The Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) Indicator Is Related to Household Food Insecurity and Farm Production Diversity: Evidence from Rural Mali

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ABSTRACT

Background: The popularity of nutrition-sensitive interventions calls for high-quality monitoring and evaluation tools. In this context, the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W), validated as a proxy of micronutrient adequacy, does fill a gap. However, because it is a newly endorsed indicator, information on its linkages with other dimensions of food and nutrition security is still scarce.

Objective: The objective of this study was to investigate whether the MDD-W is related to household food insecurity and farm production diversity.

Methods: A cross-sectional survey on a representative sample of 5046 women of reproductive age was conducted in the region of Kayes, Mali, in 2013. Dietary diversity was assessed through qualitative 24-h recall, and MDD-W was computed. MDD-W equaled 1 if the women consumed at least 5 different food groups and 0 otherwise. Food insecurity was measured using the Household Food Insecurity Access Scale and the Household Hunger Scale (HHS), and a farm production diversity score (FPDS) was calculated based on a count of food crops/livestock groups produced. Logistic regressions were used to assess the relation between MDD-W and the indicators of household food security.

Results: Only 27% of women reached the MDD-W. These women consumed animal source foods and/or vitamin A-rich vegetables and fruits more frequently than did other women. Women from extremely food insecure households (moderate to severe hunger according to the HHS) were less likely to reach the MDD-W (OR: 0.70; 95% CI: 0.50, 0.97). One more group in the FPDS increased the odds of attaining the MDD-W (OR: 1.12; 95% CI: 1.06, 1.18).

Conclusion: In the rural region of Kayes, Mali, women's dietary diversity, as measured by the MDD-W, was associated with household-level food security indicators. This study was registered at ISRCTN.org as ISRCTN08435964. *Curr Dev Nutr* 2019;3:nzz002.

Keywords: women, dietary diversity, nutrition sensitive, household food security, farm production diversity, West Africa, rural

Manuscript received August 27, 2018. Initial review completed November 5, 2018. Revision accepted January 2, 2019. Published online January 16, 2019.

The program implementation was funded by Global Affairs Canada, with support from UNICEF. The research was funded by the European Union through the International Fund for Agricultural Development, UNICEF, World Health Food Program, and Research Institute for Development, with additional support from the CGIAR Research Programs on Agriculture for Nutrition and Health (A4NH) hosted by the International Food Policy Research Institute.

LA received a research allowance from the French Ministry of Higher Education and Research through doctoral school 393 of Pierre and Marie Curie University (Sorbonne University).

Author disclosures: LA, MS, SF, YK, NEK, KF, TM, ALP and YMP, no conflicts of interest.

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Abbreviations used: CHC, community health center; EA, enumeration area; FPDS, farm production diversity score; HFIAS, Household Food Insecurity Access Scale; HHS, Household Hunger Scale; MDD-W, Minimum Dietary Diversity for Women of Reproductive Age; SDG; Sustainable Development Goal; WDDS-10, 10-Food Group Women's Dietary Diversity Score.

Introduction

Nutrition-sensitive agricultural interventions are promising instruments to accelerate the achievement of nutrition and food security, thus contributing to the second Sustainable Development Goal (SDG-2) (1, 2). Conceptual frameworks propose several hypotheses to explain how agricultural actions can affect nutrition outcomes (3–7). One of these pathways relies on diversification of on-farm production, which should increase food availability and access, and hence increase consumption of diverse foods—a precondition for adequate intake of essential nutrients (8). Consumption of more diverse foods may also be the result of purchases on the market due to higher income resulting from increased production (9). Knowledge of the linkages between agriculture and nutrition is emerging and sheds light on the importance of focusing on improving access to higher quality diets in projects promoting nutrition-sensitive agriculture (10, 11).

There is clearly a need for high-quality monitoring and evaluation tools in the context of renewed strategies emphasizing dietary diversity (12, 13). However, no indicator in the framework chosen to monitor progress toward nutrition-related SDGs captures diet quality (14). In this respect, the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W), a dichotomous indicator developed and validated as a proxy of micronutrient adequacy (15, 16), does fill a gap. Women of reproductive age are particularly vulnerable to nutritional deficiencies, and it is essential to encourage actions to improve their nutrition that may also improve children's health, particularly through interventions targeting the first 1000 d (from pregnancy to children reaching 24 mo of age). The MDD-W is currently one of the key nutrition-sensitive indicators recommended by FAO (17), and it is also proposed by the new initiative of the Gallup World Poll aimed at providing comprehensive data on the quality of people's diets worldwide (18).

The MDD-W responds to several needs, including gathering accurate and comparable data on women's diet quality at the national or subnational level, making it possible to target at-risk populations, track progress, and measure the impact of programs and policies. To date, the indicator has been tested with regard to whether it is associated with socioeconomic characteristics (19, 20). It has been used to explore linkages between diet and coronary artery disease (21), pregnancy-related outcomes (22, 23), and child growth (24), but also to develop new metrics for food biodiversity in diets (25). In Bangladesh, it has begun to be used for program evaluation (26), and its applicability to pregnant adolescent girls and women has also been tested (27). Farm production diversity was found to be positively associated with the MDD-W in 3 rural settings (24, 28, 29), and 2 studies explored the linkages between MDD-W and household food security indicators (24, 30), but the findings were inconsistent. With the aim of contributing to this emerging literature, we investigated *1*) how MDD-W is linked to household food insecurity based on the Household Food Insecurity Access Scale (HFIAS) and the Household Hunger Scale (HHS), *2*) how MDD-W is linked to farm production diversity, and *3*) whether contextual factors such as household wealth status modify these relations. As a secondary objective, in order to draw conclusions regarding the cost of dichotomization, we also examined whether all these associations held when the number of food groups consumed was used as a continuous variable.

Methods

Data source and design

We used baseline data from a 4-arm cluster randomized controlled trial conducted in 2013 in the region of Kayes in western Mali. The trial was designed to evaluate the impact of a 3-y nutrition-sensitive intervention targeting women and their children during the first 1000 d of each child's life.

Study area

The survey took place in the 3 districts where the intervention was being implemented: Bafoulabé, Diéma, and Yélimané. This area is characterized by a Sahelian climate with negligible rainfall and very frequent droughts. The dry season generally lasts from October to June, and the rainy season, characterized by intense agricultural activities, lasts from July to September. For the most vulnerable households, the lean period usually occurs in April and May. Agriculture is the main occupation, and the main crops cultivated are millet, sorghum, maize, groundnuts, and cowpeas. Livestock is also a significant source of income in the study area. Sedentary farmers belonging to the Manding ethnic group (Soninké, Bambara, and Kassonké) form the majority of the population, which also comprises transhumant pastoralists from nomadic or seminomadic minorities: Fulanis and Maures (31). Despite high agropastoral potential, populations face seasonal food insecurity and high rates of both chronic and acute malnutrition among children (32).

Our study was conducted from 11 November, 2013, to 1 January, 2014, a period that corresponded to the harvest season for sorghum and groundnuts.

Study sample

The sample comprised 5046 mother–child pairs from 4790 households. Mother–child pairs were randomly selected using a multistage cluster selection process: *1*) In each of the 76 community health centers (CHCs) of the 3 districts targeted by the intervention, 6 enumeration areas (EAs) were randomly selected; and *2*) within each EA, an exhaustive list was drawn up of households with eligible mother–infant pairs—that is, mothers living permanently in the village, having a child aged 12–42 mo. Eleven households/EAs were randomly selected from the list of eligible households. For CHCs covering less than 6 EAs, the number of households selected by EA was adjusted so that 66 mother–child pairs were surveyed in the area covered by each CHC.

Measures

Dietary diversity.

Women's dietary intake was assessed through a qualitative 24-h recall. Using a multiple-pass method, mothers were first asked to spontaneously recall all dishes, sauces, snacks, drinks, and other foods they had consumed from the time they woke up to the same time the following day. At the second pass, women were asked to describe the exact composition of all dishes they had eaten. Food items were coded directly in the field by well-trained fieldworkers and classified into a predefined list of 30 food groups, which were further aggregated into the following 10 defined food groups (16): *1*) grains, white roots and tubers, and plantains; *2*) pulses (beans, peas, and lentils); *3*) nuts and seeds; *4*) dairy; *5*) meat, poultry, and fish; *6*) eggs; *7*) dark green leafy vegetables; *8*) other vitamin A-rich fruits and vegetables; *9*) other vegetables; and *10*) other fruits. The MDD-W is a dichotomous variable that equals 1 if the women consumed at least 5 different food groups during the past 24 h and 0 otherwise. Women who achieve minimum diet diversity (consuming foods from 5 or more food groups) are expected to have a greater likelihood of meeting their micronutrient needs compared with women who consume foods from fewer food groups. Using a dichotomous indicator with an established cutoff value makes it possible to calculate the prevalence of women who achieve minimum dietary diversity, which has important operational implications. However, for research purposes, in our analysis, we also used the number of food groups consumed as a continuous variable we named the 10-Food Group Women's Dietary Diversity Score (WDDS-10), which ranged from 0 to 10.

Household food security.

We used the HFIAS and the HHS to estimate overall perceived household food insecurity and hunger, respectively. The HFIAS comprises a set of 9 questions reflecting 3 different domains of food insecurity: *1*) anxiety and uncertainty about food supply, *2*) insufficient food quality, and *3*) insufficient food intake and its physical consequences. Households were categorized into 4 levels of food insecurity according to recommendations by the US Agency for International Development's Food and Nutrition Technical Assistance III Project (FANTA) (33): food secure and mildly, moderately, and severely food insecure. The HHS was computed from the last 3 questions of the HFIAS that are specifically related to "hunger." Households were divided into 3 categories based on FANTA recommendations (34): little to no hunger in the household, moderate hunger in the household, and severe hunger in the household. Because only 2% of households were classified as experiencing severe hunger in our study, we combined the "severe hunger" and "moderate hunger" categories.

Farm production diversity.

Agricultural biodiversity is usually assessed by a simple count of species (crops, plants, and animals) produced or raised by the household or by the means of indicators such as the Shannon and Simpson indexes that, in addition, capture differences in the quantities of each product but do not take their nutrient composition into account (35, 36). Although there is no standard method for measuring on-farm diversity for nutritional purposes (17), from a nutritional standpoint, diversity implies foods from different food groups. As a result, we chose to build a food production diversity score (FPDS) based on groups rather than species. Heads of households reported details of their farm production, including the types of food crops they cultivated and types of animals they raised, during the past 12 mo. We calculated an FPDS for each household by summing the following crop and livestock groups: *1*) cereals; *2*) tubers; *3*) beans, peas, and pulses; *4*) vegetables and fruits; *5*) cattle; *6*) poultry; *7*) goats and sheep; *8*) pigs; and *9*) camels. The categories of foods were based on available data on crop production, and the livestock groups were computed based on taxonomy (small ruminants, large ruminants, pseudo-ruminants, monogastric, or poultry), like that used in a study in Kenya (37). In our analysis, the FPDS was used as a continuous variable and could range from 1 to 9.

Household wealth status.

A wealth index was constructed using a multiple correspondence analysis performed on variables that coded for housing quality (type and size of house, number of persons per room, and floor, wall, and roof material) and facilities (electricity, source of drinking water, type of cooking fuel, and type of toilet facility), for assets (television, phone, mobile phone, refrigerator, radio, torch, and kerosene lamp), and for means of transport (automobile, bicycle, and motorcycle). For each household, the coordinate on the first axis of the correspondence analysis was interpreted as an index of the economic level. We used this wealth index categorized in terciles in subsequent analyses.

Sociodemographic characteristics.

For the women, the sociodemographic factors included age, education, occupation, ethnic group, religion, and marital status. For the household, factors included the sex of the head of household and the size of the household.

Data management and statistical analyses

Data were collected using Android tablets. Data quality was ensured by quality checks at data entry and by post-survey data cleaning. Data management and analyses were performed using R software version 3.4.3. All analyses took into account the sampling design (stratification, clustering, and sampling weights) using the Survey package. Unless otherwise specified, the type I error risk was set at 0.05.

A descriptive analysis was conducted of the characteristics of the study sample. MDD-W and WDDS-10 were used as response variables to analyze the relation between women's dietary diversity and household food security and/or farm production diversity. Variables identified as potential confounders for these relations were grouped in 3 dimensions (characteristics of women, characteristics of heads of households, and socioeconomic and demographic characteristics of households). After exploring associations with covariates in each of these 3 dimensions through bivariate analyses (using a P value <0.10 to define significance), we ran a series of multivariate models including the significant covariates:

- We obtained ORs, 95% CIs, and P values for each main explanatory variable (i.e., HFIAS, HHS, and FPDS) from separate logistic regression models (A models), with the MDD-W as an outcome.
- We obtained a β-coefficient, 95% CIs, and P for each main explanatory variable from separate linear regression models (A models), with the WDDS-10 as an outcome.

In the second step, the household wealth index was added to the previously mentioned models to assess whether the relation between the main explanatory variables and women's dietary diversity held when controlling for the wealth index (B models). In the third step, potential modifier effects were also investigated by including in the models statistical interaction terms (C models) to assess whether the relation between the main explanatory variables and women's dietary diversity was similar across the household wealth terciles.

Finally, to assess whether household food security mediated the relation between farm production diversity and women's dietary diversity, we ran multivariate regression models including HFIAS, HHS, and FPDS as explanatory variables and women's dietary diversity as outcomes.

Ethical considerations

The study was registered at ISRCTN.org (ISRCTN08435964) on 9 December 2013 and received ethical approval from the Committee of the Ministry of Health of Mali. All the participants gave their informed written consent to take part in the study.

Results

Sociodemographic characteristics of the sample

The mean age of the women was 28.56 ± 0.13 y (Table 1). More than 60% of households comprised 4–8 people. Although the households were mostly headed by men, an appreciable proportion (19%) were headed by women. The majority of heads of households were Muslims and practiced polygamy. The level of education was very low among both heads of households and women. The main source of income was agriculture and livestock raising.

Household agricultural practices and food security status

Most households had harvested 3 crop groups in the preceding 12 mo (Table 1), mainly cereals (99.2%) and pulses (96.3%); ∼78% of the households had at least 1 farm animal. The animals most frequently raised by households were goats and sheep (66.3%), followed by cattle (52.3%) and poultry (51%). Less than 1% of households reported raising pigs. The FPDS ranged from 1 to 7 crops per livestock groups produced during the past 12 mo, with a mean of 4.31 ± 0.07. According to the HFIAS, nearly 20% of households experienced severe food insecurity; according to the HHS, nearly 10% experienced moderate to severe hunger.

Women's dietary diversity

The WDDS-10 ranged from 1 to 8 food groups consumed during the past 24 h, with a mean of 3.82 ± 0.05. Only 27% of women achieved the MDD-W (Figure 1). The diet of the women who consumed only 1 food group basically consisted of starchy staple foods (97%) (Figure 2). Women with a WDDS-10 = 2 generally consumed foods, nuts, and seeds that were added to a diet comprising a starchy staple food (56%) or, less frequently, vegetables other than vitamin A-rich vegetables (15%). As the WDDS-10 increased, the group "nuts and seeds" quickly reached 100%, whereas the consumption of vegetables, peas, and beans increased progressively. The shift from WDDS-10 = 4 food groups (MDD-W = 0) to WDDS-10 ≥ 5 food groups (MDD-W = 1) was mainly driven by the addition of animal source foods (dairy and flesh foods) and vitamin A-rich vegetables and fruits in the diet. For all women, the consumption of eggs and fruits other than vitamin A-rich fruits was very rare.

Bivariate analysis revealed that a number of variables were associated with women's dietary diversity: level of education of the women and of the heads of household, the women's occupation, the sex of the head of household, the number of household members, and the household wealth index (results not shown). In the multivariate regression models presented later, analyses were adjusted for these covariates.

Relation between women's dietary diversity and household food insecurity

In households experiencing either severe food insecurity according to the HFIAS or moderate to severe hunger according to the HHS, only a small proportion of women achieved minimum dietary diversity compared with women in households with no food insecurity or with

TABLE 1 Descriptive characteristics of the sample

Characteristics	Mean ± SEM or %
Household characteristics, *n* = 4790	
Household size	
2–3 people	12.2
4–8 people	62.9
≥9 people	24.9
Sources of income	
Agriculture	96.3
Livestock	72.4
Small business	27.3
Household head characteristics, *n* = 4790	
Education	
No education at all	74.1
No formal education[1]	13.1
Primary school	10.4
Secondary school or more	2.4
Muslim	99.2
Marital status	
Single/divorced/widowed	1.1
Monogamous	15.1
Polygamous	83.8
Female household head	19.0
Household agriculture practices, *n* = 4726	
Crops harvested over the past 12 mo	
No. of food crop groups	2.59 ± 0.03
Cereals	99.2
Tubers	13.1
Pulses (beans, peas, groundnuts)	96.3
Vegetables and fruits	55.6
Livestock owned over the past 12 mo	
No. of livestock groups	1.72 ± 0.05
Household owns at least 1 animal	77.8
Poultry	51.0
Cattle	52.3
Goats and sheep	66.3
Camel	2.8
Pigs	0.4
Farm production diversity score[2]	4.31 ± 0.07
Household food security, *n* = 4790	
Household Food Insecurity Access Scale	
Food secure	36.6
Moderately food insecure	16.2
Mildly food insecure	27.7
Severely food insecure	19.5
Household Hunger Scale	
Little to no hunger	90.5
Moderate/severe hunger	9.5
Women's characteristics, *n* = 5046	
Age, y	28.56 ± 0.13
Education	
No education at all	93.6
No formal schooling[1]	1.4
Primary school	4.5
Secondary or more	0.5
Occupation	
Working mothers	26.3
Housewife	68.2
Other (student/retired/seeking employment/other)	5.5

[1]Schooling outside the framework of the formal education system (e.g., Koranic School).
[2]Number of crop/livestock groups produced over the past 12 mo.

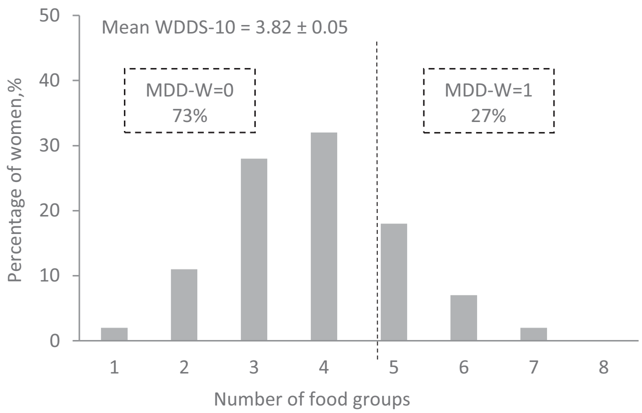

FIGURE 1 Distribution of the Women's Dietary Diversity Score (WDDS-10) and prevalence of the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W). MDD-W = 1 if the women consumed at least 5 different food groups during the past 24 h and 0 otherwise ($N = 4995$).

no or little hunger (OR: 0.76; 95% CI: 0.58, 0.99; $P = 0.06$; and OR: 0.63; 95% CI: 0.46, 0.87; $P < 0.01$, respectively; **Table 2**, A models). Similarly, women presented a lower mean WDDS-10 when they lived in households that experienced severe food insecurity according to the HFIAS (**Table 3**, A models; $\beta = -0.23$, $P < 0.01$) or in households that experienced moderate to severe hunger ($\beta = -0.34$, $P < 0.001$). When the household wealth index was added to the regression models, the association between the MDD-W or the mean WDDS-10 and the HFIAS or the HHS tended to weaken (Tables 2 and 3, B models). In all models, the household wealth index was a strong independent predictor of women's dietary diversity, with women in the wealthiest households having greater odds of reaching the MDD-W and higher mean WDDS-10. However, the wealth index had no modifying effect on the relation between these variables and the HFIAS or the HHS (interaction terms were all nonsignificant; Tables 2 and 3, C models).

Relation between women's dietary diversity and farm production diversity

We found a positive association between women's dietary diversity and farm production diversity: One more food crop per livestock group in the FPDS was associated with greater odds of attaining the MDD-W (OR: 1.12; 95% CI: 1.07, 1.18) and with a 10% increase in the mean WDDS-10 ($P < 0.001$; Tables 2 and 3, A models). When the household wealth index was added to the regression models, the association between the MDD-W or the mean WDDS-10 and the FPDS remained almost unchanged. There was only a small decrease in the magnitude of the association between the FPDS and the mean WDDS-10 (from $\beta = 0.10$ to $\beta = 0.09$), but the association remained highly significant ($P < 0.001$; Table 3, B models). The wealth index did not modify the relation between the FPDS and the mean WDDS-10, but it did modify the relation between the FPDS and the MDD-W (overall $P = 0.03$ for the interaction term; Table 2, C models). However, the tests for individual coefficients were statistically significant only for the second tercile ($P = 0.01$).

Finally, we assessed whether the relation between the FPDS and women's dietary diversity was mediated by the food security status of the household by including either the HFIAS or the HHS in regression models B. For both outcomes (MDD-W and WDDS-10), we found only very small changes in coefficients in all the models. Only 1% of the total effect of the FPDS on MDD-W was mediated by either the HFIAS or the HHS, and 0.3% of the total effect of the FPDS on WDDS-10 was mediated by either the HFIAS or the HHS.

Discussion

In the rural region of Kayes in western Mali, both the mean dietary diversity score of women and the proportion of women who reached the MDD-W (27%) were low. In exploring relations between women's dietary diversity, household food insecurity, and farm production diversity, the MDD-W performed well, as did the WDDS-10, and the

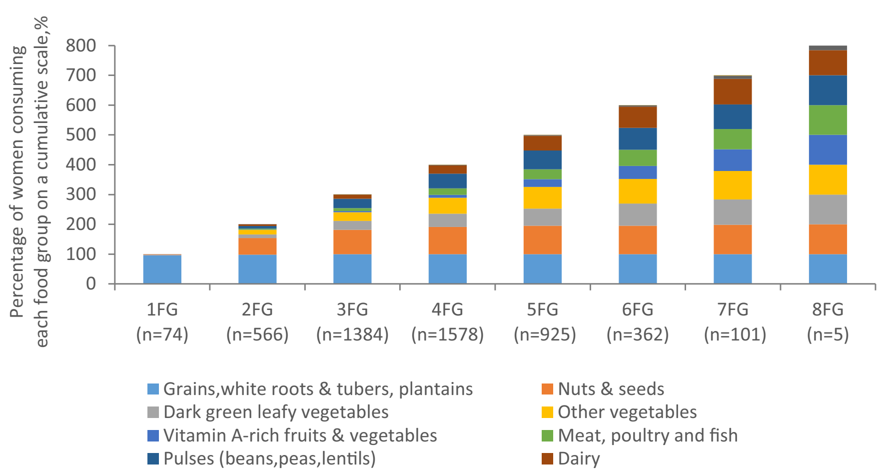

FIGURE 2 Cumulative percentage of women consuming each food group according to the value of the Women's Dietary Diversity Score (WDDS-10; $N = 4995$). This way of presenting the data was chosen to show the changes in the actual percentage of women who consume each food group according to the value of WDDS-10, ranging from 1 to 8 food groups. FG, food group.

TABLE 2 Multivariate logistic regression analysis of the association between household food insecurity, farm production diversity, and Minimum Dietary Diversity for Women of Reproductive Age (MDD-W)

			Model A[1]		Model B[2]		Model C[3]	
	n	MDD-W = 1 (%)	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Predictor: Household Food Insecurity Access Scale (HFIAS)								
HFIAS categories								
Food secure	1759	29.2	Reference	0.06	Reference	0.25	Reference	0.53
Moderately food insecure	773	30.2	1.09 (0.86, 1.38)		1.09 (0.86, 1.38)		1.35 (0.86, 2.11)	
Mildly food insecure	1297	28.6	0.99 (0.81, 1.22)		1.06 (0.86, 1.30)		1.22 (0.84, 1.78)	
Severely food insecure	892	24.1	0.76 (0.58, 0.99)		0.85 (0.64, 1.11)		1.09 (0.73, 1.61)	
Wealth index								
1 (lowest)	1534	22.9	—		Reference	0.01	Reference	0.01
2	1600	28.9	—		1.31 (1.06, 1.63)		1.64 (1.15, 2.35)	
3	1587	32.8	—		1.51 (1.16, 1.97)		1.77 (1.20, 2.60)	
HFIAS × wealth index interaction terms			—		—			0.37
Predictor: Household Hunger Scale (HHS)								
HHS categories								
Little to no hunger	4293	29.1	Reference	<0.01	Reference	0.03	Reference	0.16
Moderate/severe hunger	428	19.8	0.63 (0.46, 0.87)		0.70 (0.50, 0.97)		0.73 (0.47, 1.13)	
Wealth index								
1 (lowest)	1534	22.9	—		Reference	0.01	Reference	0.01
2	1600	28.9	—		1.31 (1.05, 1.62)		1.33 (1.06, 1.67)	
3	1587	32.8	—		1.50 (1.16, 1.95)		1.49 (1.14, 1.94)	
HHS × wealth index interaction terms			—		—			0.63
Predictor: farm production diversity score (FPDS)								
FPDS	4721	27.9	1.12 (1.07, 1.18)	<0.001	1.12 (1.06, 1.18)	<0.001	1.05 (0.97, 1.13)	0.25
Wealth index								
1 (lowest)	1534	22.9	—		Reference	<0.01	Reference	0.06
2	1600	28.9	—		1.30 (1.05, 1.61)		0.70 (0.44, 1.12)	
3	1587	32.8	—		1.54 (1.19, 1.98)		1.26 (0.76, 2.08)	
FPDS × wealth index interaction terms			—		—			0.03

[1]Adjusted on sociodemographic variables (household size, head of household level of education, sex of the head of household, women's level of education, and women's occupation).
[2]Adjusted on sociodemographic variables + household wealth index.
[3]Adjusted on sociodemographic variables + household wealth index + interaction term (predictor × wealth index).

results led to the same conclusions whichever indicator was used. This finding is reassuring in the sense that in our study, using the MDD-W, which is the recommended dichotomous indicator for operational purposes, did not result in a substantial loss of information regarding the associations with other indicators. Our findings suggest that living in a household experiencing food insecurity is associated with a higher risk of not reaching the MDD-W. This association was particularly clear when the HHS was used as a measure of food insecurity. Women in households that produced a wider variety of food crops and livestock groups had greater odds of reaching minimum dietary diversity. This relation was not mediated by household food insecurity. All these associations remained significant when adjusted for potential confounders, including household wealth.

The MDD-W is a simple tool that can be used to characterize and compare the dietary diversity of women of reproductive age within and across different contexts. Guidelines for measuring women's dietary diversity based on the recommended 10-point food group indicator were published only recently (16), and few studies have reported MDD-W prevalence values. We identified 1 study conducted in the region of Timbuktu in Mali that reported an 8% prevalence of women reaching the MDD-W (38). This is far below the prevalence we found in our study and could be related to the specificity of the area, where more than 40% of households experienced severe food insecurity based on the Food Insecurity Experience Scale (39). The prevalence of MDD-W observed in our study, however, was lower than that found in other Sahelian rural areas in the same season, for example, in 2 rural provinces of Burkina Faso [Sanguie: (49%) and Sourou (30%)] (30). Not surprisingly, we found that women's diet was largely dominated by starchy staples. The high consumption of nuts and seeds was explained by the fact that the survey was conducted during the groundnut harvesting season. Women reaching the MDD-W consumed nutrient-rich foods, such as animal source foods and vitamin A-rich fruits or vegetables, more frequently. Although half of the households reported raising poultry (mainly chickens), eggs were very rarely consumed by women, probably because in rural Mali, eggs are primarily intended for reproduction rather than for human consumption (40). We found that household wealth was an important predictor of the MDD-W, with a gradient in the odds of reaching a minimum dietary diversity and in the mean WDDS-10 as households had a better economic status. These findings are in line with those of previous studies that reported that household wealth is an important driver of women's diet in rural Mali (41, 42) and that household wealth is significantly associated with the MDD-W (19, 30). Although we did not measure household food expenditure, we hypothesize that women in wealthier households benefited from higher

TABLE 3 Multivariate linear regression analysis of the association between household food insecurity, farm production diversity, and 10-Food Group Women Dietary Diversity Score

		Model A[1]		Model B[2]		Model C[3]	
	N	*β* (95% CI)	*P*	*β* (95% CI)	*P*	*β* (95% CI)	*P*
Predictor: Household Food Insecurity Access Scale (HFIAS)							
HFIAS categories							
Food secure	1759	Reference	<0.01	Reference	0.02	Reference	0.05
Moderately food insecure	773	0.04 (−0.11, 0.20)		0.04 (−0.11, 0.19)		0.17 (−0.08, 0.43)	
Mildly food insecure	1297	0.01 (−0.11, 0.13)		0.05 (−0.08, 0.17)		0.14 (−0.05, 0.32)	
Severely food insecure	892	−0.23 (−0.39, −0.07)		−0.16 (−0.31, −0.00)		−0.08 (−0.29, 0.13)	
Wealth index							
1 (lowest)	1534	—		Reference	<0.001	Reference	<0.001
2	1600	—		0.22 (0.10, 0.33)		0.28 (0.11, 0.46)	
3	1587	—		0.28 (0.13, 0.42)		0.38 (0.21, 0.56)	
HFIAS × wealth index interaction terms		—		—			0.23
Intercept		*3.6*		*3.5*		*3.4*	
Predictor: Household Hunger Scale (HHS)							
HHS categories							
Little to no hunger	4293	Reference	<0.001	Reference	<0.01	Reference	<0.01
Moderate/severe hunger	428	−0.34 (−0.49, −0.17)		−0.27 (−0.43, −0.10)		−0.31 (−0.52, −0.09)	
Wealth index							
1 (lowest)	1534	—		Reference	<0.001	Reference	<0.001
2	1600	—		0.21 (0.10, 0.33)		0.21 (0.09, 0.32)	
3	1587	—		0.27 (0.13, 0.41)		0.26 (0.11, 2.41)	
HHS × wealth index interaction terms		—		—			0.69
Intercept		*3.6*		*3.5*		*3.5*	
Predictor: farm production diversity score (FPDS)							
FPDS	4721	0.10 (0.06, 0.13)	<0.001	0.09 (0.06, 0.12)	<0.001	0.09 (0.05, 0.13)	<0.001
Wealth index							
1 (lowest)	1534	—		Reference	<0.001	Reference	0.12
2	1600	—		0.21 (0.10, 0.32)		0.21 (−0.02, 0.44)	
3	1587	—		0.29 (0.15, 0.43)		0.28 (−0.02, 0.59)	
FPDS × wealth index interaction terms		—		—			0.99
Intercept		*3.3*		*3.1*		*3.1*	

[1]Adjusted on sociodemographic variables (household size, head of household level of education, sex of the head of household, women's level of education, and women's occupation).
[2]Adjusted on sociodemographic variables + household wealth index.
[3]Adjusted on sociodemographic variables + household wealth index + interaction term (predictor × wealth index).

income enabling them to diversify their diet through the purchase of varied foods in the market.

Although associations between food insecurity and women's dietary diversity are documented in the literature (43–45), to our knowledge, only 2 studies have examined these associations using the MDD-W (24, 30). In our study, the lowest mean WDDS-10 and the highest risk of not reaching the MDD-W were observed among women living in severely food insecure households (using the HFIAS). In rural Tanzania, no significant relation was found between the MDD-W and the HFIAS (24). The association with household's food insecurity was particularly clear when we used the HHS (i.e., an indicator that captures situations of extreme food insecurity) and remained significant even after adjusting for household wealth. The lower dietary diversity of women living in severe food insecure households was mainly due to the low consumption of nutritious foods, including animal source foods and vitamin A-rich fruits and vegetables. Seasonality may have influenced women's dietary diversity and household food security (46, 47), but seasonal variations could not be accounted for due to the cross-sectional nature of our data. However, in rural Burkina Faso, the MDD-W was found to be sensitive to seasonal changes, and an association between the MDD-W and both HFIAS and HHS was found only during the lean season (30). Other factors may play a confounding role in the relation between food insecurity and women's dietary diversity, including household size, maternal education, dependency ratio, religion, occupation, and marital status (24, 30, 45). We controlled for most of these sociodemographic characteristics, but the association between household food insecurity and women's diet diversity remained significant, thus suggesting a rather direct influence of food security on dietary diversity.

The relation between women's dietary diversity and production diversity observed in our study echoes the considerable evidence in the literature that farm production diversity contributes to household dietary diversity. However, few studies have investigated these associations at the individual woman's level, and to our knowledge, only 4 used the MDD-W (24, 28, 29, 48). Jones (35) recently stressed the importance of using validated and standardized proxy indicators of nutrient intake adequacy in order to provide firm conclusions and guidance on whether and how agriculture can contribute to nutrition. Whereas in Burkina Faso no relation between food crop diversity and the MDD-W was found (48), positive associations between the MDD-W and the diversity of production were found in Tanzania (24), Benin (28), and India (29), but the magnitude of the effect varied depending on the way production diversity was measured. The lack of consensus regarding how to measure production diversity is challenging when trying to compare findings; although further studies using the MDD-W are needed, efforts should also be encouraged to standardize the way farm production diversity (for nutritional purposes) is measured. In our study, we computed the FPDS as a count of crop per livestock groups, a method of calculation that provides an indication of nutritional diversity. Using groups (rather than species) as the unit of measure is crucial to enable appropriate interpretation. If production diversity is measured using a different unit (e.g., species) than the one used to assess dietary diversity (count of groups), associations are less likely to be identified (49). Because of data constraints, the construction of an ideal FPDS based on the exact same groups used for the MDD-W as seen in India (29), or of other relevant indicators such as nutritional functional diversity (50) or modified functional attribute diversity (51), was not possible. In a context in which agricultural policies encourage diversification of production rather than relying on a small number of staple crops (52), our study helps document the relation between individual diet quality and on-farm production diversity assessed from a nutritional perspective.

Finally, several conceptual frameworks (3–7) hypothesize that farm production diversity may affect women's dietary diversity through its positive effects on household food security. Despite the cross-sectional nature of our data, the period of time to which our indicators referred—FPDS during the past 12 mo, HFIAS and HHS during the past month, and MDD-W during the past 24 h—led us to expect we would be able to identify such a plausible pathway. However, our results revealed that food security mediated only a very small part of the total effect of FPDS on women's dietary diversity. In addition, we hypothesize that this pathway may vary with the season.

Our study has some limits. The market may play a role in the relation between agricultural diversification and individual dietary diversity (35), but it was not possible to specifically assess its contribution in the current study. We used baseline data from a randomized controlled trial in which women received either cash transfers or lipid-based nutrient supplements for their children. The baseline survey was conducted before the implementation of these two interventions, but the women were already benefiting from a nutrition program in the region, which included nutrition behavior change communication (BCC) activities. As a result, women's exposure to the BCC activities might have influenced their dietary practices. As mentioned previously, seasonality is known to influence dietary consumption, especially in rural settings in which households rely on their own agricultural production. However, the cross-sectional nature of our data, which were collected during a limited period of time, did not enable us to explore the possible effect of seasonality on the associations we found. Finally, the cross-sectional nature of our data make it impossible to draw conclusions regarding causality in the relations we found. Longitudinal studies are needed to not only identify temporal sequence of exposure and outcome but also study changes in MDD-W prevalence over time.

In conclusion, the latest validated proxy indicator of the micronutrient adequacy of women's diet, MDD-W, revealed strong associations with indicators of food insecurity and of farm production diversity. Using a dichotomous indicator could be expected to be less sensitive in identifying relations with potential determinants compared with a continuous indicator (WDDS-10), but our findings invalidated this hypothesis in our sample. By providing the cutoff point of 5 food groups, the MDD-W is a valuable tool to help identify and characterize populations at greater risk of inadequate nutrient intakes. Nonetheless, it is important to continue investigating the composition of the diet by analyzing the consumption of individual food groups. This will ensure identification of neglected food groups that are potentially the ones whose production should be promoted to achieve greater diversity. All this information is essential to help design efficient interventions to address nutrition through the improvement of dietary quality.

Acknowledgments

We thank our colleague Saidou Magagi from UNICEF for assistance with the training and supervision of the interviewers.

The authors' responsibilities were as follows—YMP, MS, ALP, and TM: contributed to the conception and design of the study; TM, NEK, and KF: responsible for program implementation; YK, SF, MS, ALP, NEK, and KF: conducted the research; LA and SF: performed statistical analysis; LA, YMP, MS, and ALP: wrote the manuscript; and all authors: read and approved the final manuscript.

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