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IZiNCG TECHNICAL BRIEF

Tools to assess dietary zinc intake in populations

Introduction

Assessment of dietary zinc intake is the best method for estimating zinc exposure in individuals and populations (1). Nevertheless, data on dietary zinc intake from lower income countries is limited, due to a variety of difficulties associated with the collection and analysis of dietary data. This has led to the development of several tools to facilitate the collection and analysis process, improve the reliability and validity of dietary data, and increase access to dietary data. Use of these tools will enhance the accuracy in which at-risk subgroups in the population can be targeted for appropriate intervention programs or vulnerable individuals identified for dietary counseling (1). This brief describes the tools and includes those available for collecting and processing dietary zinc intake data at the individual and population level, as well as those for designing, monitoring, and evaluating food-based interventions. All of these tools can also be used to assess intakes of macronutrients and other micronutrients.

Dietary zinc intake of individuals is estimated by using established quantitative methods such as food records (preferably weighed in low-income countries) or 24-hour recalls (**Purpose 1**). While one day of zinc intake is sufficient to estimate the mean intake of a population, several days of intake data are needed to describe the usual intake of an individual. The number of days required depends on the day-to-day variation of the food or nutrient of interest within one individual (i.e., intra-individual variation). However, to assess the prevalence of inadequate zinc intakes in the population (**Purpose 2**), a second day of intake data on at least a sub-set of individuals can be sufficient. Knowledge of quantitative zinc intakes is an important basis for the proper design and monitoring of zinc fortification programs (**Purpose 3**) and for the design and implementation of food-based dietary recommendations for specific population groups (**Purpose 4**).

Purpose 1: Estimating dietary zinc intake at the individual-level

Various programs exist to conduct interviewer- or self-administered 24-hour recalls, but most are country-specific with limited adaptability to other settings. This section describes a few of the current or forthcoming dietary assessment applications that can be used or adapted for use globally.

An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries

This manual contains guidelines and procedures for carrying out an interactive 24-hour recall method specifically for measuring and evaluating adequacy of iron and zinc intakes in lower income country populations. It was written by nutrition researchers Drs. Rosalind Gibson and Elaine Ferguson, and the original version was supported in part by US Agency for International Development and revised with support in part by HarvestPlus.

It is published as a technical monograph available at: http://bit.ly/hp24hrrecall.

The manual is written as a tool to guide users through the planning, design and conduct of the dietary survey, as well as the analysis and interpretation of the data. Detailed methods are described for estimating portion sizes and converting to weight equivalents, collecting and analyzing mixed dishes, compiling a local food composition table, and using algorithms for estimating intakes of bioavailable iron and zinc taking into account dietary modifiers that influence their absorption. The method has been validated against weighed food records (2). The manual is not linked to computer software to record or analyze the survey data, but provides detailed examples of calculations that can be used for generic data entry and statistical analysis software.

INDDEX24

INDDEX24 is a platform comprised of a mobile application to conduct interviewer-administered, multiple-pass 24-hour dietary recalls synchronized to a web application to manage context-specific input databases such as food lists, food composition tables, portion conversion factors, and standardized recipes. The platform is being developed and validated as part of the International Dietary Data Expansion (INDDEX) Project, which aims to increase the availability, access, and use of dietary and food consumption data globally (Coates et al, 2017). For additional information on INDDEX and forthcoming links to the INDDEX24 tool, refer to: http://bit.ly/INDDEX24.

The INDDEX24 application will use the multiple-pass method to guide respondents through the recall of foods and amounts consumed, including recipe ingredients. The INDDEX24 platform will allow output of reports of nutrient intakes, as well as raw data export files for use with statistical software packages.

CSDietary

CSDietary is a PC-based 24-hour recall data entry and analysis software program. It is used for processing 24-hour recalls collected by paper and pencil. It was developed by HarvestPlus and Servepro, and is currently available by contacting HarvestPlus (http://bit.ly/HarvestPlussite). CSDietary is currently undergoing revision and is expected to be available online in 2018.

CSDietary requires the user to create separate files for upload which contain study/country specific information on the food composition table of nutrient values, standard recipe data, unit conversion factors for portion size estimation aids, and nutrient retention factors. The program outputs the nutrient intakes at the individual level (e.g., total zinc intake for each day) or food item level (e.g., zinc intake from each food item). The food item level file can be further disaggregated to the ingredient level (e.g., zinc intake from beef as an ingredient in a mixed dish/recipe for beef curry).

ASA24

The Automated Self-Administered 24-Hour (ASA24) dietary assessment tool is a web-based tool for self-administered 24-hour recalls and food records. It was created by the U.S. National Cancer Institute and Westat. The ASA24 is designed for research studies and researchers must register their study to enable participants to access the tool. Versions are available for the US, Canada, and Australia (at: http://bit.ly/ASA24), and can be adapted to specific situations or countries with support from Westat.

ASA24 guides the respondent through an

automated multiple-pass method for 24-hour recalls, including detailed questions about the food form, preparation method, portion size, and additions to foods. Digital images assist respondents in reporting portion sizes. ASA24 has been shown to produce comparable results to interviewer-administered 24-hour recalls using the AMPM (Automated Multi-Pass Method), which was previously validated for energy intake using doubly-labeled water (3, 4). Analytic output files include daily total zinc intakes, zinc intakes from individual foods, and zinc intakes from supplements.

Purpose 2: Estimating usual zinc intake distributions and the prevalence of inadequacy in a population

Tools for this purpose are specialized software programs designed to estimate the proportion of the population at risk of inadequate zinc intakes by adjusting the distribution of observed intakes to usual zinc intakes. To meet this objective, input files that include daily total zinc intakes collected from 24-hour recalls or food records (preferably weighed), and more than one day of intake data from at least a sub-set of individuals are required. The dataset should contain at least 100 individuals per population subgroup to estimate the prevalence of inadequacy in a population. The minimum number of individuals with more than one day of intake data required to produce estimates is not clearly defined, but should probably be at least 40-50 individuals for each sub-population of interest (i.e. each life-stage group with a different zinc requirement). In general, these tools include five steps: i) preliminary data adjustments; ii) transformation of the data to generate normality; iii) estimating the mean usual intake on the transformed scale; iv) estimating the intra- and inter-individual variation and removing the intra-individual variation; v) and finally back-transforming the data to the original scale and producing the usual intake distribution. Once the usual intake distribution is established, the proportion of individuals with usual intakes in the distribution below the appropriate threshold (e.g, zinc EAR for age- and sex-specific subgroups and diet types) can be calculated. A review of the specific differences in the statistical modeling of the various programs are beyond the scope of this brief; however, the methods have been compared by simulation exercises elsewhere (5, 6). All methods provide good estimates of usual zinc intake distributions, but the NCI and MSN software also have the ability to estimate usual intake of episodically consumed foods and, therefore, could be useful for estimating usual intake food sources of zinc and total zinc intakes.

PC-SIDE/The ISU Method

PC-SIDE (PC Software for Intake Distribution Estimation) is a downloadable program developed by Iowa State University (ISU) and implements the ISU Method (7). It is available free at: http://bit.ly/ICU-PCside. PC-SIDE has been the most widely used software for estimating the prevalence of inadequate zinc intake since it has been available in earlier formats (CIDE and C-SIDE) for two decades. PC-SIDE can also analyze a dataset containing only one day of intake on all individuals by allowing the user to specify an external variance from a similar population. The program outputs the distribution of usual zinc intakes of a population or population subgroups, and the proportion of individuals with zinc intakes below or above a user-defined threshold.

The NCI Method

The NCI method is implemented using SAS software macros developed by the U.S.

National Cancer Institute (8). The three macros are available free at: http://bit.ly/NCImethod. The NCI method is based on the premise that usual intake is equal to the probability of consumption on a given day times the average amount consumed on a consumption day. The MIXTRAN and DISTRIB macros are used together to estimate the usual intake distribution of foods consumed episodically by fitting a two-part statistical model that estimates the probability of consuming a food and the consumption day amount of the food. The DISTRIB macro outputs the distribution of usual zinc intakes of a population or sub-population, and the proportion of individuals with zinc intakes below or above a user-defined threshold. The INDIVINT macro uses inputs from the MIXTRAN macro to calculate predicted values of individual intake using regression calibration for subsequent use in diet-disease models.

The Multiple Source Method (MSM)

The Multiple Source Method (MSM) is a web-based program developed by the Department of Epidemiology at the German Institute of Human Nutrition Potsdam Rehbrücke (9). It can be accessed at: http://bit.ly/multiplesourcemethod. MSM is based on a premise similar to the NCI method and also estimates the usual intake distribution of episodically consumed foods by combining estimates of probability of consumption and amounts. Both the NCI and MSM allow use of covariates that may influence intake, such as age and gender, and provide relevant regression model parameters for the covariates.

Purpose 3: Assess zinc intake in the context of fortification programs

The design of food fortification programs to address zinc deficiency should involve knowledge of foods consumed by the population and the gap between current dietary zinc intakes and requirements. This knowledge enables the identification of appropriate food vehicles, definition of the target amount of zinc fortificant, and estimation of the potential impact of the zinc-fortified food on the prevalence of dietary zinc inadequacy. Dietary intake data from 24-hour recalls or food records provides the most detailed information to conduct these assessments. Any of the tools described for Purpose 2 can be used to conduct simulations of expected impacts of zinc-fortified foods on dietary zinc adequacy, but would require that the manipulations of current zinc intakes to simulate the additional zinc from the fortified food be made outside of the tool. The IMAPP tool described in this section was explicitly designed to conduct the simulations for examining impacts of fortified foods on nutrient intake adequacy.

Fortification Rapid Assessment Tool (FRAT)

The FRAT is a questionnaire that combines a simplified 24-hour recall and food frequency questionnaire to provide information on consumption patterns of potential food vehicles for fortification and inform decisions about potential levels of zinc to add as a fortificant. The tool was developed by Healthbridge for Nutrition International and guidelines are available free at: http://bit.ly/frattool. FRAT does not assess total zinc intake or risk of inadequacy.

For each potential food vehicle, the FRAT asks about the frequency of consumption (e.g., number of days per week) by the target population and the usual amount consumed in a day. The estimation of portion sizes should follow the same methods used in a quantitative 24-hour recall, preferably using replicas of weighed portion sizes of staple foods consumed. Using the usual

daily amount of the food consumed and the zinc requirement of the target group, it is possible to estimate the fortification level of zinc to meet a user-specified percentage of the recommended intake (RNI or RDA) from that food vehicle. This can be estimated for various percentiles of the intake distribution of the food. Suggested target levels provided in the guidelines are the amount of fortified food meeting 25%-30% of the RNI of the target individual with the largest nutrient gap, or the amount of fortified food meeting at least 50% of the RNI for at least half of the target group.

Intake Modeling and Prediction Program (IMAPP)

IMAPP was developed to provide a tool to aid the implementation of the 2006 World Health Organization (WHO) / Food and Agriculture Organization (FAO) Guidelines on Food Fortification with Micronutrients (10). The software program estimates the usual zinc intake distribution and assesses dietary zinc intake adequacy of a population using the same methods as PC-SIDE. It also assesses the potential impacts of fortification on the distribution and adequacy of zinc intakes. IMAPP was developed by Iowa State University and is available at: http://bit.ly/imapptool.

IMAPP requires an input file of individual zinc intake data obtained from quantitative 24-hour dietary recalls or weighed food records, with multiple days of intake on at least a sub-set of individuals (as described in Purpose 2). Alternatively, an external variance ratio based on other intake datasets can be used if only one day of data per individual are available. In order to conduct fortification simulations, the intake data must include the amount of specified foods consumed that might be used as vehicles for fortification. IMAPP can guide decisions on the optimal amount of zinc to add for a targeted prevalence of inadequacy based on estimated average requirements (EARs) for nutrients. Users can select harmonized EARs which, except for zinc, are based primarily on the Institute of Medicine's (IOM) EARs (available at: http://bit.ly/IOMEARs). IMAPP uses the IZiNCG EARs that take into account two levels of bioavailability based on two diet types: unrefined cereal and/or legume-based diets and mixed or refined plant-based diets (11). IMAPP can also assess the prevalence of zinc intakes above the UL (IOM) before and after simulated fortification. Alternatively, user-defined EARs or ULs can be used. The program also outputs the best-linear unbiased prediction (BLUPs) used to estimate usual intake for individuals, which can be used as predictor variables in diet-disease models.

Purpose 4: Assessing the feasibility and cost of using locally available foods and/or designing dietary guidelines to meet dietary zinc recommendations

Linear programming is an analytical tool that can be used to identify a combination of locally available foods that meet the recommended zinc intake level at the lowest cost, while constraining parameters such as portion sizes or frequency of food consumption. Information on nutritious food combinations and amounts needed to meet recommended nutrient intakes may also be used to design dietary guidelines for specific population groups, such as complementary feeding guidelines for young children.

Cost of Diet

The Cost of Diet is linear programming software developed by Save the Children that selects the lowest cost combination of local foods that meet nutrient needs including zinc. It is available free at: http://bit.ly/codsoftware.

The Cost of Diet uses inputs on locally available foods and dietary habits and preferences, but does not require quantitative dietary intake data. The software imposes constraints on the frequency that foods are consumed each week and amounts of foods consumed per meal according to typical dietary habits obtained by focus groups or other existing information. The zinc requirement is based on the WHO Recommended Nutrient Intake (RNI) (12), which is equivalent to the 97.7th percentile of the normal distribution of requirements, but the software allows adjustment of recommended intakes between the 1st and 99th percentile. Users also have the ability to change the desired target amount and the degree of absorption of zinc from the diet between low (15%), moderate (30%), and high (50%) bioavailability based on certain dietary characteristics. Food costs obtained by local market surveys must be inputted by the user. The Cost of Diet output summarizes the cost of the hypothetical diet, as well as the quantity and proportion of zinc provided by the foods for an individual or household.

Optifood

Optifood is linear programming software that generates food-based dietary recommendations for children 6-23 months of age, pregnant women, and lactating women with infants under 6 months of age. It was developed by WHO, the London School of Tropical Medicine and Hygiene, FANTA, and Blue-Infinity. Optifood is not yet available for download, but information is provided at: http://bit.ly/optifood.

Optifood is similar to the Cost of Diet in that it identifies the lowest cost combination of local foods that meet nutrient needs of the target groups, indicates the limits of locally available foods to meet nutrient needs, and can identify other products that may be needed, such as fortified foods or micronutrient powders. The inputs to Optifood include quantitative dietary intake data on amounts and frequencies of foods consumed and food costs using the ProPAN market survey tool. Optifood provides reference data on food composition and recommended nutrient intakes primarily from the WHO/FAO RNI (12), but users can supplement or replace this information with other data. Optifood can identify the dietary zinc gap and suggest locally available foods to fill the gap. The recommended diets show a weekly diet with the number of servings per week and portion sizes.

ProPAN (Process for the Promotion of Child Feeding)

ProPAN is a comprehensive tool to identify problems related to young child nutrition, breastfeeding and complementary feeding within a specific target population, formulate behavior-change recommendations, and develop and monitor interventions to promote recommendations. It was developed by PAHO and UNICEF. A field manual and an Epi InfoTM-based software program and user's guide are available free at: http://bit.ly/propanpaho.

ProPAN consists of four modules that can be used alone or together. Module 1 includes quantitative and qualitative data collection instruments, including a 24-hour dietary recall and market survey. The 24-hour recall component can be used to identify a dietary zinc gap based on the recommended zinc density of complementary foods (i.e., non-breastmilk food and fluid intake) for infants and young children aged 6-8, 9-11, and 12-23 months (13, 14). Results of dietary gaps are used to inform the design of recipes and complementary feeding guidelines in subsequent modules. ProPAN includes a

used in Optifood, and outputs from the 24-hour recall can be used with Optifood for additional analyses.

Additional resources

FAO/WHO Global Individual Food consumption data Tool (GIFT). GIFT is a recently-launched global database of individual dietary intake data available on a web-based platform (at: http://bit.ly/faogift). Users can look up data on consumption of foods, food sources of nutrients including zinc, and indicators of dietary adequacy (zinc forthcoming). Users may also download datasets for their own analyses.

FAO/INFOODS/IZiNCG Global Food Composition Database for Phytate (PhyFoodComp1.0). The database is a compilation of published values for the phytate content of raw and processed foods. The current version of the database includes 18 food categories and 3377 food items. It is available at: http://bit.ly/faoinfoods and http://www.izincg.org/.

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About IZiNCG

IZiNCG is the International Zinc Nutrition Consultative Group whose primary objectives are to promote and assist efforts to reduce global zinc deficiency through interpretation of nutrition science, dissemination of information, and provision of technical assistance to national governments and international agencies. IZiNCG focuses on identification, prevention and treatment of zinc deficiency in the most vulnerable populations of low-income countries.

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