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REVIEW

Update on Analytical Methods and Research Gaps in the Use of Household Consumption and Expenditure Survey Data to Inform the Design of Food-Fortification Programs

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ABSTRACT

The lack of nationally representative, individual-level dietary intake data has led researchers to increasingly turn to household-level data on food acquisitions and/or consumption to inform the design of food-fortification programs in low- and middle-income countries (LMICs). These nationally representative, household-level data come from household consumption and expenditure surveys (HCESs), which are collected regularly in many LMICs and are often made publicly available. Our objectives were to examine the utility of HCES data to inform the design of food-fortification programs and to identify best-practice methods for analyzing HCES data for this purpose. To this end, we summarized information needed to design fortification programs and assessed the extent to which HCES data can provide corresponding indicators. We concluded that HCES data are well suited to guide the selection of appropriate food vehicles, but because individual-level estimates of apparent nutrient intakes rely on assumptions about the intrahousehold distribution of food, more caution is advised when using HCES data to select the target micronutrient content of fortified foods. We also developed a checklist to guide analysts through the use of HCES data and, where possible, identified research-based, best-practice analytical methods for analyzing HCES data, including selecting the number of days of recall data to include in the analysis and converting reported units to standard units. More research is needed on how best to deal with composite foods, foods consumed away from home, and extreme values, as well as the best methods for assessing the adequacy of apparent intakes. Ultimately, we recommend sensitivity analyses around key model parameters, and the continual triangulation of HCES-based results with other national and subnational data on food availability, dietary intake, and nutritional status when designing food-fortification programs. *Adv Nutr* 2022;13:953–969.

Statement of Significance: In this paper, we synthesized over a decade of research on the use of food-consumption data from household consumption and expenditure surveys (HCESs) to inform the design of food-fortification programs. From this body of research, we distilled best-practice methods for analyzing HCES data, including the development of a checklist to guide analysts through the process of applying these best practices, and identified research gaps in analytical methods that need to be filled to improve the utility and validity of HCES data for informing the design of fortification programs.

Keywords: food fortification, household consumption and expenditure surveys, micronutrients, nutrition, dietary data

Introduction

The successful design and management of food-fortification programs bring together a range of information, including characteristics of the local food system, supply chains, consumer behavior, domestic industrial capacity, and costs, among others. Food-consumption and nutrient intake data are essential inputs into the design of food-fortification programs that effectively increase micronutrient intake and reduce the prevalence of deficiency (1, 2). Ideally, decisions around the relevance and design of fortification programs should be informed by nationally representative food intake and biochemical data on micronutrient deficiencies (2). However, because of the resource and technical requirements associated with collecting and analyzing individual dietary intake data, they are rarely collected (3–5). Past and ongoing efforts to reduce some of the barriers to conducting large-scale, high-quality dietary intake surveys [e.g., Intake Center for Dietary Assessment and the INDDEX Project (6)] may

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increase the availability of these data to inform policy discussions around nutrition intervention programs generally, and food-fortification programs in particular. In the meantime, widely available household consumption and expenditure survey (HCES) data are increasingly being used as a proxy for individual dietary intake data (5). HCES data, which are now collected in more than 100 countries (7), have the benefit of being nationally and, typically, subnationally representative, systematically collected every 3–5 y, and are often publicly available online.

HCESs, also referred to as household income and expenditure surveys, household budget surveys, integrated household surveys, and Living Standards Measurement Study surveys, are designed to collect data on various dimensions of household socioeconomic conditions (2, 5). HCESs include modules to collect data on recent household acquisition and/or consumption of food, with significant heterogeneity across countries in the design of food-consumption and expenditure modules. The first published use of HCES data to assess fortification programs was in 2007 by Imhoff-Kunsch and colleagues (8), who used HCES data to assess Guatemala's wheat flour fortification program. Then, in 2008, Fiedler and colleagues (9) formally advocated for the use of HCES data to inform the development of food-fortification programs. Since then, HCES data have been used for assessing dietary adequacy and modeling the potential impacts of fortification and other nutrition interventions (5). During this time, limitations and methodological issues associated with the collection and use of HCES data as a source of information on food acquisition and consumption have been identified (10–12), and there have been advancements both in terms of developing recommendations for improved survey design (13, 14) and identifying analytical methods to improve the reliability of estimates based on existing HCES data.

In this paper, we focus on methods for using existing HCES data to inform the design or redesign of fortification programs, although much of the methodology is applicable to the use of these data for assessing the adequacy of diets more generally or to assess other micronutrient intervention programs (e.g., biofortification). We begin by summarizing the information needed to design effective fortification programs, identifying needs that HCES data might help inform as well as where HCES data are likely to be inadequate and thus alternative data sources are needed. Then, to illustrate specific applications of HCES data, we compile past studies that have used HCES data to answer policy questions about fortification programs. This is followed by a summary of the major limitations inherent in using HCES data for nutrition-related analyses and a review of advances over the past decade in identifying research-based "best practice" analytical methods relevant to analyzing existing HCES data for the design of food-fortification programs. We also highlight supplementary data that might need to be collected or reviewed alongside HCES data to more fully and accurately provide the information needed to design an effective fortification program. We conclude with an updated list of research gaps in analytical methods that need to be filled to improve the utility and validity of HCES data for informing fortification programs.

Current Status of Knowledge

Information needs for fortification program design and the role of HCES data

The effectiveness of a particular fortification program depends on how well the program is planned, implemented, and monitored to meet its nutrition objectives (15). In practice, fortification programs aim to increase micronutrient supplies to reduce the probability of low intakes in a population without causing risk of excessive intakes (1). Achieving this aim requires data-driven decision making.

In **Table 1**, we summarize questions related to identifying nutritional needs and predicting the impacts of fortification that should be addressed during the design (or redesign) phase of a large-scale food-fortification program, as well as the information and associated indicators that might be used to answer those questions (1, 2). HCES data can potentially be used to construct some, but not all, of the relevant indicators. In the final column of Table 1, we note some considerations for using HCES data to construct these indicators and circumstances in which HCES data cannot be reliably used and alternative data sources will likely be needed.

Designing an effective food-fortification program begins with confirming that there is a micronutrient deficiency problem of public health significance that merits a large-scale intervention, and that this problem may be effectively addressed by increasing dietary micronutrient intakes (1). Measurement of the prevalence of micronutrient deficiency requires clinical or biochemical data. Supplementing these data with information on which nutrients are insufficient in current diets can be useful to understand the potential causes of deficiency (i.e., micronutrient deficiency can be caused by inadequate intake, but health conditions such as infections that alter nutrient metabolism or absorption, or limited bioavailability due to other dietary components, may also contribute). In cases where biochemical data are not available, information on dietary patterns may be used to assess risk of deficiency of specific nutrients. The relevant indicators—mean micronutrient intake and the prevalence of inadequate dietary intake by subgroup—can be estimated using HCES data, but the usefulness of these estimates is

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Supplemental Tables 1–3 and Supplemental Materials are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/advances/.

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Abbreviations used: AME, adult male equivalent; EAR, Estimated Average Requirement; FACT, Fortification Coverage Assessment Toolkit; FAFH, foods consumed away from home; FCT, food-composition table; HCES, household consumption and expenditure survey; LMIC, low- and middle-income country.

TABLE 1 Key questions, information needs, and indicators to inform food-fortification program design[1]

Question	Information needs	Indicator(s) relevant to information need	Notes on the use of HCES data to derive indicator
Is a fortification program needed?	What are the micronutrient deficiencies among vulnerable population subgroups (e.g., young children, WRA, rural, poor)?	Prevalence and classification of public health severity of micronutrient deficiencies, by population subgroup, supplemented with data to understand the factors contributing to deficiency (e.g., inadequate intake, infection, bioavailability/absorption, etc.)	Requires biochemical data. HCES data can support understanding of factors contributing to deficiency
Which micronutrient(s) should a fortification program provide?	What nutrient(s) are lacking in current diets among vulnerable population subgroups?	Mean/median micronutrient intake and prevalence of apparent nutrient intake below the EAR (prevalence of inadequate intake), by population subgroup	Based on apparent food consumption. Individual-level estimates from HCES conditional on assumed intrahousehold food distribution mechanism (e.g., proportional to age- and sex-specific energy requirements). Even if household-level micronutrient availability is adequate, some population subgroups with high needs and/or low priority in terms of intrahousehold food distribution (e.g., young children and WRA) may not meet their needs. May require individual-level dietary intake data for some subgroups
Which food(s) should be fortified?	Which foods are regularly consumed in a fortifiable (i.e., industrially processed) form?	Percentage of households that consume the food(s) in a fortifiable form in any amount (reach)	Based on apparent food consumption. Use of HCES data depends on the nature of the food list (e.g., whether fortifiable foods are included in the list at an adequate level of disaggregation and by mode of acquisition)
At what level should micronutrients be added to fortifiable food(s)?	What are the simulated impacts on dietary adequacy at different levels of fortification for selected food(s)?	Average difference between the EAR and total dietary intake in the absence of fortification (nutrient gap)	Same as for reach and prevalence of inadequate intake
		Percentage of individuals in target group(s) whose nutrient intake status would switch from inadequate to adequate due to the consumption of the fortified food(s) at modeled fortification levels (effective coverage)	Same as for reach and prevalence of inadequate intake
		Percentage of individuals in target group(s) and other groups whose nutrient intake would exceed the UL due to the consumption of the fortified food(s) at modeled fortification levels (excessive intake)	Based on apparent food consumption. If assumptions about the intrahousehold distribution of food are not correct, HCES-based estimates of the risk of excessive intake will be inaccurate in an unknown direction

[1] EAR, Estimated Average Requirement; HCES, household consumption and expenditure survey; UL, Tolerable Upper Intake Level; WRA, women of reproductive age.

subject to the limitations inherent in using HCES data, especially for individual-level inferences.

Identifying appropriate candidate food vehicles—fortifiable foods that are regularly consumed in sufficient quantities by population subgroups at greatest risk of deficiency in a fortifiable (i.e., industrially processed) form—and setting fortification levels require indicators of reach, the "nutrient gap," effective coverage, and excessive intake that might result from consumption of fortified foods. These indicators, defined in Table 1 (and also in **Supplemental Table 1** of terminology used throughout the paper), can all be calculated using HCES data. Potential reach, or the percentage of households or individuals in a target group(s) who consume the fortifiable food(s) in any amount, can be estimated with HCES data as long as the foods under consideration are included in the HCES food list at an adequate level of disaggregation (e.g., oil is listed separately from other fats, and preferably by type of oil), and the list distinguishes between fortifiable (processed) and nonfortifiable (unprocessed) forms of relevant food vehicles and food products made from them (e.g., wheat flour–containing items such as bread and biscuits, in addition to wheat flour). The latter may be determined by information about mode of acquisition (i.e., purchased, produced at home, gifted/shared, etc.). Such indicators can be interpreted qualitatively—that is, they can provide category-based information to inform fortification program design decisions, such as whether or not reach is sufficient to pursue a given food as a fortification vehicle. Indicators that are important for setting fortification levels––for example, the nutrient gap [defined as the difference between the Estimated Average Requirement (EAR) and total dietary intake], effective coverage (the change in the prevalence of inadequate intake without and with fortification), and risk of excessive intake—require quantitative interpretations. That is, they help inform the specific concentrations of micronutrients to be added to a food via fortification, which then becomes the basis for establishing fortification standards and for monitoring and regulatory activities. While HCES data can be used to calculate these indicators, in the context of the limitations of HCES data we outline below, using them to help inform decisions surrounding fortification levels requires more caution.

Applications of HCES to food fortification

Several studies have used HCES data to construct the indicators needed to answer many of the questions identified in Table 1. In **Table 2**, we summarize a selection of these studies, which, taken together, provide a chronology of examples illustrating how HCES data from a diverse set of low- and middle-income countries (LMICs; including countries in Africa, Southeast Asia, Latin America, and the Western Pacific) can answer a range of policy-relevant questions related to fortification program design or redesign. These examples also illustrate the evolution of the use of HCES data, from measuring intake of fortified foods and the amount of nutrients they could deliver [e.g., (8)] to more comprehensive modeling of nutrient content of the rest of the diet and the marginal effects of fortification [e.g., (16, 17)]. Parallel efforts examined methodological issues related to HCES analysis, such as comparability of HCES-based results with those based on individual dietary intake data (**Supplemental Table 2**). Because detailed comparisons of household-level data collection with individual dietary assessment have been conducted in a limited number of contexts, it is difficult to draw broad conclusions about the use of HCES data as a proxy for individual intake. The extent to which individual apparent consumption based on adult male equivalent (AME) estimates will be similar to the results of individual-level data collection will likely depend on the setting, study design–related factors such as the recall period and household survey food list, and the parameters of interest (e.g., proportion consuming a food, amounts consumed, etc.). See **Supplemental Materials** for additional descriptions of and conclusions based on these comparative studies.

Limitations of and "best practice" methods for use and interpretation of HCES data for nutrition analyses

In recent years, there has been a push to improve the reliability and utility of the food-acquisition/consumption data collected via HCESs by improving the way the surveys are designed and implemented (5, 10, 13, 18). However, there remains a need to provide guidance on how to analyze and interpret existing HCES data consistently and reliably to inform the design of food-fortification programs. This begins with a comprehensive understanding of the limitations and assumptions inherent in the use of HCES data so that methodological choices related to HCES data analysis can be made to understand and reduce the impacts of these limitations, and to help ensure that underlying assumptions and remaining limitations are reflected in the interpretation of results.

A primary limitation of HCESs is that food-consumption or -acquisition data are collected at the household level rather than at the level of individual household members. As a result, indicators based on HCES data are limited to the household level unless additional assumptions about the intrahousehold distribution of food are imposed. Evidence on the validity of these assumptions on intrahousehold distribution of foods and nutrients is limited (see Supplemental Materials and Supplemental Table 2 for additional information and discussion). Also, HCES data-collection instruments typically use a closed food list to record information about food consumption or acquisition. The specificity of these food lists is, in many cases, another limitation since food lists are often short, include aggregate foods (e.g., oils), and/or are missing key foods needed to accurately characterize diets, capture all important sources of nutrients, and assess the potential for fortification of each fortifiable food of interest (10).

Another limitation of HCESs is that foods consumed away from home (FAFH) are often inadequately captured, if captured at all. Because household consumption is often recalled by 1 (or several) household members, there is a risk of underreporting of foods consumed by individuals, particularly outside the home. For example, snacks consumed by children at school or foods purchased by a household member while away from home may not be reported. As FAFH become an increasingly important source of nutrients in LMICs, this could lead to an underestimation of total nutrient intake and overestimation of the prevalence of inadequate intake.

While some HCESs ask directly about household food consumption, others ask only about food acquisition (i.e., food acquired via purchase, own production, as gifts, etc., but not necessarily consumed during the recall period) or food expenditures. [In an evaluation of food acquisition/consumption data collected via HCESs in 100 LMICs, acquisition data alone were collected 41% of the time, 26% of surveys asked about food consumption, and the remaining 33% asked about both acquisition and consumption (7).] This may lead to inaccurate estimates of the quantity of food apparently consumed, especially for foods that are acquired relatively infrequently but consumed frequently (e.g., salt), or foods that are acquired in bulk, stored, and consumed over a long period of time (14). A final limitation of HCESs is the lack of survey standardization across countries. HCESs are, justifiably, designed to meet the needs of a specific country

TABLE 2 Recent studies using HCES data to inform the design and/or management of food-fortification programs[1]

Country	Study (year) (ref)	Food vehicle(s) and micronutrient(s)	Level of analysis	Study details/questions explored using HCES data	Policy implications
Guatemala	Imhoff-Kunsch et al. (2007) (8)	Wheat flour (iron, folic acid)	National and by SES, rural/urban, and ethnicity	Assessment of existing wheat flour fortification program via *1*) reach, *2*) additional micronutrient intake from consumption fortified wheat flour, and *3*) percentage of the estimated average requirement met by consumption of the fortified wheat flour	The likely impacts of wheat flour fortification are modest and have disproportionately low impact among the rural poor. Other fortification vehicles and complementary interventions should be considered
48 Countries	Fiedler and Macdonald (2009) (41)	Vegetable oil and sugar (vitamin A); wheat flour and maize flour (iron, folic acid, vitamin B-12, thiamin, riboflavin, niacin, vitamin B-6, vitamin A, zinc)	National	Evaluation of the feasibility of vegetable oil, sugar, wheat flour, and maize flour fortification in 48 priority countries via *1*) reach, *2*) DALYs averted, and *3*) cost per DALY averted	Among feasible fortification vehicles (food apparently consumed by >25% of population), the single most cost-effective fortification vehicle was identified for each country
Uganda	Fiedler and Afidra (2010) (42)	Vegetable oil and sugar (vitamin A)	National	Evaluation of vitamin A–fortified vegetable oil program and assessment of additionally fortifying sugar via *1*) reach, *2*) additional micronutrient intake from consumption of wheat flour and/or sugar, *3*) percentage of the estimated average requirement met by consumption of wheat flour and/or sugar, *4*) DALYs averted, and *5*) cost per DALY averted	The reach of the vitamin A fortification program would expand if sugar was also fortified and most benefit those most at risk of vitamin A deficiency
Guatemala	Fiedler and Helleranta (2010) (43)	Sugar (vitamin A); wheat flour and semolina flour (iron, folic acid, thiamin, riboflavin, niacin, vitamin B-6, vitamin B-12, zinc)	National	Evaluation of existing wheat flour fortification program and assessment of potential modifications (different vehicles and different micronutrients) via *1*) reach, *2*) additional micronutrient intake from consumption of the fortified/fortifiable foods, *3*) percentage of the estimated average requirement met by consumption of the fortified/fortifiable foods, and *4*) intake above the UL	The impacts of wheat flour fortification are higher than previously estimated.[2] Additionally fortifying semolina flour could reach households not reached by wheat flour fortification. The potential for excessive intake of vitamin A above the UL should be reviewed
Zambia	Fiedler et al. (2013) (26)	Sugar and vegetable oil (vitamin A); wheat flour and maize meal (vitamin A, iron, zinc)	National and by income quintile and province	Assessment of vitamin A–fortified sugar and vegetable oil program and assessment of additionally fortifying wheat flour and/or maize meal with iron and zinc via *1*) apparent nutrient intake and prevalence of inadequate intake, *2*) reach, *3*) additional nutrient intake via consumption of fortified/fortifiable food(s), *4*) reduction in the prevalence of inadequate intake, and *5*) intake above the UL	Additionally fortifying vegetable oil and wheat flour could improve the reach and effectiveness of Zambia's current fortification program. Zambia could consider revising its mandated fortification levels in order to improve effectiveness and/or fine-tune to program to reduce the risk or excessive intake

(*Continued*)

TABLE 2 (*Continued*)

Country	Study (year) (ref)	Food vehicle(s) and micronutrient(s)	Level of analysis	Study details/questions explored using HCES data	Policy implications
Zambia	Fiedler and Lividini (2014) (16)	Sugar, vegetable oil, wheat flour, maize meal, and biofortified maize (vitamin A)	National by rural/urban	Portfolio analysis of existing (sugar fortification and high-dose vitamin A supplementation) and potential (oil, wheat, maize fortification, and maize biofortification) vitamin A interventions via *1*) apparent vitamin A intake and prevalence of inadequate intake, and, for each intervention and combinations, *2*) reach, *3*) additional micronutrient intake, *4*) change in vitamin A intake status, *5*) DALYs averted, and *6*) cost per DALY averted	Based on cost per DALY averted, introducing vitamin A–fortified vegetable oil, wheat flour, and maize meal should be considered. The cost per DALY averted for all 6 interventions combined over the 30-y period would be "very cost-effective" according to WHO/World Bank classification
Kenya, Uganda, and Zambia	Fiedler et al. (2014) (44)	Maize meal (iron, folic acid, thiamin, riboflavin, niacin, vitamin B-6, vitamin B-12, vitamin A, zinc)	National	Assessment of the feasibility of maize meal fortification via *1*) reach, *2*) cost of national maize meal fortification	Reach of fortified maize meal is relatively low, although economically feasible (not expected to have a large impact on price or consumer behavior)
Bangladesh	Fiedler et al. (2015) (23)	Vegetable oil (vitamin A)	National by poverty status, rural/urban, and division	Assessment of vitamin A–fortified vegetable oil program at the mandated fortification level via *1*) apparent vitamin A nutrient intake and prevalence of inadequate intake, *2*) reach, *3*) additional vitamin A intake by consumption of fortified oil, and *4*) reduction in the prevalence of inadequate intake by consumption of fortified oil	Validation that oil is an ideal food vehicle for vitamin A fortification in Bangladesh, as effective coverage is consistently high across income levels and geographic subgroups
Bangladesh	Fiedler et al. (2015) (17)	Vegetable oil (vitamin A); wheat flour (iron, folic acid, thiamin, riboflavin, niacin, vitamin B-6, vitamin B-12, vitamin A, zinc)	National by division	Portfolio analysis of existing (vegetable oil) and/or potential (wheat flour) fortification via *1*) apparent nutrient intake and prevalence of inadequate intake, and, for each food vehicle and combined vehicles, *2*) reach, *3*) additional micronutrient intake, *4*) change in nutrient intake status, *5*) DALYs averted, and *6*) cost per DALY averted	Based on cost per DALY averted, vitamin A–fortified vegetable oil is the most cost-effective. Additionally fortifying wheat flour would also be highly cost-effective and should be considered
Solomon Islands	Imhoff-Kunsch et al. (2019) (45)	Rice and wheat flour (iron, folic acid, thiamin, riboflavin, niacin, zinc)	National and by rural/urban and income quintile	Assessment of fortified wheat flour program and assessment of additionally fortifying rice via *1*) reach, *2*) additional micronutrient intake from consumption of the fortified/fortifiable foods, *3*) percentage of the Estimated Average Requirement met by consumption of the fortified/fortifiable foods, and *4*) intake above the UL	Apparent consumption of wheat flour is relatively low, particularly among rural households, and impacts of fortification are concentrated among urban households. Apparent consumption of rice is higher so has potential to improve impact of fortification program among all subgroups

(*Continued*)

TABLE 2 (*Continued*)

Country	Study (year) (ref)	Food vehicle(s) and micronutrient(s)	Level of analysis	Study details/questions explored using HCES data	Policy implications
India	Swaminathan et al. (2019) (46)	Salt, wheat flour, and rice (iron)	National and by state	Assessment of fortifying salt, wheat flour, and/or rice with iron, concurrently with iron supplementation, on the prevalence of anemia among women of reproductive age in India and the risk of excessive intake	Fortification of salt, wheat flour, and/or rice with iron in India may reduce the prevalence of inadequate iron intake among WRA in some states, but predicted reductions in the prevalence of anemia would be relatively small and variable across states. Intake above the UL maybe be a concern in some states, particularly when modeled together with supplementation. The authors urge careful consideration of the need for simultaneous iron supplementation and iron fortification of multiple foods
Nepal	Saville et al. (2020) (47)	Rice (vitamin A, niacin, vitamin B-6, vitamin B-12, thiamin, folate, iron, zinc, calcium, riboflavin, vitamin C)	National by state, ecological zone, social safety net area, and rural/urban	Assessment of potentially fortifying rice on the prevalence of inadequate intake and risk of intake above the UL	Modeled impacts of rice fortification at the 2016 WFP-recommended levels would help reduce the prevalence of inadequate intake or most nutrients considered, although nutrient gaps would persist for vitamin B-12 and iron
Malawi	Tang et al. (2021) (31)	Vegetable oil (vitamin A) sugar (vitamin A), wheat flour (vitamin A, thiamin, riboflavin, niacin, vitamin B-6, folate, vitamin B-12, iron, and zinc)	National and by administrative region, urban/rural, and socioeconomic position quintile	Assessment of existing vegetable oil, sugar, and wheat flour fortification program based on current and improved fortification compliance on *1*) contribution of fortification to nutrient density of the diet and apparent nutrient intake, *2*) reductions in inadequacy among WRA	Fortification of oil and sugar with vitamin A reduced the prevalence of inadequate density and intake except in rural populations of low socioeconomic position. Wheat flour fortification had limited impact on adequacy due to low levels of consumption. Additional interventions are likely needed to meet the needs of the most vulnerable

[1]DALY, disability-adjusted life-year; HCES, household consumption and expenditure survey; ref, reference; SES, socioeconomic status; UL, Tolerable Upper Intake Level; WRA, women of reproductive age.

[2]Note that this is a re-analysis of the work done by Imhoff-Kunsch et al. (8) using more recent HCES data, incorporating additional foods that contain wheat flour, adding an analysis of the predicted impacts of fortifying semolina flour, and, importantly, calculating the impact of fortification based on conditional consumption levels (i.e., amount apparently consumed among those who consumed the product) compared to the unconditional consumption levels used in Imhoff-Kunsch et al. (8).

and reflect the country-specific context. The resulting cross-country heterogeneity in questionnaires and methods used to collect food data means that measures derived from them are often not easily comparable and vary widely in quality with respect to nutrition-related measures (10, 13).

Methods for using HCES data for food-fortification programs, and "best practice" analytical methods

Within the context of these limitations and underlying assumptions and building on the general steps outlined in Imhoff-Kunsch et al. (19), in **Box 1** we provide a checklist for using HCES data. Briefly, before using HCES data, it is important to identify the specific questions of interest with regard to fortification program design or redesign and then thoroughly read the survey documentation and questionnaires to understand the degrees to which HCES data can answer those questions. Then, depending on the nature and intended use of HCES data, there are several steps involved in preparing and analyzing the data, and reviewing and interpreting the results, that require special considerations to identify the most appropriate analytical methods. Given the considerable heterogeneity in the design of food-consumption and -expenditure modules of HCESs across LMICs (10) and insufficient research comparing analytical methods, it is not possible to identify a set of best-practice analytical methods that apply to all existing HCES datasets. However, there are a few common features of existing HCES data that, depending on the analytical methods used, can influence the reliability of the data for answering some of the key food-fortification design questions identified above.

Box 1. Checklist for using HCES data to inform the design of food-fortification programs[1]

Before using HCES data

1. Identify the clear, agreed-upon policy issues to be addressed by HCES data and confirm that HCES data are generally appropriate for informing the agreed-upon policy issues.
2. Read survey documentation to identify and understand:
   - The survey sampling design and the weighting scheme (including how to use the weights appropriately in the analysis)
   - The level of representativeness (national, geographic, socioeconomic subgroups, etc.) supported by the sampling design
   - Survey details/idiosyncrasies that might be important to account for in analyzing the food data or for interpreting the results (seasonality, data-collection periods, etc.)
3. Review questionnaires to understand:
   - The nature and content of the food list (length, aggregate vs. disaggregate food items, "other" food items, foods consumed away from home, etc.)
   - Units of measure for food expenditures/consumption
   - Length of the food expenditure/consumption recall period
   - If/how purchased vs. home-produced vs gifted/shared foods were captured/differentiated
   - Extent of overlap between foods in the food list and fortifiable foods of interest
   - How household demographic information was captured

During data preparation and analyses

1. Identify data sources for food-composition information and develop an algorithm/hierarchy for selecting a specific food composition source and matching nutrient values to each item in the food list (e.g., match foods to a country-specific FCT first, and if no match is available, match to a regional FCT, then an international FCT, etc.).
2. Determine methods for estimating nutrient values for "other" foods, aggregate foods, and foods consumed away from home.
3. Select dietary reference values for each micronutrient of interest (EARs, Tolerable Upper Intake Levels, etc.) and energy requirements (for calculation of critical nutrient density).
4. Determine equivalence factors for fortifiable foods of interest contained in processed foods (e.g., proportion of wheat flour in wheat bread).
5. Calculate AME values for each household member and the total number of AMEs per household.
6. Standardize food consumption/expenditures to a common unit of measure (e.g., kilograms or grams) and calculate daily apparent household food consumption of each food.
7. Identify extreme values in daily apparent food consumption (see *Extreme values* subsection below).
8. Estimate total daily household apparent energy and micronutrient intake and/or apparent nutrient density of the household diet and identify extreme values in apparent energy and micronutrient intake/density.
9. If estimating individual intake, use the AME method to estimate apparent individual energy and micronutrient intake.
10. Compare apparent intake and/or apparent nutrient density to reference values (e.g., EAR or critical nutrient density) to determine the prevalence of inadequate or high apparent intake and/or inadequate or high apparent nutrient density of the diet
11. Estimate apparent intake of fortifiable food vehicles of interest.

12. Model the impact of food fortification on the prevalence of inadequate or high apparent intake and/or inadequate or high apparent nutrient density of the diet.

During review and interpretation of results

1. To identify possible issues with the HCES data, nutrient values, FCT values, or the analysis, consider completing the following analyses at both the national and subnational levels:
   - Compare average/median apparent energy intake estimates, and their associated ranges and standard deviations, to estimated energy requirements for the population of interest
   - Calculate the main dietary sources of energy and each micronutrient of interest to identify and further explore unexpected contributors
2. Compare estimates of the prevalence of inadequate intake/nutrient density to estimates of micronutrient deficiency via, e.g., national micronutrient survey data.[2]
3. Assess the extent to which the results of this final set of modeling activities addresses the policy issues identified at the outset of this list:
   - Are the results consistent with existing information on risk of micronutrient deficiency (based on biomarkers, dietary patterns, anthropometry, etc.)? If not, what might explain areas of inconsistency?
   - What can we conclude from the analyses based on these data?
   - What can we *not* conclude from the analyses based on these data, and what supplemental data collection might be necessary to fill this gap?
   - How can we interpret and communicate our results to stakeholders, bearing in mind the limitations inherent in using HCES data?

[1]This checklist builds upon the general steps outlined in Imhoff-Kunsch et al. (19). While the checklist focuses on food fortification, many of the steps are applicable to the use of HCES for other nutrition analyses. AME, adult male equivalent; EAR, Estimated Average Requirement; FCT, food-composition table; HCES, household consumption and expenditure survey.

[2]Inadequate micronutrient intake may not reflect micronutrient deficiency exactly, since other factors such as low nutrient absorption due to infection or disease can also lead to deficiency and the basis for selecting thresholds often differs for low intake vs. biomarkers (48).

Presented in **Table 3** (in the order in which analysts would generally encounter each issue during data preparation and analysis) are the current research-based recommendations on "best practice" analytical methods for analyzing existing HCES data to inform the design of food-fortification programs. Where research gaps exist such that a best-practice analytical method cannot be identified, we identify "common practices" used in the literature and, where possible, suggest research activities that could help establish a best practice, highlighting research priorities.

Choosing a data-collection period in a multi-visit survey. The first of these considerations is the data-collection period, or the number of times (or frequency) that food data were collected during the survey. This is different from the recall period, which is the number of days over which the respondent is asked to remember and report his/her household's food purchases or consumption. Some HCESs are designed to collect food-acquisition and/or food-consumption data only once with a specific recall period (e.g., the enumerator visits the household once and asks, "Over the past 7 days, did you or any members of your household consume any rice?"). However, some HCESs ask about food acquisition and/or consumption multiple times during a survey (e.g., the enumerator visits a household every 2 d over a period of 13 d and on each visit asks, "Over the past 2 days, did you or any members of your household consume any rice?"). In the second example, there would be data on household food consumption over a 2-wk period, represented as 7 data points that each covered 2 d of recall. Here, the analyst would have a choice between using any 1 and up to all 7 of these data points.

When using HCES data to inform the design of a food-fortification program, it is important for the analyst to be aware of the data-collection period and to think strategically about whether to use the full period or a subset of the period since the data-collection period may matter in terms of accurately identifying households that consume a particular fortifiable food vehicle and estimating consumption quantities (20). In a recent analysis of HCES data from Bangladesh that allowed for comparison of food data collected from the same households at 7 different time periods (at days 2, 4, 6, 8, 10, 12, or 14 from the beginning of the survey), the authors found consistency, at both the national and regional levels, in the estimates of apparent household consumption of nutrients and the risk of inadequate intake, as well as general dietary patterns, across all data-collection periods (20). The conditional (i.e., among consumers only) and unconditional (i.e., among both consumers and nonconsumers) mean quantities of vegetable oil (and other foods that were consumed by almost all households) apparently consumed were likewise consistent across data-collection periods. However, for less commonly consumed, nonstaple foods, including potentially fortifiable wheat flour, there was significant variation across data-collection periods in the percentage of the population apparently consuming these foods. Since there was consistency in the estimates of apparent nutrient intake and risk of inadequate intake across all data-collection periods, the recommended best practice (first row, Table 3), then, is to use all days of data collection available in the data collection period, which may

TABLE 3 Best- and common-practice analytical methods using HCES data to inform the design of food-fortification programs[1]

Methodological issue	HCES characteristic	Best-practice method	Common-practice method	Additional data collection needed	Research gaps
Selecting the data-collection period	Food data were collected from households on >1 visit	Use data from all available data-collection periods to approximate usual intake unless a food vehicle is not commonly consumed by most of the population, in which case select the data-collection period to match the period over which consumption of the food vehicle is nutritionally meaningful	Not applicable	Not applicable	The best-practice recommendation is based on an analysis from 1 country, so additional analyses of HCES with more than 1 data collection period are needed to confirm external validity
Converting reported units to standard units	Some quantities reported in nonstandard units (e.g., a bowl heap); monetary values may or may not also be reported	When nonstandard unit conversion factors are not available, conduct primary data collection to develop conversion factors for nonstandard units reported in the data	Not applicable	Market surveys to develop nonstandard unit conversion factors	None
	Only monetary values reported	Conduct a market survey to generate price per standard unit estimates (i.e., metric prices), then divide the reported monetary value by the price per gram to arrive at quantity in grams	Not applicable	Market surveys to estimate metric prices	None
Accounting for composite foods and inadequately captured foods consumed away from home	Not applicable	Not identified	National-level calorie and nutrient imputation	Not applicable	Research how subnational variation in prices, quality-related differences in price, and/or differences in the price per calorie across food groups can be integrated into the price per calorie/nutrient calculations to improve accuracy of imputation

(*Continued*)

TABLE 3 (*Continued*)

Methodological issue	HCES characteristic	Best-practice method	Common-practice method	Additional data collection needed	Research gaps
Accounting for foods categorized as "other" in each food group	"Other" foods are not specified in the data	Where available, use quantitative dietary data or qualitative data (i.e., the food list used in a dietary study) to inform the foods included in each "other" category	Not applicable	Conduct key informant interviews to identify the most commonly consumed foods that do not appear directly in the food list	For countries where both individual dietary intake data and HCES data have been collected, compare the accuracy of different methods
Identifying and addressing outliers	Not applicable	Not identified	Flag outliers by visual inspection of histograms, densities, and scatterplots. Observations >75th percentile by more than 3 times the IQR also used to flag outliers. Cross-check flagged values with related variable (e.g., price and quantity) to distinguish data error from plausible extreme values. Drop data errors, and constrain plausible extreme values to maximum plausible quantity for daily consumption	If information on maximum plausible quantity is not available, primary data collection might be required to establish constraint values	[2]Research-based guidance is needed specifying *1*) at what stage(s) in the analysis and for what variables outliers should be identified, *2*) rules for how plausible extreme outliers should be treated, *3*) and which food-fortification design indices are most sensitive to outliers
Assessing adequacy of nutrient intakes with and without fortification	Not applicable	Not identified	AME method	To predict the impact of fortification on some target groups for whom the AME, such as young children, method does not perform well, individual-level dietary intake data collection should be collected	[2]Research comparing the AME and nutrient density methods and to develop best practices for the nutrient density approach should be conducted. Alternative methods to the AME method, such as statistical disaggregation and predictive modeling, should be further explored in terms of their performance in predicting individual-level intake for young children

[1]AME, adult male equivalent; HCES, household consumption and expenditure survey.
[2]Indicates research priority.

better reflect usual intake (discussed below). A caveat to this recommendation, however, is that if one of the food vehicles under consideration is not commonly consumed by most of the population, the data-collection period should be selected to coincide with the length of time over which consumption of the food vehicle would be nutritionally meaningful (20). For example, consuming fortified flour once every few weeks would be unlikely to increase micronutrient status, so selecting a shorter data-collection period might be appropriate for selecting foods to consider fortifying, as this would refine estimates of reach to better capture households that more frequently consumed the fortified food. Because this recommendation is based on only 1 study analyzing data from 1 country, further research is needed to establish the external validity of the findings. See the Supplemental Materials for a discussion of the related issue of estimating "usual intake."

Conversion of reported units to standard units.

Once an analyst has determined the most appropriate period of data collection, one of the next tasks is to calculate the total quantity of each food apparently consumed by converting all quantities to a standard metric unit (typically grams). When recalling the quantity of food acquired or consumed during the recall period, respondents are often encouraged to report the quantity in whatever unit they choose. Allowing respondents flexibility in reporting units rather than constraining them to report quantities in a small set of standard units (e.g., grams, kilograms, liters, etc.) has been found to reduce respondent burden and improve the accuracy of the recalls (13). However, from an analytical perspective, if unit conversion factors are not available for all of the food-and-unit combinations found in the data, the task of converting the nonstandard, often locally specific, units (e.g., heap, bowl, bundle, cooking pot) into standard units is nontrivial and involves methodological choices and tradeoffs (e.g., using available data to impute conversion factors, which may be inaccurate, vs. taking time and resources to undertake primary data collection to develop conversion factors). In an evaluation of food-acquisition/-consumption data collected via HCESs in 100 LMICs, conversion to a standard metric unit was not possible in 47% of surveys based on what was available in the data and survey documentation (10). In LMICs generally, and in Africa in particular, reporting in nonstandard units is common (21).

If both quantities of foods consumed and their associated monetary values are reported, and quantities are reported in both standard and nonstandard units, 1 option for converting to standard units is to calculate an average or median price per gram using the quantity and monetary values for all quantities reported in standard units (10). Then, the monetary value of all quantities reported in nonstandard units is converted to grams by dividing the reported monetary value by the price per gram. However, a major criticism of this method is that the prices faced by households that tend to choose to report quantities in standard units may be systematically different than prices faced by households that primarily choose nonstandard units, resulting in bias in the quantity estimates generated using this method (10). As a result of this potential bias, this method is not recommended.

The recommended "best practice" method, then, is to conduct primary data collection to develop conversion factors for nonstandard units reported in the data [see Oseni et al. (21) for recent Living Standards Measurement Study/World Bank guidelines on conducting market surveys to generate conversion factors]. If only the monetary values and not the quantities of the foods acquired or consumed were collected, a market survey can be conducted to generate price per standard unit estimates (i.e., metric prices). While this alternative might be the only option available, metric prices for some foods may change over time independently of inflation, which can introduce error into estimates of quantity based on (inflation-adjusted) metric prices if the market survey is conducted in a different year than the HCES. Further, there may be substantial between-household differences in the prices that households face, even households in the same community, depending on quality, bulk purchase discounts, negotiating skills, etc., so this method is likely to produce imprecise household-level estimates (10). Conducting market surveys to generate conversion factors or metric prices will, of course, have time and monetary costs and, as noted above, when conducted after HCES data are collected, may be imprecise. Nevertheless, without conversion factors for nonstandard units, the usefulness of HCES data for assessing fortification programs is very limited.

Composite foods, foods consumed away from home, and "other" foods.

Processing HCES data involves matching each food in the food list to a food-composition table (FCT) entry. The accuracy of nutrient intake estimates depends on how well the nutrient contents of the selected FCT entry match the food actually consumed (10), and dealing with issues commonly encountered in food is not always straightforward.

HCES food lists (and other food lists used to generate indicators of dietary quality) often include composite foods, which are foods that are composed of multiple ingredients that are often consumed in processed form, such as bread, biscuits, or pastries. Composite foods can pose a challenge for analysts when they are included in a food list but do not have accompanying recipe information or cannot be readily matched to a locally relevant FCT entry. A related challenge is the way FAFH, which includes foods eaten at a restaurant, at a roadside stand, at school, etc., are collected. While most HCESs capture FAFH in some way, there is substantial variation in how this information is collected, ranging from asking a single question about total expenditures on all FAFH consumed during the recall period, to asking about both expenditures and quantities on a short list of, often, very broad categories of FAHF (e.g., mixed dishes, nonalcoholic beverages) and a very limited number of specific dishes (7). In most cases, data collected on FAFH suffer from significant measurement error (7, 10, 13). Because consuming both composite foods and FAFH is becoming increasingly common in LMICs, and these types of foods therefore represent an increasingly larger share of total nutrients, failing to adequately and accurately account for these foods will lead to an underestimation of food consumption and nutrient intake and an overestimation of the prevalence and severity of inadequate intake (7, 13). Adequately addressing this issue will require improving the way in which the surveys themselves capture composite foods and FAFH [see (13) for specific recommendations], but in the meantime, analysts need to apply analytic techniques to reduce, to the extent possible, underestimation of food consumption and nutrient intake.

Calorie imputation, a strategy developed by Subramanian and Deaton (22), is commonly used in situations where either only expenditures were collected, where expenditures and quantity were collected for some foods and only expenditures were collected for others, or where both expenditures and quantity were collected but information on nutrient content is not available (7). Calorie imputation, which can also be implemented for other nutrients (e.g., vitamin A imputation), involves first calculating an average price per calorie/nutrient for all foods for which nutrient content data are available. Then, for foods for which that analyst only knows the amount spent, the reciprocal of the average price per calorie/nutrient is multiplied by reported expenditures to estimate the quantity of calories/nutrients in the food (7). However, applying this method to FAFH and composite foods raises concerns related to subnational/geographic variation in prices, quality-related differences in prices, differences in the price per calorie across food groups (i.e., the price per calorie of meat may be much higher than the price per calorie of a staple cereal), and likely differences in the nutrient profile of FAFH compared with foods consumed at home.

To address these concerns, using data from Bangladesh, Mwangi et al. (7) explored the effects of varying the methods used to calculate price per calorie/nutrient on apparent caloric/nutrient intake. Data availability limitations and the relatively low nutrient contribution of FAFH and composite foods in Bangladeshi diets precluded the authors from making any definitive statements about both the importance of accounting for FAFH and composite foods for which quantity and/or recipe information are unavailable and also about which of the calorie/nutrient price options described above resulted in the "best" estimates of energy and nutrient intake. The authors concluded that more knowledge about how local contexts (e.g., the degree of heterogeneity in diets) affect food prices and household food demand is needed to identify the most appropriate imputation method, which is likely to be country- and context-specific.

Another issue that analysts have to contend with is that most food lists include an "other" category for each food group (e.g., other fruits) in which all foods not explicitly listed in that category are captured. In cases where foods included in each of the "other" categories are not specified, 1 option is to match the "other" category with a single entry from the same food group in an FCT. This might be a reasonable option if it is the most commonly consumed item in that particular category that is not listed explicitly or because all items that would fit into that particular "other" category are similar in nutrient composition (12). Another option used in the literature has been to take the (weighted) average of the energy and nutrient values for all other foods in that particular category listed in the FCT and assign those averages to consumption captured as "other" (12, 23). This method may not be particularly useful in circumstances where there is not a relatively local FCT and matches are instead made via several, potentially quite large, FCT databases. If available, the best option might be to use quantitative dietary data from a local dietary study or qualitative data from such a study (i.e., the food list used in the study) to inform the foods included in each "other" category. If such data are not available, another alternative is to conduct key informant interviews to help identify the most commonly consumed foods that do not appear directly in the food list. Presumably, the calorie/nutrient imputation method described above could also be applied to "other" foods, although we have not come across this method being used in practice or evaluated for accuracy.

After food matching has been completed, calculating the main dietary sources of energy and each micronutrient of interest can be a helpful check to identify and explore unexpected contributors (Box 1).

Extreme values.

Although most publicly available HCES datasets are already cleaned to some extent by the implementing organization (24), it is very likely that analysts using the food data from HCESs will encounter extreme values that should be systematically identified and dealt with. Given the nature of HCES food data, it is often difficult to distinguish between extreme values, or outliers, attributable to data errors (stemming from data reporting errors, recording errors, or entry errors) and values that are extreme but potentially legitimate values, such as large bulk purchases (12, 25). Depending on the extent of outliers in the data, the way in which the analyst identifies and addresses extreme values is not likely to have a large impact on population-level prevalence rates and percentages, but indicators based on mean values, such as average apparent consumption and the average nutrient gap, are more likely to be significantly influenced.

Extreme values for key variables, including apparent energy and micronutrient intake and apparent consumption of fortifiable foods, should be identified and flagged for further scrutiny by visual inspection of histograms or densities and scatterplots. They can also be identified using a general rule of thumb that observations exceeding the 75th percentile by more than 3 times the IQR should be flagged as potential outliers (19). Once flagged, the analyst must decide how to address the extreme values. Deleting extreme values without further inspection is not recommended, since this could compromise the sample weighting scheme and could introduce bias into the sample (25). Rather, as a first step, analysts should try to determine, to the extent possible, whether flagged values are outliers due to data errors or are extreme but plausible values. One way to do this, as recommended by Imhoff-Kunsch et al. (19), is to cross-check 2 related variables, such as the reported quantity purchased and the reported amount paid, to determine whether each variable makes sense relative to the other. If not, the extreme value is more likely due to a data error and should be considered for deletion. If related variables agree with one another (e.g., both the quantity purchased and amount paid are high), this is suggestive of legitimately extreme values that might be the result of bulk purchasing or drawing down stocks. Acknowledging that these types of extreme values stem from repurposing food-expenditure data as a proxy for food consumption, 1 strategy used in the literature is to adjust outliers on the right tail of the distribution by constraining them to be an assumed maximum plausible quantity for daily consumption, while deleting households that reported no food acquisition (12, 26). It should be noted, however, that, in the absence of another source of dietary intake data from the same or a very similar population that could be tapped to identify a maximum plausible quantity, setting the constraint values would require either strong assumptions or some primary data collection to inform the values.

It is difficult to determine a single "best practice" method for addressing extreme values in HCES food data, since the extent of the problem, and the underlying reasons for the problem, will vary from country to country and survey to survey. Certainly, extreme values should not be ignored, and once identified, they should not be changed or deleted without further inspection. When reporting results, we recommend that a detailed description of how extreme values were detected and addressed, including the number or percentage of observations that were dropped or changed, should be included in the write-up. Also, for indicators that rely on average values, it might be helpful to compare the mean and median values, and if the 2 values are significantly different, both statistics could be presented. And finally, as noted below, we also suggest running sensitivity analyses comparing all results with and without extreme values that have been deemed to be outliers.

Since the issue of extreme values will persist even as HCESs are improved, the development of practical, research-based guidelines for identifying and addressing outliers should be prioritized. The guidelines should include guidance on at what stage(s) in the analysis and for what variables extreme values should be identified, rules for how plausible yet extreme values at both ends of the distribution should be treated, and information about which food-fortification design indices are most sensitive to extreme values.

Assessing adequacy of apparent nutrient intakes with and without fortification.

Once apparent household food-consumption and nutrient intake estimates have been calculated, the analyst needs to decide how to assess dietary adequacy, including whether and how to disaggregate these household measures to the individual level. There are several methods available to disaggregate the data, but since the intrahousehold distribution of food is not observed in the data, each method is accompanied by a set of strong assumptions. One possibility is simply to divide household-level consumption and intake estimates by household size to generate per-capita estimates. This method does not make any adjustments for the demographic composition of a household (e.g., age and sex composition) and is not recommended (27). Alternatively, a commonly used method that accounts for both household size and variation in household demographic composition is the AME method. The AME method assumes that food is distributed within a household in proportion to each member's age-, sex-, and physical activity level–specific caloric needs, and AME weights are derived for each household member that reflect his/her energy requirements relative to the requirements of an adult male (28). Individual-level apparent intake can then be compared with a reference value (e.g., the EAR) to assess adequacy. However, the assumptions underlying the AME method may not be accurate if the intrahousehold distribution of food is not according to members' energy requirements (e.g., if there is gender bias in food distribution within the household). The AME method has been shown to perform poorly for young children in several settings as a result of the difficulty in accurately accounting for energy and nutrient intake from breast milk and because very young children may not consume the same foods as other household members (29, 30). As such, if fortification design questions are specific to children, collecting individual-level dietary intake data for this group may be necessary. Another potentially important limitation of the AME method is that if household members' physiological state (i.e., whether women are pregnant and/or lactating) is not identified in the HCES data, it is not possible to make appropriate adjustments to energy requirements (and hence AME weights), which may also introduce errors. Given the uncertainty in the distribution of food within households, we recommend analysts perform sensitivity analyses around key assumptions about the intrahousehold distribution of food (e.g., assumed physical activity level of various household members).

As an alternative to or in addition to a disaggregation method, some analysts have used HCES data to estimate the nutrient density of the household diet (31). Nutrient density is the quantity of a particular nutrient per 1000 kcal of the household diet, which can then be compared to the critical nutrient density (calculated as an individual's nutrient requirement divided by his/her energy requirement, multiplied by 1000) of a specific household member(s) (32). If the household nutrient density is above a particular household member's critical nutrient density, the diet is assumed to be of sufficient quality to meet nutrient requirements, assuming the household diet also meets the energy needs of its members. One study compared HCES-based estimates of nutrient density with those based on a 24-h dietary recall in Uganda and found general agreement between the 2 data sources for 80% of the nutrients analyzed for women of reproductive age and children ages 24–59 mo (33), suggesting that nutrient density may be an appropriate method for using household-level apparent food-consumption data to assess adequacy and may also provide an indicator of the magnitude of nutrient gaps, although similar comparisons are needed in other contexts (4).

Given the current evidence, more research is needed to identify a best practice for assessing nutrient adequacy with and without fortification. Since this is an issue faced by all analysts using HCES data to assess nutrient adequacy and one that can have a significant impact on findings and how findings are interpreted, research to compare the AME and nutrient density methods and develop best practices for the nutrient density approach should be prioritized.

Discussion

Where individual-level dietary intake data are not available, existing HCES data that are properly analyzed and interpreted, and used in conjunction with other nutrition and health-related data, can provide crucial information for the design of food-fortification programs.

HCES data from high-quality surveys are well suited to inform fortification program design indicators that can be interpreted qualitatively, such as broad categorizations of population groups by the extent of inadequate dietary micronutrient intake and the reach of food-fortification vehicles. However, the evidence on the validity of HCES data for estimating apparent food consumption and nutrient intake, and related prevalence of low or high apparent nutrient intake estimates, at the individual level is mixed and may be particularly unreliable for young children (29, 30, 33–38). As such, there is uncertainty around HCES-based indicators that are important for setting fortification levels, and alternative sources of information may be required to appropriately assess the sizes of the nutrient gaps, effective coverage of food vehicles at varying fortification levels, and risks of excessive intake. Where these estimates are generated, we suggest that the interpretation focus on qualitative assessments of level of risk and on the relative predicted impacts of alternative interventions.

We have highlighted a number of methodological issues that analysts may face when processing and analyzing HCES data to generate indicators for food-fortification program design. Following research-based best practices and performing sensitivity analyses around key decisions and parameters will help provide the most reliable estimates possible, given the limitations of the data. For some methodological issues, however, there is insufficient research to support a particular method as being better than other commonly applied methods. These research gaps represent untapped opportunities to provide guidance on the specific methods that will generate the most reliable estimates (typically relative to estimates based on individual dietary intake data such as 24-h dietary recall data), with implications for the quality of the evidence base from which food-fortification design decisions are made.

There is inadequate research to identify the best methods for assessing the adequacy of apparent nutrient intakes with and without fortification, and given the centrality of this issue in all analyses of HCES data to inform food-fortification program decisions, this research should be prioritized. We also suggest prioritizing the development of research-based guidelines for identifying and addressing extreme values in HCES food data as well as how best to account for composite foods, inadequately captured FAFH, and foods categorized as "other."

Another way to improve the quality of HCES-based estimates in specific cases is to collect additional data to supplement the HCES data. We have already noted that, where nonstandard unit conversion factors are not available, it is necessary to conduct market surveys to construct these conversion factors. Another example is in cases where shortcomings in HCES food lists preclude consideration of some potential fortification vehicles because they are missing from the list (e.g., condiments being considered for fortification, such as bouillon), the vehicle is combined with other foods within a single food list item, it is not possible to differentiate between fortifiable and nonfortifiable forms of the food based on the listing, or the list is missing composite foods containing the vehicle as an ingredient. These shortcomings could be addressed by conducting Fortification Coverage Assessment Toolkit (FACT) surveys or incorporating indicators derived from the FACT survey method (39, 40). The FACT method, developed by the Global Alliance for Improved Nutrition, uses household and market surveys to assess the quality, reach, and consumption of fortified foods using standardized methods and indicators, with a particular focus on the collection of information that distinguishes between consumption of the food vehicle in any form, in a fortifiable form, and in a fortified form. To date, FACT surveys have been conducted in more than 16 countries to assess large-scale food-fortification programs (40) (see **Supplemental Table 3** for a list of countries). The time frame and costs of conducting a standalone FACT survey are similar to those for conducting any national or subnational household-level survey (such as HCES); however, if other surveys or surveillance systems are routinely conducted that target the same populations of interest, then FACT modules can easily be added at minimal additional cost to ensure the distinction between the food vehicle in any form versus a fortifiable form is captured.

In some instances, the limitations and shortcomings of a specific HCES and/or the questions being asked to design a fortification program mean that the existing HCES food data are simply not an adequate or appropriate proxy for food consumption. Given the heterogeneity in existing HCES data, this is a case-by-case judgment, but one that needs to be carefully considered since relying on inadequate data could result in the implementation of costly, ineffective, and even harmful fortification design decisions.

Beyond analysis, interpreting the results of HCES data analysis is an important step in using these data to inform the design or redesign of fortification programs. Making the results as useful as possible involves not only relying on the point estimates but also presenting ranges or confidence intervals based on the standard errors, which account for the survey design and the sampling weights associated with each indicator. Sensitivity analysis should also be conducted around uncertain or particularly influential input variables and methodological choices. Including both ranges and purposeful sets of sensitivity analyses provides means by which the uncertainty inherent in the point estimates, which exists for any dietary intake method but is potentially amplified when using HCES data to proxy for dietary intake, can be communicated to people making decisions about fortification programs. Related to this, when information generated via HCES data is communicated to decision makers, the public health problems being addressed should be broadly described using mortality, morbidity, and other data that help set the context for discussion, and the general limitations of using HCES data to proxy for intake as well as any limitations resulting from the specific survey design and implementation should be made clear.

HCESs, which are widely available at regular time steps for many LMICs, are a valuable source of nationally representative information on apparent household food consumption, with the potential to inform the design of food-fortification programs as well as other nutrition programs and policies. The utility of HCES data to inform decisions about fortification programs is tempered by a range of limitations that influence the reliability of results for quantitative interpretation, including setting the micronutrient content of selected fortified foods. Some of these limitations can be minimized by following best-practice methods when analyzing the food data collected via HCES. When best practices are followed, HCES data offer numerous advantages over national food supply data, including the opportunity to examine subnational variation in apparent food consumption and nutrient intake. Additional research is needed to fill remaining gaps in our knowledge about best-practice analytical methods.

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