Systematic review of use and interpretation of dietary diversity indicators in nutrition- sensitive agriculture literature

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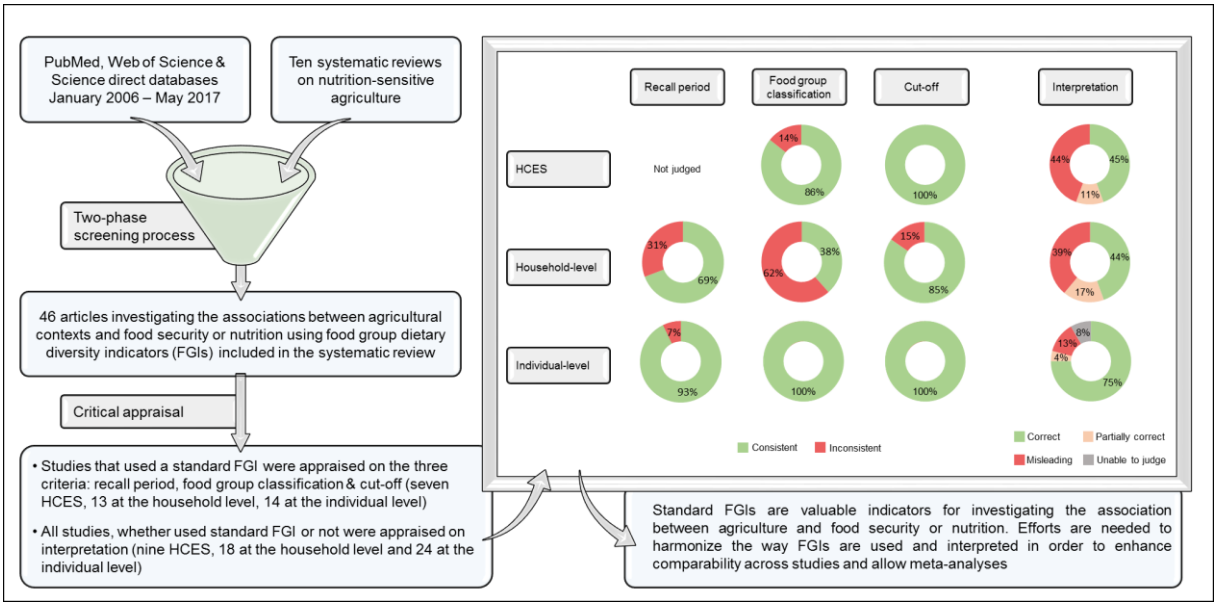
Abstract

In the past decade, food group dietary diversity indicators (FGIs) have increasingly been used to assess the impact of agriculture on food security or nutrition. Following a structured search strategy and a two-phase screening process, 46 studies investigating associations between agriculture and food security or nutrition through the use of simple FGIs were assessed for how the indicators were constructed and interpreted. Most studies based on individual level FGIs were consistent with published guidance, while many of the studies measuring households' dietary diversity were not, particularly in terms of interpretation of the indicators or of food group classification. Efforts are needed to harmonize the way FGIs are used and interpreted in order to enhance comparability across studies and allow meta-analyses of the association between agriculture and food security or nutrition.

Graphical abstract



Keywords

Dietary diversity; nutrition; food security; agricultural practices; agricultural contexts; critical appraisal.

1. Introduction

Pathways through which agriculture can improve nutrition are complex (World Bank, 2007). Conceptual frameworks elaborated to describe impact pathways from agriculture to nutrition (Kadiyala et al., 2014) follow the model of the "conceptual framework for the analysis of the causes of malnutrition", which orders causes as immediate, underlying or basic determinants of malnutrition (UNICEF, 1990). According to this framework, agriculture, as a basic determinant, impacts nutrition through underlying determinants that include access to food, care practices and health environment. In turn, underlying determinants impact nutritional status through two immediate determinants – food intake and health.

The choice of indicators in studies of the nutritional impact of agricultural interventions and programmes is a crucial issue (Webb and Kennedy, 2014). Many studies use nutritional status as the principal impact indicator, as pointed out by several authors (Masset et al., 2012; Girard et al., 2012; Pandey et al., 2016). Several reviews of relevant studies have shown little evidence of an impact on child anthropometric status, partly due to methodological limitations (Masset et al., 2012; Ruel and Alderman, 2013; Gillespie and van den Bold, 2017). This lack of evidence may be due to the multifactorial nature of nutritional status, its low sensitivity to change and to large sample requirements for detecting an impact when there is one. In a review of on-going agriculture-nutrition intervention projects, Herforth and Ballard (2016) found that almost all were using dietary indicators for assessing impact on nutrition, an important shift in focus compared to the previous decade when anthropometry was considered the only outcome of interest.

Dietary indicators are more specific and sensitive to change in food availability and access than nutritional status and require smaller samples (Herforth and Ballard, 2016). However, assessing diets is a challenging endeavour. Quantitative dietary intake assessments are cumbersome and

require highly specialized skills. To address this issue, several simple proxy dietary indicators have been developed, among which the most widely used are indicators of dietary diversity. It has been recognized that dietary diversity, a key component of diet quality, helps to ensure intake of essential nutrients (Ruel, 2003). Monotonous diets are associated with multiple nutrient deficiencies. Dietary diversity is a holistic feature of the diet in contrast with intake of single nutrients. Moreover dietary diversity is a key feature of food-based dietary guidelines (WHO, 1996).

Simple food group indicators (FGIs) assess whether people consume foods from specific food groups, defined as a set of foods that share similar nutritional properties or biological characteristics (Arimond et al., 2010). Four FGIs, developed to reflect dietary diversity of households or individuals, have been validated against multi-site quantitative food intake datasets in order to operationalize the measurement of dietary diversity at population level. They are proxies of access to a variety of foods in the field of food security (at household level) or of nutrient adequacy of the diet, one key dimension of diet quality (at individual level) (Ruel, 2003).

At the household level, a 10-country analysis showed an association between an FGI and per capita energy availability (Hoddinott and Yohannes, 2002). The Household Dietary Diversity Score (HDDS), constructed by counting the number of food groups consumed by the household over the previous 24 hours, was proposed as an indicator of the access dimension of food security. Guidelines were published to standardize the implementation of a 12-food group indicator (Swindale and Bilinsky, 2006). At the individual level, simple indicators were developed for monitoring progress in feeding practices for infants and young children. Ten datasets were used to identify indicators correlated with the mean adequacy of the micronutrient density of complementary foods across nine micronutrients. As a result, a dichotomous indicator of Minimum Dietary Diversity (MDD) of four or more food groups, out of seven,

consumed over the previous 24 hours was validated for infants and young children six to 23 months old (Working Group on Infant and Young Child Feeding Indicators, 2006). Guidelines for standardizing the implementation of the MDD were published by the World Health Organization (WHO, 2008, 2010). In parallel, a dietary diversity indicator was developed to reflect the mean probability of adequacy of women's diets across 11 micronutrients. Several dietary diversity scores were validated using five datasets (Arimond et al., 2010). Guidelines were published that promoted a simple nine food group dietary diversity score for women of reproductive age, the Women's Dietary Diversity Score (WDDS) (FAO, 2011). This was followed by an analysis of nine datasets to create and validate the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W), a dichotomous indicator of five or more food groups, out of 10, consumed over the previous 24 hours (Women's Dietary Diversity Project Study Group, 2017). FAO and FHI360 (2016) published a guidance manual.

The HDDS, MDD, WDDS and MDD-W have undergone extensive validation work, using datasets from multiple sites, to arrive at proxy indicators of diet that are approximately comparable in meaning across different contexts and over time. Their characteristics are described in Table 1. These indicators require far fewer skills than quantitative intake surveys for data collection, analysis and interpretation. They are based on a qualitative 24-hour recall, which is less prone to bias and recall error than other methods, and results of assessments are simpler to analyse (NIH-NCI, 2018). Because of their relative simplicity and demonstrated validity, these four standard FGIs have been widely used by researchers from different sectors, in particular in studies of the impact of agriculture on food security and nutrition (Herforth and Ballard, 2016). This paper reviews published studies that investigated the association between agricultural practices or agricultural contexts and food security or nutrition by using simple FGIs of dietary diversity. The purpose of the review is to assess to what extent and how studies used and interpreted common metrics of dietary diversity, which would improve comparability

across studies to produce global evidence of the impact of agriculture on nutrition and food security. We acknowledge however that not all studies have an objective of comparisons across settings. The intent of the review was not to judge the validity of the studies or their results.

2. Methods

2.1 Selection of studies for the review

Systematic reviews of research on nutrition-sensitive agriculture were examined to identify key terms and the most relevant scientific literature databases for carrying out the search (Balagamwala and Gazdar, 2013; Dury et al., 2015; Fiorella et al., 2016; Kadiyala et al., 2014; Masset et al., 2012; Pandey et al., 2016; Penafiel et al., 2011; Powell et al., 2015; Warren et al., 2015; Webb and Kennedy, 2014). Based on this first step, a structured search strategy was developed to include terms related to dietary diversity and agricultural practices or contexts[1], spanning publications from 2006 up to 23 May 2017. This search strategy was applied to three databases: PubMed, Web of Science and Science direct. Additionally, reference lists of recent systematic reviews on nutrition-sensitive agriculture and of studies included in this review were examined to identify other potentially relevant studies. The search was limited to peer-reviewed articles published in English. All populations and study designs were eligible for inclusion, from cross-sectional studies to randomized controlled trials or other impact evaluation designs.

[1] ("diet* diversity") AND (household* OR family OR woman OR women OR child* OR infant*) AND ("agricultur* intervention" OR "agricultur* program" OR "agricultur* growth" OR "home* food production" OR "farm* production" OR "household production" OR "crop production" OR "biomass production" OR "farm productivity" OR "agricultur* productivity" OR "food crop*" OR "cash crop*" OR "cash-cropping" OR "commercial agriculture" OR "farming contract" OR "agricultur* diversity" OR "production diversity" OR "crop diversity" OR "crop diversification" OR "product diversification" OR "biodiversity" OR "agrobiodiversity" OR "agro-biodiversity" OR "agricultural intensification" OR "aquaculture" OR "agriculture-aquaculture" OR "fisher*" OR "fishing" OR "livestock ownership" OR "livestock rearing" OR "bio-fortification" OR "biofortification" OR "irrigation" OR "women's empowerment" OR "seed" OR "intercropping" OR "land-use"). For the PubMed search, the terms were not truncated.

All studies identified from the initial search strategy were filed and handled using Zotero (version 4.0.28.7). A two-stage screening process was employed to select the final studies to be reviewed. At each stage, the first author screened and reviewed all studies, which were also divided among the three co-authors for a simultaneous review. All disagreements regarding eligibility were resolved through discussion.

At the first stage, all titles and abstracts were examined. Studies that were obviously irrelevant, such as those not investigating associations between any type of agricultural practice or context and food security or nutrition, ecological studies or papers discussing the associations theoretically or conceptually only, as well as reviews or meta-analyses, were excluded from further review. The studies selected at the first stage underwent a full-text screen against the second stage inclusion criterion: only studies that investigated associations between agricultural practices or contexts and food security or nutrition and that used FGIs.

To facilitate the second stage full-text screening, the following information was tabulated using a standardized data extraction form: (i) location of the study (e.g. country); (ii) study design (e.g. cross-sectional study); (iii) subjects and sample size; (iv) purpose of the study; (v) name and reference of the dietary diversity indicator used; (vi) recall period (period of time for which food group consumption is reported, e.g. previous day or previous week); (vii) food group classification; (viii) use of a cut-off; and (ix) interpretation of the dietary diversity indicator. Reasons for exclusion of studies after the second stage full-text screening included investigations of non-specific agricultural practices or contexts, such as forest cover, proximity to marine protected areas or merely rural residence, and those that did not actually measure diversity of the diet using an FGI.

2.2 Critical appraisal

Following the two screening stages, each of the remaining studies was critically appraised for use and interpretation of FGIs. First, studies were categorized by whether they measured dietary diversity at the household level, individual level or both. The studies were then categorized by whether they used a standard FGI, i.e. HDDS, MDD, WDDS, or MDD-W. Those that did use a standard FGI were assessed for consistency with the published guidance based on three criteria: 1) recall period, 2) food group classification and 3) use or not of a cut-off for creating a categorical indicator. Studies that did not use a standard FGI were excluded from the appraisal for these three criteria. For the remaining that did use a standard FGI, the recall period was judged as "consistent" if the study used a 24-hour recall, otherwise "inconsistent". Studies using secondary data from Household Consumption and Expenditure Surveys (HCES) to construct an FGI were excluded from assessment of this criterion because HCES systematically use longer recall periods. The food group classification was judged as "consistent" if the study used the recommended number of food groups and food group definitions, otherwise "inconsistent". The use of a cut-off was judged as "consistent" if the recommended thresholds for the MDD and MDD-W were used, if no ad hoc cut-off was applied to the HDDS or the WDDS since these two indicators do not have recommended thresholds, or if cut points based on a quantile distribution of the dietary diversity score were applied to the HDDS or WDDS. This element was judged as "inconsistent" if other cut-off approaches were used or were not used when appropriate to do so.

The full set of studies, including those that did not use one of the four standard indicators, was assessed on how the FGI employed was interpreted in relation to the level of analysis. The interpretation of the FGI was judged as "correct" if consistent with the level at which it was applied (e.g. interpretation in terms of access to a variety of foods in the field of food security for household measures and in terms of nutrient adequacy of the diet, one key dimension of diet quality, for individual measures). The interpretation was judged as "misleading" if it was not

consistent with the objective of the study and level of analysis. An intermediate judgment of "partially correct" was assigned when the interpretation of the results was consistent with the level of analysis, thus correct, but either the indicator was not strictly appropriate for the research question or the investigators interpreted a household level indicator as a measurement of nutrition or diet quality in the introduction or discussion section of the paper.

All disagreements among reviewing co-authors regarding the critical assessment were resolved through discussion.

3. Results

3.1 Description of the studies

As presented in Figure 1, the first stage of the systematic review identified 155 published studies. Of these, 97 were judged as clearly irrelevant at the first stage and were excluded. In addition to the remaining 58 included in the second stage, nine others were identified from reference lists of the included studies and were added for a total of 67 eligible studies for full text screening. Of these, 11 were subsequently eliminated because they did not specifically use an FGI, two because they did not investigate agricultural practices or contexts, and eight because there was no quantification of the association between agricultural practice or context and FGI. Forty-six studies were thus selected for the final review.

Overall, there was a wide heterogeneity across the 46 studies regarding the unit of analysis, the location, study design, sample size, choice of indicators and analysis of the dietary diversity data (see Appendices A, B and C for a complete list of reviewed studies). Five studies measured dietary diversity at both the household and individual level, 19 only at the individual level, and 22 only at the household level, of which nine from HCES secondary analyses. Sixteen studies

reported dietary diversity of children; nine of those included children older than 23 months (range 24–83 months).

Data from 30 different countries were reported across the 46 studies: 14 from Africa, nine from Asia, five from Latin America, and two from Eastern Europe; 16 countries were reported on only once and 14 were reported on in more than one study. Malawi was the most frequently included country, reported on in nine studies. Three of the nine studies using HCES pooled data from multiple countries, ranging from four to 15.

Forty of the 46 studies used a cross-sectional design, five reported on impact evaluation and only one used a longitudinal design. Sample sizes greatly varied from as small as 30 to over 10,000 (papers conducting multi-country secondary analyses of national HCES).

3.2 Critical appraisal of the use and interpretation of FGIs

Table 2 lists the results of the assessment based on the four criteria, shown separately for studies using HCES data, other household level data and individual level data (see Appendices A, B and C for detailed description of the reviewed studies).

3.2.1 Critical appraisal of the use of standard FGIs

Thirty of the 46 studies made reference to standard indicators (HDDS, MDD, WDDS or MDD-W) for measuring dietary diversity and were included in the critical assessment for the three criteria pertaining to recall period, food group classification and use of a cut-point.

With respect to recall period, nine out of 13 household level studies (excluding HCES studies, which were not judged on recall period) and 13 out of 14 individual level studies used a 24-hour recall period.

Of the studies using one of the four standard FGIs, five out of seven HCES, six out of 13 household level studies and all 14 individual level studies constructed the FGI according to the recommended food group classification. The main reason for being rated "inconsistent" for food group classification was using an HDDS indicator with more or fewer food groups than the recommended 12 food groups.

With respect to the use of a score-based cut-off, all seven HCES, 11 out of 13 household level and all 14 individual level indicators were consistent with published guidance. The cases rated "inconsistent" either set their own thresholds that were not based on quantiles (for HDDS or WDDS) or did not use the established thresholds for MDD or MDD-W.

3.2.2 Critical appraisal of the interpretation of FGIs

With respect to interpretation of the FGI, of the nine HCES studies, four were judged as correct, one as partially correct and four as misleading. Of the 18 household level studies, eight were judged as correct, three as partially correct and seven as misleading. Of the 24 individual level studies, 18 were judged as correct, one as partially correct, three as misleading and two as "unable to judge" (See Appendices A, B and C for more details).

The reason for the interpretation of the FGI being rated as "misleading" was a mismatch between study objective, level of analysis and interpretation. This rating was given to studies that a) specifically interpreted a household level FGI applied to households as a measure of "household diet quality", "household nutrition or nutritional status", or "food and nutrition security"; or b) applied an individual FGI indicator to individuals and interpreted results as a measure of either household food security/food access or of household dietary diversity.

A study was rated as "partially correct" when the investigators made a correct interpretation for level of analysis, but used an inappropriate indicator or incorrectly characterized the indicator

they used. In particular, this rating was given to studies that a) applied a standard household FGI to individuals to assess nutrient adequacy of individuals, or b) applied an individual FGI at household level to assess household food security/food access, or c) made statements in the introduction or discussion section of the paper that household FGIs were measures of nutrition or diet quality even when they correctly interpreted results according to the level of analysis in the results section.

4. Discussion

This systematic review was undertaken to assess how dietary diversity indicators used in studies investigating the association between agricultural practices or contexts and food security or nutrition were constructed and interpreted. To our knowledge, ours is the first review of this kind. For the large majority of individual level indicators, construction and interpretation were correct. Most studies based on HCES used the HDDS correctly regarding food group classification; however, interpretation was misleading in approximately half of the cases. For the other household level studies, a majority of which used the HDDS, less than half used the recommended food group classification. Similarly, less than half applied the correct interpretation.

4.1 Adherence to published guidance on standard FGIs

The review highlighted several areas where use of the standard, validated FGIs was inconsistent with accepted guidance: recall period, food group definitions and number, and use of a cut-point. In these cases, the inconsistencies may have been due to intentionally adapting the standard FGIs to the context-specific objectives of the studies.

The recommended recall period for the four standard FGIs is the previous 24 hours. While using a different recall period might have internal relevance within a study for reasons pertaining to the specific objective or context, it limits comparability with other studies based on standard FGIs. When longer recall periods are used, higher dietary diversity scores are expected (Drewnowski et al, 1997; Arimond and Ruel, 2004a), and established cut-points of MDD and MDD-W, validated for 24-hour intake recall, no longer apply.

Food group classifications of the standard FGIs differ according to the level of analysis: household or individual. The HDDS includes both nutrient-rich and non-nutrient-rich food groups accessed by the household, and does not provide information on nutrient intakes of individual household members. In contrast, the individual level FGIs, which were designed to reflect the nutritional quality of individual diets, include only micronutrient-rich food groups. Use of nonstandard food groups or different numbers of food groups with respect to standard indicators precludes comparability with other studies and may compromise interpretation of the dietary diversity measure.

4.2 Dietary diversity compiled from HCES consumption modules

Secondary analyses of HCES data is a valuable source for investigating dietary outcomes of agricultural practices. HCES are conducted in a large number of countries every two to ten years, enabling the analysis of trends over time. In the past two decades, data from HCES have increasingly been used in an effort to derive food and nutrition information for policy decisions (Fiedler et al., 2013; Coates et al., 2017; Moltedo et al., 2018).

Including HCES studies investigating links between agriculture and nutrition in this review has highlighted a particular set of issues in relation to both recall period and food group composition. Three of the nine HCES studies pooled data from multiple surveys to create a

common FGI from the survey-specific food lists for comparison across the different datasets. However, heterogeneity of the number of food items listed in survey-specific food consumption modules (ranging from 20 to 135 food items in the reviewed studies using HCES) is problematic because foods representative of important food groups, such as vegetables and fruits, may be missing when the number of food items is small. This lack of comprehensiveness of food items making up the food groups for measuring dietary diversity across datasets limits comparability and could affect interpretation of the results (Murphy et al., 2012). One study analysed dietary diversity from pooled HCES data with different recall periods (ranging from seven to 365 days). Problems with non-comparability of food lists and recall periods of food consumption modules across HCES have been documented by the International Household Survey Network in a large review (Smith et al., 2014). There is ongoing work to standardize food consumption modules in HCES, and a dietary diversity indicator for household data has been proposed by FAO (Moltedo et al., 2018), which should improve comparability across HCES in the future.

4.3 Age/sex population groups not represented in standard FGIs

Many of the reviewed studies measured dietary diversity on populations groups for which the standard indicators were not validated. To date, the MDD and MDD-W have been validated only for children aged six to 23 months and women of reproductive age (15–49 years), respectively. Nine studies used an FGI for children older than 23 months. MDD was developed to reflect adequacy of the micronutrient density of complementary foods of children aged six to 23 months, and thus is not appropriate to reflect the micronutrient adequacy of diets of children older than 23 months. A recent study showed that MDD-W performed better than MDD for predicting micronutrient adequacy among rural Zambian children 4 to 8 years of age (Caswell et al., 2018). Similarly, another recent study established that, using the MDD-W among pregnant women in Bangladesh, a cut-point of 6 or more food groups performed better

than the cut-point of 5 or more food groups recommended for non-pregnant women (Nguyen et al., 2018).

Dietary diversity indicators have been found to be positively correlated with the macro and/or micronutrient adequacy of diets of children aged five to 11 years (Steyn et al., 2014), adolescents (Mirmiran et al., 2004) or elderly subjects (Rathnayake et al., 2012; Tavakoli et al., 2016) but there are no internationally validated indicators of dietary diversity currently available for these age and sex groups. There is a need for multi-site validation studies for indicators covering other age and sex groups.

4.4 Interpretation of the dietary diversity indicators

In more than half of the articles using HCES data or other household level data, the investigators interpreted the FGI as measures of "household nutrition", "nutrient adequacy of household diets", "household food and nutrition security", or "dietary quality". The term "nutrition" refers to the nutritional status of individuals, their nutrient requirements and their diets, not to households. Because nutrient requirements differ according to age and sex, and allocation of food between individuals in a household depends on many factors, "household nutrition" and "nutrient adequacy or quality of household diets" are inappropriate concepts.

4.5 Strengths and limitations

A strength of this review is the categorization of the studies in three groups (HCES, other household level and individual level) which ensures a pertinent assessment for each group. Another strength is the consistent use of two or more independent screeners to reduce errors in data extraction, as recommended by Buscemi et al. (2006). A limitation is that the review included only articles published in English.

5. Conclusion

Our critical assessment of the use of FGIs in the selected studies revealed several issues in the way dietary diversity indicators were constructed or interpreted. Consequently, based on this systematic review, we propose a checklist of items that authors could consider and report on to ensure a consistent use and correct interpretation of dietary diversity indicators (Box1). In addition we make the following recommendations:

- Investigators using a dietary diversity indicator that is not standard but suits their purpose (such as focus on certain foods with more disaggregated food groups) should try, whenever possible, to also construct from their data a standard FGI for comparison purposes.
- Investigators using a standard FGI on an age or gender group for which the indicator was not validated should clearly acknowledge and discuss this point.
- Authors should avoid pooling data from several datasets, HCES in particular, that use different recall periods and that are likely to have a variable number of food items from which food groups are composed.

FGIs are valuable indicators for investigating the association between agricultural practices or agricultural contexts and food security or nutrition, and their use by research and development communities is an encouraging sign. Two recent publications reviewed the literature on links between diversity of production and dietary diversity in smallholder households (Jones, 2017b; Sibhatu and Qaim, 2018). However, further reviews and meta-analyses would greatly benefit from better efforts to harmonize the way FGIs are used and interpreted in order to enhance the comparability of studies. This will be an important contribution towards building a robust body of evidence of the impact of agriculture on nutrition and food security at global level.

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Figures, Tables and Boxes

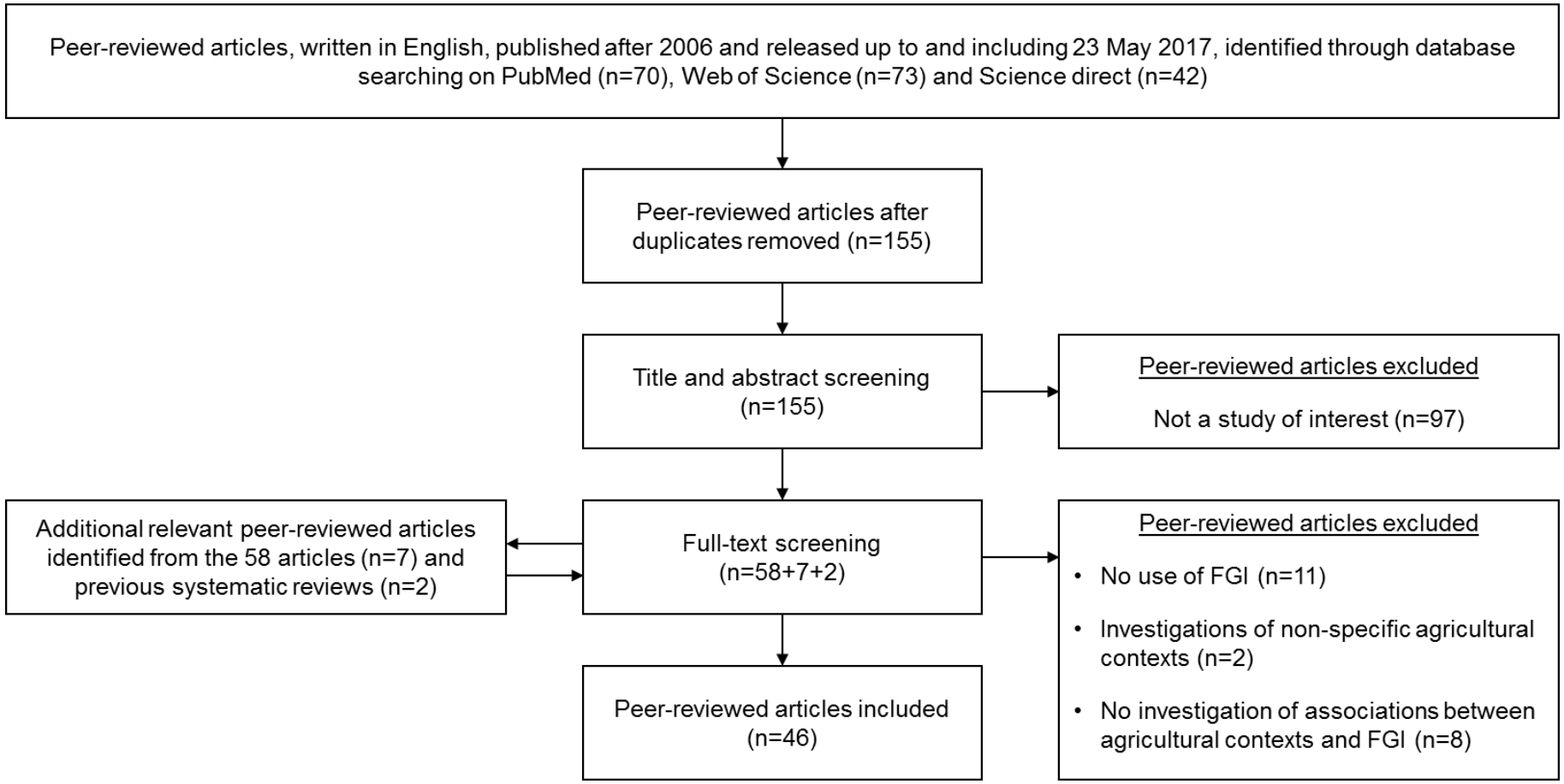

Fig. 1 Systematic literature review article selection flowchart

Table 1. Characteristics of four standard food group indicators of dietary diversity.

Characteristics	Household Dietary Diversity Score (HDDS)	Minimum Dietary Diversity (MDD)	Women's Dietary Diversity Score (WDDS)	Minimum Dietary Diversity for Women of Reproductive Age (MDD-W)
Unit of analysis	Household	Individual	Individual	Individual
Purpose	To reflect the economic ability of a household to access a variety of foods (access dimension of household food security)	Proxy of adequate micronutrient density of complementary foods of infant and young children aged 6 to 23 months	Proxy of micronutrient adequacy of diets of women of reproductive age	Proxy of micronutrient adequacy of diets of women of reproductive age
Validitation	Positively associated with household per capita energy availability in datasets from 10 countries (Hoddinott and Yohannes, 2002)	Positively associated with the mean micronutrient density adequacy of complementary foods of breastfed and nonbreastfed infants and young children aged 6 to 23 months in 10 datasets (Working Group on Infant and Young, 2006)	Positively associated with the mean probability of adequacy across 11 micronutrients in 5 datasets (Arimond et al., 2010)*	Positively associated with the mean probability of adequacy across 11 micronutrients in 9 datasets (Women's Dietary Diversity Project Study Group, 2017)
Dietary assessment and reference period	24-hour recall, inclusion all of foods consumed by household members in the home (consumption outside of the home not included)	24-hour recall, inclusion of all foods eaten by the infant or child	24-hour recall, inclusion of all foods eaten by the individual (the correlation between WDDS and mean probability of adequacy was improved when foods consumed in quantities <15g were not included)	24-hour recall, inclusion of all foods eaten by the individual (the correlation between food group diversity and mean probability of adequacy was improved when foods consumed in quantities <15g were not included)
Food classification	12 food groups: Cereals; White roots and tubers; Vegetables; Fruits; Meat; Eggs; Fish and seafood; Legumes, nuts, and seeds; Milk and milk products; Oils and fats; Sweets; Spices, condiments, and beverages	7 food groups: Grains, roots, and tubers; Legumes and nuts; Dairy products; Flesh foods; Eggs; Vitamin A–rich fruits and vegetables; Other fruits and vegetables	9 food groups: Starchy staples; Dark green leafy vegetables; Other vitamin A–rich fruits and vegetables; Other fruits and vegetables; Organ meat; Meat and fish; Eggs; Legumes, nuts, and seeds; Milk and milk products	10 food groups: Grains, white roots and tubers, and plantains; Pulses; Nuts and seeds; Dairy; Meat, poultry and fish; Eggs; Dark green leafy vegetables; Other vitamin A-rich fruits and vegetables; Other vegetables; Other fruits
Score	Count of food groups consumed: 0-12	Count of food groups consumed: 0-7	Count of food groups consumed: 0-9	Count of food groups consumed: 0-10
Dichotomous indicator[$]	No dichotomous indicator but suggestion to use distribution of scores (quantiles) for analytical purposes	Minimum Dietary Diversity = 4 or more of the 7 food groups	No dichotomous indicator but suggestion to use distribution of scores (quantiles) for analytical purposes	Minimum Dietary Diversity for women = 5 or more of the 10 food groups
Guidelines	Swindale and Bilinsky (2006) and FAO (2011)	WHO (2008) and WHO (2010)	FAO (2011)	FAO and FHI 360 (2016)

*The validation study tested four different food group combinations (dietary diversity scores based on 6, 9, 13 or 21 food groups). The conclusion was that all dietary diversity scores were significantly correlated with micronutrient adequacy of the diet, the 21-food group indicator showing the highest correlation (Arimond et al., 2010). The FAO guidelines proposed to use the 9-food group indicator because it was easier to operationalize (FAO, 2011).
[$]For MDD and MDD-W, a cut-point was validated against micronutrient adequacy of diets and the indicator is expressed as the percent of individuals consuming a number of food groups equal to or above the cut-point.

Table 2. Assessment of the use and interpretation of food group indicators of dietary diversity

	Critical appraisal				
	All studies: HCES (9) Household level (18) Individual level (24) [a]	Only studies using standard indicators: HCES (7) Household level (13) Individual level (14)			All studies: HCES (9) Household level (18) Individual level (24)
Level of analysis	Reference to a published indicator	Recall period [b]	Food group classification [c]	Cut-off [d]	Interpretation [e]
HCES	HDDS (7) Other nonstandard indicator (1) No reference (1)	Not judged	"Consistent" (6) "Inconsistent" (1)	"Consistent" (7)	"Correct" (4) "Partially correct" (1) "Misleading" (4)
Household level	HDDS (13) Other nonstandard indicator (2) No reference (3)	"Consistent" (9) "Inconsistent" (4)	"Consistent" (5) "Inconsistent" (8)	"Consistent" (11) "Inconsistent" (2)	"Correct" (8) "Partially correct" (3) "Misleading" (7)
Individual level	HDDS (1) MDD (7) WDDS (6) MDD-W (2) Other nonstandard indicator (6) No reference (5)	"Consistent" (13) "Inconsistent" (1)	"Consistent" (14)	"Consistent" (14)	"Correct" (18) "Partially correct" (1) "Misleading" (3) "Unable to judge" (2)

[a] Studies were assessed separately by level of measurement. Of the total of 46 studies, 24 included an individual measure, and three of those used two different indicators (children and women). Therefore a total of 27 individual level indicators were assessed under the first criterion of standard FGIs. Because five studies measured dietary diversity at both the household and individual level, the assessment was applied to 9 HCES, 18 individual level studies (13+5) and 24 individual level studies (19+5).

[b] "Consistent" if used a 24-h recall.

[c] "Consistent" if used 12 food groups with standard categories for HDDS, 7 food groups with standard categories for MDD; 9 food groups with standard categories for WDDS; and 10 food groups with standard categories for MDD-W.

[d] "Consistent" if used the recommended cut-off for standard indicators (MDD, MDD-W) or, in the case of indicators without a recommended cut-off (HDDS, WDDS), either did not use a cut-off or applied quantiles based on the score distribution.

[e] "Correct" if interpretation of the indicator was consistent with the objective of the study and the level of analysis; "partially correct" if the interpretation was consistent with the level of analysis but either the indicator was inappropriate or, somewhere in the paper, a household level indicator was mislabelled as measuring nutrition or diet quality; "misleading" if the interpretation of the indicator was not consistent with the objective of the study and level of analysis; and "unable to judge" when essential information was missing on the level of analysis or purpose of measuring dietary diversity.

Box 1. Checklist of items that should be described when reporting on use of dietary diversity indicators

Checklist item	#	Description of the item
Objective	1	Describe the objective of the measurement of dietary diversity (household food security or individual nutrient adequacy of the diet)
Unit of analysis	2	a) Identify whether dietary diversity is measured at the household and/or individual level b) If the measure is at the individual level, specify the sex and age group of the subjects, and the physiological status for women
Reference	3	Refer to a guidance manual if a standard FGI is used
Respondent	4	Describe who responded to the questions and whose diet was referred to
Recall period	5	a) Report the recall period b) If a recall period greater than 24 h is applied to an otherwise standard FGI, provide an explanation.
Food group classification	6	Provide detailed information on the food group classification used to construct the FGI (e.g. total number and names the food groups)
Score	7	Report how the FGI was computed
Cut-off point	8	Specify whether a cut-off point was used to create a dichotomous indicator or whether the distribution of the score (e.g. quantiles) was used for analytical purposes

Appendix A. Characteristics of household consumption and expenditure surveys using food group indicators of dietary diversity and assessment of their use and interpretation (n=9)

				Critical appraisal and details of the FGI					
Study	Location	Study design	Subjects and sample size	Is the FGI a standard one?	Reference	Recall period	Food group classification	Cut-off	Interpretation of the FGI
Jones et al. (2014)	Malawi	Secondary analysis of cross-sectional survey	Smallholder farmers (n=6623)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006)	**Not judged** Previous 7 days	**Consistent** 12 food group classification, based on consumption of 135 food items	**Consistent** No use of cut-off	**Correct** But one sentence presenting the diversity of household diets as an important nutrition outcome associated with the nutrient adequacy of diets is misleading.
Pellegrini and Tasciotti (2014)	- Albania - Indonesia - Malawi - Nepal - Nicaragua - Pakistan - Panama - Vietnam	Secondary analysis of cross-sectional surveys	Households (sample size unknown)	**Yes**	**HDDS** (FAO, 2008)	**Not judged** Range of 7 to 365 days across countries	**Inconsistent** 13 food group classification, based on a range across countries of 24 – 75 food items	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Sraboni et al. (2014)	Bangladesh	Secondary analysis of cross-sectional survey	Farm households (n=3273)	**Yes**	**HDDS** (FAO, 2011)	**Not judged** Previous 7 days	**Consistent** 12 food group classification, based on 300 food items	**Consistent** No use of cut-off	**Correct**

Benson (2015)	Malawi	Secondary analysis of cross-sectional survey	Smallholder farmers (n=9750)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006)	**Not judged** Previous 7 days	**Consistent** 12 food group classification, based on 135 food items.	**Consistent** No use of cut-off	**Correct**
Dillon et al. (2015)	Nigeria	Secondary analysis of cross-sectional survey	Smallholder farmers (n=2154)	**Yes**	**HDDS** (FAO 2011)	**Not judged** Previous 7 days	**Consistent** 12 food group classification, based on 100 food items.	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Sibhatu et al. (2015)	- Ethiopia - Indonesia - Kenya - Malawi	Secondary analysis of cross-sectional surveys	Ethiopian (n=2045), Indonesian (n=674), Kenyan (n=397) and Malawian smallholder farmers (n=5114)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006) (FAO, 2011)	**Not judged** Previous 7 days	**Consistent** 12 food group classification, based on a range across countries of 25 - 135 food items.	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Snapp and Fisher (2015)	Malawi	Secondary analysis of cross-sectional survey	Smallholder farmers (n=9189)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006)	**Not judged** Previous 7 days	**Consistent** 12 food group classification, based on 135 food items	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Zezza and Tasciotti, (2010)	- Ghana - Madagascar - Malawi	Secondary analysis of cross-	Urban households (n from 1154 to 5852)	**No**	**No reference**	**Not judged** Previous 7 days	**Not judged** 13 food group classification, based on a range	**Not judged** No use of cut-off	**Partially correct** Interpreted results correctly for level of analysis but

	- Nigeria - Bangladesh - Indonesia - Nepal - Pakistan - Vietnam - Albania - Bulgaria - Ecuador - Guatemala - Nicaragua - Panama	sectional survey					across countries of 20 – 122 food items.		stated that the household FGI measures nutrition, diet quality.
Jones (2017a)	Malawi	Secondary analysis of cross-sectional surveys	Smallholder farming households (n=3000)	**No**	(FAO and FHI 360, 2016)	**Not judged** Previous 7 days	**Not judged** 10 food group classification of the MDD-W, based on 124 food items.	**Not judged** No use of cut-off	**Correct**

Appendix B. Characteristics of studies using food group indicators of dietary diversity at household level and assessment of their use and interpretation (n=18)

				Critical appraisal and details of the FGI					
Study	Location	Study design	Subjects and sample size	Is the FGI a standard one?	Reference	Recall period	Food group classification	Cut-off	Interpretation of the FGI
Remans et al. (2011)	- Ethiopia - Kenya - Malawi	Cross-sectional survey	Ethiopian (n=60), Kenyan (n=50), and Malawian smallholder farmers (n=60)	**Yes**	**HDDS** (FAO, 2008)	**Consistent** Previous 24 hours	**Inconsistent** 15 food group classification	**Consistent** No use of cut-off	**Correct**
Anderman et al. (2014)	Ghana	Cross-sectional survey	Cacao and oil palm farmers (n=100)	**Yes**	**HDDS** (FAO, 2008)	**Inconsistent** Previous 30 days.	**Inconsistent** 13 food group classification, based on 120 food items.	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Iannotti and Lesorogol (2014)	Kenya	Longitudinal study	Pastoralist households (n≈200)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006)	**Consistent** Previous 24 hours	**Inconsistent** 9 food group classification	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Mango et al. (2014)	Zimbabwe	Secondary analysis of baseline survey	Smallholder farmers (n=120)	**Yes**	**HDDS** (Selvester et al., 2008)	**Consistent** Previous 24 hours	**Inconsistent** 14 food group classification	**Consistent** No use of cut-off	**Partially correct** Interpreted results correctly for level of analysis but stated that the household FGI measures nutrition, diet quality.

Kumar et al. (2015)	Zambia	Secondary analysis of baseline survey of an intervention	Household (n=2785)	**Yes**	**HDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Inconsistent** 7 food group classification of the MDD	**Consistent** No use of cut-off	**Partially correct** Interpreted results correctly for level of analysis but used an inappropriate indicator (individual FGI to reflect household food security/food access).
Mayanja et al. (2015)	Uganda	Cross-sectional survey	Pastoral (n=20) and agro-pastoral households (n=59)	**Yes**	**HDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Inconsistent** 8 food group classification	**Inconsistent** Cut-off of at least 4 of the 8 food groups.	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
McDonald et al. (2015)	Cambodia	Cross-sectional survey	Rural households (n=900)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006)	**Consistent** Previous 24 hours	**Consistent** 12 food group classification	**Inconsistent** HDDS score of <3 defines a low dietary diversity	**Correct**
Jodlowski et al. (2016)	Zambia	Evaluation of a year-and-half intervention	Households (n=265)	**Yes**	**HDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Inconsistent** 13 food group classification	**Consistent** No use of cut-off	**Correct**
Ng'endo et al. (2016)	Kenya	Repeated cross-sectional survey	Smallholder farming households (n=30)	**Yes**	**HDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Consistent** 12 food group classification	**Consistent** Tertiles	**Correct**

Olney et al. (2016)	Burkina Faso	Evaluation of a two-year intervention (RTC)	Household (control n=506 and treatment n=766)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006)	**Inconsistent** Previous 7 days	**Consistent** 11 food group classification, based on 57 food items, the egg food group not included because of an oversight	**Consistent** No use of cut-off	**Correct**
Romeo et al. (2016)	Kenya	Cross-sectional survey	Poor rural households (n=1353)	**Yes**	**HDDS** (Swindale and Bilinsky, 2006) (FAO, 2011)	**Inconsistent** Previous 7 days	**Consistent** 12 food group classification	**Consistent** No use of cut-off	**Correct**
Euler et al. (2017)	Indonesia	Cross-sectional survey	Farm households (n=664)	**Yes**	**HDDS** (FAO, 2011)	**Inconsistent** Previous 7 days	**Inconsistent** No description of the number of food groups but may have used the 12 food group classification, based on 134 food items	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Koppmair et al. (2017)	Malawi	Cross-sectional survey	Smallholder farm households (n=408)	**Yes**	**HDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Consistent** 12 food group classification	**Consistent** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status
Olney et al. (2009)	Cambodia	Repeated cross-sectional surveys	Household (control n=200 and treatment n=299)	**No**	**No reference**	**Not judged** Previous 3 days	**Not judged** 6 food group classification	**Not judged** No use of cut-off	**Correct**

Gallaher et al. (2013)	Kenya	Cross-sectional survey	Sack gardening households (n=153) and non-sack gardening households (n=153)	**No**	**No reference**	**Not judged** Previous 24 hours	**Not judged** 15 food group classification	**Not judged** No use of cut-off	**Correct**
Darling (2014)	Kenya	Cross-sectional survey	Households (n=113)	**No**	(Arimond and Ruel, 2004b)	**Not judged** Previous 3 days	**Not judged** 7 food group classification	**Not judged** No use of cut-off	**Partially correct** Interpreted results correctly for level of analysis but used an inappropriate indicator
Rawlins et al. (2014)	Rwanda	Evaluation of a one year intervention	Households (n=369)	**No**	**No reference**	**Not judged** Previous 2 days	**Not judged** 16 food group classification	**Not judged** No use of cut-off	**Misleading** Extrapolated results from one population group to other groups
Leonardo et al. (2015)	Mozambique	Cross-sectional survey	Households (n=80)	**No**	(FAO, 2011)	**Not judged** Previous 3 days	**Not judged** 12 food group classification that is not fully described	**Not judged** No use of cut-off	**Misleading** Interpreted results of household dietary diversity as a measure of diet quality, household nutrition or nutritional status

Appendix C. Characteristics of studies using food group indicators of dietary diversity at individual level and assessment of their use and interpretation (n=24)

				Critical appraisal and details of the FGI					
Study	Location	Study design	Subjects and sample size	Is the FGI a standard one?	Reference	Recall period	Food group classification	Cut-off	Interpretation of the FGI
Tessema et al. (2013)	Ethopia	Cross-sectional survey	Children 6–23 months of age (n=466)	**Yes**	**MDD** (WHO, 2008)	**Consistent** Previous 24 hours	**Consistent** 7 food group classification	**Consistent** Cut-off of at least 4 of the 7 food groups	**Correct**
Walton et al. (2014)	Kenya	Cross-sectional survey	Women (n=102)	**Yes**	**WDDS** (Wiesmann et al., 2009)	**Consistent** Previous 24 hours	**Consistent** 9 food group classification	**Consistent** No use of cut-off	**Correct**
Beyene et al. (2015)	Ethiopia	Cross-sectional survey	Children 6–23 months of age (n=920)	**Yes**	**MDD** (WHO, 2008)	**Consistent** Previous 24 hours	**Consistent** 7 food group classification	**Consistent** Cut-off of at least 4 of the 7 food groups	**Correct**
Kumar et al. (2015)	Zambia	Secondary analysis of baseline survey of an intervention	Children 6-23 months of age (n=1298)	**Yes**	**MDD** (WHO, 2010)	**Consistent** Previous 24 hours	**Consistent** 7 food group classification	**Consistent** Cut-off of at least 4 of the 7 food groups	**Correct**
Malapit and Quisumbing, (2015)	Ghana	Secondary analysis of baseline data of an intervention	Mothers (n=2027) and children 6-23 months of age (n=402)	**Yes**	**WDDS** (FAO, 2011) **MDD** (WHO, 2010)	**Consistent for both** Previous 24 hours	**Consistent for women** 9 food group classification **Consistent for children** 7 food group classification	**Consistent for women** No use of cut-off **Consistent for children** Cut-off of at least 4 of the 7 food groups	**Correct for both**
Malapit et al. (2015)	Nepal	Secondary analysis of cross-	Mothers (n=3076)	**Yes**	**WDDS** (Arimond et al., 2010)	**Consistent** Previous 24 hours	**Consistent** 9 food group classification that	**Consistent** No use of cut-off	**Correct**

		sectional survey					is not fully described		
Bellon et al. (2016)	Benin	Repeated cross-sectional surveys	Mothers (n=472 for the 1st round and n=482 for the 2nd round)	**Yes**	**MDD-W** (Daniels and Ballard, 2014)	**Consistent** Previous 24 hours	**Consistent** 10 food group classification	**Consistent** Cut-off of at least 5 of the 10 food groups	**Correct**
Darrouzet-Nardi et al. (2016)	Nepal	Evaluation of a two-year intervention	Children 6 months to 8 years of age (n=589)	**Yes**	**MDD** (WHO, 2010)	**Consistent** Previous 24 hours	**Consistent** 7 food group classification	**Consistent** Cut-off of at least 4 of the 7 food groups	**Correct**
Ng'endo et al. (2016)	Kenya	Repeated cross-sectional surveys	Women (n=30)	**Yes**	**WDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Consistent** 9 food group classification	**Consistent** Tertiles	**Correct**
Olney et al. (2016)	Burkina Faso	Evaluation of a two-year intervention (RTC)	Mothers of children 3-12 months of age (control n=506 and treatment n=766)	**Yes**	**WDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Consistent** 9 food group classification	**Consistent** No use of cut-off	**Correct**
Chagomoka et al. (2017)	Burkina Faso	Cross-sectional survey	Women of reproductive age (n=179)	**Yes**	**WDDS** (FAO, 2011)	**Consistent** Previous 24 hours	**Consistent** 9 food group classification that is not fully described	**Consistent** Classification in 3 categories based on the distribution of the WDDS in the sample: low (0–3), medium (4-5), or high (6–9)	**Misleading** Extrapolated results from one population group to other groups
Dangura and Gebremedhin, (2017)	Ethiopia	Cross-sectional survey	Children 6–23 months of age (n=417)	**Yes**	**MDD** (WHO, 2008)	**Consistent** Previous 24 hours	**Consistent** 7 food group classification	**Consistent** Cut-off of at least 4 of the 7 food groups.	**Correct**
Dulal et al. (2017)	Nepal	Evaluation of a two-year intervention	Mothers (n=2101) and children 6-23 months of age (n=994)	**Yes**	**MDD-W** (Martin-Prével et al., 2015)	**Inconsistent for both** Previous 7 days	**Consistent for women** 10 food group classification	**Consistent for women** Cut-off of at least 5 of the 10 food groups	**Correct for both**

					MDD (FAO, 2011)		**Consistent for children** 7 food group classification	**Consistent for children** Cut-off of at least 4 of the 7 food groups	
Koppmair et al. (2017)	Malawi	Cross-sectional survey	Mothers (n=408) and children under 5 years of age (n=519)	**Yes**	**HDDS** (FAO, 2011)	**Consistent for both** Previous 24 hours	**Consistent for both** 12 food group classification of the HDDS	**Consistent for both** No use of cut-off	**Partially correct for both** Interpreted results correctly for level of analysis but used an inappropriate indicator
Olney et al. (2009)	Cambodia	Repeated cross-sectional surveys	Mothers (control n=199 and treatment n=300) and children under 5 years of age (control n=199 and treatment n=277)	**No**	**No reference**	**Not judged** Previous 7 days	**Not judged** Same 9 food group classification for the children and women	**Not judged** No use of cut-off	**Correct**
Kalavathi et al. (2010)	India	Evaluation of a three-year intervention (repeated cross-sectional surveys)	Small and marginal coconut homesteads (n=150) implying an unknown number of adults and children below 6 years of age	**No**	**No reference**	**Not judged** Not reported.	**Not judged** 10 food group classification	**Not judged** Arbitrary classification in 5 categories from "very poor" to "excellent" (1-3/4-5/6-7/8-9/10)	**Unable to judge** Insufficient information for evaluating the relevance of the indicator
Kaufer et al. (2010)	Federated States of Micronesia	Evaluation of a two-year intervention	Women (n=40)	**No**	**No reference**	**Not judged** Previous 7 days	**Not judged** 14 food group classification, based on 33 food items	**Not judged** No use of cut-off	**Unable to judge** Insufficient information for evaluating the relevance of the indicator
Cabalda et al. (2011)	Philippines	Cross-sectional survey	Children 2-5 years of age (n=200)	**No**	(Kennedy et al., 2007)	**Not judged** Previous 24 hours	**Not judged** 10 food group classification	**Not judged** No use of cut-off	**Correct**

Jones et al. (2012)	Bolivia	Repeated cross-sectional surveys	Children less than 24 months of age (n=50)	**No**	(WHO, 2008)	**Not judged** Previous 24-hours	**Not judged** 7 food group classification	**Not judged** No use of cut-off	**Correct**
Keding et al. (2012)	Tanzania	Repeated cross-sectional surveys	Women involved in cultivation of vegetables (n=252)	**No**	(Reference to several articles to justify how they built the FGI)	**Not judged** Previous 24 hours	**Not judged** 14 food group classification	**Not judged** Terciles	**Misleading** Applied a non-defined FGI to individuals as a measure of household food security
De Brauw et al. (2015)	Mozambique	Evaluation of a three-year intervention (RCT)	Children 6-35 months of age (n=331)	**No**	(Moursi et al., 2008)	**Not judged** Previous 24 hours	**Not judged** 7 food group classification	**Not judged** No use of cut-off	**Correct**
Malapit et al. (2015)	Nepal	Secondary analysis of cross-sectional survey	Children 6-59 months of age (n=2817)	**No**	**No reference**	**Not judged** Previous 24 hours	**Not judged** 7 food group classification not fully described	**Not judged** No use of cut-off	**Correct**
Smale et al. (2015)	Zambia	Cross-sectional survey	Primary female decision maker in maize-growing farm households (n=1045)	**No**	(Arimond et al., 2010)	**Not judged** Previous 24 hours	**Not judged** 10 food group classification	**Not judged** No use of cut-off	**Misleading** Interpreted a nutrient-dense FGI applied to individuals as a measure of household food security/food access.
Hirvonen and Hoddinott, (2016)	Ethiopia	Secondary analysis of cross-sectional survey	Children 6-59 months of age (n=3448)	**No**	(WHO, 2008)	**Not judged** Previous 24 hours	**Not judged** 7 food group classification	**Not judged** No use of cut-off	**Correct** But once the authors presented the dietary diversity score of the children as

									representative for entire household
M'Kaibi et al. (2017)	Kenya	Cross-sectional survey	Children 24–59 months of age (n=477)	**No**	(FAO, 2011)	**Not judged** Two repeated 24-hour food recalls. Unclear how the authors handled the 2 different days in constructing the score.	**Not judged** 9 food group classification	**Not judged** Arbitrary cut-off of at least 4 of the 9 food groups	**Correct**