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

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Short title: Food diversity questionnaire validated

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Authorship: All authors of this study contributed equally to the processes of conceptualization, analysis, research, methodology, project management, validation, writing, review and editing.

Ethical considerations: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and was classified with minimal risk according to Resolution 8430 of 1993. All procedures involving research study participants were approved by the ethics committee of the University Research Headquarters (SIU) of the University of Antioquia. Written informed consent was obtained from all participants. For confidentiality purposes, the questionnaires and personal data were coded and were only known by the principal investigators. At the end of the research, the general results were reported to the institutions and the individual results to the participating women.
Abstract

Objective: To validate a Food Diversity Questionnaire that identifies the prevalence of the risk of deficiency in the intake of 11 micronutrients.

Design: The Food Diversity Questionnaire paper form, an online application for data entry and handling, was designed and compared with the 24-hour recall as a reference method. All data were processed in 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 of age (n = 186) who worked for the Buen Comienzo programme in 2019.

Results: When comparing the adjusted 24-hour recall technique and the Food Diversity Questionnaire, 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%, calcium 98.7%, iron 92.8%, folates 91.6%, and pyridoxine 81.8%.

Conclusions: The Food Diversity Questionnaire validated in this study is useful and faster at evaluating population-level data at risk of deficiency in the intake of calcium, iron, zinc, thiamine, riboflavin, niacin, pyridoxine, folates, vitamin B12, vitamin C, and vitamin A. Based on individual-level data, a good ability to detect deficiencies was observed in the intake of vitamin A, calcium, iron, folates, and pyridoxine.

Keywords: Validation, Questionnaire, Food Diversity, 24-Hour Recall, Women.
Introduction

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-hour 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 Food and Agriculture Organization of the United Nations (FAO)\(^9\) 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 hours, 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 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 categorize 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 grams as a cutoff 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 11 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 11 micronutrients in women of childbearing age.

**Methods**

**Type of study**

This is an observational, descriptive, cross-sectional epidemiological study and validation of 11 micronutrient intakes by the CDA compared with 24HR.

**Population**

Women of childbearing age between 19 and 50 years of age 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.

**Sample**

A total of 186 women were selected by probabilistic sampling through valid scientific inference and not by population representativeness. 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 one to two 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.* who analysed women of reproductive age in Bangladesh, disaggregated into 21 food groups and with a minimum inclusion of 15 grams: 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 confidence interval of 95%.

The Technical Directorate of the Buen Comienzo programme authorized the study at 15 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 nine 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 two-day 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:

1. **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 gr and a body height rod with a capacity of two
metres and sensitivity of 1 mm. Data were necessary to classify nutritional status according to
body mass index (BMI) kg/m2 in accordance with the values proposed by the World Health
Organization (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).

2. 24-hour 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 hours
before the survey(7). The 24HR survey took approximately 20 minutes to administer.

In this study, each woman was given a minimum of five and a maximum of seven 24HRs
distributed throughout the days of the week on nonconsecutive 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 24HRs 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.

3. 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:
3.1. 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: calcium (EAR 800 mg), iron (EAR 11.7 mg), zinc (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 B12 (EAR 2.0 µg), and vitamin C (EAR 60 mg).

3.2. 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.

3.3. 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).

3.4. Standardization 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.

3.5. Format of the Food Diversity Questionnaire

A pilot study was performed to develop and design the format of the CDA. A total of 35 questionnaires were administered to women of childbearing age between 19 and 50 years of age 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.

3.6. 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 CDAs distributed during the week on nonconsecutive days to adjust the intra- and interindividual variability\(^{(22)}\). The CDA took approximately 10 minutes to fill out.

3.7. 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 24HRs and CDA refers to the adjustment of the two CDAs), the crude standard error (SEc), the adjusted standard error (SEa) of the PC-SIDE v1 software, the 95% confidence intervals (95% CIs) 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 CDAs and to the adjustment of the five or seven 24HRs) 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 CDAs and the adjustment of the five or seven 24HRs 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.

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 24HRs and between one and two CDAs 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
1. Characterization
For each of the 186 women, the surveys were distributed on different days of the week. A total of 1,122 24HRs were submitted, for an average of six 24HRs per person (at least five and at most seven 24HRs). A total of 337 CDAs 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/m² (4.0 SD), distributed as 1% underweight, 49% normal BMI, 37% overweight, and 13% obese.

2. Comparison between the 24-hour recall and Food Diversity Questionnaire results
2.1. 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 calcium, iron, 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, e.g., vitamin C (p
= 0.6071), folate (p = 0.4667), zinc (p = 0.4524), niacin (p = 0.3703), calcium (p = 0.3533), and iron (p = 0.3391) (Table 1).

2.2. Concordance between the 24-hour 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 ICCs 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).

2.3. 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%), calcium (98.7%), iron (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 iron (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).

3. Intratechnique analysis of the Food Diversity Questionnaire
3.1. Unadjusted prevalence of risk of deficiency
When comparing the unadjusted prevalences between the first and second CDAs, no significant differences were found for any nutrients, except for vitamin C, although the CIs 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 zinc and vitamin B12 (Table 4).

3.2. Reproducibility between the first and second Food Diversity Questionnaires
To analyse the reproducibility between the first and second unadjusted CDAs, the risk of deficiency for each nutrient was classified in each questionnaire. The ICCs and Cohen's kappa measuring the agreement between the first and second CDAs 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).

### 3.3. Diagnostic performance of the first Food Diversity Questionnaire

To compare the performance of the unadjusted first and second CDAs, the risk of deficiency of each nutrient was classified in each questionnaire. The second CDA showed a high sensitivity for detecting individuals deficient in iron (90.8%), folates (90.0%), calcium (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: iron (11.2%), calcium (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 iron deficiency than in those without iron deficiency (Table 6).

**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%), calcium (98.7%), iron (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 CDAs 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: iron (90.8%), folates (90.0%), calcium (88.6%), vitamin A (66.3%), and thiamine (63.4%).
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 nonconsecutive 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 CDAs 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 CDAs as the test method and 5–7 24HRs (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 13 food groups and 26 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 21 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, 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.

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 globalization, urbanization, 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 minutes vs. 20 minutes. 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 calcium, iron, zinc, thiamine, riboflavin, niacin, pyridoxine, folates, vitamin B12, vitamin C, and vitamin A. It 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, calcium, iron, folates and pyridoxine. It is
necessary to apply two food diversity questionnaires on nonconsecutive 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.
References


20. Ministerio de Salud y Protección Social de Colombia (2016) Resolución 2465 de 2016. Por la cual se adoptan los indicadores antropométricos, patrones de referencia y puntos de corte para la clasificación antropométrica del estado nutricional de niñas, niños y adolescentes menores de 18 años de edad, adultos de 18 a 64 años de edad y gestantes adultas y se dictan otras disposiciones. Colombia.


Table 1 Adjusted prevalence of the risk of deficiency in the usual intake of micronutrients by 24-hour dietary recall and the present Food Diversity Questionnaire (n = 186)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>24HR(^*) Adjusted prevalence of deficiency</th>
<th>CDA(^*) Adjusted prevalence of deficiency</th>
<th>Crude P value‡</th>
<th>Adjusted P value</th>
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<tbody>
<tr>
<td></td>
<td>%</td>
<td>95% CI†</td>
<td>SEc‡</td>
<td>SEa§</td>
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<td>Calcium</td>
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<td>0.0520</td>
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<td>0.0497</td>
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<td>26.9</td>
<td>16.0, 37.9</td>
<td>0.0325</td>
<td>0.0558</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>4.2</td>
<td>0.0, 8.8</td>
<td>0.0147</td>
<td>0.0236</td>
</tr>
<tr>
<td>Niacin</td>
<td>20.2</td>
<td>9.7, 30.8</td>
<td>0.0294</td>
<td>0.0538</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>10.5</td>
<td>1.5, 19.4</td>
<td>0.0225</td>
<td>0.0456</td>
</tr>
<tr>
<td>Folate</td>
<td>74.9</td>
<td>64.8, 85.0</td>
<td>0.0318</td>
<td>0.0515</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>3.9</td>
<td>0.0, 9.5</td>
<td>0.0142</td>
<td>0.0287</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>25.5</td>
<td>15.0, 36.0</td>
<td>0.0320</td>
<td>0.0536</td>
</tr>
</tbody>
</table>

Abbreviations: 24HR, 24-hour 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 CDAs, 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 SEs.

‡ 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 24-hour recall and the Food Diversity Questionnaire (n = 186)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Continuous measurement</th>
<th></th>
<th>Categorical measurement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variability between methods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ICC†</td>
<td>95% CI</td>
<td>P value</td>
<td>Kappa</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.383§</td>
<td>0.254, 0.499</td>
<td>&lt; 0.0001</td>
<td>0.100</td>
</tr>
<tr>
<td>Iron</td>
<td>0.112§</td>
<td>-0.032, 0.252</td>
<td>0.0630</td>
<td>0.187</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.394§</td>
<td>0.265, 0.508</td>
<td>&lt; 0.0001</td>
<td>0.275</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>0.361§</td>
<td>0.229, 0.479</td>
<td>&lt; 0.0001</td>
<td>0.026</td>
</tr>
<tr>
<td>Thiamine</td>
<td>0.066§</td>
<td>-0.079, 0.207</td>
<td>0.1860</td>
<td>0.050</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.401§</td>
<td>0.273, 0.515</td>
<td>&lt; 0.0001</td>
<td>-0.019</td>
</tr>
<tr>
<td>Niacin</td>
<td>0.362§</td>
<td>0.230, 0.480</td>
<td>&lt; 0.0001</td>
<td>0.069</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>0.248§</td>
<td>0.109, 0.378</td>
<td>&lt; 0.0001</td>
<td>0.198</td>
</tr>
<tr>
<td>Folate</td>
<td>0.418§</td>
<td>-0.292, 0.530</td>
<td>&lt; 0.0001</td>
<td>0.288</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>0.247§</td>
<td>0.107, 0.377</td>
<td>&lt; 0.0001</td>
<td>0.110</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0.485§</td>
<td>-0.367, 0.588</td>
<td>&lt; 0.0001</td>
<td>0.179</td>
</tr>
</tbody>
</table>

The methods refer to the adjustment of the two CDAs and to the adjustment of the five or seven 24HRs.

† 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 methods on the same sample.  
§ The estimator is the same whether the interaction effect is present or not.
### Table 3 Diagnostic performance of the Food Diversity Questionnaire compared to 24-hour recall (n = 186)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Sensitivity 95% CI</th>
<th>Specificity 95% CI</th>
<th>Predictive value</th>
<th>Likelihood ratio</th>
<th>Reduction of entropy</th>
<th>Bias index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Positive 95% CI</td>
<td>Negative 95% CI</td>
<td>Positive 95% CI</td>
<td>Negative 95% CI</td>
</tr>
<tr>
<td>Calcium</td>
<td>98.7 (95.2, 99.6)</td>
<td>8.1 (2.8, 21.3)</td>
<td>81.2 (74.9, 86.2)</td>
<td>60.0 (23.1, 88.2)</td>
<td>1.074 (1.013, 1.138)</td>
<td>0.166 (0.000, 724.800)</td>
</tr>
<tr>
<td>Iron</td>
<td>92.8 (86.9, 96.2)</td>
<td>23.0 (14.2, 34.9)</td>
<td>71.2 (63.8, 77.6)</td>
<td>60.9 (40.8, 77.8)</td>
<td>1.204 (1.154, 1.257)</td>
<td>0.314 (0.158, 0.624)</td>
</tr>
<tr>
<td>Zinc</td>
<td>31.6 (15.4, 54.0)</td>
<td>94.0 (89.3, 96.7)</td>
<td>37.5 (18.5, 61.4)</td>
<td>92.4 (87.4, 95.5)</td>
<td>5.274 (2.136, 13.020)</td>
<td>0.728 (0.625, 0.847)</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>100.0 (34.2, 100.0)</td>
<td>55.4 (48.2, 62.4)</td>
<td>2.4 (0.7, 8.3)</td>
<td>100.0 (96.4, 100.0)</td>
<td>2.244 (2.191, 2.298)</td>
<td>0.000 (0.000, 0.000)</td>
</tr>
<tr>
<td>Thiamine</td>
<td>48.8 (34.3, 63.5)</td>
<td>57.9 (49.8, 65.7)</td>
<td>24.7 (16.6, 35.1)</td>
<td>80.0 (71.4, 86.5)</td>
<td>1.160 (1.013, 1.327)</td>
<td>0.792 (0.792, 0.792)</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.0 (0.0, 65.8)</td>
<td>91.9 (87.0, 95.0)</td>
<td>0.0 (0.0, 20.4)</td>
<td>98.8 (95.8, 99.7)</td>
<td>0.000 (0.000, 0.000)</td>
<td>0.000 (0.000, 0.000)</td>
</tr>
<tr>
<td>Niacin</td>
<td>26.9 (13.7, 46.1)</td>
<td>81.3 (74.5, 86.5)</td>
<td>18.9 (9.5, 34.2)</td>
<td>87.3 (80.9, 91.7)</td>
<td>1.436 (0.629, 3.278)</td>
<td>0.899 (0.808, 1.001)</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>81.8 (52.3, 94.9)</td>
<td>74.3 (67.3, 80.2)</td>
<td>16.7 (9.0, 28.7)</td>
<td>98.5 (94.6, 99.6)</td>
<td>3.182 (2.902, 3.488)</td>
<td>0.091 (0.091, 0.091)</td>
</tr>
<tr>
<td>Folate</td>
<td>91.6 (86.1, 95.0)</td>
<td>34.4 (20.4, 51.7)</td>
<td>87.0 (81.0, 91.4)</td>
<td>45.8 (27.9, 64.9)</td>
<td>1.395 (1.269, 1.534)</td>
<td>0.246 (0.150, 0.401)</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>33.3 (6.2, 79.2)</td>
<td>94.0 (89.6, 96.6)</td>
<td>8.3 (1.5, 35.4)</td>
<td>98.8 (95.9, 99.6)</td>
<td>5.545 (0.092, 334.000)</td>
<td>0.266 (0.266, 0.266)</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>19.5 (10.2, 34.0)</td>
<td>94.5 (89.5, 97.2)</td>
<td>50.0 (28.0, 72.0)</td>
<td>80.6 (74.0, 85.8)</td>
<td>3.537 (1.008, 12.410)</td>
<td>0.852 (0.802, 0.905)</td>
</tr>
</tbody>
</table>

* The diagnostic performance was compared between the adjustment of the two CDAs and the adjustment of the five or seven 24HRs.
† Method: Wilson points.
Table 4 Unadjusted prevalence of risk of deficiency in the usual nutrient intake

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>CDA1(^1)</th>
<th>CDA2(^1)</th>
<th>P value(^1)</th>
<th>24HR(^1)</th>
<th>CDA(^1)</th>
<th>P value(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>81.5 75.2, 87.7</td>
<td>83.4 77.5, 89.4</td>
<td>0.7200</td>
<td>74.2 71.7, 76.8</td>
<td>82.2 78.1, 86.3</td>
<td>0.0027</td>
</tr>
<tr>
<td>Iron</td>
<td>79.5 73.0, 86.0</td>
<td>83.4 77.5, 89.4</td>
<td>0.3450</td>
<td>67.7 65.0, 70.5</td>
<td>81.3 77.1, 85.5</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Zinc</td>
<td>40.4 32.5, 48.3</td>
<td>30.5 23.0, 37.9</td>
<td>0.0860</td>
<td>38.1 35.3, 40.1</td>
<td>35.0 29.9, 40.1</td>
<td>0.2992</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>53.0 44.9, 61.0</td>
<td>53.0 44.9, 61.0</td>
<td>1.0000</td>
<td>35.7 32.8, 38.5</td>
<td>53.7 48.4, 59.1</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Thiamine</td>
<td>54.3 46.3, 62.3</td>
<td>55.6 47.6, 63.6</td>
<td>0.8990</td>
<td>42.0 39.1, 44.9</td>
<td>53.1 47.8, 58.5</td>
<td>&lt; 0.0003</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>33.1 25.5, 40.7</td>
<td>26.5 19.4, 33.6</td>
<td>0.1930</td>
<td>19.1 16.8, 21.4</td>
<td>30.0 25.1, 34.9</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Niacin</td>
<td>48.3 40.3, 56.4</td>
<td>52.3 44.3, 60.4</td>
<td>0.5390</td>
<td>35.4 32.6, 38.2</td>
<td>49.9 44.5, 55.2</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>44.4 36.4, 52.4</td>
<td>45.7 37.7, 53.7</td>
<td>0.8940</td>
<td>32.8 30.1, 35.6</td>
<td>44.5 39.2, 49.8</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Folate</td>
<td>79.5 73.0, 86.0</td>
<td>84.8 79.0, 90.6</td>
<td>0.2150</td>
<td>75.2 72.7, 77.8</td>
<td>81.9 77.8, 86.0</td>
<td>0.0109</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>35.8 28.0, 43.5</td>
<td>29.8 22.4, 37.2</td>
<td>0.2720</td>
<td>28.0 25.4, 30.6</td>
<td>32.0 27.0, 37.1</td>
<td>0.1494</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>27.2 20.0, 34.3</td>
<td>38.4 30.6, 46.3</td>
<td>0.0220</td>
<td>47.7 44.8, 50.6</td>
<td>33.2 28.2, 38.3</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

Abbreviations: 24HR, 24-hour Recall; CDA, Food Diversity Questionnaire; CDA1, First Food Diversity Questionnaire; CDA2, Second Food Diversity Questionnaire.

\(^1\) 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.

\(^1\) Based on the McNemar test.

\(^1\) Based on the chi-squared test of independence.
Table 5 Reproducibility between the first and second Food Diversity Questionnaires (n = 151)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Continuous measurement</th>
<th>Variability between measurements</th>
<th>Categorical measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC†</td>
<td>95% CI</td>
<td>P value</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.313§</td>
<td>0.161, 0.449</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Iron</td>
<td>0.397§</td>
<td>0.254, 0.523</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.327§</td>
<td>0.177, 0.463</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>0.243§</td>
<td>0.087, 0.387</td>
<td>0.0010</td>
</tr>
<tr>
<td>Thiamine</td>
<td>0.487§</td>
<td>0.355, 0.600</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.469§</td>
<td>0.335, 0.585</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Niacin</td>
<td>0.352§</td>
<td>0.205, 0.484</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>0.391§</td>
<td>0.247, 0.518</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Folate</td>
<td>0.494§</td>
<td>0.363, 0.605</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>0.127§</td>
<td>-0.033, 0.280</td>
<td>0.0600</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0.336§</td>
<td>0.187, 0.471</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

1 The measurements refer to the crude first CDA and to the crude second CDA.
2 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.
3 The agreement or comparison between two measurements on the same samples
4 The estimator is the same whether the interaction effect is present or not.
Table 6 Diagnostic performance of the second Food Diversity Questionnaire with the first as a reference (n = 151)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Sensitivity</th>
<th>95% CI</th>
<th>Specificity</th>
<th>95% CI</th>
<th>Predictive value</th>
<th>95% CI</th>
<th>Likelihood ratio</th>
<th>95% CI</th>
<th>Reduction of entropy</th>
<th>Bias index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>88.6</td>
<td>81.8, 93.1†</td>
<td>39.3</td>
<td>23.6, 57.6†</td>
<td>86.5</td>
<td>79.5, 91.4</td>
<td>44.0</td>
<td>26.7, 62.9†</td>
<td>1.460</td>
<td>1.298, 1.642</td>
</tr>
<tr>
<td>Iron</td>
<td>90.8</td>
<td>84.3, 94.8†</td>
<td>45.2</td>
<td>29.2, 62.2†</td>
<td>86.5</td>
<td>79.5, 91.4</td>
<td>56.0</td>
<td>37.1, 73.3†</td>
<td>1.656</td>
<td>1.473, 1.862</td>
</tr>
<tr>
<td>Zinc</td>
<td>32.8</td>
<td>22.3, 45.3†</td>
<td>71.1</td>
<td>61.0, 79.5†</td>
<td>43.5</td>
<td>30.2, 57.8</td>
<td>61.0</td>
<td>51.4, 69.7†</td>
<td>1.135</td>
<td>0.861, 1.496</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>66.3</td>
<td>55.4, 75.7†</td>
<td>62.0</td>
<td>50.3, 72.4†</td>
<td>66.3</td>
<td>55.4, 75.7</td>
<td>62.0</td>
<td>50.3, 72.4†</td>
<td>1.742</td>
<td>1.590, 1.909</td>
</tr>
<tr>
<td>Thiamine</td>
<td>63.4</td>
<td>52.6, 73.0†</td>
<td>53.6</td>
<td>42.0, 64.9†</td>
<td>61.9</td>
<td>51.2, 71.6</td>
<td>55.2</td>
<td>43.4, 66.5†</td>
<td>1.367</td>
<td>1.258, 1.486</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>42.0</td>
<td>29.4, 55.8†</td>
<td>81.2</td>
<td>72.5, 87.6†</td>
<td>52.5</td>
<td>37.5, 67.1</td>
<td>73.9</td>
<td>65.0, 81.2†</td>
<td>2.233</td>
<td>1.770, 2.816</td>
</tr>
<tr>
<td>Niacin</td>
<td>58.9</td>
<td>47.5, 69.5†</td>
<td>54.9</td>
<td>42.9, 64.5†</td>
<td>54.4</td>
<td>43.5, 65.0</td>
<td>58.3</td>
<td>46.8, 69.0†</td>
<td>1.276</td>
<td>1.171, 1.391</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>59.7</td>
<td>47.7, 70.6†</td>
<td>65.5</td>
<td>54.8, 74.8†</td>
<td>58.0</td>
<td>46.2, 68.9</td>
<td>67.1</td>
<td>56.3, 76.3†</td>
<td>1.729</td>
<td>1.564, 1.912</td>
</tr>
<tr>
<td>Folate</td>
<td>90.0</td>
<td>83.3, 94.2†</td>
<td>35.5</td>
<td>21.1, 53.1†</td>
<td>84.4</td>
<td>77.1, 89.7</td>
<td>47.8</td>
<td>29.2, 67.0†</td>
<td>1.395</td>
<td>1.262, 1.542</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>42.6</td>
<td>30.3, 55.8†</td>
<td>77.3</td>
<td>68.0, 84.5†</td>
<td>51.1</td>
<td>37.0, 65.0</td>
<td>70.8</td>
<td>61.5, 78.6†</td>
<td>1.878</td>
<td>1.531, 2.303</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>61.0</td>
<td>45.7, 74.3†</td>
<td>70.0</td>
<td>60.9, 77.8†</td>
<td>43.1</td>
<td>31.2, 55.9</td>
<td>82.8</td>
<td>73.9, 89.1†</td>
<td>2.033</td>
<td>1.822, 2.268</td>
</tr>
</tbody>
</table>

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