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Validation of an instrument to assess food diversity in women of childbearing age in Medellín, Colombia

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Abstract

Objective: To validate a Food Diversity Questionnaire (CDA, for its name in Spanish) that identifies the prevalence of the risk of deficiency in the intake of eleven micronutrients.
Design: The CDA paper form, an online application for data entry and handling, was designed and compared with the 24-h recall (24HR) as a reference method. All data were processed in Personal Computer Software for Intake Distribution Estimation (PC-SIDE) v1 software. A descriptive analysis and comparisons between prevalence, concordance and reproducibility analyses were performed.
Setting: Medellín, Colombia.
Participants: Women of childbearing age between 19 and 50 years (*n* 186) who worked for the Buen Comienzo programme in 2019.
Results: When comparing the adjusted 24HR technique and the CDA, there was no significant difference in population-level data at risk of deficiency in any micronutrient intake. However, based on individual-level data of the best linear unbiased predictor, the concordance analyses were weak, and although agreements were high according to the diagnostic performance tests, a good ability to detect deficiency was only observed in a few nutrients: vitamin A 100·0 %, Ca 98·7 %, Fe 92·8 %, folates 91·6 %, and pyridoxine 81·8 %.
Conclusions: The CDA validated in this study is useful and faster at evaluating population-level data at risk of deficiency in the intake of Ca, Fe, Zn, thiamine, riboflavin, niacin, pyridoxine, folates, vitamin B_{12}, vitamin C and vitamin A. Based on individual-level data, a good ability to detect deficiencies was observed in the intake of vitamin A, Ca, Fe, folates and pyridoxine.

Keywords
Validation
Questionnaire
Food Diversity
24-h recall
Women

Throughout history, researchers have developed and perfected different methods for collecting information on dietary intake, which has been associated with eating habits, energy and nutrient consumption, and health and disease states. Some of the methods of application at the individual level are dietary history, dietary record, 24-h dietary recall (24HR) and frequency of food consumption[1,2].

In Colombia, some of these evaluation methods for dietary intake have been used in national surveys[2–4], departmental surveys[5] and municipal surveys[6]. Most of these studies have applied 24HR, considered the most appropriate method to estimate usual dietary intake distributions and to calculate the prevalence of the risk of any energy or nutrient intake deficiency[7]. However, 24HR is an expensive and time-consuming method to administer and analyse.

Currently, the academic environment and those responsible for developing public health policies are demanding new methods of evaluating dietary intake that are faster and less expensive[8]. Along these lines, the FAO of the UN[9] recommends applying the dietary (food) diversity method. The food diversity method recommended by the FAO is a proxy for the risk of nutritional deficiency[9]. They propose a qualitative technique similar to that applied in 24HR, in which they ask about food and beverages consumed during the last 24 h, but based on food groups, without determining the amount consumed. The analyses can be performed using scores calculated by adding the different consumed food groups or by eating patterns. Focusing on

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the food groups of interest, it can be applied at the household or individual level. The FAO recommends that the diversity form be adapted and validated in each population before applying[9].

Although different studies of food diversity have been conducted internationally for a couple of decades[10–13], they usually assess diet in a general way and categorise individuals according to whether their eating behaviour is considered healthy; they do not predict disease or mortality but rather measure adherence to dietary guidelines. In addition, they have used different collection instruments and have developed various methods that vary according to the objectives of the researcher[14] because there is still no consensus on the form to be used or on how to define the minimum amount of food eaten. They generally use 15 g as a cut-off to count as the consumption of a food group[9,15–17].

Taking into account two limitations – the first that a validated diversity form is not available for women of childbearing age in the Colombian population and the second that without estimating the amount of food consumed, the nutrient contribution cannot be calculated, and the prevalence of the risk of a deficiency thus cannot be calculated – we asked if a Food Diversity Questionnaire (CDA, for its name in Spanish) that estimated the amount of food consumed could serve as a proxy for the risk of deficiency in the intake of eleven micronutrients, similar to that obtained using the 24HR method. Thus, this study aimed to validate a CDA that identified the prevalence of the risk of deficiency in the intake of eleven micronutrients in women of childbearing age.

Methods

Type of study

This is an observational, descriptive, cross-sectional epidemiological study and validation of eleven micronutrient intakes by the CDA compared with 24HR.

Population

Women of childbearing age between 19 and 50 years of who worked for the Buen Comienzo (Good Start) programme of the city of Medellín, Colombia, in 2019. Buen Comienzo is a programme initiated by the municipal government of Medellín, Colombia, which, through different types of care, provides early education to families and children for their first 5 years. The educational agents of the programme are mainly women[18].

Sample

A total of 186 women were selected by probabilistic sampling through valid scientific inference and not by population representativeness[19]. The study is an analysis of two independent methods and moments – the 24HR and the CDA – applied to the same women with an interval of approximately 1 to 2 months between each method. Stata 15 software was used to run Fisher's z-test to compare two independent correlations following the methods of Arimond *et al.*[15], who analysed women of reproductive age in Bangladesh, disaggregated into twenty-one food groups and with a minimum inclusion of 15 g: the correlation of 24HR was 0·42, and a correlation of 0·7 was assumed for the CDA. The parameters for the sample calculation included a type I error of 0·05, a type II error of 0·20 and an allocation ratio $(n_2/n_1) = 1$. A two-tailed hypothesis was set with a CI of 95 %.

The Technical Directorate of the Buen Comienzo programme authorised the study at fifteen of its centres which were randomly selected, and the questionnaires were administered to all the assistants and teachers in the centres until we met the estimated sample number. Nine centres participated in the study in total. In these 9 centres, 191 participants were approached; those who were on vacation, sick leave or in other activities were contacted three more times to check on their participation; those who decided not to participate or were excluded were replaced by the next person on the list at the centre. Based on the selection criteria, two men, a lactating woman and a pregnant woman were excluded, and one additional woman decided not to participate.

Selection criteria

Inclusion criteria

Women between 19 and 50 years of age agreed to participate in this study and worked in the selected centres of the Buen Comienzo programme in Medellín, Colombia, in 2019.

Exclusion criteria

Women in the period of gestation or lactation or with a diagnosis of pathologies that affect feeding, such as diabetes, celiac disease and dyslipidaemia.

Data collection

The survey schedule was carried out according to each participant. The surveys were applied in 2-d intervals to ensure that they were not administered on consecutive days and were distributed on different days of the week. The surveys were applied during working weekdays and at the homes of the participants on weekends. Food was not provided by the institution. The four interviewers and four data entry clerks were dietitian nutritionists trained in the following techniques:

Anthropometric measurements

The interviewers were trained in the appropriate techniques for taking anthropometric measurements of weight and height, which were taken in the first interview with a digital scale with a capacity of 120 kg and precision of 100 g and a body height rod with a capacity of 2 m and

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sensitivity of 1 mm. Data were necessary to classify nutritional status according to BMI kg/m^2 in accordance with the values proposed by the WHO, to identify underweight women (<18·5), those with a normal BMI (≥ 18·5 to <25), those who are overweight (≥ 25 to <30) and those who are obese (≥ 30)[20].

24-h food recall

24HR was the reference method to calculate the prevalence of the risk of deficiency in the usual intake of nutrients. The adjusted multistep technique was applied[21], and the information was recorded on a paper form that detailed the preparations, the names of the foods, beverages, supplements, and complements, and the amount consumed by the respondent during the 24 h before the survey[7]. The 24HR survey took approximately 20 min to administer.

In this study, each woman was given a minimum of five and a maximum of seven 24HR distributed throughout the days of the week on non-consecutive days, a procedure that was necessary to adjust intra- and interindividual variability[22]. To measure the amount consumed, a set of food models, geometric figures and a photo album with life-size utensils were used, all coded and tested in Colombia[23,24]. Some dichotomous verification questions and a space for noting useful observations were included.

24HR was entered into the Dietary Intake Evaluation software (Evindi v5) of the School of Nutrition and Dietetics of the University of Antioquia[25]. This software calculates the nutrients consumed in each of the 24HR from different food composition table[26–32] labels, supplements and preparations compiled in a database. The software does not allow blank spaces because doing so would overestimate the risk of deficiency in the intake of energy and nutrients.

Food Diversity Questionnaire

The CDA was the test method. As mentioned above, there is no validated CDA for women of childbearing age in the Colombian population, nor could we find forms that defined the amount of food eaten. For these reasons, we designed a survey involving the following steps:

Selection of the estimated average nutrient requirement

The estimated average requirement (EAR) of the energy and nutrient intake recommendations (RIEN) for the Colombian population[33] was taken as the reference value for the micronutrients of greatest interest in women of childbearing age: Ca (EAR 800 mg), Fe (EAR 11·7 mg), Zn (EAR 6·50 mg), vitamin A (EAR 500 retinol equivalents (RE)), thiamine (EAR 0·9 mg), riboflavin (EAR 0·9 mg), niacin (EAR 11 mg), pyridoxine (EAR 1·1 mg), folates (EAR 320 μg of dietary folate equivalents), vitamin B_{12} (EAR 2·0 μg) and vitamin C (EAR 60 mg).

Definition of food groups

First, the source food groups of the selected micronutrients were identified, either by their high concentration of each nutrient or by a frequency and amount of consumption that made them a nutrient source in the Colombian population (Supplementary Material 1). Subsequently, foods for which 100 g[34] had a value greater than or equal to 10 % of the EAR of the selected micronutrients were identified so that these did not lead us to overestimate the micronutrient intake of each group; they were foods usually consumed according to the Food and Nutritional Security Profile of Medellín[6]. All foods within each group that had similar nutrients were grouped together. For example, the group including fruit was subdivided into two groups: the first with fruit rich in vitamin A and the second with fruit rich in vitamin C. In turn, each of these two groups was subdivided into subgroups that had a similar form of consumption, as explained below.

Definition of food subgroups

To quantify the amount consumed by the food group, all foods within each group that had a similar form of consumption were grouped, defining several subgroups. For example, the group including fruit as a source of vitamin C was subdivided into three subgroups: the first with fruits in the form of small sphere shapes, the second with fruits in the form of medium sphere shapes and the third showing figures representing the volume of fruits consumed in pieces or that have an irregular shape. In turn, each of these three subgroups was subdivided to measure them by glasses, mugs and cups when consumed as juice. Importantly, 100 ml of juice from any subgroup represents 25 % of the micronutrients of the fruits of the subgroup[25].

To facilitate the collection of data by the interviewers and to avoid having to resort to memory, a codebook was designed that showed the food models established by subgroup. Each life-size model, figure or photograph established for each subgroup has several codes representing different quantities (Supplementary Material 2).

Standardisation of weights and measures

To measure the amount of each food subgroup consumed, food models, geometric figures and photographs with life-size utensils coded and tested in Colombia were used[23,24]. Each of the foods was prepared and compared with the form that best represented it, and this amount was weighed three times to establish an average of each food per model. Finally, the average of the foods of each subgroup was calculated.

Format of the Food Diversity Questionnaire

A pilot study was performed to develop and design the format of the CDA. A total of thirty-five questionnaires were administered to women of childbearing age between

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19 and 50 years who were conveniently selected to participate in this pilot and did not participate in the main study. Five different versions of the CDA were designed and tested to establish the version that best facilitated the recall of the respondents and completion by the interviewer. The CDA was selected to prevent the interviewer repeating questions, writing the same thing several times and looking at several pages to ask and write the answers.

In the final format, the first side of the questionnaire covered identification data, control data for statistical adjustments, including the questionnaire number and day of week, useful notes for entering, and verification questions that also included the consumption and quantification of supplements and complements. The other side of the form covered subgroups and/or foods, groups, types of food, codes and quantities. To fill out this last part of the questionnaire, the first mealtime consumed the previous day was noted in the first row 'Type of food', and going down the form, all the food and/or drinks consumed at the mealtime were written, placing them in the corresponding subgroup, until all the foods consumed the previous day were listed. Lastly, the code representing each subgroup and the amount consumed the previous day in integer and/or decimal form (Supplementary Material 1) were recorded. If a number of different kinds of foods in the same subgroup were consumed, the interviewee was required to condense the foods into a single amount corresponding to the subgroup.

Application of the questionnaire

After the women answered the 24HR, it took between 1 and 2 months for the same women to receive at least one and at most two CDA distributed during the week on non-consecutive days to adjust the intra- and interindividual variability[22]. The CDA took approximately 10 min to fill out.

Data processing

To enter information for the CDA, an online application was designed that contained the same database of nutritional information as Evindi v5[25]. From an administrative perspective, the online application allowed us to select the foods that made up each subgroup and to modify or enter nutritional information on foods, supplements and complements.

For entering information in each of the surveys, all the items of the questionnaire appeared as tabs in the online application: identification, control data, CDA and questions. In the CDA with the list of supplements, complements, groups and subgroups of food, only the codes and quantities consumed were selected, without disaggregating by type of food as in the paper format.

To generate the report, the application averaged the micronutrients of the foods of each subgroup. This average was multiplied by the code and the amount consumed by subgroup in each questionnaire. Then, the micronutrients of all subgroups, supplements and complements consumed according to the questionnaire were added. Finally, the micronutrient report for each individual was obtained from the questionnaire.

Statistical analysis

The nutrient database generated in Evindi v5 for the 24HR and the database with the micronutrients of each individual recorded by the CDA were migrated and processed in Personal Computer Software for Intake Distribution Estimation (PC-SIDE) v1 of Iowa State University[35]. This software estimates the distribution of the usual nutrient intake, calculates the proportion of the population at risk of deficiency in the consumption of nutrients from the EAR according to the RIEN for the Colombian population[33] and calculates the best linear unbiased predictor (BLUP), which is an approximation of the usual intake of each nutrient per individual[35]. All analyses in PC-SIDE were adjusted with a type I error of 0·15 according to Anderson and Darling[36].

In the descriptive analysis, summary indicators such as the arithmetic mean and standard deviation were used. To compare the adjusted prevalence of the risk of deficiency in the usual intake of micronutrients between the 24HR and CDA techniques (24HR refers to the adjustment of the five or seven 24HR and CDA refers to the adjustment of the two CDA), the crude standard error (SEc), the adjusted standard error (SEa) of the PC-SIDE v1 software, the 95 % CI calculated with the SEa and the proportional difference test with the adjusted prevalence of deficiency were calculated.

The McNemar test was applied to compare the unadjusted prevalences between the first and second CDA (CDA1 refers to the crude first CDA and CDA2 refers to the crude second CDA), and the Pearson chi-squared test of independence was used to compare the unadjusted prevalences between the 24HR and CDA techniques (24HR refers to the crude first 24HR and CDA refers to the crude first CDA).

For the concordance analyses between methods (the methods refer to the adjustment of the two CDA and to the adjustment of the five or seven 24HR) and for the reproducibility analyses between measurements (the measurements refer to the crude first CDA and to the crude second CDA), the intraclass correlation coefficient (ICC) was calculated for continuous variables, and Cohen's kappa index was calculated for categorical variables. The diagnostic performance was compared between the adjustment of the two CDA and the adjustment of the five or seven 24HR and between the crude first CDA and the crude second CDA. The diagnostic performance was evaluated by its sensitivity, specificity, predictive value, likelihood ratio, entropy reduction and bias index. For all two-sided tests, a *P*-value of less than 0·05 was considered statistically significant. The data processing and analysis were performed in SPSS, Stata and OpenEpi software.

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Controlling for biases

To control for selection biases, we ensured that the participation of the women was not influenced by the researchers or interviewers and was carried out according to the checklist established with the selection criteria, sampling processes and data collection. To control observer biases, the interviewers and data entry clerks were trained and supervised, and we reviewed the quality of the data. To control information biases, life-size figures, models and photographs were used to quantify food intake. For the control of random biases, since the intake varies unpredictably, between five and seven 24HR and between one and two CDA were given to each woman to adjust the intra- and interindividual variability by the number of questionnaires and days in the week in the PC-SIDE software. To control observer bias and prevent dropout, we implemented strategies to facilitate visits, agreeing on a schedule with each woman, and visited them at work during the week and at their homes during the weekend.

Results

Characterisation

For each of the 186 women, the surveys were distributed on different days of the week. A total of 1122 24HR were submitted, for an average of six 24HR per person (at least five and at most seven 24HR). A total of 337 CDA were submitted (186 with the first questionnaire and 151 with the second questionnaire). The women had an average age of 32 years (7 SD) and a BMI of 25·5 kg/m^2 (4·0 SD), distributed as 1 % underweight, 49 % normal BMI, 37 % overweight and 13 % obese.

Comparison between the 24-h recall and Food Diversity Questionnaire results

Prevalence of adjusted risk of deficiency

The prevalence of the risk of deficiency in women by the 24HR was approximately 70 % for the micronutrients of Ca, Fe and folates. In the diversity questionnaire, the prevalence of the risk of deficiency was higher (Table 1). When comparing the adjusted prevalences between the CDA and 24HR, no significant differences were found for any of the nutrients, for example, vitamin C ($P = 0·6071$), folate ($P = 0·4667$), Zn ($P = 0·4524$), niacin ($P = 0·3703$), Ca ($P = 0·3533$) and Fe ($P = 0·3391$) (Table 1).

Concordance between the 24-h recall and the Food Diversity Questionnaire

The BLUP was obtained for the concordance analyses between the 24HR questionnaire and the CDA for each individual. The ICC and Cohen's kappa that measure the agreement between the 24HR and CDA on all micronutrients were weak. However, there were high percentages of agreement that possibly reflected the ability of the CDA to distinguish a subject with micronutrient deficiency from a subject without micronutrient deficiency (Table 2).

Diagnostic performance tests of the Food Diversity Questionnaire

For performance tests between the 24HR questionnaire and the CDA, the BLUP was obtained for each individual. The CDA showed a high sensitivity to detect individuals deficient in vitamin A (100·0 %), Ca (98·7 %), Fe (92·8 %), folates (91·6 %) and pyridoxine (81·8 %). According to the reduction in entropy after a positive test, two micronutrients with high efficacy were observed: folates (7·3 %) and Fe (3·2 %). In other words, for example, the CDA was 1·4 times more likely to return a positive result in individuals with folate deficiency than in those without folate deficiency (Table 3).

Intratechnique analysis of the Food Diversity Questionnaire

Unadjusted prevalence of risk of deficiency

When comparing the unadjusted prevalences between the first and second CDA, no significant differences were found for any nutrients, except for vitamin C, although the CI of vitamin C at some point intersected. On the other hand, when comparing the unadjusted prevalences between CDA and 24HR, statistically significant differences were found for all nutrients except Zn and vitamin B_{12} (Table 4).

Reproducibility between the first and second Food Diversity Questionnaires

To analyse the reproducibility between the first and second unadjusted CDA, the risk of deficiency for each nutrient was classified in each questionnaire. The ICC and Cohen's kappa measuring the agreement between the first and second CDA were weak for each micronutrient. However, there were high percentages of agreement that possibly reflected the ability of the first CDA to distinguish a subject with micronutrient deficiency from a subject without micronutrient deficiency (Table 5).

Diagnostic performance of the first Food Diversity Questionnaire

To compare the performance of the unadjusted first and second CDA, the risk of deficiency of each nutrient was classified in each questionnaire. The second CDA showed a high sensitivity for detecting individuals deficient in Fe (90·8 %), folates (90·0 %), Ca (88·6 %), vitamin A (66·3 %) and thiamine (63·4 %). According to the reduction in entropy after a positive test, four micronutrients for which CDA had high efficacy were observed: Fe (11·2 %), Ca (8·4 %), folate (7·4 %) and vitamin A (5·2 %). In other words, for example, it was 1·7 times more likely that the CDA returned a positive result in individuals with an Fe deficiency than in those without Fe deficiency (Table 6).

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Table 1 Adjusted prevalence of the risk of deficiency in the usual intake of micronutrients by 24HR and the present CDA (*n* 186)

	24HR*				CDA*					
	Adjusted prevalence of deficiency				Adjusted prevalence of deficiency					
Nutrient	%	95 % CI†	SEc‡	SEa§	%	95 % CI†	SEc‡	SEa§	Crude *P*-value‡	Adjusted *P*-value
Ca	78·5	69·4, 87·6	0·0301	0·0465	91·0	78·5, 103·5	0·0210	0·0637	0·0008	0·3533
Fe	61·4	51·2, 71·6	0·0357	0·0520	75·9	62·2, 89·6	0·0314	0·0701	0·0026	0·3391
Zn	17·3	7·5, 27·0	0·0277	0·0497	21·6	6·0, 37·2	0·0302	0·0798	0·2948	0·4524
Vitamin A	4·2	0·0, 10·0	0·0147	0·0297	46·2	38·0, 54·3	0·0366	0·0417	<0·0001	0·0580
Thiamine	26·9	16·0, 37·9	0·0325	0·0558	45·2	35·6, 54·8	0·0365	0·0491	0·0002	0·2860
Riboflavin	4·2	0·0, 8·8	0·0147	0·0236	16·6	4·5, 28·7	0·0273	0·0616	0·0001	0·3355
Niacin	20·2	9·7, 30·8	0·0294	0·0538	32·4	0·0, 48·4	0·0343	0·0819	0·0075	0·3703
Pyridoxine	10·5	1·5, 19·4	0·0225	0·0456	33·7	23·2, 44·1	0·0347	0·0533	<0·0001	0·2303
Folate	74·9	64·8, 85·0	0·0318	0·0515	77·7	65·8, 89·6	0·0305	0·0608	0·5254	0·4667
Vitamin B_{12}	3·9	0·0, 9·5	0·0142	0·0287	16·5	2·7, 30·2	0·0272	0·0700	0·0001	0·3442
Vitamin C	25·5	15·0, 36·0	0·0320	0·0536	16·4	4·9, 27·9	0·0271	0·0586	0·0310	0·6071

24HR, 24-h recall; CDA, Food Diversity Questionnaire; SEc, crude standard error; Sea, adjusted standard error.
*24HR refers to the adjustment of the five or seven 24HR and CDA refers to the adjustment of the two CDA, adjusted in the Personal Computer Software for Intake Distribution Estimation (PC-SIDE) v1[30] by number of questionnaires with a type I error of 0·15 according to Anderson and Darling[36].
†Calculated with the SEa.
‡SEc and crude *P*-value was added to look at differences, but SEa and adjusted *P*-value were analysed.
§Calculated in PC-SIDE v1.

Table 2 Concordance between the 24HR and the CDA (*n* 186)

				Variability between methods*			
	Continuous measurement			Categorical measurement			
Nutrient	ICC†	95 % CI	*P*-value	Kappa	95 % CI	*P*-value	% Agreement‡
Ca	0·383§	0·254, 0·499	<0·0001	0·100	−0·029, 0·230	0·0114	80·7
Fe	0·112§	−0·032, 0·252	0·0630	0·187	0·054, 0·321	0·0011	69·9
Zn	0·394§	0·265, 0·508	<0·0001	0·275	0·060, 0·490	0·0001	87·6
Vitamin A	0·361§	0·229, 0·479	<0·0001	0·026	−0·010, 0·062	0·0586	55·9
Thiamine	0·066§	−0·079, 0·207	0·1860	0·050	−0·079, 0·178	0·2221	55·9
Riboflavin	0·401§	0·273, 0·515	<0·0001	−0·019	−0·046, 0·007	0·6632	90·9
Niacin	0·362§	0·230, 0·480	<0·0001	0·069	−0·084, 0·223	0·1665	73·7
Pyridoxine	0·248§	0·109, 0·378	<0·0001	0·198	0·071, 0·325	<0·0001	74·7
Folate	0·418§	−0·292, 0·530	<0·0001	0·288	0·109, 0·467	<0·0001	81·7
Vitamin B_{12}	0·247§	0·107, 0·377	<0·0001	0·110	−0·122, 0·342	0·0280	93·0
Vitamin C	0·485§	−0·367, 0·588	<0·0001	0·179	0·023, 0·336	0·0024	78·0

24HR, 24-h recall; CDA, Food Diversity Questionnaire; ICC, intraclass correlation coefficient.
*The methods refer to the adjustment of the two CDA and to the adjustment of the five or seven 24HR.
†Type C ICC that use a definition of coherence. The variance in the intermediate measure is excluded from the variance in the denominator.
‡The agreement or comparison between two methods on the same sample[43].
§The estimator is the same whether the interaction effect is present or not.

Discussion

In this study, according to the comparisons between methods with statistical adjustment in PC-SIDE v1, the CDA was useful for detecting the prevalence of micronutrient deficiency in the population, as we did not find statistically significant differences in any micronutrient between the CDA and 24HR. However, it was not useful for detecting the individual prevalence via the BLUP, since the concordance analyses were weak, and although the agreements were high according to the diagnostic performance tests, only a good ability to detect a deficiency in some micronutrients was observed: vitamin A (100·0 %), Ca (98·7 %), Fe (92·8 %), folates (91·6 %) and pyridoxine (81·8 %).

The CDA without statistical adjustment was not useful for detecting the prevalence of micronutrient deficiency in the population, although in the intramethod analysis between the first and second CDA without statistical adjustment, there were no significant differences in the prevalence of almost all micronutrients. When comparing the prevalences between the 24HR and CDA methods without statistical adjustment, there were statistically significant differences in almost all micronutrients. Likewise, the reproducibility analyses were weak, and although the agreements were high according to the diagnostic performance tests, only a good ability to detect deficiency in some micronutrients was observed: Fe (90·8 %), folates (90·0 %), Ca (88·6 %), vitamin A (66·3 %) and thiamine (63·4 %).

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Table 3 Diagnostic performance of the CDA compared to 24HR (*n* 186)

				Predictive value			Likelihood ratio			Reduction of entropy		
Nutrient*	Sensitivity	95 % CI	Specificity	95 % CI	Positive	95 % CI	Negative	Positive	95 % CI	Negative	Positive%	Negative%	Bias index
Ca	98·7	95·2, 99·6†	8·1	2·8, 21·3†	81·2	74·9, 86·2†	60·0	1·074	1·013, 1·138	0·166	0·000, 724·800	1·6	−17·4	0·1720
Fe	92·8	86·9, 96·2†	23·0	14·2, 34·9†	71·2	63·8, 77·6†	60·9	1·204	1·154, 1·257	0·314	0·158, 0·624	3·2	−3·7	0·2043
Zn	31·6	15·4, 54·0†	94·0	89·3, 96·7†	37·5	18·5, 61·4†	92·4	5·274	2·136, 13·020	0·728	0·625, 0·847	−33·2	6·0	−0·0161
Vitamin A	100·0	34·2, 100·0†	55·4	48·2, 62·4†	2·4	0·7, 8·3†	100·0	2·244	2·191, 2·298	0·000	0·000, 0·000	−5·3	0·0	0·4409
Thiamine	48·8	34·3, 63·5†	57·9	49·8, 65·7†	24·7	16·6, 35·1†	80·0	1·160	1·013, 1·327	0·884	0·792, 0·987	−3·2	2·7	0·2151
Riboflavin	0·0	0·0, 65·8†	91·9	87·0, 95·0†	0·0	0·0, 20·4†	98·8	0·000	0·000, 0·000	1·089	0·000, 0·000	0·0	−0·4	0·0699
Niacin	26·9	13·7, 46·1†	81·3	74·5, 86·5†	18·9	9·5, 34·2†	87·3	1·436	0·629, 3·278	0·899	0·808, 1·001	−8·1	2·3	0·0591
Pyridoxine	81·8	52·3, 94·9†	74·3	67·3, 80·2†	16·7	9·0, 28·7†	98·5	3·182	2·902, 3·488	0·245	0·091, 0·656	−22·6	14·6	0·2312
Folate	91·6	86·1, 95·0†	34·4	20·4, 51·7†	87·0	81·0, 91·4†	45·8	1·395	1·269, 1·534	0·246	0·150, 0·401	7·3	−23·1	0·0430
Vitamin B_{12}	33·3	6·2, 79·2†	94·0	89·6, 96·6†	8·3	1·5, 35·4†	98·85	5·545	0·092, 334·000	0·709	0·266, 1·891	−20·4	2·0	0·0484
Vitamin C	19·5	10·2, 34·0†	94·5	89·5, 97·2†	50·0	28·0, 72·0†	80·6	3·537	1·008, 12·410	0·852	0·802, 0·905	−16·6	3·5	−0·1344

24HR, 24-h recall; CDA, Food Diversity Questionnaire.
*The diagnostic performance was compared between the adjustment of the two CDA and the adjustment of the five or seven 24HR.
†Method: Wilson points.

According to the above, it is necessary to use food models that quantify the amount consumed for the survey to be valid, to apply two questionnaires of food diversity on non-consecutive days and to send the data to PC-SIDE v1 to perform the statistical adjustment.

The CDA validated in this study, although differing in methodology from other studies[37], yielded results similar to those from studies in Mali, Mozambique, Bangladesh, Burkina Faso and the Philippines. Those studies, aiming to evaluate diversity indicators as a proxy for the adequacy of micronutrients at the population level, used 24HR and found that eight established food groups were correlated with the mean probability of adequacy, and the correlations were higher with higher levels of food group disaggregation and with the 15-g minimum requirement[15].

The reviewed studies that evaluated and validated CDA did not use the methods described in this study, mainly because they based their analyses on qualitative measures without quantifying the amount of food consumed[38]. In addition, most of them compared dependent techniques, that is, they built the reference and test indicators from the same instrument[16]. In this study, with a time interval between the application of both techniques, two independent methods were applied to the same women: 1–2 CDA as the test method and 5–7 24HR (to obtain a better fit) as the reference method. Although each study analysed food diversity differently, they almost all agreed on the food groups. The thirteen food groups and twenty-six food subgroups of this study are similar to those validated in the indicator for infants and young children, which includes seven groups: grains, roots and tubers; legumes and nuts; dairy products; meats; eggs; fruits and vegetables rich in vitamin A; and other fruits and vegetables[39]. They are also similar to groups used in the indicator of women's dietary diversity[17] that includes these same seven groups but disaggregates them into different levels to yield twenty-one subgroups.

Regarding the foods belonging to the groupings in the studies reviewed, most studies, including this one, incorporated only natural foods[40]. It is not clear whether ultraprocessed foods should be included or excluded, as some studies exclude, for example, *embutidos* (cured and dry sausages), fast food, packaged soups, packaged products and sweetened drinks[16]. In addition, some studies do not consider fortified foods, and most exclude supplements and complementary foods[41], unlike this study, which included and quantified supplements and complementary foods since they provide significant amounts of nutrients.

This study was not designed to evaluate the intake of calories, carbohydrates or fats; therefore, foods with high content of these nutrients were excluded, and the present CDA should not be used to measure their intake. In addition, although no validation tests were performed on the intake of protein or fibre, it would be worth performing these analyses because the food groups of the questionnaire include food sources of protein and fibre, and the questionnaire could be useful for these nutrients.

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Table 4 Unadjusted prevalence of risk of deficiency in the usual nutrient intake

	Unadjusted prevalence of deficiency (*n* 151)					Unadjusted prevalence of deficiency (*n* 186)				
	CDA1*		CDA2*			24HR*		CDA*		
Nutrient	%	95 % CI	%	95 % CI	*P*-value†	%	95 % CI	%	95 % CI	*P*-value‡
Ca	81·5	75·2, 87·7	83·4	77·5, 89·4	0·7200	74·2	71·7, 76·8	82·2	78·1, 86·3	0·0027
Fe	79·5	73·0, 86·0	83·4	77·5, 89·4	0·3450	67·7	65·0, 70·5	81·3	77·1, 85·5	<0·0001
Zn	40·4	32·5, 48·3	30·5	23·0, 37·9	0·0860	38·1	35·3, 40·1	35·0	29·9, 40·1	0·2992
Vitamin A	53·0	44·9, 61·0	53·0	44·9, 61·0	1·0000	35·7	32·8, 38·5	53·7	48·4, 59·1	<0·0001
Thiamine	54·3	46·3, 62·3	55·6	47·6, 63·6	0·8990	42·0	39·1, 44·9	53·1	47·8, 58·5	0·0003
Riboflavin	33·1	25·5, 40·7	26·5	19·4, 33·6	0·1930	19·1	16·8, 21·4	30·0	25·1, 34·9	<0·0001
Niacin	48·3	40·3, 56·4	52·3	44·3, 60·4	0·5390	35·4	32·6, 38·2	49·9	44·5, 55·2	<0·0001
Pyridoxine	44·4	36·4, 52·4	45·7	37·7, 53·7	0·8940	32·8	30·1, 35·6	44·5	39·2, 49·8	<0·0001
Folate	79·5	73·0, 86·0	84·8	79·0, 90·6	0·2150	75·2	72·7, 77·8	81·9	77·8, 86·0	0·0109
Vitamin B_{12}	35·8	28·0, 43·5	29·8	22·4, 37·2	0·2720	28·0	25·4, 30·6	32·0	27·0, 37·1	0·1494
Vitamin C	27·2	20·0, 34·3	38·4	30·6, 46·3	0·0220	47·7	44·8, 50·6	33·2	28·2, 38·3	<0·0001

24HR, 24-h recall; CDA, Food Diversity Questionnaire; CDA1, first Food Diversity Questionnaire; CDA2, second Food Diversity Questionnaire.
*CDA1 refers to the crude first CDA, CDA2 refers to the crude second CDA, 24HR refers to the crude first 24HR and CDA refers to the crude first CDA.
†Based on the McNemar test.
‡Based on the chi-squared test of independence.

Table 5 Reproducibility between the first and second CDA (*n* 151)

	Variability between measurements*						
	Continuous measurement			Categorical measurement			
Nutrient	ICC†	95 % CI	*P*-value	Kappa	95 % CI	*P*-value	% agreement‡
Ca	0·313§	0·161, 0·449	<0·0001	0·291	0·101, 0·481	0·0002	79·5
Fe	0·397§	0·254, 0·523	<0·0001	0·388	0·204, 0·572	<0·0001	81·5
Zn	0·327§	0·177, 0·463	<0·0001	0·041	−0·116, 0·197	0·3048	55·6
Vitamin A	0·243§	0·087, 0·387	0·0010	0·282	0·129, 0·435	0·0003	64·2
Thiamine	0·487§	0·355, 0·600	<0·0001	0·171	0·013, 0·328	0·0179	58·9
Riboflavin	0·469§	0·335, 0·585	<0·0001	0·244	0·082, 0·407	0·0012	68·2
Niacin	0·352§	0·205, 0·484	<0·0001	0·127	−0·030, 0·285	0·0585	56·3
Pyridoxine	0·391§	0·247, 0·518	<0·0001	0·251	0·096, 0·406	0·0010	62·9
Folate	0·494§	0·363, 0·605	<0·0001	0·282	0·095, 0·469	0·0002	78·8
Vitamin B_{12}	0·127§	−0·033, 0·280	0·0600	0·207	0·046, 0·368	0·0052	64·9
Vitamin C	0·336§	0·187, 0·471	<0·0001	0·274	0·119, 0·429	0·0003	67·6

CDA, Food Diversity Questionnaire; ICC, intraclass correlation coefficient.
*The measurements refer to the crude first CDA and to the crude second CDA.
†Type C intraclass correlation coefficients that use a definition of coherence. The variance in the intermediate measure is excluded from the variance in the denominator.
‡The agreement or comparison between two measurements on the same samples[43].
§The estimator is the same whether the interaction effect is present or not.

As was reported in a study that proposed a new global food quality index[42] and taking into account the changes in dietary patterns resulting from globalisation, urbanisation and the greater availability of low-cost processed foods, it would be interesting to continue developing instruments that consider multiple aspects of dietary diversity, including more food groups, both healthy and unhealthy (ultraprocessed), and to evaluate their influence on the quality of diet and health.

The CDA of this study allowed us to identify the amount of food consumed according to each food subgroup and food group, to identify whether the micronutrients consumed came from food or supplements, to identify populations at risk of deficient consumption of micronutrients and to establish policies or programmes that promote food production or nutrition education. This form is faster and less expensive to administer than 24HR, at 10 min *v.* 20 min. However, if necessary, it would be invaluable to develop an online application and generate food diversity software.

One limitation of this study is that it was validated in a specific group of women of childbearing age who work in the same programme. Trained interviewers must have expertise in identifying the amount of food consumed, taking into account that the respondent must perform an extraction and condense several foods into one model.

Conclusions

The CDA validated in this study is useful to evaluate the population-level prevalence of the risk of deficiency in the usual intake of Ca, Fe, Zn, thiamine, riboflavin, niacin, pyridoxine, folates, vitamin B_{12}, vitamin C and vitamin A. It

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Table 6 Diagnostic performance of the second CDA with the first as a reference (*n* 151)

Nutrient*	Sensitivity	95 % CI	Specificity	95 % CI	Predictive value				Likelihood ratio			Reduction of entropy		Bias index
					Positive	95 % CI	Negative	95 % CI	Positive	95 % CI	Negative	Positive %	Negative %	
Ca	88·6	81·8, 93·1†	39·3	23·6, 57·6†	86·5	79·5, 91·4†	44·0	26·7, 62·9†	1·460	1·298, 1·642	0·290	8·4	−20·6	0·0199
Fe	90·8	84·3, 94·8†	45·2	29·2, 62·2†	86·5	79·5, 91·4†	56·0	37·1, 73·3†	1·656	1·473, 1·862	0·203	11·2	−17·8	0·0397
Zn	32·8	22·3, 45·3†	71·1	61·0, 79·5†	43·5	30·2, 57·8†	61·0	51·4, 69·7†	1·135	0·861, 1·496	0·945	−1·0	0·6	−0·0993
Vitamin A	66·3	55·4, 75·7†	62·0	50·3, 72·4†	66·3	55·4, 75·7†	62·0	50·3, 72·4†	1·742	1·590, 1·909	0·545	5·2	2·7	0·0000
Thiamine	63·4	52·6, 73·0†	53·6	42·0, 64·9†	61·9	51·2, 71·6†	55·2	43·4, 66·5†	1·367	1·258, 1·486	0·682	2·5	0·2	0·0133
Riboflavin	42·0	29·4, 55·8†	81·2	72·5, 87·6†	52·5	37·5, 67·1†	73·9	65·0, 81·2†	2·233	1·770, 2·816	0·714	−5·7	6·1	−0·0662
Niacin	58·9	47·5, 69·5†	54·9	42·9, 64·5†	54·4	43·5, 65·0†	58·3	46·8, 69·0†	1·276	1·171, 1·391	0·763	0·3	1·3	0·0397
Pyridoxine	59·7	47·7, 70·6†	65·5	54·8, 74·8†	58·0	46·2, 68·9†	67·1	56·3, 76·3†	1·729	1·564, 1·912	0·616	0·6	5·3	0·0133
Folate	90·0	83·3, 94·2†	35·5	21·1, 53·1†	84·4	77·1, 89·7†	47·8	29·2, 67·0†	1·395	1·262, 1·542	0·282	7·4	−18·5	0·0530
Vitamin B_{12}	42·6	30·3, 55·8†	77·3	68·0, 84·5†	51·1	37·0, 65·0†	70·8	61·5, 78·6†	1·878	1·531, 2·303	0·743	−4·1	4·8	−0·0596
Vitamin C	61·0	45·7, 74·3†	70·0	60·9, 77·8†	43·1	31·2, 55·9†	82·8	73·9, 89·1†	2·033	1·822, 2·268	0·558	−9·9	12·6	0·1126

CDA, Food Diversity Questionnaire.
*The diagnostic performance was compared between the crude first CDA and to the crude second CDA.
†Method: Wilson points.

was not useful to individually assess the prevalence of risk of deficiency in the usual intake of micronutrients, as the concordance analyses were weak and the ability to detect deficiencies in the diagnostic performance tests was only good for vitamin A, Ca, Fe, folates and pyridoxine. It is necessary to apply two CDA on non-consecutive days and distribute them throughout the week to adjust them in the PC-SIDE software. Although in the intramethod analysis (CDA), no significant differences were found in any micronutrients, when the prevalences between the 24HR method and CDA were compared without statistical adjustment, there were statistically significant differences in almost all micronutrients.

A great variety of questionnaires, such as the one we have considered in this work, are useful instruments but are not meant to replace other instruments, such as 24HR recalls, that capture daily food consumption. Together with the appropriate statistical methodologies, 24HR recalls still provide the most precise assessment of usual intake distributions and the prevalence of inadequacy. Therefore, national-level interventions such as food fortification should still rely on the more precise individual-level, replicated, 24HR recalls.

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research, the general results were reported to the institutions and the individual results to the participating women.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S1368980022000854

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