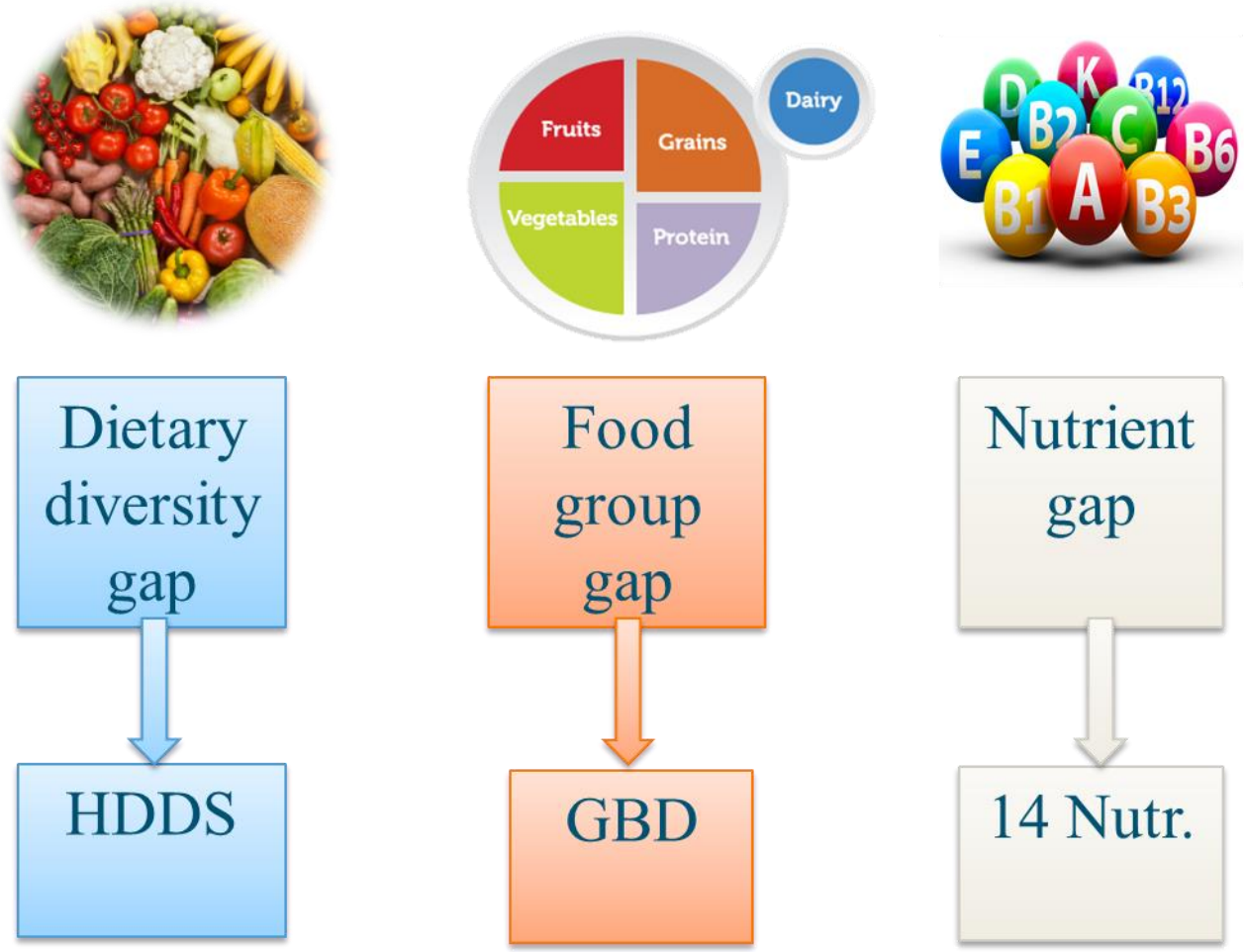
Healthy diet targets for food system transformation: a dietary gap analysis using public available datasets in Ethiopia, Nigeria, Bangladesh & Vietnam



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Abbreviations

AFE	Adult female equivalent
AI	Adequate Intake level
BIHS	Bangladesh integrated household survey
DDS	Dietary diversity score
EAR	Estimated Average Requirements
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organization
FCTs	Food composition tables
GBD	Global Burden of Disease
HCES	Household consumption and expenditure surveys
HDDS	Household dietary diversity score
HH	Household
IFPRI	International Food Policy Research Institute
LMIC	Low -and middle-income countries
LSMS	Living standards measurements studies
LSMS-ISA	Living standards measurements study – integrated surveys on agriculture
NCD's	Non-communicable diseases
USDA	United States Department of Agriculture
VHLSS	Vietnam household living standards survey

Abstract

Many low -and middle-income countries are experiencing important food system transformations due to globalization, urbanization, and changes in lifestyle. As diets mainly rely upon our food systems, the design of integrated and multidimensional interventions to provide high quality diets to everyone, everywhere needs to be based on a food system approach. To guide such an approach, the overall quality of diets and the dietary patterns should be assessed to identify specific food and nutritional gaps and to formulate targets for investments and strategies for food system transformations towards healthier diets.

The objective of the paper is to analyse the dietary gap for four countries and to identify targets for food system interventions. Dietary gap analysis within these countries will enable us to understand in which way food patterns need to change in order to reach a healthy diet at population level. For this study three indicators have been assessed: 1) Household dietary diversity score (HDDS) as indicator of household access to foods indicating a possible diversity of the diet. 2) A derived score for a healthy reference diet based on the Global Burden of Disease (GBD) study - a high overall GBD score indicating a better adherence to the healthy diet, which also counts for the partial scores for protective and limit food groups. And 3) nutrient adequacy as indicator of a nutritious diet to maintain health. Household consumption and expenditure surveys (HCES) data from the living standards measurements studies (LSMS) were used. After data cleaning, the final total samples included 4254 households in Ethiopia, 3901 households in Nigeria, 6436 households in Bangladesh and, 9329 households in Vietnam.

The total mean HDDS were lower in the African compared to the Asian countries and were 6.8 (1.9) in Ethiopia, 8.7 (2.0) in Nigeria, 10.0 (1.5) in rural Bangladesh, and 10.1 (1.4) in Vietnam. The mean GBD score was 3.9 (0.7) in Ethiopia, 3.9 (0.9) in Nigeria, 4.1 (0.7) in rural Bangladesh and 2.6 (1.0) in Vietnam. Ethiopia, Nigeria and Bangladesh showed a low protective food group score but a high limit food group score; while Vietnam showed a low score for both. Mean intakes for the protective food groups were all lower compared to the recommendations and for the limit food groups "Sugar sweetened beverages" intake was above the recommendation for all countries except Bangladesh. Vietnam shows that more than 50% of households have intakes below the estimated average requirement (EAR) - the intake to meet the requirement for a specific nutrient for half of the healthy individuals of a specific age, sex, and life-stage - for energy and the highest number of nutrients (for nine out of 12 nutrients, shown in red and orange), followed by Bangladesh (eight out of 12 nutrients), Ethiopia (six out of 12 nutrients) and Nigeria (six out of 12 nutrients).

In dietary gap analysis, a combination of indicators measuring diversity and quantitative intake of healthy food groups and of those whose intake should be limited, provide important information and targets for interventions aiming to improve consumption of healthy diets. The use of large surveys recalculated into intake data are useful to shape interventions especially when comparing between countries for programming purposes.

Introduction

Many low -and middle-income countries (LMIC) are experiencing important food system transformations due to globalization, urbanization, and changes in lifestyle. This transition is characterised by increased food diversification and a shift towards consumption of more non-staple foods, such as vegetables and fruits, meat and fish, dairy, and edible oils. However, these changes go along with a greater demand for processed and energy dense foods[1,2]. The nutrition transition and dietary pattern shifts brings new challenges related to health, especially diet-related non-communicable diseases (NCD's). Besides the significant but slow progress in fighting undernutrition, the burden of overweight and obesity and NCDs is greatly increasing, also in low -and middle-income countries[3,4]. According to the Global Burden of Disease (GBD) study, cardiovascular diseases and diabetes were ranking higher in 2017 compared to three decades ago[5].

While there is no single dietary pattern that delivers good health in each context, there is broad agreement on what elements should be included in healthy or high-quality diets. The World Health Organization recommends a diverse diet, with a diversity of food groups and foods which are safe and nutrient rich, and advises to eat plenty of fruit, vegetables, wholegrains, pulses, fibre, nuts and seeds, fish, and some dairy and lean high-quality meats in moderation, and to limit intake of free sugars, sugary snacks and beverages, processed meats, trans-fats and salt[6]. GBD formulates quantitative targets for intake of the above food groups and foods to be within the healthy or unhealthy range[5].

As diets mainly rely upon our food systems, there is general consensus that the design of integrated and multidimensional interventions to provide high quality diets to everyone, everywhere needs to be based on a food system approach[1,2,7]. To guide such an approach, the overall quality of diets and the dietary patterns should be assessed to identify specific food and nutritional gaps and to formulate targets for public and private investments and strategies for food system transformations towards healthier diets. Single nutrients approaches can be successful if specific deficiencies or target groups are targeted. However, at population level and for the prevention of multifactorial NCDs such as diabetes and cardiovascular diseases, an integrated study of the overall dietary patterns is more meaningful[8]. In addition, healthy or more protective food components as well as unhealthy food components that should be limited coexist in the diet, justifying the need to study food groups consumed and dietary patterns rather than focusing only on single nutrients and foods[9].

Dietary intake data that are recent and national representative are not available for many LMIC, and alternative datasets need to be used for dietary gap analysis. Living standards measurements studies (LSMS) and household consumption and expenditure surveys (HCES) are publicly available data sets originally designed to monitor poverty, but were recently also used to assess food and nutritional gaps at the household level[10]. Availability for a large number of countries, being frequently collected so relative recent and being representative at the country level make these datasets attractive for the assessment of household dietary patterns and trends herein, and for comparison of these between countries[11].

The objective of the present paper is to analyse the dietary gap for four countries as case studies by using publicly available datasets and to identify targets for food system interventions in Ethiopia, Nigeria, Bangladesh, and Vietnam. Located in two different continents and being at different stages of development, these four countries are experiencing a different food system transition with related dietary pattern shifts and diseases trends. Dietary gap analysis within these four countries will enable us to understand in which way food patterns need to change in order to reach a healthy diet at population level. Dietary patterns are characterised by three different levels; dietary diversity, food groups and nutrients[12]. Therefore, for this study three indicators have been assessed: Household dietary diversity score (HDDS)[13] as indicator of household access to foods indicating a possible diversity of the diet; a derived score for a healthy reference diet based on the GBD[5]; and nutrient adequacy[14] as indicator of a nutritious diet to maintain health.

Methodology and analysis

Household consumption expenditure survey (HCES) data

In this study, HCES data from the LSMS were used for four different countries: Ethiopia, Nigeria, Bangladesh and Vietnam. In Ethiopia, data were collected over seven days, based on the living standards measurements study – integrated surveys on agriculture (LSMS-ISA). The LSMS-ISA is collected by the Central Statistical Agency of Ethiopia and the World Bank LSMS team. Only wave 3 (20015/2016) data are used as the number of food items in wave 3 is more detailed than in the two previous waves and allows to distinguish between rural and urban areas. The total sample included 4954 households. In Nigeria, data were collected over seven days, based on the general household survey. Panel 2015/2016 wave 3 was used. The total sample included 4580 households. In Bangladesh, data were collected over seven days, based on IFPRI's Bangladesh integrated household survey (BIHS). The second round of 2015 was used and the total sample included 6436 rural households. In Vietnam, data were collected over thirty days, based on Vietnam household living standards survey (VHLSS) 2016. The total sample included 9399 households. For all countries the sample was representative at the country level including rural and urban areas except for Bangladesh (only rural).

Data preparation and cleaning

Different steps of data preparation and cleaning were applied. Unknown and unfamiliar measurement units were checked and corrected with experts. The units of food quantities were checked and converted into grams. The total quantity of each food item consumed was compared to the total amount of food from own stock, purchases and gifts. Furthermore, the total consumption expenditure was checked whether it aligned with market prices per unit of food items. Food quantities were defined as outliers when the corresponding unit prices were within and above the third interquartile above or below the median price of that food per area[15]. In these cases, the total amount consumed was imputed based on the total spending on a given food item using the median price indicated by other households in the same area.

The HCES survey questionnaire does not define edible portions of food items. We assume that respondents report consumption of the non-treated, non-prepared product. Waste factors were thus applied to the food items before further analysis[16,17]. For those foods without waste factors available, those from similar foods were used. The caloric and nutrient intake of the household was calculated using the countries respective food composition tables (FCTs) complemented with data from FCTs from neighbouring countries and lastly the USDA[17–28]. To account for changes in energy and nutrient content due to processing and preparation of food items, retention factors were applied[29].

To present the results based on the intake of one person, and not the whole household, the consumer unit approach was applied to convert household intake data to intake of a reference individual based on energy requirements[30]. Although it does reflect individual intake, the consumer unit approach provides a proxy for intra-household food distribution. Studies have used the adult male equivalent with HCES data and found comparable calculated intake to individual 24 hour recall intake data[31]. Since target groups in nutrition programming are usually not the adult male, in this research we used the adult female equivalent (AFE). Energy requirements for different age and gender groups were used based on the FAO Human Energy Requirements[32]. Children under 6 months of age were assumed to be exclusively breastfed and thus not to consume foods (their AFE is set to zero). Children between 6-24 months were assumed to be partly breastfed, thus proportional calculation was done according to findings from Dewey and Brown[33]. Values for adults 18-19 and 19-20 years old were not available, thus imputations were made based on the average of the age groups below and above. The reference AFE (AFE = 1) was set to a female of 20-30 years of 59.4kg with moderate physical activity. Due to lack of information on physical activity level and anthropometrics, moderate physical activity level was used and no adjustments were made for body size. For all other age and gender groups an AFE value was established by dividing their energy requirement by the energy requirement of one AFE. For each household, the household AFE was calculated by summing up the AFEs of individual household members. This approach was used for

the healthy diet and nutrient adequacy analysis, but not for the household dietary diversity analysis as this is an indicator on the household level and not on the individual level. Energy intake per day for 1 AFE below 500 kcal or above 5000 kcal were considered as outliers and removed from the dataset [34]. After data cleaning, the final total samples included 4254 households in Ethiopia, 3901 households in Nigeria, 6436 households in Bangladesh and, 9329 households in Vietnam.

Household Dietary Diversity Score

Household dietary diversity was assessed using FAOs HDDS[13], a composite measure and proxy for household's average food access. The HDDS is calculated based on whether anyone in the household consumed any food from the twelve food groups over the past 7 days (30 days for Vietnam) as a total score out of twelve. These food groups are: cereals; white roots and tubers; vegetables; fruits; meat, poultry; eggs; fish and other sea food; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; spices, condiments and beverages. Total HDDS scores were calculated per household as well as the proportion of households consuming the food group.

Healthy diet: Global Burden of Disease Score

The healthy diet analysis was based on food groups that should be included or limited in a healthy or high quality diet, according to the global burden of disease (GBD) study food group recommendations[5]. The GBD recommendations are globally applicable and not country specific and based on a comparative risk assessment framework of dietary risk factors for NCDs. This resulted in fifteen dietary recommendations of which nine food group recommendations. Wholegrain food consumption could not be extracted from the available datasets and was therefore excluded. In total our GBD score consists of five food groups; fruit (250g), vegetables (360g), legumes (60g), nuts and seeds (20.5g) and milk (435g) that are recommended to be consumed above the mentioned amount in grams per day (further referred to as protective food groups), and three food groups whose intake should be limited (further referred to as limit food groups); red meat (22.5g), processed meat (2g) and sugar sweetened beverages (2.5g). For each country, food items were grouped into these eight GBD food groups. The total amount consumed for each household per food group in gram was calculated by summing the intake of all foods in one food group and divided by 7 (30 for Vietnam) to correct for the 7 (30) days recall. Intake in gram per food group for each household was divided by the total household AFE to present intake for one AFE. For the protective food groups the consumed amount was divided by the recommended amount. The maximum of the scoring for each component was set to 1. For the limit food groups a dichotomous scoring was used: if the consumed amount was below the recommended amount, it was scored as 1; if the consumed amount was above the recommended amount, it was scored as 0. Both total scores and partial scores were calculated per household AFE as well as the proportion consuming and fulfilling the food group requirement.

Nutrient adequacy

Energy and nutrient intakes were assessed for 1 day by dividing the intake by 7 (30 for Vietnam) to correct for the 7 (30) days recall. The adequacy was calculated for the following nutrients: protein, fat, calcium, zinc, iron, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin C and vitamin A, along with energy and based on the Estimated Average Requirements (EARs) of the European Food Safety Authority (EFSA)[35]. The EAR for iron was adjusted to reflect 5% bioavailability. The prevalence of nutrient inadequacy was calculated as the proportion of household AFE with reported intake below EAR[36]. For Vitamin B12 only the Adequate Intake level (AI) is available and therefore no inadequacy could be calculated.

Statistics

Descriptive analysis were calculated with Microsoft Excel 2016 and analysed by country and split by urban and rural areas, for all countries except Bangladesh. The weighted averages were calculated by using the population sample weights in order to ensure the representativeness of national, rural and urban population.

Results

Household Dietary Diversity Score (HDDS)

The total mean HDDS were lower in the African compared to the Asian countries and were 6.8 (1.9) in Ethiopia, 8.7 (2.0) in Nigeria, 10.0 (1.5) in rural Bangladesh, and 10.1 (1.4) in Vietnam (**Table 1**). There was no large difference between rural and urban areas mean HDDS (6.2 , (1.7) and 8.0 (1.7), respectively), except for Ethiopia. Most households consumed the food groups "Cereals" , "Vegetables", "Oils and fats" and "Spices, condiments and beverages". The consumption of animal based product was higher in Asia compared to Africa while " Fish and other seafood" was hardly consumed in Ethiopia. In Ethiopia, five food groups were consumed by less than 50% of households (red coloured in Table 1): " Fruits", "Meat", "Eggs", "Fish and other seafood", and "Milk and milk products", while for all food groups the proportion of households consuming them were lower in rural compared to urban areas. In Nigeria three food groups ("Fruit", "Eggs" and "Milk and milk products") and in Bangladesh and Vietnam two food groups were consumed by less than 50% of the households ("Meat" and "Milk and milk products", for Bangladesh and "White roots and tubers", "Milk and milk products" in Vietnam).

Table 1 *Mean Household Dietary Diversity Scores (HDDS) and percentages of households consuming HDDS food groups per country and rural and urban areas*

	Ethiopia			Nigeria			Bangladesh	Vietnam		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Rural	Urban	Total
HDDS[1]	6.2 (1.7)	8.0 (1.7)	6.8 (1.9)	8.3 (2.0)	9.3 (1.8)	8.7 (2.0)	10.0 (1.5)	9.9 (1.4)	10.6 (1.2)	10.1 (1.4)
Food groups HDDS, % consumption per household[1]										
Cereals	99.1	99.8	99.4	98.4	99.5	98.7	100	100	100	100
White roots and tubers	51.0	80.0	61.2	78.4	91.1	82.6	98.0	27.2	44.0	32.3
Vegetables	87.9	97.5	91.3	96.4	98.4	97.1	99.9	99.1	99.6	99.2
Fruits	20.8	45.8	29.6	44.6	57.0	48.6	81.3	80.6	94.3	84.7
Meat	17.7	44.8	27.2	52.9	65.2	56.9	49.2	98.7	99.2	98.9
Eggs	11.1	30.9	18.1	11.5	29.0	17.2	72.1	86.8	93.0	88.7
Fish and other seafood	2.0	1.6	1.9	66.6	80.8	71.3	95.2	95.0	97.7	95.8
Legumes, nuts and seeds	63.2	87.3	71.7	87.6	92.9	89.3	78.5	79.2	86.1	81.3
Milk and milk products	37.8	37.7	37.8	32.4	49.1	37.9	48.2	38.5	54.9	43.5
Oils and fats	81.6	93.8	85.9	96.3	98.3	96.9	99.7	98.8	99.5	99.0
Sweets[2]	45.3	84.9	59.2	70.6	74.3	71.8	77.4	87.3	94.7	89.5
Spices, condiments and beverages	99.4	99.6	99.5	97.8	99.4	98.3	100	97.7	99.1	98.1

Ethiopia: Rural n=2761, Urban n=1492, Total n=4253; Nigeria: Rural n=2625, Urban n=1275, Total n=3900; Bangladesh: Rural n=6321; Vietnam: Rural n=6519, Urban n=2810, Total n=9329

[1] Consumed by % of households: green ≥80%, yellow 50-80%, red ≤50%

[2] For the food group Sweets, consumed by % of households: red ≥80%, yellow 50-80%, green ≤50%

Healthy diet: Global Burden of Disease Score

A high overall GBD score indicates a better adherence to the healthy diet, which also counts for the partial scores for protective and limit food groups. The mean GBD score was 3.9 (0.7) in Ethiopia, 3.9 (0.9) in Nigeria, 4.1 (0.7) in rural Bangladesh and 2.6 (1.0) in Vietnam (**Table 2**). Ethiopia, Nigeria and Bangladesh showed a low protective food group score but a high limit food group score (1.1 (0.6) and 2.8 (0.5) in Ethiopia, 1.4 (0.8) and 2.5 (0.6) in Nigeria, and 1.3 (0.7) and 2.9 (0.4) in Bangladesh, respectively); while Vietnam showed a low score for both (1.1 (0.7) and 1.5 (0.9), respectively). In the protective food group scores, scores were mostly attributable to "Legumes" in Africa and to "Vegetables" in Asia. The food group "Milk" was least credited throughout the four countries. For the limit food groups, most scores were received for "Meat" and "Sugar sweetened beverages" and this last group much more in urban Ethiopia and in rural and urban Vietnam. Mean intakes for the protective food groups were all lower compared to the recommendations and for the limit food groups "Sugar sweetened beverages" intake was above the recommendation for all countries except Bangladesh (**Table 3**).

Table 4 shows the percentages of households consuming the GBD food groups and fulfilling the recommended intakes. The food group "Vegetables" and to a certain extent also "Legumes" was consumed by almost all households (>90% and therefore colour coded green) but did not often reach the recommendations (<15% and therefore colour coded red). "Milk" and "Nuts and Seeds" were only consumed by few households and in insufficient amounts by any country and were colour coded red. In Ethiopia and Nigeria, the percentage of households consuming fruits is below 50% while in Bangladesh and Vietnam more than 80% of households consume fruit. However, in all countries the amount of fruits consumed is below the recommendation. None of the limit food groups were consumed by many households nor in high quantities except for "Red meat" consumption in Vietnam (by 98% of the households and above the recommended quantity). Sugar sweetened beverages were consumed by more urban then rural households and only in urban Vietnam less than 50% did not pass the recommendations.

Table 2 *Global Burden of Diseases (GBD) recommendations and scores per food group per households adult female equivalent per country and rural and urban areas*

		Ethiopia			Nigeria			Bangladesh	Vietnam		
	Recommended intake, g/day	Rural n=2761	Urban n=1492	Total n=4253	Rural n=2625	Urban n=1275	Total n=3900	Rural n=6321	Rural n=6519	Urban n=2810	Total n=9329
Total GBD score [a], mean (SD)		3.9 (0.6)	3.9 (0.8)	3.9 (0.7)	3.9 (0.9)	3.8 (0.9)	3.9 (0.9)	4.1 (0.70)	2.7 (1.0)	2.5 (1.0)	2.6 (1.0)
Protective food group score [b]	-	1.0 (0.5)	1.4 (0.7)	1.1 (0.6)	1.3 (0.8)	1.4 (0.7)	1.4 (0.8)	1.3 (0.7)	1.2 (0.7)	0.9 (0.6)	1.1 (0.7)
Fruit	250	0.04 (0.14)	0.10 (0.17)	0.06 (0.15)	0.22 (0.33)	0.28 (0.35)	0.25 (0.34)	0.21 (0.26)	0.22 (0.22)	0.29 (0.24)	0.24 (0.23)
Vegetables	360	0.17 (0.18)	0.42 (0.28)	0.24 (0.24)	0.23 (0.20)	0.30 (0.20)	0.25 (0.20)	0.61 (0.26)	0.29 (0.25)	0.36 (0.22)	0.38 (0.24)
Legumes	60	0.59 (0.40)	0.69 (0.37)	0.62 (0.40)	0.60 (0.37)	0.65 (0.35)	0.62 (0.36)	0.25 (0.25)	0.37 (0.31)	0.17 (0.21)	0.31 (0.30)
Nuts and seeds	20.5	0.12 (0.30)	0.12 (0.29)	0.12 (0.30)	0.23 (0.34)	0.19 (0.29)	0.22 (0.32)	0.09 (0.26)	0.11 (0.20)	0.03 (0.09)	0.08 (0.17)
Milk	435	0.07 (0.15)	0.08 (0.16)	0.07 (0.16)	0.02 (0.06)	0.02 (0.4)	0.02 (0.05)	0.09 (0.15)	0.09 (0.16)	0.10 (0.19)	0.09 (0.17)
Limit food group score [c]	-	2.9 (0.4)	2.5 (0.7)	2.8 (0.5)	2.6 (0.6)	2.4 (0.7)	2.5 (0.6)	2.9 (0.4)	1.5 (0.9)	1.6 (1.0)	1.5 (0.9)
Red meat	22.5	0.92 (0.27)	0.74 (0.44)	0.87 (0.34)	0.74 (0.44)	0.61 (0.49)	0.68 (0.46)	0.90 (0.31)	0.25 (0.44)	0.40 (0.50)	0.30 (0.46)
Processed meat	2	-	-	-	0.99 (0.3)	0.99 (0.03)	0.99 (0.03)	1.00 (0.00)	0.54 (0.50)	0.73 (0.44)	0.60 (0.49)
Sugar sweetened beverages	2.5	0.96 (0.21)	0.78 (0.42)	0.90 (0.29)	0.82 (0.38)	0.79 (0.41)	0.81 (0.39)	0.96 (0.19)	0.70 (0.46)	0.45 (0.50)	0.62 (0.49)

[a] Maximum total GBD score = 8, a higher score indicates better adherence.

[b] Maximum protective food group score = 5, a higher score indicates better adherence; The score for protective food groups is calculated dividing the consumed amount by the recommended amount. The maximum scoring for each component is set to 1.

[c] Maximum limit food group score = 3, a higher score indicates better adherence. The score for the limit food group is dichotomous. If the consumed amount is below the recommended amount it is scored as 1; if the consumed amount is above the recommended amount, it is scored as 0.

Table 3 *Global Burden of Diseases (GBD) recommendations and household mean intake in g/day per household adult female equivalent of GBD food groups per country and rural and urban areas*

		Ethiopia			Nigeria			Bangladesh	Vietnam		
		Mean intake, g/day (SD)			Mean intake, g/day (SD)			Mean intake, g/day (SD)	Mean intake, g/day (SD)		
Food groups	Recommended intake, g/day	Rural n=2761	Urban n=1492	Total n=4253	Rural n=2625	Urban n=1275	Total n=3900	Rural n=6321	Rural n=6519	Urban n=2810	Total n=9329
Fruit	250	11.8 (56.8)	25.5 (54.9)	15.6 (56.6)	70.4 (140.2)	96.9 (197.8)	81.5 (167.4)	57.6 (87.0)	56.3 (66.9)	75.6 (75.2)	62.4 (70.2)
Vegetables	360	64.0 (117.2)	166.4 (169.6)	92.6 (141.5)	87.0 (137.6)	110.2 (92.6)	96.8 (121.3)	236.3 (177.6)	145.2 (114.1)	133.0 (105.0)	141.4 (111.5)
Legumes	60	60.4 (69.6)	67.3 (63.1)	62.3 (67.9)	47.9 (45.2)	55.3 (52.1)	51.1 (48.3)	15.8 (17.9)	25.0 (26.1)	10.8 (19.7)	20.5 (25.1)
Nuts and seeds	20.5	6.0 (21.8)	6.0 (29.5)	6.0 (24.2)	6.5 (14.2)	4.6 (9.1)	5.7 (12.3)	3.5 (16.0)	2.3 (4.8)	0.6 (2.0)	1.8 (4.2)
Milk	435	30.7 (76.9)	35.7 (83.1)	32.1 (78.7)	7.4 (24.4)	7.6 (19.0)	7.5 (22.3)	40.1 (66.8)	38.5 (75.7)	47.3 (107.9)	41.3 (87.3)
Red meat	22.5	5.3 (17.5)	18.6 (47.3)	9.0 (29.7)	15.8 (25.6)	22.6 (31.3)	18.7 (28.4)	5.6 (17.0)	41.8 (29.4)	31.8 (24.0)	38.6 (28.2)
Processed meat	2	-	-	-	0.1 (1.9)	0.0 (0.1)	0.0 (1.5)	0.8 (6.2)	18.1 (87.8)	119.1 (274.4)	49.9 (176.8)
Sugar sweetened beverages	2.5	2.1 (16.3)	14.9 (42.0)	5.6 (26.7)	6.7 (20.6)	9.5 (24.6)	7.9 (22.4)	0.0 (0.0)	4.8 (7.7)	3.4 (7.7)	4.3 (7.7)

Table 4 *Percentage of households consuming and fulfilling the recommendations of the Global Burden of Diseases (GBD) food groups per household adult female equivalent per country and rural and urban areas*

	Ethiopia						Nigeria						Bangladesh		Vietnam					
	HH consuming %			HH fulfilling %			HH consuming %			HH fulfilling %			HH consuming %	HH fulfilling %	HH consuming %			HH fulfilling %		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Rural	Rural	Urban	Total	Rural	Urban	Total
Healthy food groups in GBD																				
Fruit[1]	20.7	45.8	29.5	1.4	0.8	1.2	44.6	57.0	48.6	8.2	11.4	9.3	80.8	3.7	81.6	91.9	84.7	1.9	3.5	2.3
Vegetables [a]	84.8	97.3	89.1	1.4	7.3	3.5	97.1	98.6	97.6	1.1	1.2	1.2	99.9	14.8	99.2	99.3	99.2	4.3	3.2	4.0
Legumes [a]	70.8	23.2	76.2	32.7	42.4	36.1	80.8	89.5	83.6	27.8	30.2	28.6	77.3	3.0	85.2	64.9	79.1	7.4	1.3	5.5
Nuts and seeds [a]	14.4	15.4	14.7	8	6.4	7.4	43.5	46.7	44.6	9.6	5.8	8.4	14.7	5.1	35.1	13.6	28.6	1.0	0.1	0.7
Milk[a]	33.7	36	34.5	1.5	0.8	1.2	32	48.5	37.4	0.0	0.0	0.0	48.2	0.1	42.9	44.8	43.4	0.5	1.0	0.7
Limit food groups in GBD																				
Red meat [b,c]	16.7	42.4	25.7	91.2	71.8	84.4	48.6	58.7	51.9	74.7	60.3	70.0	17.0	89.5	98.6	96.9	98.1	26.1	39.0	30.0
Processed meat [b,c]	-	-	-	-	-	-	0.0	0.1	0.1	100.0	99.9	99.9	0.0	100	44.1	27.2	39.0	56.8	73.1	61.7
Sugar sweetened beverages [b,c]	5.6	23.2	11.8	94.6	77.1	88.4	17.0	23.1	19.0	83.0	77.1	81.1	0.5	96.2	30.5	53.5	37.5	70.0	46.9	63.0

Ethiopia: Rural n=2761, Urban n=1492, Total n=4253; Nigeria: Rural n=2625, Urban n=1275, Total n=3900; Bangladesh: Rural n=6321; Vietnam: Rural n=6519, Urban n=2810, Total n=9329

[a] Protective food groups consumed by % of households: green ≥80%, yellow 50-80%, red ≤50%

[b] Limit food groups consumed by % of households: red ≥80%, yellow 50-80%, green ≤50%

[c] Limit food groups fulfilling GBD recommendations by % of households: green ≥80%, yellow 50-80%, red ≤50%

Table 5 *Estimated Average Requirements (EAR) and mean energy and nutrient intake per household adult female equivalent per country and rural and urban areas*

		Ethiopia			**Nigeria**			**Bangladesh**	**Vietnam**		
	EAR	Mean intake			Mean intake			Mean intake	Mean intake		
Nutrients, mean (SD)		Rural n=2761	Urban n=1492	Total n=4253	Rural n=2625	Urban n=1275	Total n=3900	Rural n=6321	Rural n=6519	Urban n=2810	Total n=9329
Energy, kcal	2,078	2493 (1034)	2548 (1034)	2508 (1035)	2443 (1059)	2134 (953)	2313 (1027)	2390 (693)	2001 (623)	1720 (614)	1913 (634)
Protein, g	38.6	61.8 (30.1)	69.1 (32.5)	63.8 (30.9)	62.8 (32.5)	57.3 (31.1)	60.5 (32.0)	64.8 (24.1)	71.6 (33.2)	75.6 (48.3)	72.9 (38.6)
Fat, g	69.3	35.7 (23.2)	49.0 (31.6)	39.4 (26.5)	54.7 (30.9)	54.1 (33.6)	54.5 (32.1)	39.8 (19.3)	38.7 (17.5)	39.7 (18.1)	39.0 (17.7)
Calcium , mg	750	514.8 (453.4)	640.2 (406.6)	549.8 (444.4)	329.8 (216.8)	320.8 (218.0)	326.0 (217.3)	390.3 (370.5)	395.7 (182.5)	432.9 (211.6)	407.4 (192.9)
Iron [a], mg	25.2	82.5 (62.4)	118.6 (63.6)	92.6 (64.8)	20.2 (13.5)	14.7 (9.1)	17.9 (12.2)	11.3 (5.5)	10.4 (3.7)	10.0 (4.0)	10.2 (3.8)
Zinc, mg	10.2	10.5 (6.1)	8.8 (5.3)	10 (5.9)	11.1 (5.5)	10.0 (5.2)	16.6 (5.4)	10.7 (3.6)	10.3 (3.4)	9.5 (3.5)	10.0 (3.5)
Thiamine, mg	0.63	11.3 (18.2)	9.6 (14.4)	10.8 (17.2)	2.4 (1.4)	1.8 (1.1)	2.2 (1.3)	0.9 (0.4)	0.8 (0.3)	0.8 (0.3)	0.7 (0.3)
Riboflavin, mg	1.3	1.3 (0.7)	1.6 (0.7)	1.4 (0.7)	0.9 (0.5)	0.8 (0.5)	0.8 (0.5)	0.8 (0.5)	0.6 (0.3)	0.7 (0.3)	0.6 (0.3)
Niacin, mg	11.3	12.6 (6.1)	13.7 (6.8)	12.9 (6.3)	15.8 (8.6)	12.3 (7.3)	14.4 (8.2)	18.2 (7.2)	12.4 (4.3)	11.8 (4.6)	12.2 (4.4)
Vitamin B6, mg	1.3	2.2 (1.1)	2.2 (1)	2.2 (1.0)	2.8 (1.6)	2.4 (1.4)	2.6 (1.5)	1.8 (2.1)	1.2 (0.5)	1.2 (0.5)	1.2 (0.5)
Folate, µg	250	259.5 (157.4)	347.4 (179.3)	284 (168.5)	455.4 (251.1)	449.5 (262.7)	452.9 (256.1)	167.9 (81.3)	155.4 (86.6)	174.9 (95.1)	161.6 (89.8)
Vitamin B12 [b] , µg	4 [b]	0.2 (0.4)	0.2 (0.8)	0.2 (0.5)	2.0 (2.9)	2.5 (2.7)	2.2 (2.8)	1.1 (1.5)	1.5 (0.9)	1.7 (0.9)	1.6 (0.9)
Vitamin C, mg	80	33.6 (41.7)	57.7 (72.2)	40.3 (53.1)	107.7 (117.3)	111.2 (88.1)	109.2 (106.0)	89.1 (69.0)	50.0 (41.6)	68.1 (55.7)	55.7 (47.3)
Vitamin A, µg	490	306.6 (977.3)	432.6 (760.5)	341.8 (923.6)	1510.3 (1146.6)	1623.5 (1243.6)	1558.0 (1189.8)	314.1 (351.2)	274.1 (195.4)	316.0 (192.1)	287.3 (195.3)

[a] EAR based on EFSA 2014

[b] adjusted from EFSA using 5% bioavailability

[c] reflects Adequate Intake level as no EAR for vitamin B12 is available

Nutrient adequacy

The estimated average requirement (EAR) represents the intake to meet the requirement for a specific nutrient for half of the healthy individuals of a specific age, sex, and life-stage. The EAR's and intake for the macro and micronutrients are given in **table 5**. **Table 6** presents the % household AFE with intakes below the EAR, representing a high probability of insufficient intake. Vietnam shows that more than 50% of households have intakes below the EAR for energy and the highest number of nutrients (for nine out of 12 nutrients, shown in red and orange), followed by Bangladesh (eight out of 12 nutrients), Ethiopia (six out of 12 nutrients) and Nigeria (six out of 12 nutrients). Although in Vietnam no major differences were seen between rural and urban areas, in Ethiopia rural areas and in Nigeria urban areas were worse off. Overall fat, calcium and zinc EAR requirements were not met in any country. Iron and riboflavin intake was below the EAR in all countries except in Ethiopia. Folate intake was low especially in Bangladesh and Vietnam. Vitamin A intake was low in all countries except Nigeria.

Table 6 *Percentage of households with adult female equivalent intakes below the Estimated Average Requirements (EAR) for energy and nutrients per country and rural and urban areas*

	Ethiopia			Nigeria			Bangladesh	Vietnam		
	HH < EAR, %			HH < EAR, %			HH < EAR, %	HH < EAR, %		
Nutrients [a]	Rural	Urban	Total	Rural	Urban	Total	Rural	Rural	Urban	Total
Energy	38.4	37.7	38.1	43.0	53.4	46.4	35.8	60.8	75.1	65.1
Protein	25.4	18.3	22.9	27.0	31.8	28.6	8.4	6.5	8.6	7.2
Fat	90.8	79.8	87.0	75.1	75.0	75.1	93.6	94.4	93.5	94.1
Calcium	82.8	72.3	79.1	95.4	96.0	95.6	91.5	95.9	93.3	95.1
Iron [b]	17.7	5.2	13.3	75.0	88.5	79.4	98.3	99.3	99.1	99.2
Zinc	53.7	68.3	58.8	50.6	58.9	53.3	50.6	55.2	63.5	57.7
Thiamine	5.4	2.5	4.4	4.3	7.8	5.5	16.4	33.4	36.1	34.2
Riboflavin	48.5	39.6	45.4	78.9	86.7	81.5	86.9	97.8	95.9	97.2
Niacin	44.5	42.4	43.7	36.8	53.3	42.2	12.5	45.1	51.6	47.0
Vitamin B6	18.7	16.0	17.7	13.4	19.1	15.3	20.3	63.8	65.6	64.4
Folate	60.8	34.1	51.5	21.3	20.2	20.9	87.4	88.4	84.4	87.2
Vitamin B12 [c]										
Vitamin C	89.6	78.4	85.7	53.4	43.8	50.3	54.9	84.6	75.1	81.7
Vitamin A	85.7	75.1	82.0	11.3	6.0	9.6	82.2	89.4	86.5	88.6

Ethiopia: Rural n=2761, Urban n=1492,Total n=4253; Nigeria: Rural n=2625, Urban n=1275, Total n=3900; Bangladesh: Rural n=6321; Vietnam: Rural n=6519, Urban n=2810, Total n=9329

1Protective food groups consumed by % of households: green ≥80%, yellow 50-80%; red ≤50%

[a] % of households AFE below the EAR: red ≥80%, yellow 50-80%, green ≤50%

[b] adjusted from EFSA using 5% bioavailability

[C] For vitamin B12 no EAR is available and therefore no % below the EAR can be calculated.

Discussion

In this paper we analysed the dietary gap for four countries with public available datasets using diversity, food group intake of healthy and foods that should be limited, and nutrient adequacy. The use of a combination of indicators has advantages to using one of the indicators in isolation as important dietary gaps can be missed. Often the dietary diversity score is used as a proxy indicator of nutrient adequacy [37], but does not provide information on the quantities consumed. DDS results show lower values and so higher risk of micronutrient deficiencies in Ethiopia and Nigeria compared to Vietnam and Bangladesh. However, the nutrient adequacy data showed that intakes in Vietnam and Bangladesh were insufficient for a higher number of nutrients compared to the other countries. In addition, the relative high percentages of households consuming vegetables in the DDS, hide the fact that vegetables were consumed in insufficient quantities, as shown by the GBD indicators. This was also the case for "legumes", and although "Legumes" did not have a solitary count in the DDS (as it is combined with "Nuts and Seeds") the GBD indicators showed that a large number of households do consume legumes but in much lower quantities than recommended. In addition, the separate assessment of intake of healthy food groups and those whose intake should be limited in the GBD indicator, provides a more comprehensive overview of diet quality. The importance of assessing intake of both types of food groups was shown by Imamura et al[38] reporting that the consumption of healthy foods increased in the last twenty years but that also the consumption of unhealthy foods increased greatly. Our data indicate that from the limit food groups, especially "Sweets" and "Sugar sweetened beverages" are of concern, although with the current nutrition transition one could argue that although the consumption of other limit food groups is low, it might be expected to increase over time and therefore deserves close attention[39].

The combined interpretation of the used indicators provides important directions for intervention needed. Used indicators have different meanings. The dietary diversity shows the number of households (not) consuming specific food groups and a low diversity shows the need to convince households to eat specific food groups they do normally not eat. The adherence to healthy diets according to the GBD, in addition, indicates whether households, if consuming specific food groups, eat them in sufficient quantities. Convincing households to start eating certain food groups or to increase the quantities already consumed do ask for different strategies. The results of the dietary diversity indicate that interventions in Ethiopia and Nigeria should aim to increase the number of households that consume more diverse food groups, especially fruits, eggs, meat, seafood and fish. In Bangladesh and Vietnam interventions should aim to have more households consume " milk and milk products" for both countries and "Meat" for Bangladesh and "White roots and tubers" in Vietnam.

In addition, for Ethiopia and Nigeria interventions should aim to increase quantities consumed of "Fruits", "Nuts and Seeds" and "Milk". For all four countries results indicate that the food groups "Vegetables" and "Legumes" are consumed by most households, but not in sufficient quantities and increasing quantities should be specifically targeted, for example by increasing portion sizes or frequency of consumption. Especially for Vietnam the consumption of the limit food groups is of concern. "Sugar sweetened beverages" are consumed by a relatively low number of households and quantities consumed do not reach the maximum level of intake (except for Vietnam). However, considering the both the number of households and the quantities consumed are higher in urban areas, one might expect that intakes increase rapidly warranting further action.

Our study has several limitations that are inherent to large datasets publicly available where the underlying assumptions and data collection processes and tools used are not easily to be find nor understood. The general limitation of HCES/LSMS data is that they are based on a recall of foods consumed over a longer time (generally 7 days; in Vietnam 30 days) affecting the accurateness of the data provided as respondents are prone to forget consumption when recall periods are longer than 24 hour[40]. In addition, estimated portions were self-reported by respondents and may have been over or underreported[41]. Furthermore, the number of foods included in the food lists used in the HCES/LSMS studies differed by country, affecting country comparisons. In addition, the

exclusion of foods eaten out-of-home underestimate consumption of especially unhealthy food, and of energy and macronutrients intakes. This could explain the high percentage of households that did not meet the EAR for energy, especially for Vietnam where out of home consumption is a common practice[42]. To capture out of home consumption remains understudied and while this practice is becoming more common in low and middle income countries, most national household surveys focus on the evaluation of consumption only at home. We used the LSMS and HCES dataset with the assumption that the food is shared among household members on the base of age-sex specific energy requirements and does not account for unequal distribution or absence and presence of guests. However, for two of our sample countries, a detailed comparison was done between individual 24h recall data and household LSMSL/HCES data and showed that these datasets and applying an energy based distribution can be used to derive conclusions across several nutrients and for the majority of population groups[31,43].

Conclusion

In dietary gap analysis, a combination of indicators measuring diversity and quantitative intake of healthy food groups and of those whose intake should be limited, provide important information and targets for interventions aiming to improve consumption of healthy diets. The use of large surveys recalculated into intake data are useful to shape interventions especially when comparing between countries for programming purposes.

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