



Technical Brief

Determining the risk of zinc deficiency: Assessment of dietary zinc intake

An assessment of the prevalence of inadequate intakes of dietary zinc in a population can provide information on the risk of zinc deficiency in a population. Inadequate dietary intake of bioavailable forms of zinc is the most likely cause of zinc deficiency. Plant-based diets consumed in many developing countries are often based on unrefined cereals and legumes. These foods contain a high content of phytate, a substance that significantly inhibits the body's absorption of zinc. Other diets based on starchy roots or tubers have a low total zinc content.

There are five main steps to assessing the adequacy of zinc intake in a population (Figure 1). Each step is described below.

Step 1. Determine the survey design

Two levels of information can be drawn on population zinc intakes, as determined by the basic survey design.

1a. Survey designed to estimate the prevalence of inadequate zinc intake in a population

The preferred survey design allows the description of the distribution of usual zinc intakes by a population; that is, both the mean and variance about the mean are estimated. When the usual distribution of zinc intakes is known, the prevalence or probability of inadequate zinc intakes in the population can be estimated. In this case, food intake must be determined for two non-consecutive days or three consecutive days. It is preferable that multiple days of intake data are collected for all individuals in the population. However, if this is not possible, then at least two non-consecutive days of dietary intake data from a subsample of 30 to 40 individuals per stratum should be collected.

1b. Survey designed to estimate the mean zinc intake in a population

If dietary intake data can only be collected on one day per individual in the sample, then only the mean zinc intake of the population can be determined. This method measures average intake but cannot show variability among individuals, so the data cannot be used to provide a precise estimate of the prevalence of inadequate intakes. However, such data can still be used to identify foods that are the primary contributors of zinc and other specific nutrients and anti-nutrients in the habitual diet, and to identify possible food vehicles for use in food fortification programs. It can also provide a rough estimate of the proportion of individuals with inadequate zinc intakes, as described in Step 5.

Step 2. Select a representative population sample

The sample size for the dietary survey must be large enough

to ensure that it is representative of the population of interest. The sample size required depends on both the anticipated prevalence of inadequate zinc intakes and the desired degree of precision of the estimate—or the size of the confidence interval.

Figure 1: Flowchart summarizing steps in assessing the dietary adequacy of zinc intakes in populations

Step 1 Determine the survey design

Determine the distribution of usual zinc intakes: Collect at least two days of intake data for the entire sample, or at least for a subsample (i.e., 30-40 individuals per stratum)
or Determine the mean zinc intake of the population:
 Collect one day of dietary intake data per individual

Step 2 Select a representative population sample

Estimate an adequate sample size based on:
 Expected prevalence of inadequate zinc intakes
and The desired confidence interval

Step 3 Determine food intakes

Use either weighed food records or 24-hour recalls, adapted for the population of interest

Step 4 Estimate dietary intake of absorbable zinc

Based on food intakes, calculate the dietary intake of total zinc and total phytate

Calculate the phytate:zinc molar ratio of the diet, or estimate the phytate:zinc molar ratio based on diet type. Alternatively, one may also calculate the assumed percent zinc absorption and the amount of absorbable zinc

Step 5 Determine the prevalence of inadequate zinc intakes

If the distribution of usual zinc intakes is known, one can determine the prevalence of zinc intakes below the EAR. The EAR is specific for age, sex, physiological status and the phytate:zinc molar ratio of the diet.

Alternatively, one may estimate the prevalence of absorbable zinc intakes below the appropriate physiological requirement for absorbed zinc, specific for age, sex and physiological status.

If the distribution of usual zinc intakes is known, one may also calculate the probability of inadequate zinc intakes, using the probability approach.

The anticipated prevalence of inadequate zinc intakes can be determined from:

- i. Pre-existing dietary data on a similar population group that provide an estimate of the proportion of individuals within the population whose usual zinc intakes fall below the Estimated Average Requirement (EAR);
- ii. Often, pre-existing data on zinc intakes are not available. In this case, an indirect estimate derived from food balance sheet data may be used [1]. These data provide the estimated percent of the population within the country at risk of inadequate zinc intake, based on the national food supply of the country [2].

The desired confidence interval should also be taken into account.

Example calculations of sample sizes based on estimated prevalence of inadequate intakes and desired confidence intervals are shown in Table 1. These sample sizes should be applied to each stratum or sub group of interest, based on age, sex, physiological status, or area of residence.

Table 1: Estimated sample sizes for dietary surveys assessing usual zinc intakes of individuals within a population by anticipated proportion of individuals with inadequate intakes and desired precision (half the width of 95% confidence interval)

Estimated proportion ¹	DESIRED PRECISION				
	±0.02	±0.03	±0.04	±0.05	±0.06
0.05	457	203	115	73	51
0.10	865	385	217	139	97
0.15	1225	545	307	196	137
0.20	1537	683	385	246	171
0.25	1801	801	451	289	201
0.30	2017	897	505	323	225
0.40	2305	1025	577	369	257
0.50	2401	1068	601	385	267

¹ Anticipated proportion of individuals with zinc intakes below the estimated average requirement (EAR).

Step 3. Select a food intake measurement method

The next step is to select a method for measuring food intakes. Intakes can be measured using either in-home weighed food records or 24-hour recalls. Weighed food records require a trained interviewer to measure the quantity of each food consumed over one day and is generally the most accurate method of measuring food intake. In low income countries, weighed food records are often the method of choice for non-literate populations. Detailed protocols for training the interviewers [3] and collecting weighed food records [4] are available elsewhere.

Alternatively, 24-hour recalls can be used. This method requires that portion sizes can be recalled accurately and, again, that trained interviewers conduct the recalls. Several strategies are available to improve portion size estimates and to reduce memory lapses during the 24-hour recall interviews². It is advisable to confirm the feasibility, validity, and reproducibility of using this 24-hour recall method described in the dietary manual for the specific population group and setting before adopting this procedure for the proposed study.

Food frequency questionnaires are also sometimes used for assessing absorbable zinc intakes but there are limited data on their validity to measure zinc intakes.

Step 4. Assess the intake of absorbable zinc in the diet

There are three stages involved in assessing the intake of absorbable zinc in the diet: the total zinc and phytate intakes must be calculated, then the phytate:zinc molar ratio determined, and lastly the appropriate EAR selected.

4a. Calculate total zinc and phytate intakes

Intakes of both zinc and phytate can be calculated from the food intake data measured in Step 3, using an appropriate food composition database and dietary assessment software. Details on how to compile a local food composition table have been described [3]. Where possible, local food composition data for zinc and phytate should be used, as these can vary with both local soil conditions and food preparation and processing methods [5,6]. Some available sources of information on the zinc and phytate content of foods have been listed [2].

Information on the zinc and phytate content of local plant-based staples may be found from regional and national centers of the International Network of Food Data Systems (INFOODS) and in the 1st IZiNCG technical document [2]. For example data for six countries (Egypt, India, Indonesia, Kenya, Mexico, and Senegal) are available through the WorldFood Dietary Assessment System, 2.0. These food composition tables, together with the dietary assessment software, can be downloaded free of charge from the INFOODS website (http://www.fao.org/infoods/software_worldfood_en.stm).

Note that the US Department of Agriculture (USDA) food composition database also contains a comprehensive list of values for zinc (but not phytate) which can be downloaded from the internet. Phytate values for this USDA database are available from the University of Minnesota Nutrition Coordinating Center Nutrient Database.

4b. Calculate phytate:zinc molar ratio

If the intakes of zinc and phytate have been calculated from the food intake data, the next stage is to calculate the phytate:zinc molar ratio of the diets of each individual to provide an estimate of zinc absorption. These ratios are calculated for each individual using the following equation:

²Several strategies for improving portion size estimates are described in detail in the dietary manual especially compiled for measuring intakes of absorbable zinc (and iron) in lower-income countries [3].

$$\frac{\text{mg phytate per day} / 660}{\text{mg zinc per day} / 65.4}$$

For example, if the phytate intake is 883 mg/d and the zinc intake is 7 mg/d, then the phytate:zinc molar ratio is 12.5. The mean phytate:zinc molar ratio, may then be used to classify diets as having low or average zinc bioavailability. If information on the phytate content of the diet cannot be calculated, then diets should be categorized as having low or average zinc bioavailability based on certain dietary characteristics. For example, unrefined cereal and/or legume-based diets (eg., phytate:zinc >18) would have a low zinc bioavailability (zinc absorption of 18% for males and 25% for females), whereas mixed diets or refined plant-based diets (phytate:zinc 4-18) would have average bioavailability (zinc absorption of 26% for males and 34% for females).

Alternatively, the total zinc intake and the phytate:zinc molar ratio can be used to estimate the percent bioavailable zinc and subsequently the amount of absorbable zinc for each individual using an algorithm presented by IZiNCG [2].

4c. Select the appropriate EAR

The final stage is to select the most appropriate EAR to assess the adequacy of zinc intakes by life-stage and diet type. IZiNCG has developed EARs appropriate for international use (Table 2). Use of the IZiNCG EAR values will enable cross-country comparisons of the adequacy of zinc intakes.

Step 5. Estimating the prevalence of inadequate zinc intakes

The process of assessing the prevalence of inadequate zinc intake depends on the survey design chosen. If the preferred survey design is used—and food intakes are measured on two

Table 2: IZiNCG Estimated Average Requirement (EAR) for zinc by life stage and diet type

AGE	SEX	REFERENCE BODY WEIGHT(KG)	IZiNCG EAR FOR ZINC (MG/D)	
			Mixed or refined plant-based diets	Unrefined, plant-based diets
6-11 months	M+F	9	3	4
1-3 years	M+F	12	2	2
4-8 years	M+F	21	3	4
9-13 years	M+F	38	5	7
14-18 years	M	64	8	11
14-18 years	F	56	7	9
Pregnancy	F	-	9	12
Lactation	F	-	8	9
>19 years	M	65	10	15
>19 years	F	55	6	7
Pregnancy	F	-	8	10
Lactation	F	-	7	8

non-consecutive or three consecutive days (1a.)—the assessment involves first correcting the distribution of observed zinc intakes, generated in Step 4, to represent usual zinc intakes, and then applying the EAR cut-point method. If the less preferred survey design is used—wherein only a single day’s intake is measured (1b.)—an estimate of the coefficient of variation (CV) of usual intakes of the population must be used. Then the EAR cut-point method, which determines the proportion of individuals with zinc intakes below the EAR, can be applied.

5a. Preferred survey design

- i. Correct the observed zinc intakes to represent usual zinc intakes.

The distribution of observed zinc intakes in each of the age- and sex-specific subgroups must be adjusted to remove the variability introduced by day-to-day variation in an individual’s zinc intake. This can be done using specialized software programs (eg., PC-SIDE, Iowa State University, Department of Statistics and Statistical Laboratory, Ames, Iowa, USA) [7], provided a series of replicate observations has been obtained on at least a subsample of individuals. The adjustment process provides estimates of usual zinc intake distributions for each of the age- and sex-specific subgroups. An example comparing the adjusted distributions of usual zinc intakes with the observed zinc intakes for New Zealand adult females aged 19-50 years is shown in Figure 2. Note that the adjustment process used yields a distribution with reduced variability that preserves the shape of the original distribution [6].

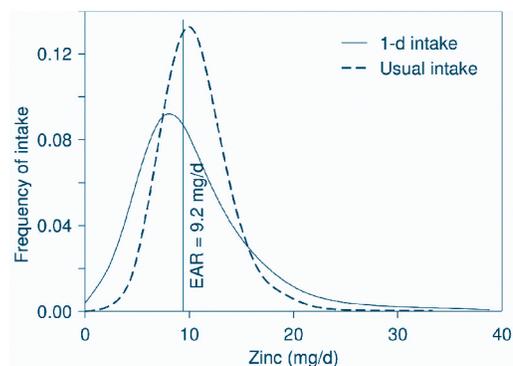


Figure 2: Estimates of usual intake distribution for zinc for New Zealand adults obtained from 24-h recall data and adjusted with replicate intake data using the refined NRC method. The y-axis (frequency of intake) shows the likelihood of each level of intake in the population.

The method used by PC-SIDE to estimate usual intake distributions is made up of four routines: preliminary data adjustments, semiparametric transformation to normality because data on observed zinc intakes are generally not normally distributed, estimation of intra- and inter-individual variation in intakes, and finally back-transformation of the usual intake distribution from the normal into the original scale.

- ii. Apply the EAR cut-point method. This entails counting the number of individuals with usual intakes below the appropriate zinc EAR, for age- and sex-specific subgroups and diet types (see Step 4).

5b. Less-preferred survey design

- i. When only a single day's intake is collected from each individual in the population, neither the true intra-individual variation, nor the distribution of usual zinc intakes in the survey population is known. Hence, for this survey design, the distribution of observed zinc intakes cannot be adjusted to usual intakes. Instead, a coefficient of variation (CV) of usual zinc intakes must be assumed. The value

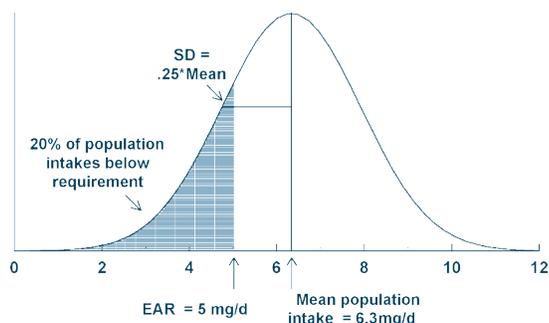


Figure 3: Hypothetical, graphical representation of the estimation of the proportion of adult women with dietary zinc intakes below the estimated average requirement (EAR) for zinc from a typical mixed diet, assuming a mean intake of 6.3 mg/day and CV of the corrected distribution of usual intakes of 25%

recommended for this CV is 25%³ and is based on data from a national survey of young people aged 4 to 18 years in the United Kingdom [8].

- ii. Next, the EAR cut-point method can be applied to crudely estimate the proportion of individuals with inadequate intakes. This stage can be performed using a cumulative distribution function such as CDF.NORM in SPSS, where the SD of intakes is assumed to 0.25 times the mean, as shown in the hypothetical example for adult women in Figure 3. Note that caution must be used when this approach is applied.

Finally, it is noteworthy that several other factors besides the survey objectives, such as availability of resources, will determine the final survey design.

An elevated risk of zinc deficiency in the population is said to exist when 25% or more of the population have zinc intakes less than the EAR, irrespective of the survey design [2]. To assist with the interpretation of the risk of zinc deficiency, however, it is recommended to combine estimates of adequacy of zinc intakes with biochemical data on serum zinc concentrations.

³The coefficient of variation, 0.25, is represented as a percentage.

This technical brief was prepared by Dr. Rosalind S. Gibson and was reviewed by members of the IZiNCG Steering Committee

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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. The Steering Committee of IZiNCG consists of 11 well-recognized international scientists with longstanding expertise in zinc nutrition and public health programs.

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