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Nutrient adequacy and dietary diversity in rural Mali: association and determinants

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Objective: To examine the association between nutrient adequacy and dietary diversity, and to assess and compare the determinants for the two constructs in an adult population in rural Mali.
Design: Cross-sectional study assessing food intake by a validated 7-day quantitative food frequency questionnaire. Two different dietary diversity indexes were created: food variety score (FVS), a simple count of food items, and diet diversity score (DDS) a count of food groups. Mean adequacy ratio, the mean ratio of intake to recommended intake (each truncated at one) of energy and nine nutrients, was calculated as an indicator of nutrient adequacy. Information on household and individual characteristics, including demography, socioeconomic conditions and food production strategies was obtained using precoded questionnaires.
Setting: Bafoulabé district, Kayes region, Western Mali.
Subjects: In total, 502 subjects (55% women) aged 15–45 y from 319 different households.
Results: Both FVS and DDS had a positive correlation with mean adequacy ratio (MAR). Multivariate analysis (linear regression) showed that the most important factors explaining MAR was the number of milk products, vegetables and green leaves consumed, as well as sex and the number of crops produced in the household. Dietary diversity was associated with socioeconomic status, residence and age.
Conclusion: Dietary diversity is useful as an indicator of nutrient adequacy. It is important to examine how various food groups contribute to the nutrient adequacy of the diet in an area.
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Introduction

Indexes of dietary quality are increasingly used as a tool in monitoring population's adherence to dietary advice (Kennedy *et al*, 1995; Haines *et al*, 1999; Stookey *et al*, 2000). In industrialized countries, these indexes are often composed of several dimensions such as nutrient adequacy, dietary diversity, proportionality (more of some food groups and less of others) and moderation (limiting the intake of food constituents that contribute to excess risk) (Kennedy *et al*, 1995). In developing countries where the main concern is dietary deficit, nutrient adequacy alone is often used to refer to dietary quality. However, quantifying intake of nutrients is often expensive, time consuming and associated with methodological challenges in developing countries. Dietary diversity, a simple count of food items or food groups used in the household or by the individual over a certain time period, has been considered a potential 'proxy' indicator to reflect nutrient adequacy (Ruel, 2002). Several studies have shown that the overall nutritional quality of the diet improved with increasing number of food items and food

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groups (Hatløy *et al*, 1998; Ogle *et al*, 2001; Torheim *et al*, 2003).

Although dietary diversity and nutrient adequacy are related, they do not reflect the exact same constructs. When using the simple count of food items or food groups as indicator of the more complex nutrient adequacy, it is important to be aware of the similarities and differences between the two. This paper examines the association between dietary diversity (number of food items and food groups consumed) and nutrient adequacy (the mean ratio of intake to recommended intake of energy and nine nutrients) in a rural Malian adult population. More specifically, the purpose of the paper was to assess to which degree dietary diversity could predict nutrient adequacy, when controlling for other factors. A second objective was to compare the determinants of dietary diversity and nutrient adequacy as an element in assessing the differences between the two.

Subjects and methods

Area and subjects

This work was part of a project designed to assess and monitor the nutrition security situation in an area in rural Mali, and involved researchers from Mali and Norway in collaboration with a local nongovernmental organization (NGO) (Torheim *et al*, 2001). The NGO operates in the Bafoulabé district in the Kayes region of Western Mali, an area characterized by seasonal food insecurity. The survey took place in two of the NGO's intervention sectors in Bafoulabé, Oussoubidiania and Ouassala. Oussoubidiania sector comprised 15 villages with 7500 inhabitants and Ouassala sector 13 villages with 7220 inhabitants. All villages in the two sectors were included. Households (here defined as those eating food prepared in the same pot) were selected randomly from household registers at open meetings in each village. The households were selected with probability proportional to village size, but with a minimum of 10 households per village. Only one household in Oussoubidiania refused to participate, and this was not replaced. Overall, 199 households in Oussoubidiania and 163 households in Ouassala were included.

For the dietary assessment, one man and one woman aged 15–45 y were randomly selected from each participating household. However, in 42% of the households, it was only possible to include either a man or a woman, and in 12% of the households, nobody met the age criterion. The final sample included for dietary assessment was 502 persons (275 women and 227 men) from 319 different households (179 in Oussoubidiania and 140 in Ouassala). The survey was conducted during 7 weeks from October–December 1997, which corresponded to the harvest season for sorghum and groundnuts.

The study protocol was approved by the Regional Committee for Medical Research Ethics in Norway. Local authorities granted study permission. The village leaders and each head of household gave their verbal consent after the study had been fully explained to them.

Data collection

The data were collected by five teams consisting of one supervisor and one fieldworker with at least 12 years of education and experience from doing similar surveys. All persons involved in the data collection participated in a 2-week intensive training program before the study.

Information on household and individual characteristics was obtained using precoded questionnaires administered by interview in a local language. The questionnaires were based on a previous qualitative study in the same area (Oshaug *et al*, 1997), and pretested in a nonparticipating village.

The household questionnaire directed to the household head included demographic information, socioeconomic conditions (ownership of items), food production, food expenditure (only on nonstaple foods such as sauce ingredients, meat, milk powder etc) and nonfood expenditures. The households were also asked whether they had experienced food shortage during the last year and whether they had received assistance from emigrated family members.

The questionnaire directed to the selected adults (15–45 y) in the households, included individual food producing- and income-generating activities, health status and anthropometric measurements. The participants were weighed lightly clothed, using digital scales (Soehnle 7505, 100 g precision). Standing height was measured using wooden boards with a measuring tape (0.1 cm precision) that were produced locally based on the UNICEF model from 1986 (National Household Survey Capability Programme, 1986).

The 7-day quantitative food frequency questionnaire (QFFQ) for assessing food intake consisted of a food list with 104 items, and a part for recording frequency, estimated portion size and mealtime (breakfast, lunch, dinner or snack) for each item. Estimation of portion sizes and calculation of nutrient intake have been described elsewhere (Parr *et al*, 2002).

Validity of the dietary assessment

The QFFQ has been validated twice (Torheim *et al*, 2001; Parr *et al*, 2002). Both validation studies showed that the QFFQ could rank and classify subjects adequately, but better for men than for women.

In order to identify under- and over-reporters of food intake in the current study, cutoff values for the ratio of reported energy intake to basal metabolic rate (EI_{rep}/BMR_{est}) were defined (Goldberg *et al*, 1991; Black, 2000). Estimates of BMR were calculated from standard formulas based on weight, age and sex (FAO *et al*, 1985). Since individual activity levels were unknown, the lowest physical activity level (PAL) was assumed to be 1.55 (low activity level) and the highest 2.10 (high activity level) (FAO *et al*, 1985). Using

95% confidence limits for the two PAL-values, a diet recording period of 7 days and coefficients of variation as described by Black (2000) the cutoff value for under-reporting was calculated to be 1.05 and for over-reporting 3.10.

Dietary quality

As a measure of overall nutrient adequacy, mean adequacy ratio (MAR) was calculated as the mean of the nutrient adequacy ratios (NARs) for the intake of energy and nine nutrients, each truncated at 1 (Table 4). See Torheim *et al* (2003) for further definitions of MAR.

Food variety score (FVS) is here calculated as the number of different food items consumed during the 7 days covered by the QFFQ (see Table 3). All food items were given an equal score of one as in Torheim *et al* (2003), and the maximum score possible was 76. The method has been modified from Krebs-Smith *et al* (1987).

Diet diversity score (DDS) is here calculated as the number of food groups consumed during the diet-recording period (Table 3). In this study, DDS was based on cereals, legumes, oil/sugar, fruit, vegetables, meat, milk, fish, eggs and green leaves. Food items not included in the mentioned groups ('other' in Table 3) were excluded from the score. This is a modified version of the DDS described by Kant *et al* (1991), and similar to the one used by Torheim *et al* (2003).

A validation study of how well the QFFQ could rank and classify subjects according to MAR, FVS and DDS compared to 2-day weighed records showed adequate results for men, but not for women (Torheim *et al*, 2003).

Determinants examined

The individual characteristics examined as potential determinants for the three dietary quality indexes (MAR, FVS and DDS) were age, sex, education and illness. It was hypothesized that male sex and having attended public (French) school would be positively associated with dietary quality. Illness was believed to have a negative impact, while the effect of age was uncertain.

The examined household level determinants for dietary quality were classified into demographic factors and socio-economic conditions/livelihood strategies. Demographic factors included sector residence, household size, dependency ratio (% of household members younger than 15 or older than 65 years) and ethnic group. Dietary quality was thought to be higher in Ouassala than in Oussoubidiania, which is more remote. Household size can have a positive impact on food security and dietary quality due to more diversified income sources (Toulmin, 1986). On the other hand, household size has also been shown to be negatively associated with food security (Haddad *et al*, 1994). Dietary quality was expected to decrease with increasing dependency ratio. We did not make any specific assumptions about the effect of ethnicity.

The second group of investigated household level determinants included the number of crops (types of cereals, vegetables, green leaves, legumes and fruit) cultivated in the household, the number of income-generating activities by the household members, food expenditure, nonfood expenditures (on farming, health, education and housing), assistance from emigrated family members, and experience of food shortage during the last year. In addition, a socio-economic score (SES) was created based on the variety of domestic animals and agricultural equipment in the household, and household items such as radio, bicycle, lamp, etc. All assets were given one point and added for the total SES, which was used in the analyses. Except for food shortage, all variables in this category were hypothesized to be positively associated with dietary quality.

Statistical analysis

Mean and s.d. are reported for continuous variables that were normally distributed, median and 25th-, 75th percentiles for skewed variables, and frequency distributions for categorical variables. The tests used for comparing groups were Student's *t*-test, Mann–Whitney *U*-test, and Pearson χ^2 test corresponding to the three categories of variables, respectively. Pearson's correlation was used for measuring linear trends between two continuous variables. Linear regression analyses were used for assessing the association between MAR and both FVS and DDS.

Associations between determinants (individual and household characteristics) and the three dietary quality indexes (MAR, FVS and DDS) were tested using ANOVA. Continuous determinants were divided into tertiles. Differences between categories, as well as linear trends were tested for significance.

Multivariate analysis was used to verify if the identified determinants remained significant after controlling for confounding factors. Each index (MAR, FVS and DDS) was the dependent variable in a two-step model using linear regression analysis. All covariates showing linear association with the indexes ($P<0.10$) were included in a preliminary model. Variables contributing to the variation in the model ($P<0.10$) were included in the final model. Sex and sector were known to influence food intake, and therefore, these variables were always included. The association between the use of food groups and SES was examined by χ^2 test for trend (Altman, 1997). The significance level was <0.05. Owing to missing values, between 481 and 500 cases were used in the regression equations. The analyses of MAR included a maximum of 500 subjects since body weight was missing for two subjects. All analyses were performed with SPSS, version 11.0 (SPSS, 2001).

Results

Characteristics of the sample

Table 1 describes the total sample. Both men and women had relatively low body mass index (BMI) and 19% of the sample

Table 1 Description of the study participants (Mali 1997)

	Men (n=227)	*Women* (n=275)	*Total sample* (n=502)
Age, (y)[a]	29 (9)	27 (9)	28 (9)
Weight, (kg)[a]	61.9 (8.5)	55.4 (8.3)	58.3 (9.0)
Height, (cm)[a]	174.2 (8.3)	164.2 (6.4)	168.7 (8.8)
BMI, (kg/m^2)[a]	20.3 (2.1)	20.4[d] (2.3)	20.3 (2.3)
<18.5 (%)	17	21	19
18.5⩽BMI⩽25 (%)	81	75	78
>25 (%)	1	4	3
Illness last 2 weeks (%)[b]	50	56	53
Education (%)[c]	23	12	17

[a]Values are mean (s.d.).
[b]Illnesses/symptoms reported by more than 5% of the sample were fever/malaria, headache, abdominal pain, fatigue and common cold.
[c]Education is defined as more than 3 y of primary education in the French educational system.
[d]Body mass index (BMI) does not include pregnant women (*n*=49).

was underweight (BMI < 18.5 kg/m^2). Illness was prevalent, especially malaria/fever (20% of the sample). The number of subjects with formal education was low, especially among women. Agriculture was practiced by 94%, animal husbandry by 55% and petty trade by 22%.

Household characteristics are presented by intervention sector in Table 2. Households were larger in Oussoubidiania than in Ouassala. Nonfood expenditure was similar in the two sectors, with median per capita expenditure equivalent to 6–8 US$ per year. As many as 35% of the households in Oussoubidiania reported to have received assistance (mainly financial) from emigrated family members, while this was the case for 11% in Ouassala. In Oussoubidiania, 66% of the emigrated family members resided outside Africa, compared to 19% in Ouassala. For those receiving financial assistance, the median amount per household per year was equivalent to 124 US$ in Oussoubidiania and 43 US$ in Ouassala. Most households reported using the money for food purchase or agricultural investments. In all, 62% of the households in Oussoubidiania and 71% in Ouassala said they had experienced food shortage at least once during the last 12 months.

Dietary intake, nutrient adequacy and dietary diversity

The food groups and food items used by the subjects during the 7 days covered by the QFFQ are listed in Table 3. All subjects had eaten cereals, legumes, vegetables and green leaves. Groundnuts, used both in sauces and as snacks, were consumed in considerable amounts by all subjects (median intake of 140 g/day). Onion, hot pepper, okra and pumpkin were the most frequently consumed vegetables. More than 90% reported to eat fish, but in Oussoubidiania fish (smoked and dried) was only used in small amounts as spice. In Ouassala larger amounts of fresh fish were consumed. Fruit pulp and leaves from the Baobab tree (*Adansonia digitata*) were the most important wild foods in season during the study. The intake of fruit and meat was low, especially in Oussoubidiania.

Table 4 shows that the mean FVS and DDS were 23.0 and 7.8, respectively. The lowest recorded FVS was 7 and the highest number of different foods consumed was 47. DDS ranged from 4 to 10 different food groups. The proportion of subjects below recommended nutrient intake was high for calcium (80%), vitamin A (70%), iron (49%) and vitamin C (48%). Mean MAR was 0.87 for the total sample. A diet that covers the recommended intake for all nutrients has a MAR of 1, and 10% of the sample reached this value.

Table 2 Household characteristics[a] (Mali 1997)

	Oussoubidiania (n=176)	*Ouassala* (n=140)
Household size, *individuals*[b]	11 (7, 17)	8 (6, 13)***
Dependency ratio, *% HH-members <15 or >65 y*[b]	53 (43, 60)	48 (37, 58)**
Ethnic group		
Kassonké	90%	15%
Malinké	5%	58%
Other	5%	27%
Nonfood expenditure per capita per year, *FCFA*[b,c,d]	3370 (1718, 7558)	4424 (2004, 8573)
Weekly food expenditure per capita, *FCFA*[b,c]	50 (0, 151)	30 (0, 111)*
Varieties of domestic animals[b]	3 (2, 4)	2 (1, 3)***
Pieces of agricultural equipment[b]	5 (4, 7)	5 (4, 8)
Number of household items[b]	11 (9, 14)	12 (9, 15)*
Number of crops cultivated[b]	12 (9, 16)	9 (7, 13)***
Number of income sources[b]	4 (2, 8)	4 (2, 7)
Assistance from emigrated family members	35%	11%***
Value received, *FCFA*[b,c,e]	72 000 (27 812, 150 000)	25 000 (10 000, 50 000)
Experience of food shortage last 12 months	62%	71%

[a]Differences between sectors tested with Mann–Whitney or χ^2 test, $^*P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.
[b]Values are median and (25th, 75th percentiles).
[c]Exchange rate during the survey (1997) was 581 FCFA (franc of the African Financial Community) for US$1.
[d]Includes expenditure on farming, health, education and housing.
[e]Amounts are reported for households receiving assistance.

Table 3 Food groups and food items used by more than 10% of the subjects in Oussoubidiania and Ouassala[a]. Mali 1997

	Oussoubidiania (n=279)				*Ouassala (n=223)*					
Food groups	*Food group use (%)*	*No. of food items (mean)*	*Amount, (g/day)*[b]	*Percentage of subjects using*	*Food group use (%)*	*No. of food items (mean)*	*Amount, (g/day)*[b]	*Percentage of subjects using*	P^c	P^d
Cereals	100	2.3	448	77 Mais 62 Sorghum 42 Rice 28 Wheat 20 Bread	100	3.1	428	80 Sorghum 57 Wheat 48 Bread 48 Rice 47 Mais 12 Fonio	—	<0.01
Legumes	100	1.8	136	100 Groundnuts 67 Cowpeas 14 Bambara groundnuts	100	1.8	172	100 Groundnuts 64 Cowpeas 19 Bambara groundnuts	—	0.63
Oil/sugar	94	2.0	44	92 Sugar 41 Honey 40 Groundnut oil 27 Sweets	98	2.4	72	96 Sugar 81 Groundnut oil 39 Sweets 28 Honey	0.02	<0.01
Fruit	41	0.7	14	19 Lemon 10 Baobab pulp 10 Dates	69	1.5	23	34 Lemon 21 Red sorrel 17 Guava 16 Baobab pulp 13 Orange 11 Watermelon	<0.01	<0.01
Vegetables	100	4.7	110	86 Onion 83 Okra 72 Hot pepper 68 Pumpkin 40 Bitter tomato 26 Tomato 15 Sweet potato 15 Yam 15 Sweet pepper 14 Tomato paste 14 Cabbage 13 Cassava	100	6.8	102	100 Onion 73 Pumpkin 70 Hot pepper 69 Tomato 66 Sweet pepper 60 Tomato paste 55 Okra 41 Sweet potato 31 Cabbage 30 Bitter tomato 24 Garlic 21 Radicle, African fan palm 21 Cassava	—	<0.01
Meat	51	0.6	23	36 Beef	60	0.7	34	46 Beef 10 Mutton	0.04	0.49
Milk	60	0.8	144	54 Cow milk, fresh 19 Milk powder	80	1.1	104	74 Cow milk, fresh 24 Milk powder	<0.01	<0.01
Fish	95	1.1	3	93 Smoked fish 18 Dried fish	94	1.8	31	79 Smoked fish 72 Fresh fish 29 Dried fish	0.42	<0.01
Eggs	10	0.1	7	—	26	0.3	7	—	<0.01	<0.01
Green Leaves	100	2.6	34	100 Baobab leaves 80 Onion leaves 64 Pumpkin leaves	100	2.4	29	99 Baobab leaves 66 Unspecified green leaves 44 Onion leaves 17 Cowpea leaves 12 Pumpkin leaves	—	<0.01

Table 3 (*continued*)

	Oussoubidiania (n=279)				Ouassala (n=223)					
Food groups	*Food group use (%)*	*No. of food items (mean)*	*Amount, (g/day)*[b]	*Percentage of subjects using*	*Food group use (%)*	*No. of food items (mean)*	*Amount, (g/day)*[b]	*Percentage of subjects using*	*P*[c]	*P*[d]
Other	100	3.9	17	100 Salt 100 Beef cube 83 Soumbala 76 Tea 16 Coffee 12 Kalium	100	4.2	23	100 Salt 100 Beef cube 88 Tea 85 Soumbala 31 Kalium 13 Coffee	—	<0.01

[a] $<10\%$ also reported the following food items: *cereals*: millet, macaroni; *fruit*: black plum (*Vitex doniana)*, apple, mango, papaya, banana, sweetsop (*Annona squamosa*), fig; *vegetables*: potatoes, fruit of the African fan palm, carrots, cucumber, ginger, lettuce; *meat*: goat, pork, poultry; *milk*: fermented cow's milk; *fish*: sardines; *green leaves*: amaranth leaves; *other*: beer.
[b] Median amounts are reported for consumers of the food groups.
[c] *P*-value of Pearson's χ^2 test for differences in food groups between sectors.
[d] *P*-value of Student's *t*-test for differences between sectors in number of food items in each food group.

Table 4 Description of dietary diversity and nutrient adequacy (*n*=502) (Mali 1997)

	Mean (s.d.)	*% below recommended nutrient intake*	*Recommended nutrient intake*
Food variety score[a]	23.0 (7.1)		
Diet diversity score[b]	7.8 (1.3)		
NAR[c] energy	1.29 (0.53)	33	M: 1.78*BMR[e] F: 1.64*BMR
NAR protein	2.12 (1.03)	8	Weight*0.75 g[e]
NAR fat	1.75 (0.56)	6	M: 15% of energy[f] F: 20% of energy
NAR vitamin A	0.81 (0.61)	70	M: 600 μg/day[g] F: 500 μg/day
NAR thiamine	2.10 (0.97)	5	M: 1.2 mg/day[g] F: 1.1 mg/day
NAR riboflavin	1.69 (0.80)	18	M: 1.3 mg/day[g] F: 1.1 mg/day
NAR niacin	1.63 (1.08)	23	M: 16 mg/day[g] F: 14 mg/day
NAR vitamin C	2.01 (4.74)	48	45 mg/day[g]
NAR calcium	0.72 (0.46)	80	1000 mg/day[g]
NAR iron	1.35 (1.00)	49	M: 27 mg/day[g] F: 59 mg/day
MAR[d]	0.87 (0.11)		

[a] Number of food items consumed in the study period.
[b] Number of food groups used in the study period.
[c] NAR for a given nutrient is the ratio of a subject's intake to the current recommended nutrient intake.
[d] MAR is the mean of all the 10 NARs, each truncated at 1.
[e] Average requirements, as defined by FAO/WHO/UNU 1985.
[f] FAO & WHO, 1994. This is minimum fat intake and not recommended intake.
[g] FAO & WHO 2001.

Association between nutrient adequacy and dietary diversity

Table 5 shows how MAR correlated with FVS, DDS and the number of food items consumed within each food group. All correlations, except for legumes, were significant, also when controlling for sex and sector. The correlation between MAR and food group variety was highest for vegetables and milk (Pearson's $r=0.31$ and 0.30, respectively). The food group 'eggs' had only one item, so the relationship with MAR was tested with *t*-test. Those who had eaten eggs had a significantly higher MAR than those who had not (MAR$=0.91$ *vs* MAR$=0.86$, $P<0.001$). The amounts consumed of the different food groups increased with the number of food items in all groups except staples and green leaves (data not shown).

MAR, FVS and DDS were positively correlated with energy intake (Pearson's $r=0.66$, 0.38 and 0.29, respectively) and the associations remained significant after controlling for sex and sector (data not shown). BMI was not associated with any of the three dietary quality indexes.

Table 5 Pearson's correlation coefficient (*r*) between MAR and number of food items within each food group[a], and dietary diversity (*n*=500) (Mali 1997)

Food group (number of items[b]*)*	r[c]
Cereals (8)	0.17
Legumes (3)	0.04[d]
Oil/sugar (4)	0.25
Fruit (15)	0.19
Vegetables (20)	0.31
Green leaves (6)	0.17
Meat (5)	0.16
Milk (3)	0.30
Fish (4)	0.13
Other (7)	0.18
Food variety score	0.34
Diet diversity score	0.30

[a] The food group 'eggs' is excluded.
[b] The maximum number of different food items possible in each food group.
[c] Unless otherwise specified, $P<0.001$.
[d] $P>0.05$.

Determinants of nutrient adequacy and dietary diversity
Multivariate analysis was used to identify which factors explained the variation in MAR. We identified background variables that were significantly associated with MAR using bivariate analyses (ANOVA) ($P<0.10$) (see Annex 1). All variables showing linear association with MAR in Annex 1 were entered into a preliminary model together with either FVS or DDS. The variables that significantly added to the variation, as well as sex and sector, were included in the final model, which explained 21% of the variation in MAR (Table 6). Both FVS and DDS contributed significantly to the variation in the model. However, FVS contributed most, and was therefore included in the final model. The background variables that contributed to the explanation of MAR were sex and number of crops cultivated by the household. Women had a lower MAR than men, and a large variety of crops increased MAR.

We wanted to examine whether variation in some food groups contributed more to the explanation of MAR than others. The food groups with variation significantly correlated with MAR (Table 5) were therefore included in the model, replacing FVS. The number of food items within the food groups vegetables, milk and green leaves contributed significantly to MAR, and were included in the final model (Table 7). It was found that consuming a large variety of leaves had an effect on MAR in Oussoubidiania but not in Ouassala. The inclusion of an interaction for sector and green leaves did not increase R^2 considerably (data not shown).

In order to examine the factors associated with FVS and DDS, a similar procedure was followed. All variables showing linear association with FVS (all marked in bold in Annex 1, except food expenditure and nonfood expenditure) were entered into a preliminary model. The variables that significantly added to the variation, as well as sex and sector, were included in the final model, which explained 24% of the variation in FVS (Table 8). Male sex (nonsignificant), residence in Ouassala, Kassonké ethnicity, high SES and no experience of food shortage were positively associated with FVS, while age was negatively associated. Further analysis showed that the number of food items within each food group decreased with age, except for green leaves (data not shown). However, BMI was positively correlated with age. No interactions were found between the variables.

The final regression model for DDS contained five variables, explaining 22% of the variation in DDS (Table 9). DDS was positively associated with male sex, education, residence in Ouassala and high socioeconomic score, while

Table 6 Individual and household characteristics and FVS as determinants of MAR (Mali 1997, n=500)

Variable	*Unadjusted effect*	*95% CI*	P-*value*	*Adjusted effect*[a]	*95% CI*	P-*value*
Constant				0.71	(0.67, 0.74)	<0.001
Sex[b]	0.06	(0.04, 0.08)	<0.001	0.06	(0.04, 0.08)	<0.001
Sector[c]	0.01	(−0.009, 0.03)	0.31	−0.02	(−0.04, −0.002)	0.03
Crops cultivated	0.002	(0.001, 0.004)	0.006	0.002	(0.000, 0.004)	0.01
FVS	0.005	(0.004, 0.006)	<0.001	0.005	(0.004, 0.007)	<0.001
R^2				0.21		

[a]Adjusted for all other variables in the table in multiple regression analysis.
[b]Sex: 0=female, 1=male.
[c]Sector: 0=Oussoubidiania, 1=Ouassala.

Table 7 Individual and household characteristics and the number of different food items within food groups as determinants of MAR (Mali 1997, n=500)

Variable	*Unadjusted effect*	*95% CI*	P-*value*	*Adjusted effect*[a]	*95% CI*	P-*value*
Constant				0.71	(0.67, 0.75)	<0.001
Sex[b]	0.06	(0.04, 0.08)	<0.001	0.06	(0.04, 0.08)	<0.001
Sector[c]	0.01	(−0.009, 0.03)	0.31	−0.02	(−0.04, 0.000)	0.05
Crops cultivated	0.002	(0.001, 0.004)	0.006	0.002	(0.000, 0.003)	0.04
Vegetables	0.01	(0.008, 0.02)	<0.001	0.009	(0.006, 0.01)	<0.001
Green leaves	0.02	(0.01, 0.03)	<0.001	0.02	(0.006, 0.03)	0.002
Milk	0.04	(0.03, 0.05)	<0.001	0.03	(0.02, 0.04)	<0.001
R^2				0.25		

[a]Adjusted for all other variables in the table in multiple regression analysis.
[b]Sex: 0=female, 1=male.
[c]Sector: 0=Oussoubidiania, 1=Ouassala.

Table 8 Individual and household characteristics as determinants of FVS (Mali 1997, *n*=490)

Variable	*Unadjusted effect*	*95% CI*	P-*value*	*Adjusted effect*[a]	*95% CI*	P-*value*
Constant				22.53	(19.9, 25.1)	<0.001
Age	−0.15	(−0.22, −0.08)	<0.001	−0.17	(−0.24, −0.11)	<0.001
Sex[b]	0.87	(−0.34, 2.11)	0.17	0.64	(−0.49, 1.77)	0.27
Sector[c]	5.54	(4.39, 6.70)	<0.001	7.41	(5.66, 9.17)	<0.001
Ethnic group (Malinké)[d]	2.37	(1.02, 3.73)	0.001	−2.67	(−4.54, −0.80)	0.005
Ethnic group (other group)[e]	2.76	(1.02, 4.50)	0.002	−0.82	(−2.90, 1.26)	0.44
SES	0.21	(0.09, 0.34)	0.001	0.15	(0.04, 0.26)	0.009
Food shortage[f]	1.21	(−0.09, 2.51)	0.07	1.38	(0.18, 2.59)	0.024
R^2				0.24		

[a]Adjusted for all other variables in the table in multiple regression analysis.
[b]Sex: 0=female, 1=male.
[c]Sector: 0=Oussoubidiania, 1=Ouassala.
[d]Ethnic group: 0=Kassonké or other, 1=Malinké.
[e]Ethnic group: 0=Kassonké, 1=Malinké or other.
[f]Food shortage: 0=yes, 1=no.

Table 9 Individual and household characteristics as determinants of DDS (Mali 1997, *n*=481)

Variable	*Unadjusted effect*	*95% CI*	P-*value*	*Adjusted effect*[a]	*95% CI*	P-*value*
Constant				7.58	(7.1, 8.1)	<0.001
Age	−0.03	(−0.04, −0.02)	<0.001	−0.37	(−0.05, 0.03)	<0.001
Sex[b]	0.28	(0.05, 0.50)	0.016	0.24	(0.03, 0.45)	0.03
Education[c]	0.46	(0.16, 0.76)	0.003	0.36	(0.08, 0.64)	0.01
Sector[d]	0.78	(0.56, 0.99)	<0.001	0.74	(0.53, 0.95)	<0.001
SES	0.06	(0.04, 0.08)	<0.001	0.05	(0.03, 0.07)	<0.001
R^2				0.22		

[a]Adjusted for all other variables in the table in multiple regression analysis.
[b]Sex: 0=female, 1=male.
[c]Education: 0=no, 1=yes.
[d]Sector: 0=Oussoubidiania, 1=Ouassala.

age was negatively associated. Tests for interactions showed that the effect of education was stronger in Oussoubidiania than in Ouassala. However, the inclusion of this interaction term in the model increased R^2 by only 1% (data not shown).

The effect of SES on DDS was caused by only some food groups. The use of fruit, meat, milk and eggs increased significantly across the SES-tertiles, while for the other food groups, there was no difference (Table 10).

Number of crops cultivated in the household was associated with MAR but not with FVS or DDS, whereas SES was associated with FVS and DDS but not with MAR in the multivariate model. These results were surprising, and therefore, further analysis to investigate the relationship between the two household characteristics and the diet quality indexes were conducted. We found a significant positive correlation between number of crops and SES ($r=0.33$, $P<0.001$). When substituting SES with number of crops cultivated in the regression model for FVS, number of crops contributed as much to the model as did SES. For DDS, however, number of crops did not contribute significantly to the model. In the model for MAR, SES did not contribute to the model when substituting number of crops (data not shown).

Validity of the dietary assessment

The mean value of the ratio EI_{rep}/BMR_{est} with 95% confidence limits for the 7-day QFFQ was 2.34 (2.22, 2.47) for men and 2.08 (1.97, 2.18) for women ($P=0.001$). Low energy intake ($EI_{rep}/BMR_{est}<1.05$) was found for 4% of the men and 7% of the women. Energy intake above the upper cutoff limit ($EI_{rep}/BMR_{est}\geq 3.10$) was found for 17% of the men and 11% of the women. When the potential under- and over-reporters were excluded from the analyses, the models were not altered.

Discussion

This study illustrates that dietary diversity is positively associated with nutrient adequacy. This confirms results from other studies from developing countries (Hatløy *et al*, 1998; Ogle *et al*, 2001; Torheim *et al*, 2003). The correlation

Table 10 SES[a] and the frequency (%) of consumption of some food groups[b] included in the DDS (Mali 1997)

	SES1	*SES2*	*SES3*	χ^{2c}	P
		n			
	160	*181*	*150*		
Oil/sugar	95	97	96	0.21	0.65
Fruit	44	56	59	6.44	0.01
Meat	44	56	65	13.80	0.002
Milk	53	75	77	21.40	<0.001
Fish	94	94	97	0.81	0.37
Eggs	13	16	22	4.31	0.04

[a]Tertiles of SES.
[b]Only food groups consumed by less than 100%. Thus, cereals, legumes, vegetables and green leaves have been excluded.
[c]χ^2 test for trend as described by Altman (1997).

coefficients were similar to those found in two other studies from the same area (Torheim *et al*, 2003). They were also comparable to the coefficients reported from a study among children in an urban area in Mali (Hatløy *et al,* 1998).

The number of food items consumed (FVS) predicted nutrient adequacy (MAR) also when controlling for other factors. However, the variations in only a few food groups contributed to the model for MAR. The number of different vegetables, green leaves, and types of milk consumed significantly contributed to explaining the variation in MAR, together with sex, sector and number of crops cultivated. The three food groups were important sources of the nutrients most limiting to MAR, that is, vitamin A, vitamin C and calcium. All the items in the food group 'milk' had similar nutritional composition. It is therefore likely that the positive relationship with MAR was due to the increasing amount of milk consumed, and not the food group variety as such. This might be true for vegetables as well; also in this food group the amounts increased with number of items consumed. For green leaves, however, there was no relationship between number of items and amounts, thus, the effect on MAR seems to be mainly due to the variation.

In the search for indicators on dietary quality that are easy to collect, dietary diversity has been identified as a potentially useful candidate (Hatløy *et al*, 1998; Ruel, 2002). However, a simple count of food groups or food items does not give a full picture of the nutrient adequacy of the diet. It also does not tell which food groups or food items that are contributing most to the dietary quality. By initially conducting a quantitative or qualitative study, the most important contributors to the diet can be identified. Once these associations are established, further monitoring of the population's food intake can be done by simple food recalls by recording the number and types of foods consumed. Not only should the number of food items (FVS) and the number of food groups (DDS) be monitored, but also the variation within each food group. The focus should in our example be on the variation in vegetables, green leaves and milk products.

FVS and DDS were determined by different factors than MAR. This reconfirms that there are important differences between the two types of dietary quality indicators. Increased SES was associated with increased dietary diversity but not with nutrient adequacy in the multivariate model. This was surprising because most of the food items consumed to a greater extent in the higher socioeconomic groups were relatively nutrient dense (see Table 10). It might be that although the higher socioeconomic groups consumed a greater variety of these foods, the amounts were too small to contribute significantly to the nutrient intake. This reflects that dietary diversity is a count of all food items consumed, and type of food or amounts are not considered.

The association between dietary diversity and SES confirms earlier studies in low-income countries (Gittelsohn *et al*, 1998; Hatløy *et al*, 2000; Hoddinott & Yohannes, 2002). These studies, however, compared the households' socio-economic status with dietary diversity at household level, not at individual level as in the current study. Sector residence was also important for dietary diversity: subjects from Ouassala, where there was a greater availability and selection of foods, generally had a more varied diet compared to those from the more isolated Oussoubidiania. Thus, in order to enhance the dietary diversity in this community, it is important to improve both the general food availability as well as the capacity of people to acquire the foods.

A validation study of the three dietary quality indexes presented here showed satisfactory correlation and classification values for men, while the results were weaker for women (Torheim *et al*, 2003). However, in the current study, the inclusion of women strengthened the association between the independent variables and MAR/FVS/DDS. Thus, to achieve maximum power in the statistical analyses, all subjects were included.

The high mean value for the ratio of calculated energy intake to estimated BMR in the present study might reflect an elevated energy need during the harvest season. However, it could also be due to over-reporting. The validation study of the QFFQ conducted in Oussoubidiania, found that food intake was over-reported (Torheim *et al*, 2001) while under-reporting was the case in the validation study conducted in Ouassala (Parr *et al*, 2002). These two studies were conducted in small villages, and it is uncertain whether the results can be extrapolated to the respective sectors. It seems, however, unlikely that the results presented here are caused by systematic errors.

Conclusion

The results from this study confirm that simple counts of food items and food groups can be used as indicators of nutrient adequacy in this area in rural Mali. However, it may be useful to initially do a quantitative or qualitative study to identify the food items and food groups that are main contributors to the nutrient adequacy. Nutrient adequacy and dietary diversity had different determinants which confirm the differences between the two.

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Appendix 1

See Table A1.

Table A1 Associations between selected individual and households characteristics and MAR, FVS and DDS[a] (*n*=502). Mali 1997

	MAR		*FVS*		*DDS*	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
Age (tertiles)						
1 (15–21 y)	0.87	(0.11)	**24.3**	**(6.4)**	**8.2**	**(1.2)**
2 (22–32 y)	0.87	(0.11)	**23.6**	**(7.1)**	**7.9**	**(1.3)**
3 (33–45 y)	0.88	(0.10)	**21.2**	**(7.5)**	**7.4**	**(1.3)**

Table A1 (*continued*)

	MAR		*FVS*		*DDS*	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
Sex						
Female	**0.84**	**(0.11)**	22.6	**(7.5)**	**7.7**	**(1.4)**
Male	**0.91**	**(0.08)**	23.6	**(6.6)**	**8.0**	**(1.2)**
Illness last 2 weeks						
Yes	**0.86**	**(0.11)**	**22.4**	**(7.0)**	**7.8**	**(1.3)**
No	**0.88**	**(0.10)**	**23.8**	**(7.2)**	**7.9**	**(1.3)**
Education						
No	**0.87**	**(0.11)**	**22.6**	**(7.1)**	**7.7**	**(1.3)**
Yes	**0.89**	**(0.08)**	**24.9**	**(7.1)**	**8.2**	**(1.2)**
Sector						
Oussoubidiania	0.87	(0.12)	**20.6**	**(6.1)**	**7.5**	**(1.2)**
Ouassala	0.88	(0.09)	**26.1**	**(7.2)**	**8.3**	**(1.3)**
Household size (tertiles)						
1 (2–7)	**0.86**	**(0.10)**	22.8	(7.0)	**7.7**[b]	**(1.4)**
2 (8–13)	**0.87**	**(0.11)**	23.2	(7.1)	**7.9**[b]	**(1.3)**
3 (14–49)	**0.88**	**(0.10)**	23.1	(7.3)	**8.0**[b]	**(1.2)**
Dependency ratio (tertiles)						
1 (0–43%)	0.87	(0.10)	**24.0**	**(7.0)**	**8.0**	**(1.3)**
2 (44–56%)	0.88	(0.10)	**23.1**	**(7.4)**	**7.8**	**(1.3)**
3 (56–86%)	0.88	(0.11)	**22.0**	**(6.8)**	**7.7**	**(1.3)**
Ethnic group						
Kassonké	0.87	(0.12)	**21.6**	**(6.7)**	**7.6**	**(1.3)**
Malinké	0.88	(0.09)	**24.8**	**(6.5)**	**8.1**	**(1.2)**
Other	0.88	(0.09)	**25.2**	**(8.4)**	**8.2**	**(1.3)**
Nonfood expenditure per capita (tertiles)						
1 (0-2 200 *FCFA*)	0.86	(0.11)	**21.9**[b]	**(7.8)**	**7.5**	**(1.4)**
2 (2 201-5 800 *FCFA*)	0.88	(0.10)	**23.6**[b]	**(7.4)**	**7.9**	**(1.3)**
3 (5 839-159 855 *FCFA*)	0.88	(0.11)	**23.8**[b]	**(5.9)**	**8.2**	**(1.2)**
Daily food expenditure per capita (tertiles)						
1 (0-4.0 *FCFA*)	0.87	0.11	**24.1**[b]	**(8.0)**	**8.0b**	**1.3**
2 (4.2-94 *FCFA*)	0.88	0.11	**21.9**[b]	**(6.5)**	**7.7b**	**1.3**
3 (100-4 500 *FCFA*)	0.87	0.10	**23.2**[b]	**(6.6)**	**8.0b**	**1.2**
SES (tertiles)						
1 (4–12)	**0.85**	**(0.11)**	**22.0**	**(7.0)**	**7.4**	**(1.4)**
2 (13–17)	**0.88**	**(0.10)**	**23.1**	**(7.1)**	**7.9**	**(1.2)**
3 (18–29)	**0.89**	**(0.11)**	**24.4**	**(7.2)**	**8.2**	**(1.2)**
Crops cultivated (tertiles)						
1 (1–9)	**0.86**	**(0.11)**	23.0	(7.2)	7.8	(1.3)
2 (10–13)	**0.87**	**(0.10)**	23.5	(7.0)	7.8	(1.3)
3 (14–33)	**0.89**	**(0.10)**	22.7	(7.2)	7.8	(1.2)
Income sources (tertiles)						
1 (0–3)	**0.85**	**(0.11)**	**21.2**	**(7.0)**	**7.4**	**(1.3)**
2 (4–7)	**0.88**	**(0.11)**	**24.4**	**(6.7)**	**8.1**	**(1.2)**
3 (8–27)	**0.89**	**(0.10)**	**23.5**	**(7.4)**	**8.0**	**(1.2)**
Aid from family member						
No	0.87	(0.11)	22.6	(7.1)	7.8	(1.2)
Yes	0.88	(0.10)	23.2	(7.1)	7.9	(1.4)
Food shortage						
No	**0.88**	**(0.10)**	**23.9**	**(7.1)**	**8.0**	**(1.3)**
Yes	**0.87**	**(0.11)**	**22.6**	**(7.1)**	**7.8**	**(1.3)**

[a]Numbers in bold indicate that $P<0.1$ (ANOVA).
[b]The association is nonlinear (Pearson's correlation, $P\geqslant 0.1$).