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Food Groups Associated with a Composite Measure of Probability of Adequate Intake of 11 Micronutrients in the Diets of Women in Urban Mali[1–4]

Gina Kennedy,[5,6]* Nadia Fanou-Fogny,[5,7] Chiara Seghieri,[8] Mary Arimond,[9] Yara Koreissi,[5,10] Romain Dossa,[7] Frans J. Kok,[5] and Inge D. Brouwer[5]

[5]Division of Human Nutrition, Wageningen University, 6700 EV Wageningen, The Netherlands; [6]Nutrition and Consumer Protection Division, FAO, 00153 Rome, Italy; [7]Department of Nutrition and Food Sciences, Faculty of Agronomic Sciences, University of Abomey Calavi, 01 BP 526 Cotonou, Benin; [8]Scuola Superiore Sant'Anna, 56126 Pisa, Italy; [9]Program in International and Community Nutrition, University of California, Davis, CA 95616; and [10]Institute of Rural Economics, Regional Center of Agronomic Research, Food Technology Laboratory, Bamako, Mali

Abstract

The prevalence of micronutrient deficiency is high among women of reproductive age living in urban Mali. Despite this, there are little data on the dietary intake of micronutrients among women of reproductive age in Mali. This research tested the relationship between the quantity of intake of 21 possible food groups and estimated usual micronutrient (folate, vitamin B-12, calcium, riboflavin, niacin, vitamin A, iron, thiamin, vitamin B-6, vitamin C, and zinc) intakes and a composite measure of adequacy of 11 micronutrients [mean probability of adequacy (MPA)] based on the individual probability of adequacy (PA) for the 11 micronutrients. Food group and micronutrient intakes were calculated from 24-h recall data in an urban sample of Malian women. PA was lowest for folate, vitamin B-12, calcium, and riboflavin. The overall MPA for the composite measure of 11 micronutrients was 0.47 ± 0.18. Grams of intake from the nuts/seeds, milk/yogurt, vitamin A-rich dark green leafy vegetables (DGLV), and vitamin C-rich vegetables food groups were correlated (Spearman's rho = 0.20–0.36; $P < 0.05$) with MPA. Women in the highest consumption groups of nuts/seeds and DGLV had 5- and 6-fold greater odds of an MPA > 0.5, respectively. These findings can be used to further the development of indicators of dietary diversity and to improve micronutrient intakes of women of reproductive age. J. Nutr. 140: 2070S–2078S, 2010.

Introduction

Micronutrient malnutrition is a global public health problem; it undermines the health, development, and economic potential of millions of people worldwide. Women of reproductive age are among the most vulnerable to micronutrient deficiencies due to physiologically higher micronutrient requirements during the reproductive life stage (1). The impact of poor maternal micronutrient status is transmitted intergenerationally from mother to child, resulting in less optimal fetal growth and

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development (2). In Bamako, Mali, it is estimated that 54% of women 15–49 y with a child under 5 y suffer from anemia (3) and that the Mali national gross domestic product is decreased by 2.7% due to vitamin and mineral deficiencies (4).

Food-based approaches have been cited as one of the primary means to improve micronutrient status and control other problems related to poor diet quality (5). However, women's dietary intake receives insufficient attention in many developing countries. In Mali, there are no nationally representative data on women's food intake. Available dietary intake information is often fragmented and, due to diverse data collection methodologies, cannot be compared internationally or over time within the same country. This is partly due to the fact that collecting information on dietary intake is costly and time consuming. The challenges of collecting accurate quantitative information on dietary intake can be even greater in developing countries, where literacy levels are low, restricting the types of survey instruments that can be used (6). In addition, shared-plate eating requires adaptation of survey instruments and additional time for data collection (7).

Because of the challenges associated with quantitative dietary data collection, simpler methods yielding information on dietary intake are needed. Simple counts of the number of food groups consumed have been shown in developing country settings to be adequate proxy indicators of micronutrient intake among children (8–12) and also among adults in diverse settings (13–15). Although the use of food group diversity indicators (FGI)[11] has shown promise in different settings, methodologies for indicator construction have varied (16). For infants and children aged 6–23 mo, the WHO (17) has defined a FGI that sums 7 food groups. For older children and adults, there is currently no standard indicator and no consensus on the level of aggregation of foods or number of food groups to sum when creating FGI.

This study used 2 nonconsecutive days of 24-h dietary recall to examine the correlation between a set of 6 and 21 food groups, micronutrient intakes, and mean probability of adequacy (MPA), a summary measure of probability of adequacy (PA) across 11 micronutrients, among a sample of women of reproductive age in Bamako, Mali. The results highlight specific food groups that may have potential to improve the micronutrient adequacy of the diet of women of reproductive age in Mali and help to advance knowledge about FGI construction.

Materials and Methods

The data used in this study are from a cross-sectional food consumption survey undertaken as part of the FONIO project funded by the Sixth European Union Framework Program. Some results presented in this paper were part of a multi-site study, the Women's Dietary Diversity Project (WDDP), funded by the Food and Nutrition Technical Assistance II Project and its predecessor project, Food and Nutrition Technical Assistance. Full results of the Mali site report are available elsewhere (18). The main objective of the WDDP was to analyze the relationship between simple FGI and the micronutrient adequacy of the diet of women in resource-poor settings. A standardized protocol used by all collaborators specified the micronutrients of focus (folate, vitamin B-12, calcium, riboflavin, niacin, vitamin A, iron, thiamin, vitamin B-6, vitamin C, and zinc) and provided standardized methods for indicator construction and calculation of PA. A description of the research protocol can be found in the summary paper in this supplement (13).

Study site and sampling methodology. Study participants were women 15–49 y living in Bamako, Mali. Ethical clearance for the study was obtained from National Institute of Public Health Research in Mali. All women included in the study were informed of the study purpose and provided verbal consent.

A total sample size of 108 women was calculated based on the original FONIO objective to provide an estimate of iron intake. Five women dropped out of the survey sample, leaving 103 women with dietary intake data available from the first recall. Of the 103 women with dietary intake from the first recall, 6 did not participate in the second recall due to unavailability. During analysis, 1 woman was considered a severe outlier and was deleted from analysis, leaving a total sample of 102 women with 1 d of intake data and a subsample of 96 women with 2 nonconsecutive days of recall.

Women were selected using a 3-stage cluster sampling method (19). The initial sampling frame consisted of Bamako's 72 quarters; 12 were selected for sampling using probability proportional to size. In each selected quarter, 9 households were randomly selected using the random walk method. All women aged 15–49 y living in the selected households were listed, and 1 apparently healthy nonpregnant, nonlactating woman belonging to a Malian sociolinguistic group was randomly selected from eligible women in each household. If the selected woman was not responsible for food preparation on the recall day, amounts of ingredients used in recipes were obtained from the person responsible for meal preparation on the recall day.

Dietary intake data collection. Two 24-h dietary recalls were performed from February to April 2007, which corresponds to the postharvest season. The 2 recalls were from nonconsecutive days with 2–11 d separating the recall periods. Weekends and special event days were excluded. The participants' daily food intake was assessed by a quantitative 24-h recall method adapted to the context of shared-plate eating, which involved asking the respondent to use known-weight utensils on the recall day to help them visualize the amount of food consumed (7). Participants were asked to name all the food and drinks consumed during the preceding day, including anything consumed outside the home. Then they were asked to describe ingredients and cooking methods of any mixed dishes and the place and time of consumption. Finally, the amounts of all foods, beverages, and ingredients of mixed dishes were estimated either in household units or monetary value[12]. For meals consumed within the household, the total amount of the cooked food and the amount consumed by the respondent were estimated in household units to derive the proportion consumed by the respondent from the total volume of the dish. Food weights were measured using digital dietary scales (Soehnle, Plateau Art, model 65086, 10 kg maximum) and recorded to the nearest 2 g. Information on consumption of fortified food products was not collected. However, most of the fortified foods commonly available in the study area are designed for infants and preschool children. These foods were not consumed by any of the women in our study.

Food composition data. The food composition values used in this study are based on a food composition table developed for a larger project [a detailed description of the food composition table's development is provided elsewhere (20)] and relied primarily on the Table de Composition des aliments du Mali (TACAM) (21). The nutrients for all

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*To whom correspondence should be addressed. E-mail: s_g_kennedy@yahoo.com.

[11] Abbreviations used: AI, adequate intake; DGLV, vitamin A-rich dark, green, leafy vegetables; EAR, estimated average requirement; FGI, food group diversity indicator; MPA, mean probability of adequacy; PA, probability of adequacy; RE, retinol equivalent; TACAM, Table de Composition des aliments du Mali; WDDP, Women's Dietary Diversity Project; YORV, vitamin A-rich deep yellow, orange, and red vegetables.

[12] When a monetary unit was used to describe a portion, these foods or ingredients were converted from monetary value to weight equivalent by using the mean weight per fixed monetary value obtained from several vendors in the main market areas.

TABLE 1 Food groups

Food groups (6)	Food groups (21)
All starchy staples	Grains and grain products
	All other starchy staples
All legumes and nuts	Cooked dry beans and peas
	Soybeans and soy products
	Nuts and seeds
All dairy	Milk/yogurt
	Cheese
Other animal source foods	Organ meat
	Eggs
	Small fish eaten whole with bones
	Large whole fish/dried fish/shellfish and other seafood
	Beef, pork, veal, lamb, goat, game meat
	Chicken, duck, turkey, pigeon, guinea hen, game birds
	Insects, grubs, snakes, rodents, and other small animals
Vitamin A-rich fruits and vegetables	Vitamin A-rich DGLV
	Vitamin A-rich YORV
	Vitamin A-rich fruits
Other fruits and vegetables	Vitamin C-rich vegetables
	Vitamin C-rich fruits
	All other vegetables
	All other fruits

staple foods in TACAM are expressed as cooked. To account for nutrient losses during cooking in other foods where only raw values are provided in TACAM, such as fish, meat, and vegetables, USDA Retention Factors release 6 (22) were applied to the nutrient values of the raw foods. Twelve percent of the nutrient values were not in TACAM,[13] including 10 foods for which all values were taken from other sources. For other foods, missing values were replaced most commonly for vitamin B-6, folate, and zinc. Missing values were first obtained from USDA release 20 (23) and, if necessary, from the International Mini List (24). Retinol equivalents (RE) were calculated as the sum of retinol and β-carotene, using the following conversions: 1 μg retinol = 1 μg RE and 1 μg β-carotene = 0.167 μg RE, as recommended by the FAO/WHO (1). Nutrient values from sources other than the TACAM were adjusted to account for differences in moisture content.[14]

Food groups and food group intakes. Food group combinations based on 6 and 21 food groups were used in this analysis (**Table 1**). For simplicity of presentation, results from only the most disaggregated set of food groups (21 food groups) are presented in most tables and figures. Notable results based upon the least disaggregated set of food groups (6 food groups) are described in the text. Construction of FGI was based on food group intakes (grams) reported on only the first day of recall to coincide with the overall aim of the WDDP to test 1-d FGI that could be used in large-scale surveys.

Assessing usual micronutrient intakes, PA, and MPA. The probability approach (25) was used to estimate adequacy for all micronutrients except calcium, where the PA was calculated following the recommendations of Foote (26). Nutrient intake distributions and intra-individual SD distributions based on both days of intake were skewed for most micronutrients and were Box-Cox transformed prior to analysis. Estimated usual micronutrient intakes were calculated as best linear unbiased predictors (27). Estimated average requirements (EAR) were used to assess the PA of thiamin, riboflavin, niacin, vitamin B-6, vitamin B-12, vitamin C, vitamin A, zinc, folate, and iron. An adequate intake (AI) was used for calcium. Because iron requirements are skewed, the PA for iron was estimated using the Institute of Medicine tables for adult women (28). Iron and zinc requirements were based on a bioavailability assumption of 10% for iron and 34% for zinc, determined on the basis of the dietary pattern of the sample (1). The PA associated with estimated usual intake for each micronutrient was calculated taking into account nutrient requirement distributions and inter- and intra-individual variation in intake. MPA was constructed as a summary indicator, taking the mean of all PA.

Statistical methods. The relationship between food group intake (grams) and estimated usual micronutrient intake and food group intake and MPA was assessed by Spearman correlation due to the fact that food group intake (grams) was not normally distributed and was untransformed. For food groups observed to have a significant correlation with MPA, a categorical variable of food group intake was created. Categories of intake were defined as follows: *1*) for those food groups for which all women consumed at least 1 g, a low, middle, and high consumer category was created based on tertiles of food group intake; *2*) for other food groups, the low intake category was defined as an intake of 0 g and the middle and high intake categories defined by using the median intake among consumers as the cutpoint.

Binary logistic regression models were used to assess these categorical food group intake variables as predictors of MPA > 0.50. Because energy intake from individual food groups, most notably nuts/seeds, is endogenous to the model, logistic regression models controlled for total energy intake from other food groups and age. However, results were not influenced by age in any model. Therefore, only results unadjusted for age are presented. STATA/IC version 10 was used for all analyses (29). $P < 0.05$ was considered significant. Values in the text are means $\pm$ SD or medians (25th and 75th interquartile range).

Results

Sample characteristics. The mean age in the sample was 31 $\pm$ 10.5 y, with 16% adolescents (15–18 y) (**Table 2**). The literacy rate, defined as having attended primary school or Islamic school, was 65%. Median energy intake was 8474 kJ (2024 kcal) (6753 kJ, 10,521 kJ), with 11% of dietary energy from protein, 57% from carbohydrates, and 32% from fat.

Diet patterns and food group intake. The diet of this urban sample is based on a starchy staple, mainly refined white rice, refined wheat flour or millet, accompanied by a sauce typically made from vegetables and beef or fish. The most commonly consumed food groups did not differ substantially between recall days. Of the 21 possible food groups, those most commonly consumed on both recall days (based on the subsample of women with data for 2 recall days) included grains and grain products (grains); vitamin-C rich vegetables; vitamin A-rich deep yellow, orange, and red vegetables (YORV); and nuts and seeds (nuts/seeds) (**Fig. 1**). The food groups beef, pork, veal, lamb, goat, and game meat (red meat); large whole fish/dried fish/shellfish and other seafood (large fish); all other vegetables (other vegetables); milk and yogurt (milk/yogurt); vitamin-A rich dark, green, leafy vegetables (DGLV); and all other starchy staples (other staples) were consumed by the majority of women on at least 1 recall day. The food groups soybeans and soy products; cheese; organ meat; chicken, duck, turkey, pigeon, guinea hen, and game birds; insects, grubs, snakes, rodents, and other small animals; and other fruit were not consumed by any women on either day of recall. Those food groups not con-

[13] Vitamin B-6 values reported for cooked staples in the Table de Composition des aliments du Mali were very low, so vitamin B-6 values for cooked staples from the USDA and International Mini List were used.

[14] International Mini List tables do not report moisture content. The moisture content for foods taken from the International Mini List was estimated based on the closest food match from the USDA.

TABLE 2 Descriptive statistics of Malian women[1,2]

Variable	
Age, *y*	31.5 ± 10.5
Education,[3] *% literate*	65
Energy, *kJ/d*	8600 ± 3000
Total carbohydrate, *g/d*	310 ± 112
Total fat, *g/d*	73 ± 35
Total protein, *g/d*	58 ± 26

[1] Adapted with permission from (18).
[2] Values are means ± SD or %, n = 102.
[3] Percentage of women who reached at least primary school level or went to Islamic school.

sumed by any woman are not presented in the remainder of the analysis.

Micronutrient intakes, PA, and MPA. Median micronutrient intakes were below the EAR for folate, vitamin B-12, riboflavin, niacin, vitamin A, and the AI for calcium (**Table 3**). Median intakes were above the EAR for vitamin B-6, vitamin C, and zinc and equal to the EAR for thiamin. The PA was <0.25 for vitamin B-12 and folate; ranged between 0.25 and 0.49 for riboflavin, calcium, and niacin; and was ≥0.50 for iron, vitamin A, vitamin B-6, thiamin, zinc, and vitamin C. The MPA for the 11 micronutrients was 0.47 ± 0.18.

Contribution of food groups to nutrient intakes. The contribution of each food group (of the 21 groups) to nutrient intake depended on both the quantity consumed (grams) and the nutrient density of the food items consumed within that group (**Tables 4** and **5**). Median intake of grains was 775 g, which accounted for 43% of the total energy intake of the sample, over 50% of the total thiamin intake, and over one-third of the total vitamin B-6, iron, and zinc intakes. Nuts/seeds provided the next largest contribution to energy, although median intake was only 2 g. Nuts/seeds also supplied over one-third of the niacin intake and 10% or more of the thiamin, folate, and iron intakes. The median intake of vitamin C-rich vegetables, which included cabbage, tomatoes, and onions, was 209 g. This food group supplied two-thirds of the vitamin C intake, one-third of the folate intake, and over 10% of the riboflavin, vitamin B-6, vitamin A, and iron intakes. Milk/yogurt supplied only 5% of the energy intake but >20% of the riboflavin, vitamin B-12, vitamin A, and calcium intakes. Eggs did not supply >5% of the intake for any micronutrient. Red meat supplied <5% of the total energy intake but one-third of the vitamin B-12 intake and >10% of the niacin and zinc intakes. DGLV supplied <1% of the total energy intake but 36% of the vitamin A intake and 10% or more of the folate and calcium intakes.

Correlations between grams of intake from individual food groups, micronutrient intakes, and MPA. When using the highest level of food group aggregation (6 food groups), intake (grams) for each food group was positively correlated with estimated usual intakes (mg, μg, or RE) of between 4 and 7 individual micronutrients ($P < 0.001$–0.01) and with MPA ($P < 0.001$–0.01) (**Table 6**). With further disaggregation into 21 food groups, associations became more specific to certain subgroups. Grams of intake from the food groups nuts/seeds, milk/yogurt, DGLV, and vitamin C-rich vegetables were signifi-

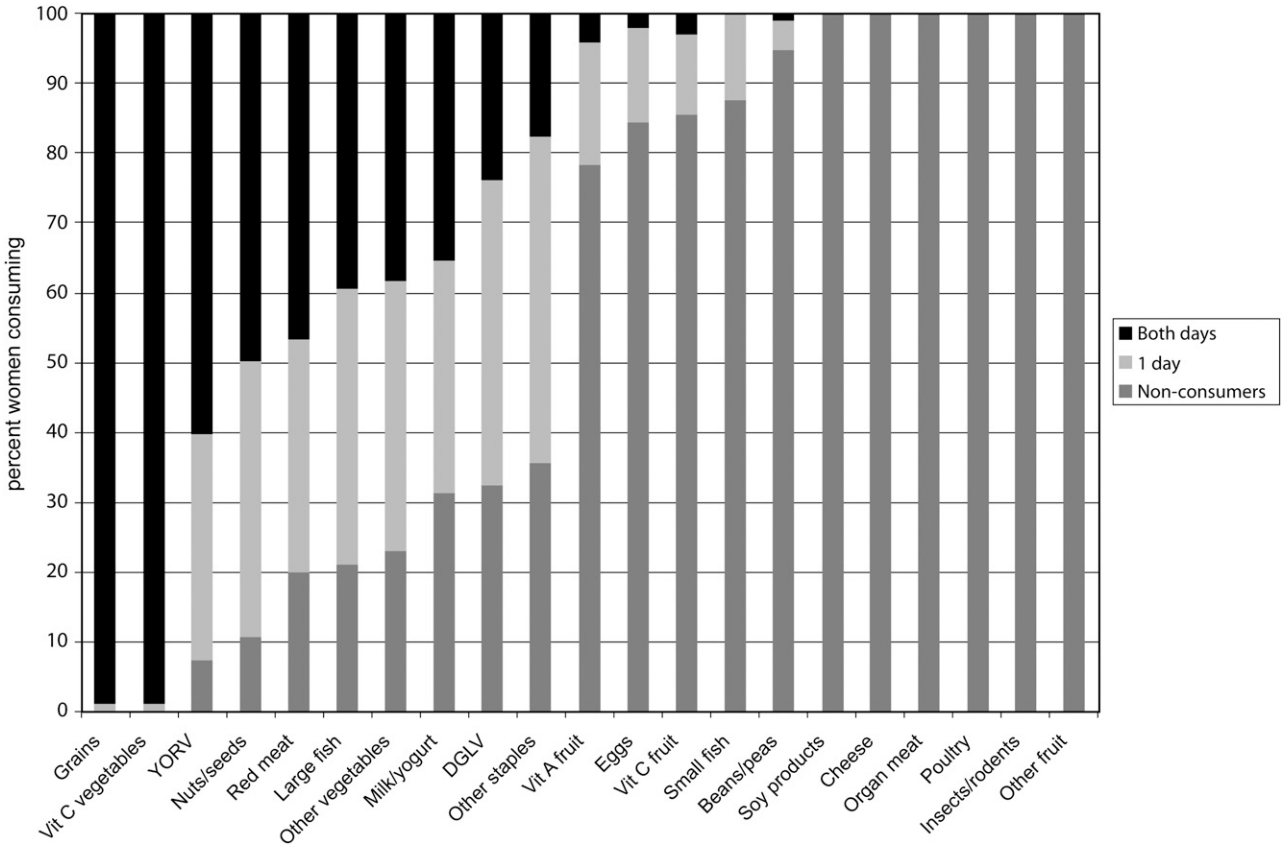

FIGURE 1 Percent of Malian women consuming individual food groups on both, one, or no days of recall (n = 96). Figure is reproduced with permission from (38).

TABLE 3 Micronutrient intakes, EAR, and PA for Malian women[1–3]

Nutrient	Mean	Median	EAR	SD[4]	PA (mean)
Folate, *μg/d*	131 ± 82.5	119	320[5,9]	32.0	0.00
Vitamin B-12, *μg/d*	1.5 ± 1.0	1.3	2.0[5]	0.2	0.17
Calcium, *mg/d*	444 ± 318	375	1,000[7,9]	–	0.27
Riboflavin, *mg/d*	0.8 ± 0.4	0.7	0.9[6,9]	0.09	0.28
Niacin, *mg/d*	10.6 ± 6.5	8.3	11[6,9]	1.65	0.31
Vitamin A, *RE/d*	358 ± 295	245	270[5,9]	54.0	0.50
Iron, *mg/d*	16.1 ± 8.8	14.2	–[8]	–	0.54
Thiamin, *mg/d*	1.0 ± 0.5	0.9	0.9[6]	0.09	0.59
Vitamin B-6, *mg/d*	1.2 ± 0.5	1.2	1.1[6,9]	0.11	0.67
Vitamin C, *mg/d*	62.6 ± 34.5	58.4	38[6]	3.8	0.88
Zinc, *mg/d*	10.2 ± 5.8	8.8	6.0[9,10]	0.75	0.96
MPA	0.47 ± 0.18	0.48			

[1] Adapted with permission from (18).
[2] Mean and median nutrient intakes are for the first observation day. PA are based on estimated usual intake, calculated using repeat observations for a subset of the sample, incorporating information from both rounds of data collection.
[3] Values are means ± SD.
[4] All SD were calculated based on EAR and CV, which was assumed to be 10% for all micronutrients except 15% for niacin (39), 20% for vitamin A (27), and 25% for zinc (40).
[5] Values are taken directly from the WHO/FAO 2004 requirements (41).
[6] EAR were back-calculated from recommended nutrient intake values of WHO/FAO 2004 requirements (38).
[7] Not an EAR, but rather AI (42). Following Foote et al. (26), PA are calculated to be: 0% when intake was ≤ 0.25 AI; 25% for intakes > 0.25 AI and ≤ 0.50 of the AI; 50% for intakes > 0.50 and ≤ 0.75 of the AI; 75% for intakes > 0.75 and ≤ AI; and 100% for intakes above the AI.
[8] PA for iron intake were estimated using the Institute of Medicine tables for adult women (27). A bioavailability assumption of 10% was used for this study (41).
[9] For the adolescent group (15–18 y; $n = 16$), a EAR value of 0.8 ± 0.08 mg was used for riboflavin, 12 ± 1.2 mg for niacin, 7.0 ± 0.9 mg for zinc (30% bioavailability), 365 ± 73 RE for vitamin A, 330 ± 33 μg for folate, 1.0 ± 0.1 mg for vitamin B-6, and 1300 mg AI for calcium.
[10] This value is the estimated median requirement of zinc to be used for diets with a higher bioavailability (mixed of refined vegetarian diets), as suggested by the International Zinc Nutrition Consultative Group (IZiNCG) (40).

cantly correlated with intakes (mg, μg, or RE) of 5 or more individual micronutrients (**Table 7**) and with MPA ($P < 0.001$–0.01).

The 3 micronutrients with the lowest PA were folate, vitamin B-12, and calcium. Beans/peas, nuts/seeds, DGLV, and vitamin C-rich vegetables were significantly correlated with folate intakes (micrograms); milk/yogurt, eggs, and red meat were significantly correlated with vitamin B-12 intakes (micrograms); and milk/yogurt was significantly correlated with calcium intakes (milligrams).

Logistic regression of MPA > 0.50 and grams of intake from significant food groups. Binary logistic regression results for the 4 food groups (of the 21) that were significantly correlated with MPA did not differ when controlling for age but did change slightly when adjusted for energy intake from other food groups (**Table 8**). The MPA was higher for the highest consumers within each food group compared with the lowest consumers with a linear trend for consumers of nuts/seeds (P-trend < 0.01) and DGLV groups (P-trend < 0.01).

Discussion

The results indicate that macronutrient distributions, with the exception of fat, were within acceptable population intake ranges of 15–30% fat, 10–15% protein, and 55–75% carbohydrate as defined by the WHO/FAO (30); however, MPA of the sample was low.

Grains, nuts/seeds, YORV, vitamin C-rich vegetables, and all other vegetables were the most commonly consumed food groups. This is similar to other studies of dietary patterns in rural Mali, where grains, nuts/seeds, vegetables, and DGLV were consumed by all households in the survey (15). Grams of food group intake from d 1 were significantly correlated with MPA for nuts/seeds, milk/yogurt, DGLV, and vitamin C-rich vegetables. Logistic regression results showed the highest consumers of nuts/seeds had 5 times higher odds than nonconsumers to have an MPA > 0.50. Consumers in the highest category of DGLV intake had 6 times higher odds of an MPA > 0.50 than nonconsumers.

Study limitations. Both the data for individual food groups consumed and the estimated usual micronutrient intakes were calculated from the same 24-h recall data; however, estimated usual micronutrient intakes, PA, and MPA were based on 2 recall days, whereas food group intakes represent intakes from only d 1. Use of the same round 1 data could lead to artificially higher correlations. Conversely, the random error inherent in all dietary data collection can attenuate correlations (31). The sample size for the original study was designed to measure iron intake. Sample sizes required to measure other micronutrients may be smaller or larger than that needed to estimate iron intake. The relatively small size of the sample may not be adequate to detect significant differences for all micronutrients, particularly vitamin A, vitamin B-12, calcium, folate, and niacin, which had a larger CV than iron in our sample. Additionally, we did not control for some potential confounders of MPA such as educational level and socioeconomic status.

PA were low for several micronutrients and MPA was only 0.47. Due to the combination of low MPA and small sample size, only 47 women had an MPA > 0.50, 25 had an MPA >0.60, and 11 had MPA > 0.70. For these reasons, MPA > 0.50 was used throughout the analysis. There are no clear guidelines on how to define an acceptable MPA level. Ideally, the benchmark chosen to define acceptable MPA would be higher, e.g. 0.80, 0.90. To use a higher and more desirable probability, the sample population studied would need to have micronutrient intakes higher than those observed in this population.

Food group intakes, MPA, and intakes of individual micronutrients. Despite significant correlation with MPA, the logistic regression results for consumer categories and MPA were not significant for the highest consumers of milk/yogurt or any consumer category of vitamin C-rich vegetables. The lack of significant differences for consumers of vitamin C-rich vegetables could relate to the fact that all women consumed some amount of this food group, whereas for the other 3 food groups that were significant predictors of MPA, the reference category was nonconsumers. Another interesting result was that women who consumed 1–94 g of milk/yogurt had significantly higher odds of better MPA than nonconsumers whereas women in the highest consumption (> 94 g) did not. Reasons for this finding were not evident. For example, removing certain outliers did not alter the results. Additionally, there were very few types of milk/yogurt consumed and thus the difference observed is not likely due to consumption of different types of these products.

The nutrients with the lowest estimated prevalence of adequacy were folate, vitamin B-12, calcium, riboflavin, and niacin. These results are similar to those of nonpregnant, nonlactating women in urban Burkina Faso, where the lowest

TABLE 4 Intake of food groups by Malian women[1,2]

Food group	All women, n = 102		Consumers	Consumers only	
	g/d		*%*	*g/d*	
Grains	743 ± 333	775.5 (497, 958)	100	743 ± 333	775.5 (497, 958)
Other staples	61 ± 93	0 (0, 92)	42	144 ± 103	124 (81, 176)
Beans/peas	5 ± 5	0 (0, 0)	4	134 ± 76	121.5 (67, 212)
Nuts/seeds	37 ± 37	2 (0, 80)	70	53 ± 56	25 (2, 99)
Milk/yogurt	75 ± 136	0 (0, 86)	48	155 ± 161	94 (35, 287.5)
Red meat[3]	42 ± 38	41.5 (0, 67)	70	61 ± 31	52 (40, 81)
Large fish[4]	25 ± 38	12 (0, 38)	56	45 ± 41	35 (19, 56.5)
Small fish[5]	0.3 ± 2	0 (0, 0)	5	6 ± 4	5 (3, 10)
Eggs	4 ± 15	0 (0, 0)	8	52 ± 16	57.5 (55, 60)
DGLV[6]	30 ± 56	0 (0, 25)	41	73 ± 67	87.5 (7, 125)
YORV[7]	8 ± 9	5 (3, 8)	82	9 ± 9	5 (4, 9)
Vitamin C-rich vegetables	212 ± 115	209.5 (121, 283)	100	212 ± 115	209.5 (121, 283)
All other vegetables	16 ± 22	11 (0, 26)	60	27 ± 22	24 (14.5, 35)
Vitamin A-rich fruits	4 ± 13	0 (0, 0)	12	32 ± 24	20 (13, 50.5)
Vitamin C-rich fruits	15 ± 68	0 (0, 0)	9	167 ± 174	42 (12.5, 357)

[1] Values are means ± SD or median (interquartile range).
[2] Adapted with permission from (21).
[3] Beef, pork, veal, lamb, goat, and game meat.
[4] Large whole fish/dried fish, shellfish, and other seafood.
[5] Small fish eaten whole with bones.
[6] Vitamin A-rich DGLV.
[7] Vitamin A-rich YORV.

PA were for vitamin B-12, folate, iron, and riboflavin (32). In similar studies in rural Mali, which considered only 7 of our 11 micronutrients, calcium and vitamin A were most limited in the diets of adults (15) and vitamin A, calcium, vitamin C, and riboflavin had the lowest adequacy ratio for children (8).

Our Spearman correlation results indicate that increasing intakes of red meat, DGLV, nuts/seeds, and milk/yogurt could increase intakes of some of the key nutrients deficient in our study population. Each of these food groups was consumed on at least 1 recall day by a majority of women, indicating that there are no cultural barriers to consumption of foods within these groups. However, for many of the food groups, median portion sizes were small. Qualitative research methods could be used to explore constraints and opportunities related to increasing consumption frequency and quantity of foods within these food groups. These food groups could form the basis of focus for both programmatic efforts and individual dietary choices where the goal is to promote micronutrient adequacy through food-based approaches.

TABLE 5 Contribution of food groups (21) to energy and micronutrient intakes[1–3]

Food groups	Energy	Folate	Vitamin B-12	Calcium	Riboflavin	Niacin	Vitamin A	Iron	Thiamin	Vitamin B-6	Vitamin C	Zinc
						%						
Grains	43.0	8.8	0.2[4]	10.5	24.8	14.7	3.3	40.3	53.0	35.1	0.8	39.4
Other staples	3.1	6.1		1.5	2.0	5.9	1.3	2.2	5.9	12.9	15.0	1.2
Beans/peas	0.2	8.3		0.3	0.4	0.2		0.8	1.1	0.4		0.7
Nuts/seeds	10.3	13.0		5.6	6.2	37.5	0.1	17.6	10.6	8.3		9.0
Milk/yogurt	4.6	5.0	30.4	43.4	29.4	4.4	20.2	0.3	5.0	3.6	0.9	19.5
Red meat	4.8	1.6	30.6	1.0	8.4	14.4		9.4	6.9	4.3		17.0
Large fish	2.0	2.3	31.1	5.7	3.7	6.9	0.4	4.5	1.7	5.3	0.4	3.8
Small fish		0.1	0.5	0.7		0.2		0.1		0.2		0.1
Eggs	0.3	0.6	4.1	0.4	1.5	0.1	1.7	0.5	0.4	0.5		0.6
DGLV	0.4	12.2		10.6	7.3	2.1	35.7	5.8	2.3	3.3	6.4	1.2
YORV	0.2	1.8		0.5	0.8	1.5	11.6	1.0	1.1	2.1	0.6	0.4
Vitamin C-rich vegetables	3.9	33.0		17.1	11.7	8.8	12.3	14.1	8.8	17.0	66.5	6.2
All other vegetables	0.1	1.9		0.5	1.0	0.5	3.5	0.6	0.9	1.3	1.8	0.4
Vitamin A-rich fruits	0.5	0.1		0.1	0.1	0.1	7.5	0.1	0.1	0.1	2.1	
Vitamin C-rich fruits	0.6	2.2		0.3	0.6	0.8	0.6	0.1	0.5	3.9	2.7	0.3

[1] Reproduced with permission from (18).
[2] Percentages might not total 100 due to nutrient contributions from foods excluded from the groups comprising the FGI (e.g. fats, sweets, alcohol).
[3] Empty cells mean no contribution.
[4] This value comes from butter croissant (0.16 μg/100 g).

TABLE 6 Correlations between intakes of 6 food groups (g/d) and estimated usual micronutrient intakes or MPA[1]

Food group	Folate	Vitamin B-12	Calcium	Riboflavin	Niacin	Vitamin A	Iron	Thiamin	Vitamin B-6	Vitamin C	Zinc	MPA
	μg			*mg*		*RE*			*mg*			
All starchy staples	0.13	−0.08	0.12	0.11	0.17	−0.04	0.34*	0.47*	0.50*	0.22*	0.40*	0.25*
Legumes and nuts	0.42*	−0.03	0.13	0.15	0.56*	0.13	0.37*	0.36*	0.21*	−0.01	0.27*	0.35*
All dairy	0.10	0.50*	0.54*	0.49*	−0.01	0.36*	−0.09	0.02	0.01	−0.02	0.28*	0.25*
Other animal source foods	0.22*	0.55*	0.26*	0.32*	0.18	0.15	0.11	0.22*	0.15	0.28*	0.22*	0.27*
Vitamin A-rich fruits and vegetables	0.43*	0.05	0.13	0.19	0.19	0.55*	0.17	0.09	0.21*	0.29*	0.09	0.28*
Other fruits and vegetables	0.26*	0.05	0.08	0.14	0.16	0.02	0.19	0.29*	0.35*	0.36*	0.20*	0.22*

[1] Estimated usual micronutrient intakes and MPA incorporate information from both rounds of data collection. *$P < 0.05$.

Implications for development of proxy indicators of micronutrient adequacy. Part of the overall goal of the WDDP was to analyze the relationship between simple indicators of dietary diversity and diet quality for women. The analysis in this paper, which had a more in-depth focus on performance of individual food groups, helped to draw attention to the performance and role of certain food groups in achieving better MPA in this particular population from urban Mali.

Of the other 4 sites participating in the WDDP, the 3 food groups with the strongest correlation with MPA (controlling for energy intake) were DGLV, vitamin A-rich fruits, and red meat in Burkina Faso (32); vitamin A-rich fruit, DGLV, and other vegetables in Mozambique (33); milk, organ meat, and other vegetables in the Philippines (34); and DGLV, nuts/seeds, and small fish in Bangladesh (35). A similar study among urban adults in Benin found higher intakes of the food groups vegetables and legumes/nuts were the most strongly associated ($P < 0.001$) with a micronutrient adequacy ratio (36). An analysis of diets of rural schoolchildren in Kenya found that vegetables, fruits, and dairy had the strongest correlations to a diet most likely to be adequate in micronutrients (37). A study of the adequacy of micronutrient density of complementary foods from 9 countries tested how well selected nutrient-dense food groups ("sentinel" food groups) predicted this dimension of diet quality (9). The study also tested FGI. The most consistent sentinel group across all countries was animal source foods, which included dairy and/or eggs and/or meat/fish/poultry. Additionally, in some countries, dairy alone, vitamin-A rich fruits and vegetables, and/or other fruits and vegetables were good indicators of better diet quality of complementary foods. This was related to different diet patterns in the sites; e.g. in Malawi almost no animal source foods were consumed and DGLV were the best sentinel food group to predict micronutrient density.

Based on the convergence of evidence from these studies, dairy, eggs fruits and vegetables, particularly DGLV, fish, red meat, and legumes and nuts, or their subgroups are key food groups for developing proxy indicators of micronutrient adequacy based on dietary diversity scores. However, for operational purposes, it is important to note that the food groups contributing most to micronutrient adequacy varied by study site. These findings support using combinations of food groups rather than single food groups in isolation serving as sentinel food groups, because no individual food group seems to perform equally well across diverse contexts.

In conclusion, this analysis showed a strong and positive association between the quantity of intake (grams) of the food groups nut/seeds and DGLV and higher MPA. The food groups milk/yogurt and vitamin C-rich vegetables were also positively and significantly correlated with MPA, although the relationship was not as strong. These results suggest that dietary diversification

TABLE 7 Correlations between intakes of 21 (g/d) food groups and estimated usual micronutrient intakes and MPA[1]

Food group	Folate	Vitamin B-12	Calcium	Riboflavin	Niacin	Vitamin A	Iron	Thiamin	Vitamin B-6	Vitamin C	Zinc	MPA
	μg			*mg*		*RE*			*mg*			
Grains	0.09	−0.11	0.09	0.07	0.15	−0.11	0.33*	0.44*	0.44*	0.17	0.39*	0.19
Other staples	0.14	0.09	0.09	0.11	0.01	0.24	0.00	0.06	0.19	0.21*	0.03	0.14
Beans/peas	0.30*	−0.06	−0.09	−0.11	−0.03	0.02	0.04	0.02	−0.08	−0.17	0.05	−0.05
Nuts/seeds	0.29*	−0.02	0.16	0.18	0.57*	0.12	0.35*	0.37*	0.24*	0.05	0.24*	0.36*
Milk/yogurt	0.10	0.50*	0.54*	0.49*	−0.01	0.36*	−0.09	0.24	0.01	−0.02	0.28*	0.25*
Eggs	0.10	0.25*	0.10	0.14	−0.09	0.17	−0.12	−0.07	−0.00	0.05	−0.15	0.09
Small fish	0.10	0.00	0.02	0.02	0.19	0.07	0.18	0.00	0.17	0.07	0.13	0.08
Large fish	−0.01	0.14	0.04	−0.03	0.17	−0.15	0.11	0.10	0.19	0.05	0.06	0.09
Red meat	0.16	0.28*	0.14	0.23*	0.07	0.16	0.05	0.15	−0.02	0.18	0.21*	0.14
DGLV	0.42*	0.03	0.18	0.22*	0.27*	0.45*	0.34*	0.11	0.09	0.12	0.22*	0.27*
YORV	0.01	0.03	−0.04	−0.07	0.03	−0.02	−0.04	0.09	0.18	0.16	0.07	0.03
Vitamin C-rich vegetables	0.25*	0.04	0.07	0.12	0.16	−0.03	0.18	0.27*	0.30*	0.33*	0.20*	0.20*
Vitamin A-rich fruits	0.02	0.01	−0.03	−0.01	−0.06	0.24*	−0.13	−0.03	0.03	0.16	−0.16	0.04
Vitamin C-rich fruits	0.06	0.08	0.01	0.04	−0.12	0.15	−0.21*	−0.15	0.02	0.14	−0.26*	−0.01
All other vegetables	0.06	0.06	0.13	0.11	0.03	0.14	0.14	0.16	0.19	0.18	0.15	0.15

[1] Estimated usual micronutrient intakes and MPA incorporate information from both rounds of data collection. *$P < 0.05$.

TABLE 8 Energy-adjusted odds ratios for MPA > 0.50 and selected food groups[1–3]

Food group	Intake, *g*	MPA[4]	OR [95%CI]	*P*-value[5]
Nuts/seeds	0	0.41 ± 0.18	1.0	
	1–25	0.45 ± 0.18	1.5 (0.5, 4.5)	
	>25	0.55 ± 0.17	4.7 (1.5, 14.0)	<0.01
Milk/yogurt	0	0.43 ± 0.17	1.0	
	1–94	0.54 ± 0.22	5.8 (1.8, 18.9)	
	>94	0.50 ± 0.16	1.4 (0.65, 4.2)	0.26
DGLV	0	0.43 ± 0.18	1.0	
	1–88	0.52 ± 0.17	1.8 (0.6, 5.4)	
	>88	0.54 ± 0.17	6.1 (1.7, 21.6)	<0.01
Vitamin C-rich vegetables	<141	0.44 ± 0.20	1.0	
	141–262	0.46 ± 0.18	0.8 (0.3, 2.3)	
	>262	0.51 ± 0.16	1.0 (0.3, 3.1)	0.91

[1] Adjusted for the effect of total energy intake, excluding energy provided from that food group.
[2] Cutoff points to form 3 comparison categories were based upon intake distributions for each food group.
[3] Intakes are from first 24-h recall. MPA incorporates information from both rounds of data collection.
[4] Values are mean ± SD or odds ratio (95% CI).
[5] *P*-value for linear trend across categories.

is a valid strategy to improve micronutrient intake of women of reproductive age, because several food groups contributed substantially to estimated intakes of different individual micronutrients. In Mali, a particular focus on increasing intake of nuts and seeds and DGLV could be used to help improve micronutrient intakes in vulnerable populations.

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