Current Comments

Estimating prevalence of inadequate nutrient intake

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Abstract
In assessing food intake patterns in groups of individuals, it is usually important to know how many of these individuals present nutrient intakes above or below a determined criterion. This information is relevant for planning healthcare actions, both in monitoring and in assessing such interventions, and also for the purposes of regulating commercial activities. This paper discusses a new methodology for estimating the prevalence of inadequate nutrient intake, with the Dietary Reference Intakes as the reference values. The utilization of diet surveys that allow the most accurate quantitative estimate possible is dealt with. These should use repeated measurements of food intake, on non-consecutive days. The food intake should be adjusted for between-person and within-person variance, so as to obtain a corrected distribution for the nutrient intake values. After constructing this distribution curve based on the corrected estimated parameters (average and standard deviation), the EAR method (Estimated Average Requirement) can be used as a cutoff point for verifying the proportion of individuals that has inadequate nutrient intake. This corresponds to the area of the curve below this reference value. It is concluded that this new approach minimizes the error in the calculation of the prevalence of inadequate nutrient intake, since it takes into consideration the random characteristics of the diet.

INTRODUTION

The objective of this work was to discuss a methodology for estimating the prevalence of inadequate nutrient intake. This is an important topic in studies of the prevalence of the intake of different nutrients. Such studies provide backing for establishing hypotheses regarding the relationships between diet and health. In assessing diets within groups of individuals, it is often of interest to determine how many of these individuals present intakes that are above or below a given criterion. This information is relevant for planning healthcare actions, both in monitoring and in assessing such interventions, and also for the purposes of regulating commercial activities.

ASSESSMENT OF DIETS WITHIN GROUPS

To estimate the prevalence of inadequate intake of a certain nutrient, it is necessary to calculate its consumption within the population group of interest and compare this with reference standards. The Dietary Reference Intakes (DRI), one of the standards available, are quantitative estimates for planning and assessing diets for healthy populations that were initially developed by Americans and Canadians. The DRIs include the Recommended Dietary Allowances (RDA), as individual consumption targets, and a further three additional standards: Adequate Intake (AI), Estimated Average Requirement (EAR) and Tolerable Upper Intake Level (UL). These concepts have al-

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ready been discussed in previous Portuguese-language publications.[1,8,12]

The RDA, or some percentage of it, has been utilized as a cutoff point for assessing the prevalence of inadequate nutrient intake. This approach has led to erroneous quantification of the proportion of individuals with inadequate intake.[6] Beaton (1994)[4] suggested a method that, by comparing the distribution of the habitual intake with the EAR, would lead to an unbiased estimate of the prevalence.

The statistical methods presented in the literature for estimating the prevalence of inadequate nutrition intake consist of probabilistic approaches and approaches using EAR as a cutoff point. The latter method is considered to be a simplification of the former[9] and, as well as being simple, it does not require great parametrical presuppositions for its utilization.[13,14] Thus, EAR is an appropriate reference estimate for assessing inadequate nutrient intake, defined as the nutrient intake that corresponds to the estimated average need for a given stage of life and gender.

In this method, the prevalence of inadequacy is the proportion of individuals whose intake is less than the EAR. To utilize the EAR as a cutoff point, it is necessary to determine the distribution of the habitual intake among the population, the variance in food consumption and the EAR. The premises of the method are:

1. Nutrient need and intake are independent variables.
2. The distribution of the needs is symmetrical (and not necessarily normal).
3. The variance in the intake of the distribution of the needs is relatively small in relation to the variance in the distribution of the intake. Or in other words, the individual variation in intake is greater than the variation of the needs among the population.

Small deviations in relation to these premises have a small effect on the performance of the method. However, this method does not function well when consumption and need are highly correlated, as is the case with energy, or with iron among women of fertile age, whose needs are known to have asymmetrical distribution.[4,6]

ESTIMATION OF THE HABITUAL DIET

For the assessment of the inadequacy of the consumption, whatever the nutrient in question, it is fundamental to determine the habitual diet, since the effects of inadequate intake of the nutrient, no matter whether this is an excess or deficiency, will not appear after only a few days. The *habitual diet* can be defined as the average food consumption over a long period of time, over which a dietary pattern is maintained.[10,17] On the other hand, the *present diet* refers to the average food consumption over a short period of time around the present day.[21]

The quantitative assessment of inadequacy of dietary intake requires an accurate determination of the habitual quantities of foods consumed by the individual. It must take into consideration all the foods that contribute towards the total nutrient intake.[9,11,20,21]

Among the methods most utilized for estimating the diet, the Food Frequency Questionnaire (FFQ), the 24-hour Recall (24hR) and Daily Records (DR) can be highlighted. The FFQ, although it estimates the habitual diet and is greatly utilized in epidemiological studies for verifying diet-disease relationships, rarely has sufficient accuracy to be utilized for assessing the adequacy of nutrient intake, among individuals or in groups. This is due to the particular characteristics of this method.[21,13] In the FFQ, foods are presented on a pre-established list that therefore does not consider all the foods available for consumption, and it utilizes standardized measurements. In addition to this, different foods are often aggregated within the same item.[21] More accurate estimates can be obtained by the methods of Daily Records and 24-hour Recall. These methods, besides being based on individuals' recent memories, allow open responses, thereby enabling a more detailed picture of the population's consumption to be obtained.[9]

Consideration also has to be given to the difficulty of accurately and precisely estimating the diet, because of its variable nature.[21] The daily variability of the diet depends on the real variation in foods consumed by individuals, which is due to the diversity, heterogeneity and fluctuations in day-to-day consumption. It must also be noted that individuals have intrinsically different characteristics, such as preferences, which lead them to select distinct foods. Furthermore, people may react differently on different occasions, for example at breakfast time, when one day they eat biscuits and the next day they eat bread.[5] According to Beaton et al[3] (1979), the influence of factors such as seasonality, days of the week, sequences of questionnaire application or different interviewers explains a small proportion of the variability in consumption. Thus, the habitual diet could be explained by the following model:[21]

$$Y = \mu + \text{individual}_i + \varepsilon \qquad \text{(equation 1)}$$

where:

Y= nutrient intake

μ = true average intake

Individual i = effect of variance between individuals

ε = error term

In this model, the habitual intake of a nutrient is formed by the true average (μ), influenced by the effect of each individual in the population, for which the variability is measured by the *variance between individuals* and is denoted by (S_b^2). Since this function cannot be measured directly, the true average intake cannot be measured free of error.[7]

The variations in the habitual intake given by day-to-day fluctuations in food intake can be measured by the *variance within individuals*, denoted by (S_w^2). This function represents an individual's variability around his own average, when and whenever it is evaluated through multiple observations.

In addition to these, a third source of variation must be mentioned: the variation given by the measurement error of the instrument utilized. This is defined as the difference found between the observed value and the true intake. The result of these two components can be referred to as the error term (ε).[7]

The estimate of the intake distribution includes an estimate of all the percentiles and allows the subsequent calculation of other statistical parameters such as the arithmetic mean, standard deviation, coefficient of variation and also tests of hypotheses relating to the habitual intake.[9] Even if the average and median values of the food intake for groups can be calculated with just one measurement, within-person variance may distort the estimates of percentiles above or below the average by increasing the total variance of the distribution, which makes the distribution wider and inflated. Thus, an estimate of the prevalence of nutrient intake within a defined population that is based on the consumption on a single day may overestimate the percentage of individuals with inadequate intake, regardless of whether the nutrient intake is excessive or deficient.

The application of statistical methods gives the possibility of removing the day-to-day variability that is due to variation in within-person consumption. In such cases, the distribution will then solely reflect the variation that exists between the individuals in the group. The "adjusted" distribution of the habitual intake has less variance than the distribution estimated using only one day of dietary intake (Figure 1).

To apply the statistical methods to the adjustment of the diet, it is necessary to have at least two independent measurements from at least one representative sample of the individuals evaluated, on non-consecutive days. Only by means of repeated observations is it possible to estimate the variability of the daily nutrient intake.[18]

Hoffmann et al[9] (2002), in a study made with the objective of estimating the distribution of dietary intake from repeated measurements over the short term, such as via the use of multiple 24hR, concluded that only two repeated measurements were necessary for this estimate, although the sample of the repeated days needed to cover all the seasons of the year and days of the week.

After choosing the method, it must be emphasized that there are no methods capable of measuring dietary intake exactly, or in other words, free from errors. Measurement error is intrinsic to any method for assessing food consumption.[2,21]

CALCULATION OF THE PREVALENCE OF INADEQUATE CONSUMPTION

After estimating the distribution of the habitual intake, it must be verified whether this is normally distributed. If it is not, a transformation to remove the asymmetry can be suggested.[7] Logarithmic transformation is often utilized, although this is just one of the alternatives. Following this, to estimate the proportion of individuals whose habitual intake is above or below a given reference value (EAR), the distribution of the nutrient must be obtained, free from the effect of within-person variability.

It is therefore necessary to calculate the within-person variance (S_w^2) and between-person variance (S_b^2).

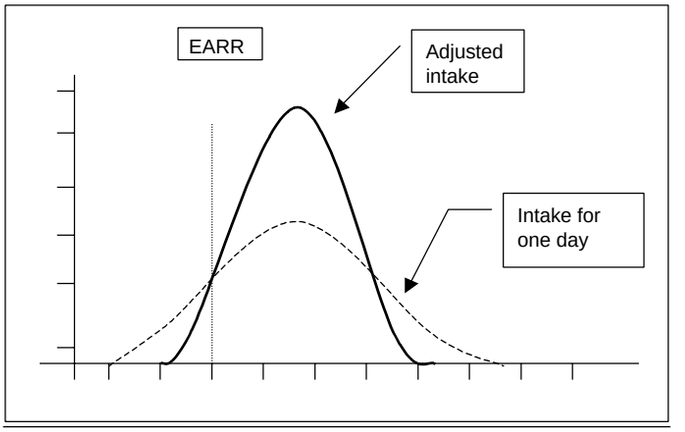

Figure 1 - Effect of within-person variation in the distribution of the frequency of intake values.

To obtain these components, variance analysis (ANOVA) is utilized. It is stressed that, since the within-person variance is of interest, at least two days of information for each person is required.

The estimates of within-person variance are calculated in accordance with the following relationships:

$RMS_w = S_w^2$

$RMS_b = S_w^2 + k\, S_b^2$

$S_b^2 = (RMS_b - S_w^2) / k$ (equation 2)

The total variance S_{obs}^2 of an observed distribution is given by the sum of the within-person and between-person variances:[18,7]

$S_{obs}^2 = S_w^2 + (S_b^2) / k$ (equation 3)

Rearranging equation 3, we have the relationship between the ratio of the standard deviation for the whole population and the standard deviation of the within-person variation (S_{obs}/S_b)[18] (equation 5):

$S_{obs}^2/S_b^2 = (S_b^2+(S_w^2/k))/S_b^2 = (1+S_w^2/k(S_b^2)$ (equation 4)

Taking the square root:

$S_{obs}/S_b = ((1 + S_w^2 / k(S_b^2))^{1/2}$ (equation 5)

To remove the within-person variance, the equation put forward by the US National Academy of Science Subcommittee on Criteria for Dietary Evaluation can be used – equation 6.[18] For data with normal distribution, this approach allows the reconstruction of the whole distribution from the average and the variance, thereby also enabling the recalculation of all the percentiles.[18,9]

$$\text{Adjusted value for the nutrient} = \text{average} + (x_i - \text{average}) * S_b/S_{obs} \quad \text{(equation 6)}$$

where:

the average is the average value for the group

x_i is the value observed for each individual

the ratio S_b/S_{obs} is the inverse of the ratio in equation 5

The next step is to adjust the distribution of the nutrient, by utilizing the values obtained from equation 6. Since the average is unaffected by the within-person variance (S_w), the adjusted distribution and the raw distribution must maintain the same average value, although the dispersion of the values is expected to be less.

The final step will be to verify the prevalence of inadequacy in the population group. For this, the adjusted distribution is utilized, so as to remove the within-person variability. This prevalence corresponds to the proportion of individuals in the group whose habitual intake is less than the EAR established for the nutrient (Figure 2).

To calculate the area of the curve that corresponds to the proportion of individuals with inadequate consumption, a distribution known as the reduced normal distribution is utilized:

$Z = (EAR - \text{average}) / SD$ (equation 6)

where:

average is the adjusted average for the group

SD is the standard deviation for the adjusted distribution

EAR is the estimated average requirement of the nutrient

These calculations require that the nutrient distribution should follow a normal distribution. It is emphasized that these corrections are appropriate for estimates of groups of individuals, but that they cannot be utilized for identifying *individuals* who are below the cutoff point.

EXAMPLE: PREVALENCE OF INADEQUATE PHOSPHORUS INTAKE IN A GROUP OF ADOLESCENTS

The prevalence of inadequate phosphorus intake was estimated for a group of 79 female adolescents,

Table 1 – Variance analysis (ANOVA).

Source	Degrees of freedom	Root mean square (RMS)	Expected root mean square (ERMS)
Between-person	N-1	RMS_b	$S_w^2 + k\, S_b^2$
Within-person	N(k-1)	RMS_w	S_w^2

RMS_b: Between-person root mean square
RMS_w: Within-person root mean square
N: number of individuals
K: number of repetitions

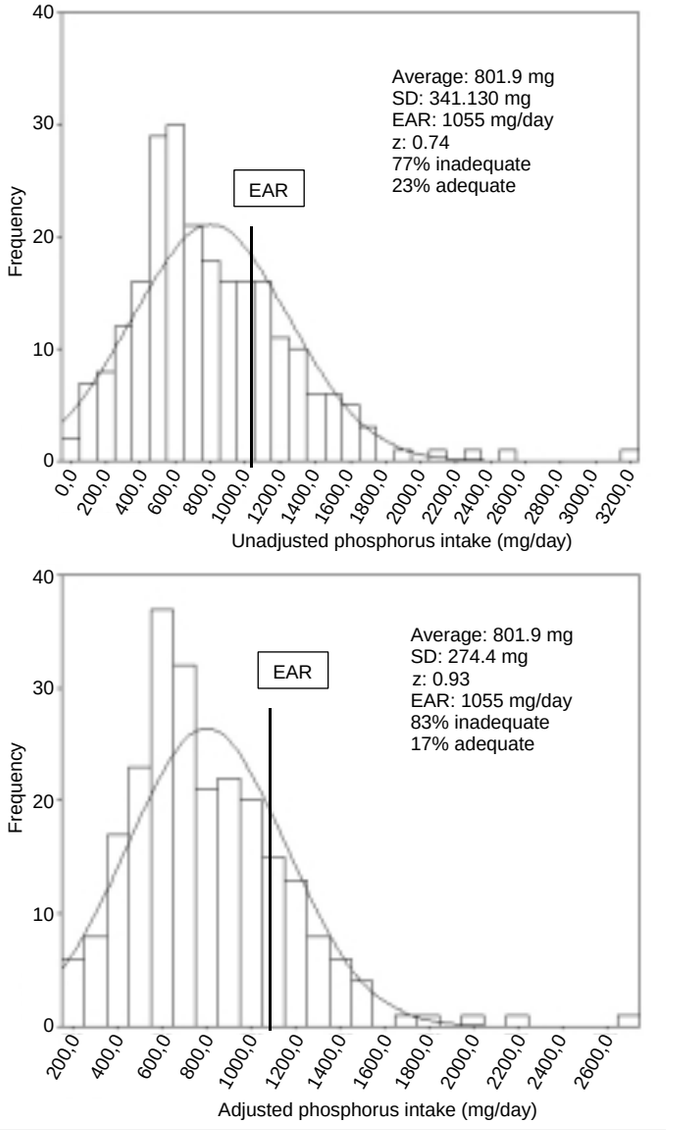

Figure 2 - Adjusted and unadjusted distribution of the estimated phosphorus intake among female adolescents.

S_w^2 = 126498.429

S_b^2=(349103.677–126498.429)/3=74201.749

Calculating the ratio S_{obs}/S_b:

$S_{obs}/S_b=(1+(126498.429/(3*74201.749))^{1/2}$ =1.252303

S_b/S_{obs} = 0.798529

Correcting the distribution according to equation 6

Adjusted value for phosphorus =801.9+(x_i–801.9)* 0.798529

The adjusted and unadjusted curves can be seen in Figure 2.

FINAL CONSIDERATIONS

Many of the errors in assessing dietary intake derive from comparing average nutrient intake with the RDA. When the average intake for a population or group extrapolates the RDA, it may be concluded that the evaluated group has reached or exceeded the recommendations. However, the RDA was established as a target for individual consumption, as revised by the NRC (1980 and 1989).[16,15] In fact, the variation in consumption generally exceeds the variation in the recommendation for the majority of nutrients. The average for the habitual intake needs to be greater than the RDA for there to be a low prevalence of inadequate consumption. Even in the case of the average reaching or extrapolating the RDA, a certain proportion of the individuals will present inadequate consumption.

utilizing data from Slater et al. (2003).[19] The method utilized was 24-hour recall, with three repeated measurements over an interval of 45 days, none of which on consecutive days. After variance analysis (ANOVA), the following data were obtained:

Following the steps and utilizing the equations, the following were obtained:

The median or average for the intake of a population must not be utilized for estimating the prevalence of inadequate consumption when this nutrient has an EAR. The prevalence of inadequacy must be observed from the starting point of a distribution of the frequencies of the intake values, with verification of the format and variability of the curve for the population studied. In the case of nutrients without

Table 2 - Variance analysis for a sample of three days, for 79 female adolescents.

Source	Sum of squares	Degrees of freedom	Root mean square	Expected root mean square
Between-person	27230086.8	78	349103.677	$s_w^2 + k\, S_b^2$
Within-person	19986751.7	158	126498.429	s_w^2
Total	47216838.5	236		

an EAR, prevalence estimates utilizing these reference standards (the DRIs), *cannot* be made. The DRI Committee[9] recommends caution in the interpretation of the descriptive statistics (average, median and percentiles). When the average intake of the nutrient exceeds the AI, it is expected that there will be low prevalence of inadequacy. However, when the average intake of the nutrient for the population is less than the AI, no conclusion can be reached in relation to the percentage of individuals with inadequate intake of the nutrient.

With regard to the utilization of this methodology for nutritional recommendations other than the DRIs, such as those from the Instituto de Nutrición de América Latina y Panamá (INCAP) and Sociedade Brasileira de Alimentação e Nutrição (SBAN), it will only be possible when these recommendations present the average value for the needs and not just the target intake to be attained, as well as when the premises of the method are followed, of course. Likewise, the defects already discussed in relation to the use of this approach will continue to apply, in other words, the inflation of estimates of the prevalence of inadequate intake of the nutrient in the population studied.

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