Introduction to the SIMPLE Macro, a Tool to Increase the Accessibility of 24-Hour Dietary Recall Analysis and Modeling

Hanqi Luo,1,2 Kevin W Dodd,3 Charles D Arnold,1,2 and Reina Engle-Stone1,2

1Institute for Global Nutrition, University of California, Davis, Davis, CA, USA; 2Department of Nutrition, University of California, Davis, Davis, CA, USA; and 3National Cancer Institute, NIH, Bethesda, MD, USA

ABSTRACT

Background: Information on long-term dietary intake is often required for research or program planning, but surveys routinely use short-term assessments such as 24-h recalls (24HRs). Methods to reduce the impact of within-person variation in 24HRs, such as the National Cancer Institute (NCI) method, typically require extensive training and skill.

Objectives: We introduce the Simulating Intake of Micronutrients for Policy Learning and Engagement (SIMPLE) macro, a new tool to increase the accessibility of 24HR analysis. We explain the underlying theory behind the tool and provide examples of potential applications.

Methods: The SIMPLE macro connects the core NCI statistical code to estimate usual intake distributions and includes additional code to enable advanced analyses such as predictive modeling. The related SIMPLE-Iron macro applies the full probability method to estimate inadequate iron intake, and the SIMPLE-1D macro is used for descriptive or modeling analyses of data with a single 24HR per person. The macros and associated documentations are freely available. We analyzed data from the US National Health and Nutrition Examination Survey (NHANES) and the Cameroon National Micronutrient Survey to compare the SIMPLE macro to 1) the core NCI code using the Estimated Average Requirement cut point method, and 2) the IMAPP software for iron only, and to demonstrate the applications of the SIMPLE macro for estimating usual intake and predictive modeling.

Results: The SIMPLE macro generates identical results to the core NCI code. The SIMPLE-Iron macro also produces estimates of inadequate iron intake comparable to the IMAPP software. The examples demonstrate application of the SIMPLE macro to 1) descriptive analyses of nutrient intake from food and supplements (NHANES), and 2) analyses accounting for breast-milk nutrient intake and modeling fortification and supplementation programs (Cameroon).

Conclusions: The SIMPLE macros may facilitate the analysis and modeling of dietary data to inform nutrition research, programs, and policy. J Nutr 2021;00:1–12.

Keywords: dietary analysis, dietary modeling, National Cancer Institute, micronutrients, 24-h dietary recalls

Introduction

Poor diet contributes to each of the diverse forms of malnutrition that now coexist across the globe, from wasting and micronutrient deficiencies to diet-related noncommunicable disease (1, 2). High-quality information on usual dietary intake is a critical input to plan effective and efficient programs to improve nutritional status and related outcomes (3). Such data are needed to understand food consumption patterns, assess which nutrients may be of public health concern (either because intakes are low or because they are high), and determine which population subgroups are most affected. Information on the predicted effect of hypothetical nutrition intervention programs on dietary intake and other outcomes may also guide decisions regarding how to address population-specific nutrition problems.

Analysts of dietary intake data are typically interested in information on usual, or long-term average, nutrient intake, including parameters such as the mean, median, and interquartile range (IQR) of the distribution, or the prevalence of inadequate or excessive usual nutrient intakes. In contrast, surveys routinely rely on short-term assessments of dietary intake, such as 24-h recalls (24HRs), to collect information on population intake. Estimation of usual intake is challenging when such methods are used, however, because the distribution of dietary intake measured on ≥1 d is subject to substantial within-person variation (due largely to the day-to-day variation of a person’s dietary intake in relation to their usual intake). To address this problem, researchers have developed methods to mathematically adjust for this day-to-day variation to estimate the distribution of usual intake using short-term data (4–8).
Among these methods, the National Cancer Institute (NCI) method has been widely used for analysis of foods or nutrients in 24HR data (8), using freely available SAS macro code. Although the NCI method is very flexible and powerful, it has a fairly steep learning curve. Applying the method requires understanding the theoretical basis for analyzing dietary intake data, mastery of multiple SAS macros, and a high proficiency in SAS coding to enable data-set-specific modifications.

Researchers and policymakers are also often interested in knowing how a population’s diet can be improved by hypothetical nutrition-related interventions, such as micronutrient fortification, dietary supplementation, or interventions intended to improve diet quality or diversity (9–15). Modeling the effect of nutrition interventions involves complex dietary analysis and can be conducted with the NCI macro code, but further effort and technical skill are necessary to modify the input data or code to meet these objectives. Organizations that are willing and able to invest in building this capacity must also consider the time required to do so; this time lag may result in lost opportunities to make dietary data available during critical decision-making periods. The need for global efforts to standardize guidance for dietary data analysis and interpretation has been repeatedly emphasized by recent nutrition initiatives (3, 16, 17).

To improve the utilization of dietary data by helping researchers and analysts conquer the difficulties of applying the NCI method, the University of California, Davis (UCD) and NCI jointly developed the UCD/NCI Simulating Intake of Micronutrients for Policy Learning and Engagement (SIMPLE) macro. The SIMPLE macro provides a single tool that can be used for both basic and advanced dietary analysis and modeling. Two primary advantages of this tool are that 1) it combines the several existing NCI macros that need to be used jointly to estimate distributions of usual intake for any dietary components consumed by nearly everyone nearly every day (“nearly-daily”), which reduces the time required for analysts to do this linking themselves; and 2) in addition to typical descriptive analyses, the tool allows for advanced dietary analysis and modeling, such as incorporating nutrient intake from supplements and breast milk into total nutrient intake or simulating the effect of micronutrient fortification of foods. The dietary components that can be analyzed with the SIMPLE macro include nutrients, energy, food, or other dietary components, but, for simplicity, in this article we use “nutrients” to refer to all dietary components consumed nearly daily.

Variations of this macro, the SIMPLE-Iron and SIMPLE-1D, are available to address specific challenges, such as the need to apply the full probability method to assess nutrient adequacy for iron and the availability of only a single day of 24HR per person (18). The SIMPLE, SIMPLE-Iron, and SIMPLE-1D macros and example codes are available online (Open Science Framework link: https://osf.io/yt434/); the corresponding SIMPLE macro user manual and a detailed description of the method used in the SIMPLE-Iron are provided with this article (Supplemental User Manual 1, Supplemental Method 1). We hope the detailed user manual and examples will allow users to modify the example codes for their own dietary research.

The objectives of this article are to describe the general structure and features of the SIMPLE macro, explain the underlying theory, and present example applications of the SIMPLE macro for descriptive analyses and dietary modeling. We first provide an overview of the NCI macros, which form the underlying analytical method of the SIMPLE macro. We then describe the general structure and features of the SIMPLE macro (including the SIMPLE-1D and SIMPLE-Iron variations) and compare the usual intake distribution estimated by the SIMPLE macro with that generated by the standard NCI macros; we also compare the results from applying the full probability method for estimating inadequate iron intake using the SIMPLE-Iron macro with the same analysis conducted with the IMAPP software (5). Next, we describe the core methods applied within the SIMPLE macro to implement selected advanced analyses and modeling techniques. Finally, we present example applications of the SIMPLE macro to national survey data from the United States (19) and Cameroon (20) and comment on the strengths and limitations of the SIMPLE macro with respect to other approaches to dietary analysis.

Methods

Overview of the NCI method for estimating usual nutrient intake

The NCI method for estimating usual intake distributions is implemented in 2 macros written in the SAS programming language: MIXTRAN and DISTRIB (21). Figure 1A shows an overview of how the NCI method estimates usual intake distributions. The MIXTRAN macro transforms dietary intake data to approximate normality, models the transformed data as the sum of a covariate-based prediction function and 2 kinds of deviations from that function (between- and within-person deviations), and produces parameter estimates and covariate-based predictions used as inputs for the DISTRIB macro. In turn, the DISTRIB macro generates a simulated data set of estimated usual intakes based on the 24HRs, by, first, multiply imputing the between-person deviations and then adding them to each sampled person’s prediction, and, second, converting the imputed values back to the original scale. By only imputing between-person deviations and by using a numerical integration for the back-transformation, this approach analytically corrects for within-person variation. Percentiles of usual intake and proportions of the population with usual intake below or above specified values can be estimated from the simulated data set. Advanced analyses are also supported by using the option of saving the data set. The MIXTRAN macro will not run on data sets without repeated recalls on at least a subsample of individuals, but using the approach of Luo et al. (22), the MIXTRAN macro can be replaced with a different macro (TRAN1) that uses an external ratio of within- and between-person variance and more restrictive assumptions to perform the modeling step with only one 24HR per person.

Obtaining Standard Errors (SEs) essential to inference for parameter estimates from MIXTRAN and usual intake percentiles or proportions from DISTRIB is not straightforward (Figure 1A). For some complex survey designs, SEs can be calculated using the Balanced Repeated Replication (BRR) method (23); for other survey designs or in simple randomized samples, a bootstrap approach is required. Both methods entail running the MIXTRAN/DISTRIB combination many times on modified input data, saving the desired output each time, then

Supported by Bill & Melinda Gates Foundation award OPP1709661 (to RE-S), USDA National Institute of Food and Agriculture Hatch project 1013897 (to RE-S), and the National Cancer Institute (to KWD).

Author disclosures: the authors report no conflicts of interest.

Supplemental User Manual 1 and Supplemental Method 1 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/jn/.

Address correspondence to HL (e-mail: hluo@ucdavis.edu).

Abbreviations used: BRR, Balanced Repeated Replication; CNMS, Cameroon National Micronutrient Survey; EAR, Estimated Average Requirement; IOM, Institute of Medicine; IQR, interquartile range; NCI, National Cancer Institute; NHANES, National Health and Nutrition Examination Survey; SE, Standard Errors; SIMPLE, Simulating Intake of Micronutrients for Policy Learning and Engagement; UCD, University of California, Davis; UL, Tolerable Upper Intake Level; 24HR, 24-h recall.
estimating SEs from the replicated output using code such as that provided by the NCI BRR_PVALUE_CI macro (21). A substantial amount of SAS programming is required to automate this approach for application to a variety of nutrients and/or data sets, with careful attention paid to properly combining the MIXTRAN and DISTRIB macros.

**Overview of the NCI/UCD SIMPLE macro**

The SIMPLE macro is a single macro that links 3 NCI macros, the MIXTRAN, DISTRIB, and BRR_PVALUE_CI, to facilitate estimation of usual intake distributions for food and nutrients consumed “nearly-daily.” The SIMPLE macro also includes additional features, such as carrying out checks on the input data sets and supporting a variety of specific analyses, including modeling nutrition-related interventions (13, 15, 24, 25); however, before this article, the associated codes and analytical details have not been published, which may have limited the extent to which other researchers could then apply these methods to their own data.

Figure 1 shows the relation between the SIMPLE macro and the core NCI macros. Because the SIMPLE macro serves as a connector of the existing NCI macros without modifying any core part of the NCI macros, the results of using the SIMPLE macro are exactly the same as those of using several NCI macros jointly. We applied the SIMPLE macro to the example data provided by the NCI website for estimating the usual intake distribution of added sugars (21). The results generated by the SIMPLE macro were identical to the results provided on the NCI site that correspond to the example data and codes for the MIXTRAN, DISTRIB, and BRR_PVALUE_CI macros (Table 1). This observation has been confirmed through extensive testing of the SIMPLE macro on 3 nationally representative surveys: multiple cycles of the National Health and Nutrition

---

**FIGURE 1** Comparison of the procedures between the SIMPLE macro and NCI method. BRR, Balanced Repeated Replication; NCI, National Cancer Institute; SE, Standard Errors; SIMPLE, Simulating Intake of Micronutrients for Policy Learning and Engagement; UCD, University of California, Davis; 24HR, 24-h recall. The shaded boxes show that the SIMPLE macro condenses steps [1] to [7] of the NCI method. For data sets with a single 24HR per person, the NCI MIXTRAN macro will be replaced with the UCD/NCI TRAN1 macro and an external variance ratio to estimate the distribution of usual intake, and the SIMPLE macro will be replaced with the SIMPLE-1D macro and an external variance ratio to estimate the distribution of usual intake.
Examining the Simple Macro inputs, processes, and outputs. Data sets and macro options are selected for formatting and model specification errors before starting analysis; if any errors are detected, the macro provides guidance for correcting them. The output from a successful run includes a formatted spreadsheet (suitable for use in reports or manuscripts) containing estimates and associated SEs for characteristics of the usual intake distribution, such as the median, IQR, and proportions of the population within adequate or excessive nutrient intake. The core SIMPLE macro estimates inadequate nutrient intake using the Institute of Medicine Estimated Average Requirement (EAR) cut-point method, defining prevalence of inadequate intake as the proportion of individuals with intake below each individual’s age- and sex-specific EAR for a given nutrient; likewise, excessive intake is defined as intake above the corresponding Tolerable Upper Intake Level (UL) (27). The SIMPLE macro also outputs model parameters such as within- and between-person variance components and coefficients for included covariates that influence the distribution of usual intake.

**SIMPLE-Iron**

The EAR cut-point method requires several assumptions, including the assumption that the distributions of nutrient requirements are symmetrical (27), which is known to be violated in the case of iron requirements for populations such as menstruating women. Although the SIMPLE macro can be used to estimate some parameters of iron intake distribution (mean, median, IQR, and proportions of the population with inadequate or excessive nutrient intake). The core SIMPLE macro estimates inadequate nutrient intake using the Institute of Medicine Estimated Average Requirement (EAR) cut-point method, defining prevalence of inadequate intake as the proportion of individuals with intake below each individual’s age- and sex-specific EAR for a given nutrient; likewise, excessive intake is defined as intake above the corresponding Tolerable Upper Intake Level (UL) (27). The SIMPLE macro also outputs model parameters such as within- and between-person variance components and coefficients for included covariates that influence the distribution of usual intake.

**SIMPLE-1D**

Although it is always recommended to collect repeated 24HRs per person, some food consumption surveys and research studies have included only 1 single 24HR per person, owing to logistical challenges or limited resources (25, 28). Therefore, the SIMPLE-1D macro was developed as an extension to the SIMPLE macro and can be used to perform the same types of descriptive and advanced analyses on these “single-day” data sets. Technically, just as the SIMPLE macro leverages the ability to manipulate the input to DISTRIb by replacing the MIXTRAN with the TRAN1 macro, the SIMPLE-1D macro leverages the ability to manipulate the input to DISTRIb by replacing the MIXTRAN with the TRAN1 macro, which uses external data on the ratio of within- and between-person variance (22).

**Application of the SIMPLE macros for advanced analyses and modeling**

In the following paragraphs, we explain how the SIMPLE macro modifies the NCI macros to perform dietary analysis and modeling beyond the estimation of usual intake distributions. The SIMPLE macro leverages the ability to manipulate the simulated data set produced by DISTRIb to easily perform some advanced analyses. The SIMPLE macro expands on this technique by including additional variables that add specified amounts to the simulated usual intakes themselves. This option is intended to account for sources of usual nutrient intake not routinely captured by 24HRs, such as dietary supplements and breast milk, which are often quantified via longer-term assessments (29, 30). For dietary supplements in particular, these values may cluster around a small number of dosages that are extremely high compared with the continuous distribution of usual intakes from food sources. For example, iron supplements commonly provide 30 mg Fe/d, which is likely to be substantially higher than usual food iron intake. In the United States, >50% of the adult population regularly consumes dietary supplements, and dietary supplements substantially contribute to total nutrient intake (31, 32). Thus, when evaluating the prevalence of inadequate or excessive intake, estimating usual nutrient intake from food sources only provides an incomplete picture of dietary patterns (29). Similarly, for infants and young children, breast milk is an important source of nutrients. Whereas individual-level data on usual breast milk intake and nutrient composition are rarely available, published estimates can be used to approximate the contribution of breast milk to total nutrient intake. To capture nutrient intake from dietary supplements (reported or hypothetical) or breast milk intake, the SIMPLE macro adopts the “shrink-then-add” (30) approach to estimate distributions of usual intake from multiple data sources with different temporal scopes. The macro can use either individual-level data (e.g., from a dietary supplement questionnaire or data on an individual child’s breast milk intake measured using isotope dilution) or group-level data (e.g., estimated average nutrient intake from breast milk across age groups or geographic strata). The latter case is also relevant for simulating the effects of national dietary supplement distribution programs, where a fixed dosage of a dietary supplement is proposed (e.g., 30 mg/d of iron supplements for pregnant women) (33) and
coverage of dietary supplements is hypothesized or estimated from external data sources (14, 15, 25).

Like supplementation, fortification of staple foods, condiments, or other products can be an effective means to reduce micronutrient deficiency. Modeling is useful to assess the likely impact of such a strategy before investing in a national program (14, 15, 25). Because fortification involves changes to the nutrient content of foods which are captured by a 24HR, it is appropriate to modify 24HR observations to reflect hypothetical fortification before applying the NCI method (i.e., the “add-then-shrink” method) (30). This modeling can be accomplished by adjusting the food composition table value for the hypothetical fortified product, or in the 24HR database by multiplying the amount of fortifiable food consumption by the fortification level and adding this to the total nutrient intake calculated without fortification.

In all, the extended advanced modeling capabilities of the SIMPLE macro allow evaluation of the effects of proposed combinations of fortification and supplementation programs on inadequate or excessive nutrient intake. Researchers and policy advocates can use this information to answer questions relevant to program or policy design, such as comparing the effectiveness and safety of alternative fortification scenarios or supplement distribution strategies.

Results

In this section, we present 4 example analyses for the purpose of illustrating the potential applications of the SIMPLE macro. The code, sample data, and a detailed user guide are available online (Open Science Framework: https://osf.io/ytd34/). Users can download additional results from all the examples online (https://osf.io/8ygh3/download). The first example uses data from adult women in the NHANES 2011–2014 (19) to perform a descriptive analysis of usual calcium intake from food sources alone and from the combination of food sources and dietary supplements. The second example uses the same data from the NHANES to estimate inadequate iron intake using the full probability method among children and adolescents 9–18 y old with the SIMPLE-Iron macro. The third example uses data from the CNMS (20) to model the effects of hypothetical vitamin A fortification and supplementation programs among preschool children, accounting for the contribution of breast milk intake to vitamin A intake. The fourth uses the first 24HR per person from the CNMS and implements the same analyses as the third example, to illustrate use of the SIMPLE-1D macro. We strongly recommend that users thoroughly review the NCI measurement error webinar series (34) and the measurement error webpage (35) that explains the theory underpinning the SIMPLE macro. We also recommend that users personally work through the provided examples to gain practical experience before applying the SIMPLE macro to their own studies.

Example 1: Descriptive analysis using the EAR cut-point method and data from NHANES 2011–2014

This example uses data on women 19 y of age and older from NHANES 2011–2014 (19). In this population, individual women have different corresponding EAR and UL values owing to their physiological status, such as pregnancy or lactation. In this example, we applied the SIMPLE macro to estimate 1) the distribution of usual calcium intake from food sources and the proportions of the population with inadequate and excessive usual intakes using a single cutoff for all individuals; 2) the distribution of usual calcium intake and prevalence of inadequate and excessive intakes from food sources using individual-specific EAR and UL cutoffs (i.e., applying appropriate cutoffs to account for the age of each individual in the data set); and 3) the distribution of usual calcium intake and prevalence of inadequate and excessive intakes from dietary supplements using individual-specific EAR and UL cutoffs (i.e., applying appropriate cutoffs to account for the age of each individual in the data set).
Table 2: Usual iron intake estimated by the IMAPP software and the UCD/NCI SIMPLE macro among children and adolescents 9–18 y of age by sex and age using data from the NHANES 2011–2014.

| Subgroup | IMAPP Inadequate intake, % | IMAPP Mean, mg/d | IMAPP 25th percentile, mg/d | IMAPP 50th percentile (median), mg/d | IMAPP 75th percentile, mg/d | SIMPLE Inadequate intake, % | SIMPLE Mean, mg/d | SIMPLE 25th percentile, mg/d | SIMPLE 50th percentile (median), mg/d | SIMPLE 75th percentile, mg/d |
|----------|--------------------------|------------------|-----------------------------|--------------------------------------|-----------------------------|--------------------------|------------------|-----------------------------|--------------------------------------|-----------------------------|
| Female (9–13 y) | 1.2 | 0.6 (0, 2.4) | 13.0 | 13.1 (12.1, 14.0) | 10.7 (10.1, 11.3) | 10.8 (9.7, 11.8) | 12.8 (12.3, 13.3) | 12.8 (12.0, 13.5) | 15.2 (14.5, 15.9) | 15.0 (13.2, 16.9) |
| Female (14–18 y) | 14.5 | 15.2 (12.4, 18.0) | 12.3 | 12.3 (11.8, 12.8) | 9.8 (9.3, 10.3) | 9.8 (9.3, 10.3) | 11.9 (11.4, 12.4) | 11.9 (11.4, 12.4) | 14.3 (13.6, 15.3) | 14.5 (13.0, 15.3) |
| Male (9–13 y) | 0.0 | 0.0 (0, 0.1) | 15.8 | 15.9 (14.5, 17.3) | 13.4 (12.8, 14.0) | 13.6 (12.2, 15.0) | 15.5 (14.3, 16.1) | 15.6 (14.0, 17.0) | 18.0 (17.2, 18.8) | 17.3 (16.0, 19.9) |
| Male (14–18 y) | 4.6 | 2.7 (0.5, 5.5) | 19.0 | 18.9 (17.5, 20.3) | 13.8 (13.0, 14.8) | 13.6 (12.1, 15.0) | 17.6 (16.8, 18.4) | 17.7 (16.3, 19.0) | 22.6 (21.2, 24.0) | 22.3 (21.1, 24.7) |

1Values generated from the SIMPLE macro are mean (95% CI). IMAPP only produces SEs for percentiles by default when estimating iron usual intake; therefore, we only present the CIs for percentiles. Estimates from IMAPP are within the CIs of the estimates from the SIMPLE macro. Usual iron intake was estimated based on the assumption of 18% iron absorption and mixed oral contraceptive use among females. The SIMPLE macro was applied in a way that is analogous to the way IMAPP functions (stratifying analyses of different age and sex groups, without applying any other covariates). NCI, National Cancer Institute; NHANES, National Health and Nutrition Examination Survey; SIMPLE, Simulating Intake of Micronutrients for Policy Learning and Engagement; UCD, University of California, Davis.
| Race                        | n     | Inadequate intake, % | Excessive intake, % | Total nutrient intake, mg/d | Nutrient intake from supplements, mg/d | 25th percentile of total nutrient intake, mg/d | 50th percentile (median) of total nutrient intake, mg/d | 75th percentile of total nutrient intake, mg/d |
|-----------------------------|-------|----------------------|---------------------|----------------------------|----------------------------------------|-----------------------------------------------|------------------------------------------------|------------------------------------------------|
| Calcium intake from food using single EAR (800 mg/d) and UL (2500 mg/d) |       |                      |                     |                            |                                        |                                               |                                                |                                                |
| Overall                     | 4110  | 45.8 ± 1.5           | 0.0 ± 0.0           | 862 ± 12                   | 0.0 ± 0                            | 656 ± 10                          | 830 ± 11                                       | 1033 ± 16                                     |
| Mexican American            | 442   | 36.6 ± 2.9           | 0.0 ± 0.0           | 927 ± 20                   | 0.0 ± 0                            | 714 ± 22                          | 895 ± 20                                      | 1103 ± 22                                     |
| Other Hispanic              | 397   | 50.8 ± 3.6           | 0.0 ± 0.0           | 824 ± 24                   | 0.0 ± 0                            | 629 ± 22                          | 795 ± 24                                      | 984 ± 27                                      |
| Non-Hispanic white          | 1659  | 41.1 ± 1.9           | 0.0 ± 0.0           | 894 ± 15                   | 0.0 ± 0                            | 688 ± 12                          | 861 ± 14                                      | 1064 ± 20                                     |
| Non-Hispanic black          | 1024  | 63.6 ± 2.0           | 0.0 ± 0.0           | 742 ± 13                   | 0.0 ± 0                            | 562 ± 13                          | 712 ± 13                                      | 891 ± 15                                      |
| Non-Hispanic Asian          | 471   | 62.9 ± 3.3           | 0.0 ± 0.0           | 747 ± 21                   | 0.0 ± 0                            | 563 ± 19                          | 715 ± 21                                      | 895 ± 25                                      |
| Other race—including multiracial | 117   | 62.4 ± 7.8           | 0.0 ± 0.0           | 751 ± 52                   | 0.0 ± 0                            | 565 ± 45                          | 718 ± 51                                      | 904 ± 60                                      |
| Calcium intake from food using individual-specific EARs and ULs |       |                      |                     |                            |                                        |                                               |                                                |                                                |
| Overall                     | 4110  | 57.1 ± 1.4           | 0.0 ± 0.0           | 862 ± 12                   | 0.0 ± 0                            | 656 ± 10                          | 830 ± 11                                       | 1033 ± 16                                     |
| Mexican American            | 442   | 42.5 ± 2.6           | 0.0 ± 0.0           | 927 ± 20                   | 0.0 ± 0                            | 714 ± 22                          | 895 ± 20                                      | 1103 ± 22                                     |
| Other Hispanic              | 397   | 59.8 ± 2.8           | 0.0 ± 0.0           | 824 ± 24                   | 0.0 ± 0                            | 629 ± 22                          | 795 ± 24                                      | 984 ± 27                                      |
| Non-Hispanic white          | 1659  | 54.4 ± 1.8           | 0.1 ± 0.0           | 894 ± 15                   | 0.0 ± 0                            | 688 ± 12                          | 861 ± 14                                      | 1064 ± 20                                     |
| Non-Hispanic black          | 1024  | 71.5 ± 1.8           | 0.0 ± 0.0           | 742 ± 13                   | 0.0 ± 0                            | 562 ± 13                          | 712 ± 13                                      | 891 ± 15                                      |
| Non-Hispanic Asian          | 471   | 70.7 ± 2.9           | 0.0 ± 0.0           | 747 ± 21                   | 0.0 ± 0                            | 563 ± 19                          | 715 ± 21                                      | 895 ± 25                                      |
| Other race—including multiracial | 117   | 68.2 ± 7.8           | 0.0 ± 0.0           | 751 ± 52                   | 0.0 ± 0                            | 565 ± 45                          | 718 ± 51                                      | 904 ± 60                                      |
| Calcium intake from food and supplements using individual-specific EARs and ULs |       |                      |                     |                            |                                        |                                               |                                                |                                                |
| Overall                     | 4110  | 40.1 ± 1.2           | 4.2 ± 0.4           | 1017 ± 14                   | 209 ± 1                            | 733 ± 11                          | 973 ± 13                                       | 1301 ± 21                                     |
| Mexican American            | 442   | 36.3 ± 2.5           | 1.0 ± 0.3           | 1017 ± 24                   | 90 ± 1                             | 755 ± 22                          | 962 ± 22                                      | 1217 ± 29                                     |
| Other Hispanic              | 397   | 49.1 ± 2.8           | 2.5 ± 0.9           | 953 ± 34                   | 129 ± 2                            | 688 ± 22                          | 865 ± 26                                      | 1123 ± 39                                     |
| Non-Hispanic white          | 1659  | 34.7 ± 1.4           | 5.5 ± 0.6           | 1146 ± 18                   | 252 ± 1                            | 790 ± 13                          | 1045 ± 17                                     | 1392 ± 27                                     |
| Non-Hispanic black          | 1024  | 60.1 ± 2.0           | 1.1 ± 0.2           | 851 ± 17                   | 109 ± 1                            | 597 ± 14                          | 779 ± 15                                      | 1019 ± 21                                     |
| Non-Hispanic Asian          | 471   | 48.9 ± 2.8           | 2.5 ± 0.7           | 960 ± 26                   | 215 ± 2                            | 638 ± 21                          | 859 ± 28                                      | 1180 ± 35                                     |
| Other race—including multiracial | 117   | 55.6 ± 8.0           | 2.6 ± 1.3           | 901 ± 70                   | 149 ± 4                            | 602 ± 51                          | 794 ± 63                                      | 1095 ± 84                                     |

1Values are mean ± SE. Individual-specific EARs refers to EAR = 800 mg/d for women aged ≤50 y and EAR = 1000 mg/d for women aged >50 y; individual-specific ULs refers to UL = 2500 mg/d for women aged ≤50 y and UL = 2000 mg/d for women aged >50 y. Table reformatted from the output of the SIMPLE macro. EAR, Estimated Average Requirement; NCI, National Cancer Institute; NHANES, National Health and Nutrition Examination Survey; SIMPLE, Simulating Intake of Micronutrients for Policy Learning and Engagement; UCD, University of California, Davis; UL, Tolerable Upper Intake Level.
TABLE 4 Usual iron intake from food and/or supplements in children and adolescents 9–18 y of age and older by sex using data from the NHANES 2011–2014, estimated using the UCD/NCI SIMPLE macro

| Sex   | Inadequate intake, % | Total nutrient intake, mg/d | Nutrient intake from supplements, mg/d | 25th percentile of total nutrient intake, mg/d | 50th percentile (median) of total nutrient intake, mg/d | 75th percentile of total nutrient intake, mg/d |
|-------|---------------------|----------------------------|---------------------------------------|-----------------------------------------------|-----------------------------------------------------|-----------------------------------------------|
| Overall | 4.0 ± 0.7          | 15.1 ± 0.3                 | 0.0 ± 0.0                             | 11.5 ± 0.2                                    | 14.6 ± 0.2                                           | 17.9 ± 0.5                                    |
| Male   | 0.9 ± 0.4          | 17.0 ± 0.4                 | 0.0 ± 0.0                             | 13.5 ± 0.2                                    | 16.4 ± 0.3                                           | 19.9 ± 0.7                                    |
| Female | 7.1 ± 1.1          | 13.2 ± 0.3                 | 0.0 ± 0.0                             | 10.3 ± 0.3                                    | 12.6 ± 0.2                                           | 15.5 ± 0.4                                    |

Iron intake from food and supplements using the full probability method

| Overall | 3.8 ± 0.7          | 16.1 ± 0.3                 | 1.0 ± 0.01                            | 11.7 ± 0.2                                    | 14.8 ± 0.2                                           | 18.8 ± 0.6                                    |
| Male    | 0.8 ± 0.4          | 17.9 ± 0.4                 | 0.9 ± 0.02                            | 13.6 ± 0.3                                    | 16.8 ± 0.3                                           | 20.7 ± 0.7                                    |
| Female  | 6.8 ± 1.1          | 14.3 ± 0.3                 | 1.2 ± 0.02                            | 10.4 ± 0.3                                    | 12.9 ± 0.2                                           | 16.1 ± 0.5                                    |

1Values are mean ± SE. Table reformatted from the output of the SIMPLE macro. NCI, National Cancer Institute; NHANES, National Health and Nutrition Examination Survey; SIMPLE, Simulating Intake of Micronutrients for Policy Learning and Engagement; UCD, University of California, Davis.

Example 4: Descriptive analysis and modeling of supplementation and fortification programs using the CNMS with only a single 24HR per person

To demonstrate application of the SIMPLE-1D macro, we used the same data set as the previous example (20) but retained only the first 24HR per person. The example includes all 4 scenarios of vitamin A analysis and modeling among children 1–5 y of age as shown in Example 3. For single-day dietary data, users cannot estimate the ratio of within- and between-person variance components internally (i.e., from the same data set), which they can when they analyze dietary data that include repeated recalls on the same person. Thus, an external variance ratio, defined as a ratio estimated from a similar population (from a different study), is often used (22, 36). In this example, we used the ratio of within- and between-person variance components of vitamin A intake estimated from Example 3 (i.e., an internal variance components ratio from the same data set) and, therefore, our results for Example 4 are similar to those of Example 3 (Table 5). However, if the assumed external variance ratio deviates from the true variance ratio, the resulting usual intake estimates can be biased (22, 36); therefore, users should be cautious when applying an external variance ratio to their single-day dietary data and should always conduct sensitivity analyses with a range of external ratios.

Discussion

The UCD/NCI SIMPLE macro provides a streamlined structure for 24HR analysis that builds on the existing core NCI macros for estimating usual or long-term dietary intakes from multiple 24HRS. As for other similar dietary analysis tools, users need to understand the theoretical basis for analysis of 24HR data and have familiarity with basic computer code. With this background, the new, freely available tool simplifies both basic descriptive analyses and complex analyses of 24HR data, including accounting for supplement and breast milk intake, and modeling the impact of hypothetical fortification or supplementation programs, and their combinations. Extensions of the tool permit analyses of special cases when the full probability method is required to assess dietary adequacy, and when only a single day of dietary data is available for each person. With these in place, the tool allows “shortcuts” in programming capacity that can dramatically shorten the time from data cleaning to presentation of a final results table.

To strengthen data and information systems for nutrition and provide timely information for policy decision making, the Global Nutrition Report in 2017 proposed the concept of the “nutrition data value chain,” which has 5 critical processes—data prioritization, creation and collection, curation, analysis, and interpretation/recommendation—before the final step, decision making (16, 37). To date, enormous effort has been spent overcoming the early challenges in this chain: dietary data collection and curation. Open-source and standardized dietary data collection tools, such as ASA24 (38) and Intake24 (39), have been developed, validated, and used in multiple national surveys and research studies. For low-income countries, standardized data collection methods were proposed >2 decades ago (40). More recently, mobile- or tablet-based dietary data collection tools have been independently developed by nutrition researchers, such as the mobile application– and web-based dietary database by the International Dietary Data Expansion (INDEX) (3) and the mobile-based, open-source dietary collection tool by Caswell et al. (41). In contrast, less progress has been achieved in streamlining the analysis of detailed dietary intake data, such as those collected using 24HR methods (17). Although technical guidelines exist for best practices in analysis of usual nutrient intake (34, 42), 24HR analysis still relies primarily on certain statistical packages that require both a high level of proficiency in computer coding and a deep understanding of the theoretical bases of 24HR analysis (6, 8) or software that is accessible to new users but has more limited features (5, 7).

The SIMPLE macro is a multifunctional dietary software tool that can be applied to diverse global contexts to help fill the gap in the nutrition data value chain between data collection and interpretation for decision making. Because the SIMPLE macro has simplified procedures for data processing using the
TABLE 5  Vitamin A intake from food, breast milk, a simulated dietary supplementation program, and a simulated oil fortification program in children <5 y of age by zone using data from the Cameroon National Micronutrient Survey 2009, estimated using the UCD/NCI SIMPLE macro  

| Intake, by zone | n | Inadequate intake, % | Total nutrient intake, μg RAE/d | Nutrient intake from supplements, μg RAE/d | 25th percentile of total nutrient intake, μg RAE/d | 50th percentile (median) of total nutrient intake, μg RAE/d | 75th percentile of total nutrient intake, μg RAE/d |
|----------------|---|----------------------|-------------------------------|------------------------------------------|-----------------------------------------------|------------------------------------------------|-----------------------------------------------|
| Vitamin A intake from food | Overall | 872 | 64.2 ± 6.5 | 212 ± 7 | 0 ± 0 | 77 ± 7 | 157 ± 9 | 288 ± 9 |
| | South | 301 | 44.2 ± 11.7 | 290 ± 12 | 0 ± 0 | 141 ± 16 | 240 ± 15 | 385 ± 15 |
| | North | 295 | 92.7 ± 4.9 | 101 ± 5 | 0 ± 0 | 48 ± 5 | 80 ± 5 | 130 ± 6 |
| | Cities | 276 | 61.2 ± 8.1 | 214 ± 8 | 0 ± 0 | 95 ± 12 | 175 ± 12 | 292 ± 11 |
| Vitamin A intake from food and breast milk  
2 | Overall | 872 | 50.2 ± 2.2 | 254 ± 6 | 0 ± 0 | 119 ± 12 | 222 ± 11 | 329 ± 9 |
| | South | 301 | 33.9 ± 4.8 | 333 ± 11 | 0 ± 0 | 185 ± 22 | 289 ± 16 | 452 ± 23 |
| | North | 295 | 68.2 ± 2.2 | 161 ± 5 | 0 ± 0 | 81 ± 8 | 136 ± 7 | 251 ± 3 |
| | Cities | 276 | 56.1 ± 2.8 | 227 ± 7 | 0 ± 0 | 119 ± 17 | 197 ± 13 | 308 ± 11 |
| Vitamin A intake from food, breast milk, and a simulated dietary supplementation program  
3 | Overall | 872 | 11.8 ± 22 | 404 ± 6 | 150 ± 0 | 270 ± 11 | 373 ± 11 | 487 ± 8 |
| | South | 301 | 5.8 ± 1.7 | 482 ± 11 | 150 ± 0 | 335 ± 21 | 445 ± 16 | 605 ± 20 |
| | North | 295 | 18.8 ± 3.0 | 312 ± 5 | 150 ± 0 | 239 ± 8 | 290 ± 7 | 412 ± 5 |
| | Cities | 276 | 13.4 ± 2.2 | 378 ± 7 | 151 ± 0 | 269 ± 16 | 353 ± 13 | 485 ± 11 |
| Vitamin A intake from food, breast milk, a simulated dietary supplementation program, and a simulated oil fortification program  
4 | Overall | 872 | 6.1 ± 1.0 | 499 ± 8 | 150 ± 0 | 341 ± 14 | 462 ± 10 | 620 ± 12 |
| | South | 301 | 4.3 ± 1.0 | 541 ± 13 | 150 ± 0 | 374 ± 20 | 506 ± 15 | 691 ± 23 |
| | North | 295 | 7.8 ± 1.5 | 400 ± 8 | 150 ± 0 | 299 ± 12 | 396 ± 10 | 480 ± 8 |
| | Cities | 276 | 7.3 ± 0.7 | 563 ± 12 | 150 ± 0 | 384 ± 24 | 537 ± 17 | 726 ± 16 |

1 Values are mean ± SE. Table reformatted from the output of the SIMPLE macro. NCI, National Cancer Institute; RAE, retinol activity equivalent; SIMPLE, Simulating Intake of Micronutrients for Policy Learning and Engagement; UCD, University of California, Davis.

2 We assumed that breastfed children in the North, South, and Cities consumed 550.6, 232.2, and 473.2 μg RAE/d of vitamin A from breast milk, respectively. The regional variation in vitamin A intake from breast milk reflects differing estimates of breast-milk vitamin A concentrations by region.

3 The simulated dietary supplementation program was assumed to deliver a daily dose of 167 μg retinol to a random sample of 90% of the target population.

4 The simulated oil fortification program was assumed to fortify all industrially refined cooking oil with 12 μg retinol/g of oil.

core NCI method as well as the ability to automatically output a spreadsheet containing the information typically requested on usual intake (e.g., mean, median, inadequate or excessive intake), timely reporting of results can be achieved more easily. It is important to note that, because the SIMPLE macro uses the existing NCI macros, the SIMPLE macro does not shorten the computation time. Instead, the SIMPLE macro reduces the time spent on 1) learning the in-depth theory of advanced dietary analysis and the NCI approach in particular, to allow appropriate manipulation of the NCI macros; and 2) creating the code to modify several NCI macros and the output data sets for each NCI macro. Using the existing NCI macros for descriptive analyses requires implementing a minimum of 6 steps to apply the MIXTRAN, DISTRIB, and NCI_BGR_PVALUE_CI macros, and additional steps may be required to conduct any advanced modeling work. In contrast, the SIMPLE macro serves as an “all-in-one” macro “shell” that can be used to carry out a wide range of analyses in a single step. The capability to model nutrition intervention programs, such as food fortification programs, is important to assess the likely impacts of such programs on dietary adequacy or excess; this information is useful both when generated in advance to guide the planning process, and after programs are in place, to guide later program management decisions. In the United States, scientists and policymakers rely heavily on the scientific evidence generated from analyzing NHANES to develop the Dietary Guidelines for Americans. Our extensive testing demonstrates that the SIMPLE macro can be successfully applied to NHANES data, so researchers could use the SIMPLE macro to explore new research questions or to make the results of the latest cycles of NHANES available in a speedy manner. In addition, there is an increasing push to improve research capacity at institutions in low- and middle-income countries. The SIMPLE macro can facilitate these efforts by providing a user-friendly platform for researchers to conduct advanced dietary analysis and modeling, as well as report relevant findings to local governments and the international community, with substantial reductions in the time and cost required to do so.

The SIMPLE macro also has several limitations. First, the SIMPLE macro was developed to analyze “nearly-daily” consumed dietary components. The tool was designed to estimate population distributions of usual intake and does not incorporate the NCI method’s approach to predict the relation between usual dietary intake and health outcomes (e.g., the relation between whole wheat consumption and cardiovascular health). Second, the tool cannot analyze dietary components that are episodically consumed by a population (e.g., whole wheat products in the United States, or preformed retinol in some populations with very low animal-sourced food consumption). Third, the SIMPLE macro can only generate unbiased results when the dietary data are of high quality and represent the population’s dietary intake. It cannot correct for errors in data collection or misreporting, such as extreme or unreasonable values of food or nutrient intake, that can exist in 24HR data. Careful data cleaning and mobile- or tablet-based dietary data collection applications that have the built-in feature of automatically cleaning the dietary data (e.g., range
FIGURE 3  Distribution of vitamin A intake (μg RAE/d) from food, breast milk, simulated supplementation program and oil fortification program among children 1 to 5 years of age from the Cameroon National Micronutrient Survey 2009, estimated using the UCD/NCI SIMPLE macro. NCI, National Cancer Institute; RAE, Retinol Activity Equivalent; UCD, University of California, Davis. We assumed that breastfed children in the North, South, and Cities consumed 550.6, 232.2, and 473.2 μg RAE/d of vitamin A from breast milk. The regional variation in vitamin A intake from the breast milk are due to varying vitamin A concentrations in mothers’ breast milk by region. The simulated dietary supplementation program was assumed to deliver a daily dose of 167 μg retinol to a random sample of 90% of the target population. The simulated oil fortification program was assumed to fortify all industrially refined cooking oil with 12 μg retinol/g of oil.

checks on portion sizes to avoid entering improbable values), in addition to rigorous, standardized training of interviewers, may help to minimize misreporting of dietary intake. Fourth, the SIMPLE macro has specific technical requirements. Users need to have both SAS (SAS Institute) and Microsoft Excel installed. As the non-academic-based SAS license is expensive, resource-constrained analysts or those who are not affiliated with an academic institution may need to partner with universities to carry out dietary analysis with this tool. In addition, users are required to have basic SAS programming skills, which requires time and access to appropriate training materials. These user requirements may block the usage of the SIMPLE macro from a wider audience. In the future, we aim to improve the use of the SIMPLE macro and address these limitations. To facilitate use of the current macro version, we have designed training materials to enhance the usage of the SIMPLE macro and build the capacity of researchers and policy analysts (training materials are available upon request). Plans to expand the current SIMPLE macro tool include the addition of new functionalities, such as analysis of episodically consumed nutrients and foods. In the longer term, we envision development of a web-based tool based on the SIMPLE macro to further increase the accessibility of the method and decrease the time and resources required to make dietary data results available.

In conclusion, although the value of dietary analysis for nutrition research and program planning is widely recognized (3), such data may be underutilized owing to the complexity of appropriate statistical analyses and the corresponding capacity needs. By providing a more user-friendly structure around the existing core NCI macros, the SIMPLE macro streamlines basic descriptive analyses of 24HR data while also providing extra functionality to enable more complex analyses. Specifically, the tool permits users to estimate the observed contributions of supplements or breast milk to usual nutrient intakes and model the effects of hypothetical nutrition intervention programs, such as supplementation or food fortification. Variations of the tool help to overcome other technical challenges, such as applying the full probability method to estimate inadequate iron intake and estimating usual intake distributions with only a single day of data per person. The SIMPLE macro has the potential to make analysis of 24HR data more accessible by reducing the time and resources needed to conduct high-quality dietary analyses, facilitating the availability of dietary intake data for research and to inform nutrition policies and programs.

Acknowledgments
We appreciate the comprehensive review from Dr. Bess Caswell on the SIMPLE macro sample code and manual. We also appreciate comments from Stephen Vosti, Caitlin French, Demewoz Woldegebreal, Justin Kagin, Katherine Adams, and Kenneth Brown from the MINIMOD project (UC Davis); Christine Stewart (UC Davis Institute for Global Nutrition and Department of Nutrition); Tibebu Moges and Biniyam Tesdaye (Ethiopian Public Health Institute); and Mengxi Du and Fang Fang Zhang (Tufts University). We gratefully acknowledge Martin Nankap (UNICEF, Cameroon); Alex Njdebayi, Jules Martial Guintang Assiene, and Ismael Teta (HKI, Cameroon); and Georges Okala, Japhet Tata, and Christian Bela (Ministry of Public Health, Cameroon) for contributions to collection and interpretation of the data used in the CNMS example. The authors’ responsibilities were as follows—HL and KWD: developed the method and wrote the paper; CDA: provided editing and statistical support; RE-S: provided overall guidance on the project; and all authors: contributed to the model design and interpretation of the data, critically revised the manuscript, and read and approved the final manuscript.
References

1. Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. Lancet 2020;395:65–74.

2. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, Mullany EC, Abate KH, Abafati C, Abebe Z, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 2019;393:1958–72.

3. Coates J, Colaezei B, Bell W, Charrondiere U, Leclercq C. Overcoming dietary assessment challenges in low-income countries: technological solutions proposed by the International Dietary Data Expansion (IDDEX) Project. Nutrients 2017;9:289.

4. Nusser SM, Carriquiry AL, Dodd KW, Fuller WA. A semiparametric transformation approach to estimating usual daily intake distributions. J Am Statist Assoc 1996;91:1440–9.

5. Iowa State University. Software for intake distribution estimation [Internet]. Ames (IA): Iowa State University of Science and Technology; 2003. [Cited 2020 Oct 27]. Available from: http://www.side.stat.iastate.edu/pc-side.php.

6. Dekkers AL, Verkaik-Kloosterman J, van Rossum CT, Ocké MC. STAPE, a new statistical program to estimate habitual dietary intake from multiple food sources and dietary supplements. J Nutr 2014;144:2083–91.

7. Harttig U, Haubrock J, Knippel S, Boeing H. The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. Eur J Clin Nutr 2011;65:857–81.

8. Tooze JA, Kipnis V, Buckman DW, Carroll RJ, Freedman LS, Guenther PM, Krebs-Smith SM, Subar AF, Dowswell T. A new statistical model approach for estimating the distribution of usual intake of nutrients: the NCI method. Statist Med 2010;29:2857–68.

9. Hamner HC, Tinker SC. Fortification of corn masa flour with folic acid in the United States: an overview of the evidence. Ann N Y Acad Sci 2014;1312:8–14.

10. Hamner HC, Mullinare J, Cogswell ME, Flores AL, Boyle CA, Carriquiry AL, Dodd KW, Uauy R. Effects of iron fortification on the prevention of neural tube defects: modeled impact of corn masa flour fortification. Birth Defects Res A Clin Mol Teratol 2013;97:649–57.

11. Haile D, Luo H, Vosti SA, Dodd KW, Arnold CD, Engle-Stone R. Micronutrient fortification of commercially available biscuits is predicted to have minimal impact on prevalence of inadequate iron intake for young children: options for Cameroon. Ann N Y Acad Sci 2020;1465:161–80.

12. Tinker SC, Devine O, Mai C, Hamner HC, Reefhuis J, Gilboa SM, Wang C-Y, Carriquiry AL, Devine O. Predicted contribution of folic acid fortification of corn masa flour to the usual folic acid intake for the US population: National Health and Nutrition Examination Survey 2001–2004. J Am Clin Nutr 2009;89:305–15.

13. Hauser HC, Tinker SC, Berry RJ, Mullinare J. Modeling fortification of corn masa flour with folic acid: the potential impact on exceeding the tolerable upper intake level for folic acid, NHANES 2001–2008. Food Nutr Res 2013;57:19146.

14. Tinker SC, Devine O, Mai C, Hamner HC, Reethuis J, Gilboa SM, Dowling NF, Holm MA. Estimate of the potential impact of folic acid fortification of corn masa flour to the prevention of neural tube defects: modeled impact of corn masa flour fortification. Birth Defects Res A Clin Mol Teratol 2013;97:649–57.

15. Haile D, Luo H, Vosti SA, Dodd KW, Arnold CD, Engle-Stone R. Micronutrient fortification of commercially available biscuits is predicted to have minimal impact on prevalence of inadequate micronutrient intakes: modeling of national dietary data from Cameroon. Curr Dev Nutr 2020;4:nzaa132.

16. Engle-Stone R, Ndjebayi AO, Nankap M, Brown KH. Consumption of potentially fortifiable foods by women and young children varies by ecological zone and socio-economic status in Cameroon. J Nutr 2012;142:553–65.

17. National Cancer Institute (NCI). Single regularly-consumed or episodically-consumed food or nutrient [Internet]. Bethesda (MD): NCI Division of Cancer Prevention; 2019. [Cited 2020 Oct 27]. Available from: https://prevention.cancer.gov/research-groups/biometry/measure-ment-error-impact/software-measurement-error/single-regularly-consumer-0.

18. Luo H, Dodd KW, Arnold CD, Engle-Stone R. A new statistical method for estimating usual intakes of nearly-daily consumed foods and nutrients through use of only one 24-hour dietary recall. J Nutr 2019;149:1667–73.

19. National Center for Health Statistics (US), editor. Estimating usual dietary intake from National Health and Nutrition Examination Survey data using the National Cancer Institute method. Hyattsville (MD): US Department of Health and Human Services, CDC, National Center for Health Statistics; 2018.

20. Du M, Luo H, Blumberg JB, Rogers G, Chen F, Ruan M, Shan Z, Biever E, Zhang FF. Dietary supplement use among adult cancer survivors in the United States. J Nutr 2020;150:1499–508.

21. Vosti S, Engle-Stone R, Waldegebreul D, Luo H, Asfaw E, Kagin J, Moses T, Tesfaye B. Estimated effectiveness and cost-effectiveness of a fortified edible oils program in Ethiopia. Curr Dev Nutr 2020;4:1735.

22. Ethiopian Public Health Institute. Ethiopian National Food Consumption Survey. Addis Ababa (Ethiopia): Ethiopian Public Health Institute; 2013.

23. Institute of Medicine (US) Subcommittee on Interpretation and Uses of Dietary Reference Intakes, Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Using the Estimated Average Requirement for nutrient assessment of groups. In: DRI Dietary Reference Intakes: applications in dietary assessment [Internet]. Washington (DC): National Academies Press (US); 2000. p. 73–105. [Cited 2020 Oct 27]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK222898/.

24. Rivera JA, Pedraza LS, Aburto NC, Batis C, Sánchez-Pimenta TG, González de Cosío T, Lónez-Olmedo N, Pedrosa-Tobias A. Overview of the dietary intakes of the Mexican population: results from the National Health and Nutrition Survey 2012. J Nutr 2016;146:1851S–5S.

25. Bailey RL, Dodd KW, Luo H, Vosti SA, Arnold CD, Engle-Stone R. Estimated effectiveness and cost-effectiveness of the NCI method for estimating usual intakes of nearly-daily consumed foods and nutrients episodically-consumed food or nutrient [Internet]. Bethesda (MD): NCI Division of Cancer Prevention; 2019. [Cited 2020 Oct 27]. Available from: https://prevention.cancer.gov/research-groups/biometry/measure-ment-error-impact/software-measurement-error/single-regularly-consumer-0.

26. Bailey RL, Gahche JJ, Dwyer JT, Cook AD, Jun S, Eicher-Miller HA, Guenther PM, Bhadra A, Thomas PR, et al. Best practices for dietary supplement assessment and estimation of total usual nutrient intakes in population-level research and monitoring. J Nutr 2019;149:181–97.

27. Garriguet D. Combining nutrient intake from food/beverages and dietary supplements. Health Rep 2010;21:8–94.

28. Bailey RL, Gahche JJ, Lentinu CV, Dwyer JT, Engell JS, Thomas PR, Betz JM, Sempos CT, Picciano MF. Dietary supplement use in the United States, 2003–2006. J Nutr 2011;141:261–6.

29. Kennedy ET, Luo H, Houser FR. Dietary supplement use pattern of U.S. adult population in the 2007–2008 National Health and Nutrition Examination Survey (NHANES). Ecol Food Nutr 2013;52:76–84.

30. Peña-Rosas JP, De-Regil LM, García-Casal MN, Dowswell T. Daily oral iron supplementation during pregnancy. Cochrane Database Syst Rev 2015;(7):CD004736.

31. Bailey RL, Gahche JJ, Lentinu CV, Dwyer JT, Engell JS, Thomas PR, Betz JM, Sempos CT, Picciano MF. Dietary supplement use in the United States, 2003–2006. J Nutr 2011;141:261–6.

32. NCHS. NHANES—National Health and Nutrition Examination Survey homepage [Internet]. Hyattsville (MD): NCHS; 2020. [Cited 2020 Sep 24]. Available from: https://www.cdc.gov/nchs/nhanes/index.htm.

33. Peña-Rosas JP, De-Regil LM, García-Casal MN, Dowswell T. Daily oral iron supplementation during pregnancy. Cochrane Database Syst Rev 2015;(7):CD004736.

34. Epidemiology and Genomics Research Program (EGRP)/Division of Cancer Control & Population Sciences (DCPPS)/National Cancer Institute (NCI)/NIH. Measurement error webinar series [Internet]. Bethesda (MD): EGRP/DCCPS/NCI/NIH; 2020. [Cited 2020 Oct 27]. Available from: https://prevention.cancer.gov/research-groups/biometry/measure-ment-error-impact/software-measurement-error/single-regularly-consumer-0.

35. National Cancer Institute. Measurement error: impact on nutrition research and adjustment for its effects [Internet]. Bethesda (MD): Division of Cancer Prevention; 2019. [Cited 2020 Oct 27]. Available from: https://prevention.cancer.gov/research-groups/biometry/measure-ment-error-impact.

36. French CD, Arsenault JE, Arnold CD, Haile D, Luo H, Dodd KW, Vosti SA, Slusky CM, Engle-Stone R, The Variance Components of

Downloaded from https://academic.oup.com/jn/article/110/3/1649/616503 by guest on 10 April 2021
Nutrient Intakes Data Working Group. Within-person variation in nutrient intakes across populations and settings: implications for the use of external estimates in modeling usual nutrient intake distributions. Adv Nutr 2020;11:144.

37. Piwoz E, Rawat R, Fracassi P, Kim D. Strengthening the nutrition data value chain for accountability and action: progress, gaps and next steps. Sight Life 2019;33:38–43.

38. Epidemiology and Genomics Research Program (EGRP)/Division of Cancer Control & Population Sciences (DCCPS)/National Cancer Institute (NCI)/NIH. ASA24® dietary assessment tool [Internet]. Bethesda (MD): EGRP/DCCPS/NCI/NIH; 2020. [Cited 2020 Oct 27]. Available from: https://epi.grants.cancer.gov/asa24/.

39. Simpson E, Bradley J, Poliakov I, Jackson D, Olivier P, Adamson A, Foster E. Iterative development of an online dietary recall tool: INTAKE24. Nutrients 2017;9:118.

40. Gibson RS, Ferguson E. An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries [Internet]. Washington (DC): HarvestPlus; 2008. [Cited 2020 Oct 27]. Available from: https://assets.publishing.service.gov.uk/media/57a08bac40f0b64974000cd6/tech08.pdf.

41. Caswell B, Arnold C, Davis J, Miller J, Engle-Stone R, Maleta K, Stewart C. OpenDRS: an open-source 24-hour recall for mobile devices (P13-004-19). Curr Dev Nutr 2019;3:nzz036.P13–004-19.

42. Tooze JA. Estimating usual intakes from dietary surveys: methodologic challenges, analysis approaches, and recommendations for low- and middle-income countries [Internet]. Washington (DC): Intake—Center for Dietary Assessment/FHI Solutions; 2020. [Cited 2020 Oct 27]. Available from: https://www.intake.org/sites/default/files/2020-01/Intake-Episodic-Foods-Tooze-Jan2020.pdf.

43. Slavin JL. The challenges of nutrition policymaking. Nutr J 2015;14:15.