20, 36)	57 (44,57)	64 (55, 73)	616 (499, 646)	25 (25, 25)	55 (52, 57)	46 (40, 52)	1.1	2.0	1.1	1.3
Lower	10	5	0	1	273 (262, 284)	52 (46, 59)	–	68 (68, 68)	400 (400, 400)	20 (18, 22)	–	83 (83, 83)	0.7	2.6	–	0.8
Region																
East Asia and Pacific	11	6	2	3	637 (317, 762)	20 (20, 24)	113 (111, 115)	75 (71, 78)	620 (534,648)	22 (19,25)	65 (65,65)	58 (58,58)	1.1	1.0	1.8	1.4
Europe and Central Asia	31	8	11	25	442 (370, 535)	87 (87, 107)	112 (90, 120)	48 (25, 59)	400 (400,600)	30 (30,30)	52 (14,71)	32 (32,40)	1.0	3.2	3.7	1.4
Latin America & the Caribbean	20	10	4	7	303 (273, 352)	133 (133, 146)	57 (57, 57)	18 (14, 30)	406 (400,435)	10 (10,12)	54 (47,56)	32 (26,32)	0.7	11.5	1.3	0.9
Middle East and North Africa	3	1	1	2	375 (375, 575)	123 (123, 123)	116 (116, 116)	22 (22, 22)	425 (360,492)	58 (58,58)	26 (26,26)	26 (26,26)	1.1	2.1	4.5	1.0
North America	1	1	0	1	437 (437, 437)	175 (175, 175)	–	50 (50, 50)	448 (448,448)	58 (58,58)	–	32 (32,32)	1.0	3.0	–	1.5
South Asia	4	2	0	0	217 (179, 254)	41 (29, 52)	–	–	400 (400,400)	22 (22,22)	–	–	0.7	2.6	–	–
Sub-Saharan Africa	2	2	1	1	163 (163, 163)	48 (44, 75)	42 (42, 42)	15 (15, 15)	400 (400,400)	30 (29,35)	80 (80,80)	30 (30,30)	0.4	2.1	0.5	0.5

^a Weighted by country population.

^b Adjusted for losses in weight during cooking and adjusted for non-edible food portions using estimates from the USDA's Nutrient Data Base.

^c Median intake is different in [Tables 1 and 2](#) because only some countries have country-specific FBDGs for each food group and are therefore included in [Table 2](#).

red and processed meat intake, and 39 had published valid guidelines for fish and seafood intake.

The countries included in the sample are described in Table 1 relative to global FBDGs and Table 2 relative to country-specific FBDGs (see Supplementary File 3 for further detail: Table S4 for individual country guidelines, and Table S5 and S6 for countries by region and income). Country-specific FBDGs for fruit and vegetables and sugar are, on average, more stringent than global FBDGs (see Tables 1 and 2), with a higher intake of fruit and vegetables and a lower intake of sugar being recommended.

Trends in food supply alignment from 1961 to 2013

Fig. 1 illustrates the alignment between the food supply from 1961 to 2013 and national and global FBDGs, with a ratio of one (marked by a horizontal line on the graphs) indicating alignment between the two.

For the whole sample, the food supply overall increased in quantity between 1961 and 2013. Relatively stringent country-specific guidelines for fruit and vegetable and sugar intake are reflected in substantial deviation from alignment by 2013, with the fruit and vegetable supply falling short of recommendations (alignment of 0.9, see Table 2), and the sugar supply being more than double the recommended amount for intake (alignment of 2.3). Red and processed meat was out of alignment from 1961, which grew over time by increasing supply (alignment of 2.3 in 2013). While the increasing supply of fish and seafood during this period meant that it was briefly aligned with recommendations in the 1990s, there is now an over-supply (alignment of 1.4).

For completeness, results relative to global FBDGs are presented separately for countries with and without country-specific FBDGs, as well as for the whole sample. For fruit and vegetables, the same underlying increase in the quantity of food in the food supply represented a change towards increased alignment with global guidelines, moving from around half the recommended amount being available in the food supply, to slightly more than the recommended amount (alignment of 1.2, see Table 1). A similar trend can be observed for red and processed meat (alignment of 1.1). For sugar, the food supply diverged from

alignment over this time, transitioning from a food supply approximately aligned with recommendations to an over-supply of sugar by 2013 (alignment of 1.2).

Food supply alignment by income group

Fig. 2 illustrates the alignment between the food supply from 1961 to 2013 and national and global FBDGs, with a ratio of one (marked by a horizontal line on the graphs) indicating alignment between the two. Countries are grouped by income.

The increase in the supply of fruit and vegetables appear to be chiefly driven by an increasing supply in upper middle-income countries, resulting in an over-supply (alignment of 1.6 in 2013, see Table 1) relative to global guidelines. High-income countries remain roughly aligned with recommendations, although lower-income countries are under-supplied (alignment of 0.7).

The supply of sugar has increased in all countries, with high-income countries being severely misaligned relative to global guidelines (2.2 in 2013) and country-specific guidelines (3.1 in 2013, see Table 2). Other income groups are over-supplied with sugar relative to more stringent country-specific guidelines (2.0 in upper middle income and 2.6 in lower income), though not relative to global guidelines (0.9 for both in 2013).

For red and processed meat, the trend in high- and lower-income countries has remained relatively stable, with high-income countries remaining over-supplied relative to global guidelines (alignment of 1.9 in 2013) and lower-income countries remaining under-supplied (alignment of 0.2). The increasing supply of red and processed meat in upper middle-income countries has brought them out of alignment (1.3) relative to global guidelines. Relative to country-specific guidelines, misalignment for red and processed meat in high-income countries is more pronounced (3.5 in 2013, see Table 2). This reflects higher consumption of red and processed meat in high-income countries with FBDGs for this food group.

For fish and seafood, supply increased in quantity for all income groups, with different repercussions for alignment. In high- and upper middle-income countries, there was an over-supply of fish and seafood

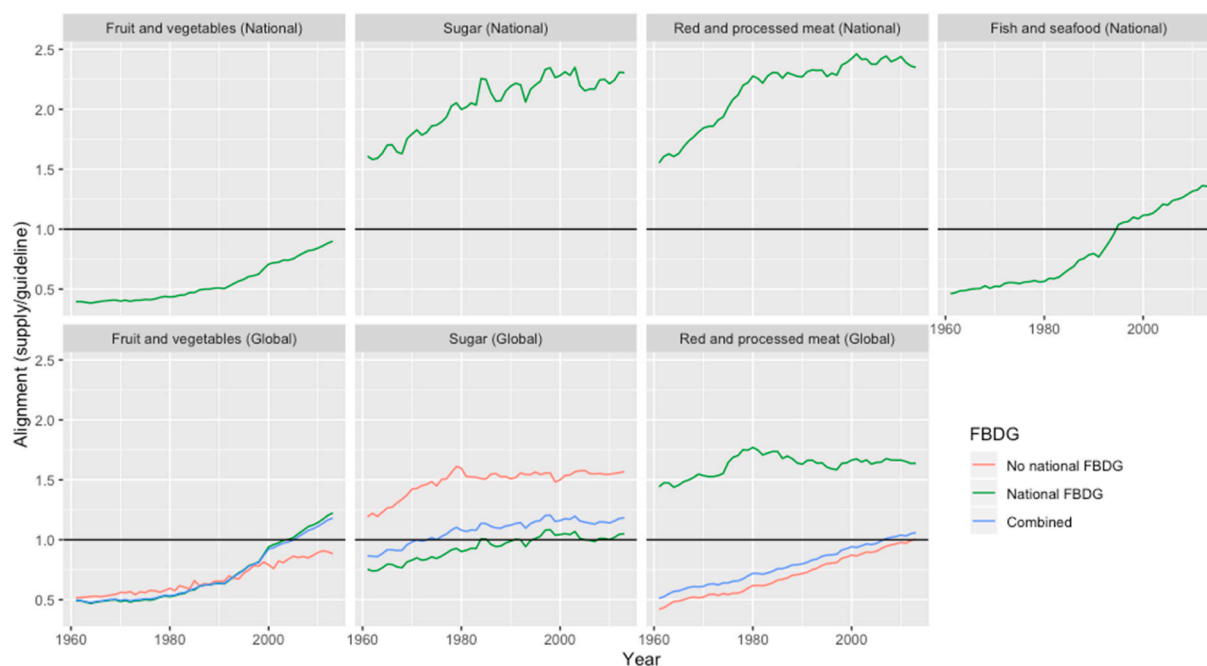


Fig. 1. Alignment between food supply and national and global FBDGs, 1961–2013 (All countries)

Alignment = food supply/recommended daily intake; 1 = Perfect alignment; 2 = Twice the recommended amount is available in the food supply; 0.5 = Half the recommended amount is available in the food supply; for global FBDGs $n = 89$; for national FBDGs: fruit and vegetables $n = 72$; sugar $n = 30$; red and processed meat $n = 19$; fish and seafood $n = 39$. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

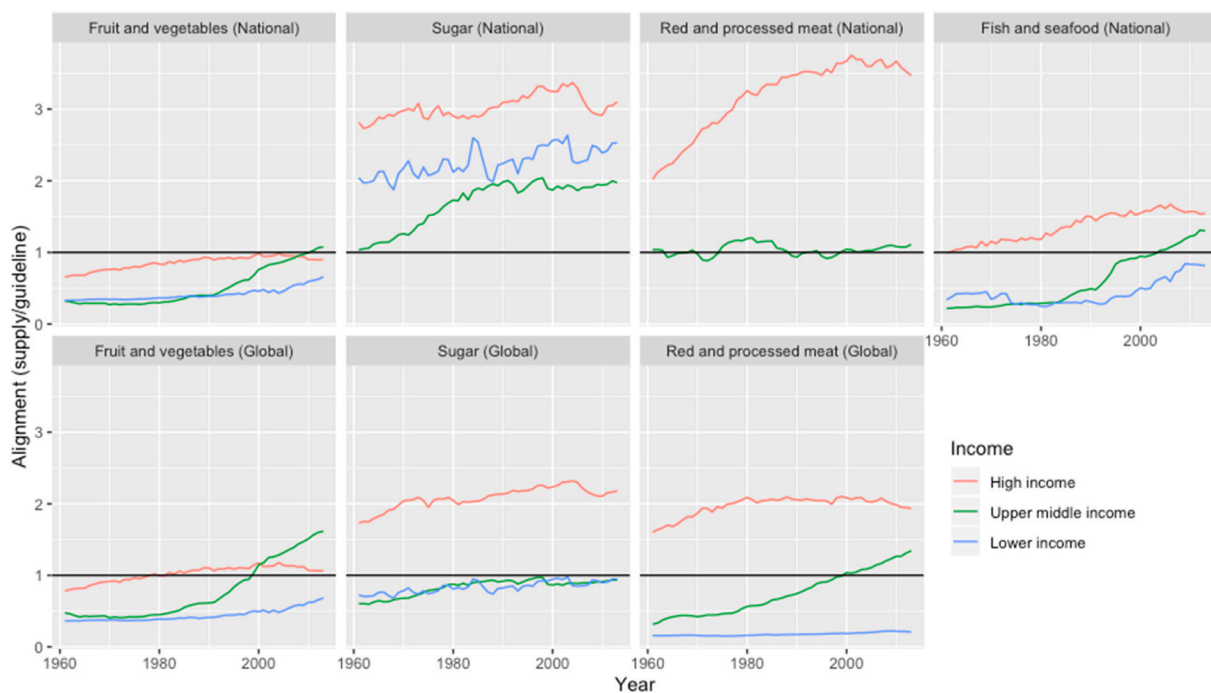


Fig. 2. Alignment between food supply and national and global FBDGs, 1961–2013 (by income)
 Alignment = food supply/recommended daily intake; 1 = Perfect alignment; 2 = Twice the recommended amount is available in the food supply; 0.5 = Half the recommended amount is available in the food supply; for global FBDGs n = 89; for national FBDGs: fruit and vegetables n = 72; sugar n = 30; red and processed meat n = 19; fish and seafood n = 39.. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

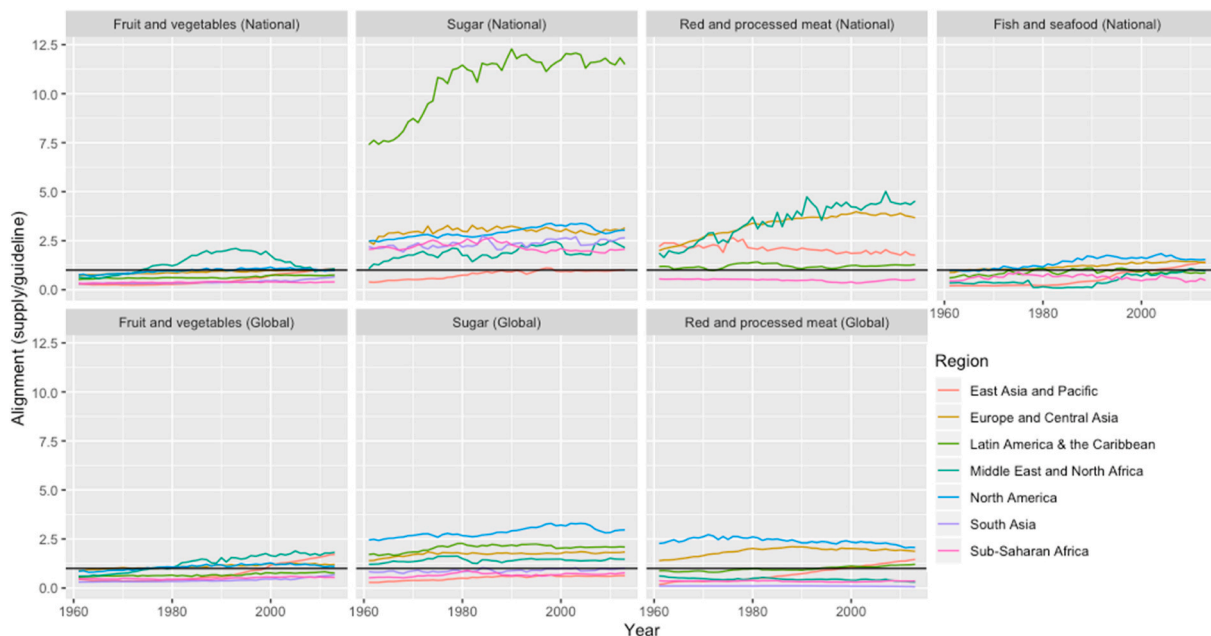


Fig. 3. Alignment between food supply and national and global FBDGs, 1961–2013 (by region)
 Alignment = food supply/recommended daily intake; 1 = Perfect alignment; 2 = Twice the recommended amount is available in the food supply; 0.5 = Half the recommended amount is available in the food supply; for global FBDGs n = 89; for national FBDGs: fruit and vegetables n = 72; sugar n = 30; red and processed meat n = 19; fish and seafood n = 39.. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

by 2013 (alignment of 1.5 and 1.3 respectively). Meanwhile, in lower-income countries, the food supply continues to provide less than guideline recommendations despite a substantial increase (alignment of 0.8).

Food supply alignment by region

Fig. 3 illustrates the alignment between the food supply from 1961 to 2013 and national and global FBDGs, with a ratio of one (marked by a horizontal line on the graphs) indicating alignment between the two. Countries are grouped by geographic region. Alignment, and changes in

alignment over time, vary substantially by geographic region. [Figure S1](#) (Supplementary File 4) presents a closer look at this figure.

Global trends conceal regional variation: in 1961, countries in North America and Europe were close to alignment for fruit and vegetables relative to global guidelines, while other regions were under-supplied. As a result of increases in supply in these two regions, as well as sharp increases in East Asia and the Pacific and the Middle East and North Africa, by 2013 all four regions were somewhat over-supplied. The world's remaining regions, despite small increases, remained misaligned, with supply being less than guidelines recommendations.

With regard to sugar, increases in the supply since 1961 have meant that most regions are now substantially over-supplied, with the most misaligned relative to global guidelines being North America (3.0), followed by Latin America and the Caribbean (2.1) and Europe and Central Asia (1.8). Exceptions are Sub-Saharan Africa (0.8) and East Asia and the Pacific (0.6). Misalignment for sugar in Latin America and the Caribbean in particular is more pronounced relative to country-specific FBDGs (11.5, see [Table 2](#)), reflecting more stringent guidelines on sugar in this region. Given the negative impacts of sugar on health, an under-supply may be protective for population health, while the pronounced over-supply in most of the world's regions is a cause for concern.

Despite a decrease in the per capita supply of red and processed meat in North America since 1961, countries in this region remain the most misaligned relative (alignment of 2.1 relative to global guidelines by 2013). Misalignment in Europe and Central Asia also remains high (1.9). Increases in East Asia and the Pacific and Latin America and the Caribbean mean these countries are now also over-supplied.

The supply of fish and seafood has increased in all regions. North America, Europe and Central Asia, and East Asia and the Pacific were all over-supplied in 2013 (alignments of 1.5, 1.4 and 1.4 respectively). Sub-Saharan Africa remains under-supplied relative to guidelines (0.5).

Discussion

Key findings

At the global level, the supply of all of the food groups included in this analysis increased between 1961 and 2013, with different impacts for food supply alignment with FBDGs by food group. Food supply alignment for fruit and vegetables improved steadily across the five decades, and by 2013 the global food supply approached alignment with both global and country-specific FBDGs. For red and processed meat, an increase in supply led to misalignment at the global level, particularly for countries where FBDGs for this food group have been published. Similarly, the increase in the supply of sugar also led to an over-supply, and this over-supply was more pronounced in countries where FBDGs for sugar had not been published. Finally, an increase in the supply of fish and seafood also brought the food supply out of alignment relative to national FBDGs.

Food supply alignment also showed substantial differences in levels and trends across region and country income. High-income countries were particularly over-supplied with sugar and red and processed meat, while lower-income countries remained under-supplied with fruit and vegetables by 2013, despite some increases in supply over the period under study. Many regions were over-supplied with sugar, particularly North America and Latin America and the Caribbean, while the supply of sugar in East Asia and Sub-Saharan Africa was relatively low, despite being on the rise. Sub-Saharan remained under-supplied for all food groups examined here, and its food supply was not characterised by the overall increase in volume per capita identified in other regions.

Exceeding or falling short of food supply alignment has different repercussions for the four food groups examined here. An over-supply of sugar or red and processed meat is likely to have negative repercussions for population health, while in contrast an over-supply of fruit and vegetables or fish and seafood may be positive. However, an over-supply of all types of food may represent a tension with environmental

sustainability, though the gravity of this misalignment may vary based on the resource implications of producing different types of foods.

Strengths and limitations

This study uses FAO Food Balance Sheets to provide an analysis of the food supply and understand its role in structurally supporting or undermining population-level compliance with dietary guidelines. As a measure of the food supply, the Food Balance Sheets have a number of advantages. They are the most commonly-used source of food availability information at the national level and a useful tool for international comparison and understanding change over time ([Thar et al., 2020](#)). However, this analysis only includes data up to 2013. Future studies may examine how food supply alignment has evolved up to the present day.

This analysis provides a comprehensive picture of food supply alignment around the world and over time, including all countries that have published FBDGs. However, as it uses national guidelines and country-level data, it cannot account for sub-national variation. There may, for example, be pronounced differences in the food supply between urban and rural regions within countries.

Finally, home production of food, such as home gardens and subsistence hunting and fishing, are not captured by the Food Balance Sheets. This may lead to an under-estimation of the supply of some food groups, which may be more pronounced in certain countries and for certain populations, such as indigenous groups.

The future of food-based dietary guidelines

Despite the FAO/WHO initiative to support the development of FBDGs, we only identified FBDGs from fewer than half of the world's countries. While recommendations from global health organisations, such as those used in this study, can also be helpful in tracking progress towards healthier diets, these may not take into account local variation in dietary patterns, which may achieve a healthy and balanced diet through different compositions of food groups.

In order to understand how countries' food supplies structurally support or undermine adherence to their own FBDGs, we restricted our sample to countries that had published FBDGs which met our inclusion criteria, including food supply alignment relative to global guidelines to highlight the extent to which variations in food supply alignment were attributable not only to differences in the food supply but also to more or less stringent guidelines. As a result, countries that did not have any FBDGs that met our inclusion criteria were excluded. However, the presence or absence of national FBDGs could be indicative of the state of the food supply in a given country. For example, our results show that, within this sample, countries with an FBDG for red and processed meat were more over-supplied with red and processed meat than other countries. Publishing FBDGs may indicate a government's perception that consumption of a certain food group in their population is problematic for health. In contrast, however, countries without an FBDG for sugar were more over-supplied with sugar than other countries. Further research could examine this dynamic, examining how food supply alignment in countries with and without FBDGs compares, and whether changes in food supply alignment at the country level precede or follow the publication of FBDGs.

Very few countries have guidelines that reference issues around sustainability ([Gonzalez Fischer & Garnett, 2016](#)). For the food groups analysed in this study, with the exception of fruit and vegetables, median guidelines identified here fall outside the range proposed by the EAT-Lancet commission as being compatible with planetary boundaries ([Willett et al., 2019](#)). This is in keeping with Springmann and colleague's study modelling the health and sustainability impacts of adherence to national FBDGs, which found that global adherence to most countries' FBDGs were incompatible with environmental targets ([Springmann et al., 2020](#)). A more explicit endorsement of sustainable

diets in FBDGs is urgently required.

In some countries, recently published FBDGs have moved away from presenting specific quantities as guidelines, instead encouraging populations to eat more or less of certain foods, or consume moderate amounts (Canadian Government. Cana, 2019; Ministry of Health of Bra, 2015). While these types of guidelines may be more useful for individuals attempting to change their diets, there may also be a role for quantitative targets in evaluating policies and tracking progress towards food supply alignment.

Implications for policy and future work

Experts are increasingly urging a global transition toward healthy, sustainable and equitable food systems. To facilitate this transition, there is a need to develop and use system-level measures that can help national and local governments to understand their current food supply alignment with dietary guidelines. This will enable them to prioritise areas for action and develop and evaluate policies that support this transition. This analysis highlights a persistent misalignment between dietary guidelines and the composition of the food supply. Although some trends have improved over time, there remains an over-supply of sugar and red and processed meat, and an under-supply of fruit and vegetables and fish and seafood.

This analysis also encourages increased attention to the tensions between FBDGs, healthier diets, and the sustainability of the food supply. It highlights the importance of increasing the supply of healthier and more sustainable food such as fruit and vegetables, which are currently under-supplied nearly universally, and decreasing the supply of less healthy and sustainable foods such as sugar and red and processed meat. For fish and seafood, a balance must be struck, as this food group has positive repercussions for health, but may be harmful for sustainability.

This analysis explores food supply alignment over time. An increase in the supply of fruit and vegetables per capita, attributable to a combination of factors including technological innovations in agriculture and food transportation, rising incomes and trade liberalisation (Even-son & Gollin, 2003; Huang, 2004), led to better alignment for this food group. In particular, upper-middle income countries and countries in East Asia and the Pacific have seen a marked increase in fruit and vegetable supply. This is consistent with existing analysis of trends and levels in the supply of fruit and vegetables in East Asia and the Pacific, which attributed these changes to rapid economic development in this region (Mason-D'Croz et al., 2019). Though substantially lower than vegetable supply, vegetable intake in this region is estimated to be higher than WHO recommendations (Kalmipourtzidou et al., 2020), which evidence suggests is beneficial to health (Aune et al., 2017). Meanwhile, some country groups are still under-supplied, while even in regions with an adequate supply of fruit and vegetables, dietary surveys suggest that, at the individual level, many are still not consuming enough (Joffe & Robertson, 2001). While ensuring an adequate supply of fruit and vegetables is an important first step, further action is needed to ensure that intake is also adequate.

With respect to red and processed meat, a sharp increase in supply has occurred in upper middle-income countries. Increasing affluence in this group may have led to increased affordability and consumption (Godfray et al., 2018). While there is some evidence in these results that we may be approaching 'peak meat' in high-income countries, misalignment in these countries remains very high. This situation presents a cause for concern in terms of both health and sustainability.

The mechanisms behind regional variation in food supply alignment are worthy of additional exploration. The causes of this variation may be complex, including the actions and development of domestic and international legal regimes, the nutrition transition, global investment and trade, and international food industry actors, which may focus on developing infrastructure and growing their market in particular regions. A recent survey suggests that there is substantial variation in how

countries 'implement' FBDGs by aligning fod policies and programmes with them (Wijesinha-Bettoni et al., 2021). A number of approaches exist, including providing educational materials for school; using FBDGs to develop regulations around public procurement in institutions such as schools and hospitals; and supporting farmers and food producers to grow foods recommended by FBDGs (Wijesinha-Bettoni et al., 2021). Additional research could evaluate the effectiveness of these different approaches to implementing FBDGs in improving food supply alignment, in order to inform policy decisions. The role that other potential drivers play in shaping both food policy and the food system itself could also be explored.

Variation in food supply alignment by region and income may contribute to country-level variation in health outcomes. For example, Europe and North America have a relatively high incidence rate of colorectal cancer, for which a diet high in red and processed meat is a risk factor (Safiri et al., 2019), while North America and Latin America and the Caribbean have a high incidence of Type 2 diabetes, for which a diet high in sugar is a risk factor (Lin et al., 2020). Further research could examine the role of food supply alignment as an upstream risk factor for disease, as well as the potential moderating role of factors such as healthcare provision.

This analysis also expands how we should think about food availability, as extending beyond the food available in small-scale local environments and encompassing the food available at the macro-level in terms of the composition of national and global food supplies. This expanded definition points to the broad array of upstream policy instruments that determine food availability and that can be deployed to support healthy and sustainable diets. While the existing public health arsenal of labelling and marketing regulations, education and taxation have an important role to play, focus must also extend to the agricultural and trade policies, multinational commercial activity, and other macro-level determinants of the composition of domestic and global food supplies.

Meanwhile, the findings presented here may complement existing and future research into the healthfulness of smaller-scale food environments, such as at the neighbourhood and retail level (Ejlerskov et al., 2018; Lam et al., 2018). Understanding country-level food supply alignment, upstream determinants and changes over longer time scales can highlight priority areas for action and sub-national inequalities, and shed light on how foods eventually arrive in retailers and homes around the world.

Conclusion

As of 2013, the global food supply was not aligned with food-based dietary guidelines provided by both international bodies and specific countries, and this misalignment was consistent across five decades. While some movement has occurred in the desired direction for selected food groups, misalignment persisted, and substantial country-level inequities remain. FBDGs are a valuable first step toward creating a food supply that provides for a healthy and sustainable diet for all, but food supply alignment must be supported by other food policies as well.

This work demonstrates the utility of a measure of food supply alignment, which could support the surveillance and evaluation of future policies implemented to support the transition to a healthy, sustainable and equitable food system.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The food supply data used in this study is available from <http://www.fao.org/faostat/en/#data>. The analysis code used for the study can also be found on the project webpage at www.globalfoodypolicy.org/

Author contributions

TLP conceived and designed the study with input from EA and PM. CCA prepared the data with input from EA and KC and conducted formal data analysis. CCA prepared the manuscript with support from TLP. All authors contributed significantly to manuscript revisions and have read and approved the final manuscript.

Funding

CCA and TLP acknowledge research support from York University, Toronto, Canada.

Declaration of competing interest

The authors declare that they have no competing interests.

Acknowledgements

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2021.100866>.

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