

Dietary Reference Intakes: summary of applications in dietary assessment

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Abstract

Objective: To summarise the applications and appropriate use of Dietary Reference Intakes (DRIs) as guidance for nutrition and health research professionals in the dietary assessment of groups and individuals.

Design: Key points from the Institute of Medicine report, *Dietary Reference Intakes: Applications in Dietary Assessment*, are summarised in this paper. The different approaches for using DRIs to evaluate the intakes of groups vs. the intakes of individuals are highlighted.

Results: Each of the new DRIs is defined and its role in the dietary assessment of groups and individuals is described. Two methods of group assessment and a new method for quantitative assessment of individuals are described. Illustrations are provided on appropriate use of the Estimated Average Requirement (EAR), the Adequate Intake (AI) and the Tolerable Upper Intake Level (UL) in dietary assessment.

Conclusions: Dietary assessment of groups or individuals must be based on estimates of usual (long-term) intake. The EAR is the appropriate DRI to use in assessing groups and individuals. The AI is of limited value in assessing nutrient adequacy, and cannot be used to assess the prevalence of inadequacy. The UL is the appropriate DRI to use in assessing the proportion of a group at risk of adverse health effects. It is inappropriate to use the Recommended Dietary Allowance (RDA) or a group mean intake to assess the nutrient adequacy of groups.

Keywords

Dietary Reference Intake (DRI)
Estimated Average Requirement (EAR)
Adequate Intake (AI)
Tolerable Upper Intake Level (UL)
Assessing individual intakes
Assessing group intakes
Prevalence of inadequacy
EAR cut-point
Probability approach

The report, *Dietary Reference Intakes: Applications in Dietary Assessment*¹, is designed to provide guidance on the interpretation and use of Dietary Reference Intakes (DRIs). The term 'Dietary Reference Intakes' refers to a set of four nutrient-based reference values that represents the new approach adopted by the Food and Nutrition Board to provide quantitative estimates of nutrient intakes for use in assessing and planning diets and other purposes. The DRIs replace and expand on the periodic updates and revisions of the Recommended Dietary Allowances (RDAs) for the USA² and the Recommended Nutrient Intakes (RNIs) for Canada³. Specifically, this report provides guidance to nutrition and health professionals for the applications of DRIs in dietary assessment. The report encourages nutritional evaluation from a quantitative perspective, as did the 1986 National Research Council report⁴ on nutrient adequacy, by providing the theoretical underpinnings of the various methods discussed.

Throughout its report¹, the Subcommittee on Interpretation and Use of DRIs distinguishes between methods of evaluating nutrient intakes of individuals and methods for evaluating intakes of groups, as these are two very different applications. Thus, the present paper provides separate discussions of these two assessment applications.

Definition of the DRIs

Where adequate information is available, each nutrient has a set of DRIs. A nutrient has either an Estimated Average Requirement (EAR) and an RDA, or an Adequate Intake (AI). When an EAR for the nutrient cannot be determined (and, therefore, neither can the RDA), then an AI is set for the nutrient. In addition, many nutrients have a Tolerable Upper Intake Level (UL).

Each DRI is defined briefly as follows:

- **Estimated Average Requirement (EAR):** a nutrient intake estimated to meet the requirement of half the healthy individuals in a particular life-stage and gender group.
- **Recommended Dietary Allowance (RDA):** the average daily dietary intake level sufficient to meet the nutrient requirement of nearly all (97–98%) healthy individuals in a particular life-stage and gender group.
- **Adequate Intake (AI):** a recommended intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of healthy people that are assumed to be adequate – used when an RDA cannot be determined.

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- **Tolerable Upper Intake Level (UL):** the highest average daily nutrient intake level likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the risk of adverse effects increases.

Like the former RDAs and RNIs, each type of DRI refers to the average daily nutrient intake of apparently healthy individuals over time. Intakes may vary substantially from day to day without ill effect in most cases.

DRI for nutrients reviewed to the year 2000 can be found in three Institute of Medicine (IOM) reports^{5–7}, and are summarised in *Dietary Reference Intakes: Applications in Dietary Assessment*¹. The chosen criterion of nutritional adequacy on which the DRI is based is different for each nutrient and is identified in these reports. In some cases the criterion for a nutrient may differ for individuals at different life stages.

Using the DRIs to assess nutrient intakes of individuals

It can be appropriate to compare the intakes of individuals with specific DRIs, even though dietary intake data alone cannot be used to ascertain an individual's nutritional status. Dietary assessment is one component of a nutritional status assessment, provided that accurate dietary intake data are collected, the correct DRI is selected for the assessment, and the results are interpreted appropriately. Ideally, intake data are combined with clinical, biochemical and anthropometric information to provide a valid assessment of an individual's nutritional status.

The EAR in assessment of individuals

Comparing an individual's intake with his or her requirement for a nutrient is difficult because: (1) a given individual's actual *requirement* is not known; and (2) it is seldom possible to measure an individual's long-term *usual intake* of the nutrient, owing to day-to-day variation in intake. The probability of inadequacy can be calculated theoretically for an individual's usual nutrient intake using the EAR and the standard deviation of the requirement. However, because *usual intake* of a nutrient is almost never known, a statistical approach has been developed that allows estimation of the confidence one has that usual intake is above (or below) an individual's requirement, based on the observed intake.

This approach is based on the following considerations:

- The EAR is the best estimate of an individual's requirement.
- There is person-to-person variation in requirement. The standard deviation of the requirement is an indicator of how much the individual's requirement for a nutrient can deviate from the median requirement (EAR) in the population.

- Mean observed intake of an individual is the best estimate of an individual's usual intake.
- There is day-to-day variation in intake for an individual. The within-person standard deviation of intakes is an indicator of how much observed intake might deviate from usual intake.

Inferences about the adequacy of an individual's diet can be made by looking at the difference between the mean observed intake and the median requirement. If this difference is large and positive, i.e. if observed intake is much greater than the median requirement, then it is likely that an individual's intake is adequate. Conversely, if the difference is large and negative, i.e. observed intake is much less than the median requirement, then it is likely that an individual's intake is not adequate. The recommended statistical approach considers both the person-to-person variation in requirements, and the day-to-day variation in intake, to determine the level of confidence that a given intake is above the requirement for an individual.

For practical purposes, many users of the DRIs may find it useful to consider that observed intakes below the EAR very likely need to be improved (because the probability of adequacy is 50% or less), and those between the EAR and the RDA probably need to be improved (because the probability of adequacy is less than 97–98%). Only if intakes have been observed for a large number of days and are at or above the RDA, or observed intakes for fewer days are well above the RDA, should one have a high level of confidence that the intake is adequate.

The AI in assessment of individuals

Some nutrients have an AI because the evidence was not sufficient for establishing an EAR and thus an RDA. The approach described above for the EAR cannot be used for nutrients that have an AI. However, a statistically based hypothesis testing procedure for comparing the observed intake with the AI may be used. This is a simple *z-test*, which is constructed using the standard deviation of daily intake of the nutrient¹.

If an individual's usual intake exceeds the AI after applying this statistical test, it can be concluded that the diet is almost certainly adequate. If, however, intake falls below the AI, no quantitative (or qualitative) estimate can be made of the probability of nutrient inadequacy. Professional judgement, based on additional types of information about the individual, should be exercised when interpreting intakes below the AI.

The UL in assessment of individuals

To assess whether an individual's usual nutrient intake is so high that it poses a risk of adverse health effects, usual intake is compared with the UL. A hypothesis test similar to the one proposed above for the AI can be used to decide whether usual intake is below the UL. For some nutrients,

the intake to be considered is from supplements, fortificants and medications only, while for other nutrients, intake from foods is also considered.

The UL is set at the highest level that is likely to pose no risk of adverse health effects for almost all individuals in the general population, including sensitive individuals; but it is not possible to know who is most sensitive⁸. If usual intake exceeds the UL, it may pose a risk for some healthy individuals. The consequences of nutrient excess are much more severe for some nutrients than for others, and for some nutrients the consequences may be irreversible⁵⁻⁷.

Illustration of assessing individual diets using the DRIs

A hypothetical example of a dietary assessment for a man aged 78 years is shown in Table 1. This individual reported three days of dietary data, and intakes have been calculated for five nutrients (thiamin, folate, calcium, vitamin D and iron). Using the within-person standard deviation of intake for thiamin (0.69 mg day^{-1})¹, one can calculate that there is an 85% confidence that an intake of 1.3 mg day^{-1} was above this person's requirement (as represented by the EAR of 1.0 mg day^{-1}). It is important to note that even though intake was well above the EAR, and indeed even above the RDA of 1.2 mg day^{-1} , there is still a 15% probability of inadequacy due to the day-to-day variation in intake. For folate, the intake is well below the EAR, and the confidence of adequacy is only 5%. Calcium does not have an EAR or RDA, but only an AI of 1200 mg day^{-1} . The subject's intake was 1300 mg day^{-1} , above the AI, and therefore likely to be adequate if true long-term intake was captured accurately. However, because of the day-to-day variation in calcium intake, the confidence of adequacy is less than 80%. A reversed situation is illustrated for vitamin D, where the intake is below the AI. In this situation, no confidence of adequacy can be calculated because the distribution of requirements for vitamin D is not known. Evaluation of intakes of vitamin D is problematic in any case, because there are no national survey data to provide information on day-to-day variation in intakes, nor is sun exposure usually known. Finally, the adequacy of iron intake is unknown because new DRIs have not yet been set for iron. The person's

intake was below the 1989 RDA, but the confidence of adequacy cannot be calculated. Thus, based on these analyses, intake of folate clearly should be improved, and intakes of calcium and thiamin also should be increased. Although the confidence of adequacy cannot be calculated for either vitamin D or iron, intakes are not at a desirable level and should be improved.

A similar approach would be used to determine if intakes of this individual are below the UL. For the five nutrients in the illustration, ULs have been set for three: folate (from supplements and fortificants only), calcium and vitamin D. None of the individual's intakes is close to the corresponding UL, so excessive intake is not a concern.

Using the DRIs to assess nutrient intakes of groups

Determining the proportion of a group with usual intake of a nutrient that is less than their requirement for the same nutrient is critically important from a public health perspective. Clearly, the implications are different if 30% vs. 3% of the individuals in a group have inadequate intake. It is also important to estimate what proportion of the group has usual intake of a nutrient so high that it places them at risk of adverse health effects.

The EAR in assessment of groups

Assessment of the prevalence of inadequate intakes for groups involves choosing between two methods: the probability approach^{1,4} or the EAR cut-point method^{1,9}. Regardless of the method actually chosen to estimate the prevalence of inadequacy, the EAR is the appropriate DRI to use when assessing the adequacy of group intakes.

The probability approach

The probability approach is a statistical method that combines the distributions of requirements and intakes in the group to produce an estimate of the expected proportion of individuals at risk for inadequacy^{1,4}. For this method to perform well, little or no correlation should exist between intakes and requirements in the group. The approach is based on statistical probabilities: at very low intakes the risk of inadequacy is high whereas at very high intakes the risk of inadequacy is negligible. In fact, with

Table 1 Evaluation of a hypothetical individual's diet. Male, 78 years old, three days of intake

Nutrient	Mean intake	Requirement	Confidence of adequacy	UL	Confidence that intake is < UL
Thiamin (mg)	1.3	1.0 (EAR)	85%	None set	Unknown
Folate (μg)	200	320 (EAR)	5%	1000	>98%
Calcium (mg)	1300	1200 (AI)	80%	2500	>98%
Vitamin D (μg)	3	15 (AI)	Unknown	50	>98%
Iron (mg)	8	10 (1989 RDA)	Unknown (no DRIs yet)	None (no DRIs yet)	Unknown

UL – Tolerable Upper Intake Level; EAR – Estimated Average Requirement; AI – Adequate Intake; RDA – Recommended Dietary Allowance.

information about the distribution of requirements for the group, a value for risk of inadequacy can be attached to each intake level. Because in a group there is a range of usual intakes, the prevalence of inadequacy in the group – the average group risk – is estimated as the weighted average of the risks at each possible intake level.

The EAR cut-point method

With some additional assumptions, a simpler version of the probability approach can be applied. The EAR cut-point method can be used if no correlation exists between intakes and requirements (as is also needed for the probability approach above), if the distribution of requirements can be assumed to be symmetrical around the EAR, and if the variance of intakes is greater than the variance of requirements.

The EAR cut-point method is simpler because, rather than estimating the risk of inadequacy for each individual's intake level, one simply counts how many individuals in the group of interest have usual intakes that are below the EAR (Fig. 1). That proportion is the estimate of the proportion of individuals in the group with inadequate intakes. (For a theoretical justification of this simplified cut-point method, see Carriquiry⁹.)

Adjusting intake distributions

Regardless of the method chosen to assess prevalence of inadequate nutrient intake in a group of individuals, information is required about the distribution of usual intakes of the nutrient in the group. Adjustment of the distribution of observed intakes is needed to partially remove the day-to-day variability in intake (within-person variation). The resulting estimated intake distribution, referred to as the *usual intake distribution* or the *adjusted intake distribution* of a nutrient, should then better reflect the individual-to-individual variation of intake of that nutrient within the group.

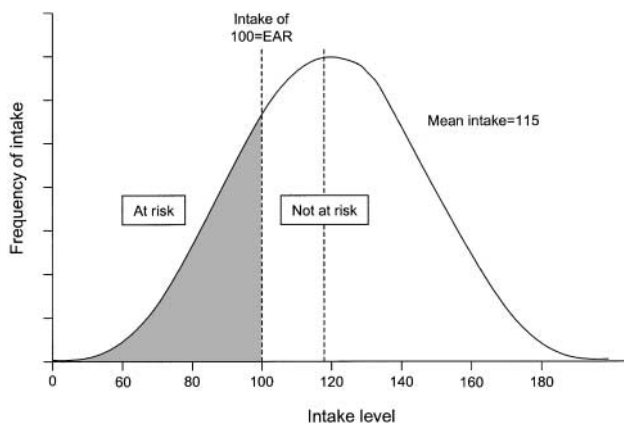


Fig. 1 The EAR cut-point method. The shaded area of the usual intake distribution represents the proportion of individuals in the group whose intakes are below the Estimated Average Requirement (EAR), while the non-shaded area represents the proportion with usual intakes above the EAR

Usual intake distributions can be estimated by statistically adjusting the distribution of intake of each individual in the group. This general approach was proposed by the National Research Council⁴ and was developed further by Nusser *et al.*¹⁰. To adjust intake distributions, at least two independent days or three consecutive days of dietary intake data are needed for a representative sub-sample of individuals in the group.

If intake distributions are not properly adjusted for both within-person variation and survey-related effects such as interview method and interview sequence, the prevalence of nutrient inadequacy will be estimated incorrectly no matter which of the approaches discussed above is chosen. If only one day of intake data is available for each individual in the sample, it may still be possible to adjust the observed intake distribution by using an estimate of within-person variation in intakes estimated from other datasets (Fig. 2).

The RDA is inappropriate for assessment of groups

The RDA, by definition, is an intake level that exceeds the requirements of 97–98% of all individuals when requirements in the group have a normal distribution. Thus, the RDA should *not* be used as a cut-point for assessing the nutrient intakes of groups because it would seriously overestimate the proportion of the group at risk of inadequacy.

The group's mean intake is inappropriate for assessment of groups

Mean or median intake seldom, if ever, can be used to assess nutrient adequacy of group diets. In the past, nutrient intake data have frequently been evaluated by comparing mean intakes with RDAs. In particular, studies that found mean intakes equal to or exceeding the RDA

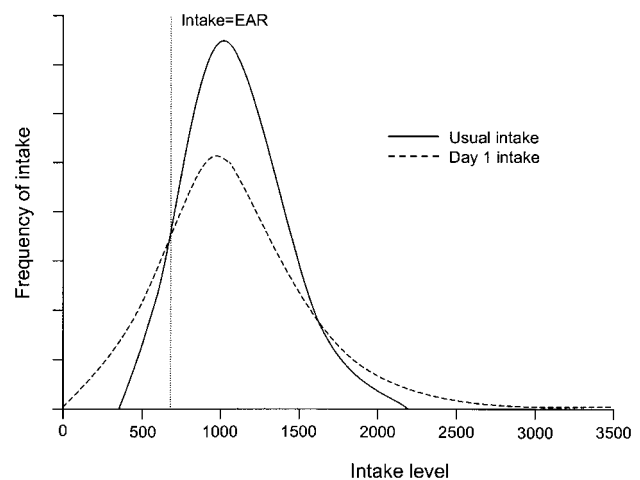


Fig. 2 Estimates of usual intake distribution of a nutrient obtained from one day of intake data and adjusted with replicate intake data using the Iowa State University method¹⁰. The y-axis (Frequency of intake) shows the likelihood of each level of intake in the population. EAR – Estimated Average Requirement

often concluded that group diets were adequate and conformed to recognised nutritional standards. However, this is inappropriate because the prevalence of inadequacy depends on the shape and variation of the usual intake distribution, not on the mean intake. Indeed, for most nutrients, the group's mean intake must exceed the RDA to have an acceptably low prevalence of inadequate intakes. Moreover, the greater the variability in usual intake relative to the variability in requirement, the greater the mean usual intake must be relative to the RDA to ensure that only a small proportion of the group has inadequate intake. If group mean intake equals the RDA, there will be a substantial proportion of the group with usual intake less than the requirement.

The AI in assessment of groups

When the AI represents the mean intake of an apparently healthy group (or groups) of people, similar groups with mean intakes at or above the AI can be assumed to have a low prevalence of inadequate intakes for the defined criteria of nutritional status. For AIs that were either derived experimentally or developed from a combination of experimental and intake data, a similar assessment can be made, but with less confidence. Each AI is described in terms of its derivation and selected criterion of adequacy in the individual DRI reports^{1,5–7}. When mean intakes of groups are below the AI it is not possible to make any assumptions about the prevalence of inadequacy.

The UL in assessment of groups

The UL is the appropriate DRI to use to assess the risk of adverse health effects from excessive nutrient intake. Depending on the nutrient, the UL assessment requires accurate information on usual daily intake from all sources, or from supplements, fortificants and medications only. Usual intake distributions will allow determination of the fraction of the population exceeding the UL. This fraction may be at risk of adverse health effects.

Difficulties arise in attempts to quantify the risk (likelihood) of adverse health effects in the general population from daily nutrient intakes exceeding the UL. The use of uncertainty factors to arrive at the UL reflects inaccuracies in reported nutrient intake data, uncertainties

in the dose–response data on adverse health effects, extrapolation of data from animal experiments, severity of the adverse effect, and variation in individual susceptibility⁸. As more accurate data from human studies become available, predicting the magnitude of the risk associated with intakes exceeding the UL may become possible. For now it is advisable to use the UL as a cut-off for safe intake.

An example of assessing group intakes

Table 2 summarises a dietary assessment for a group of children aged 4 to 8 years who participated in a national dietary survey, the Continuing Survey of Food Intake of Individuals, 1994–1996. Only five nutrients are shown for the purposes of illustration. Prior to analysing the prevalence of inadequacy, the intakes were adjusted for day-to-day variation in nutrient intake as described above.

Although the table shows mean intake, this information should not be used to assess the prevalence of inadequacy. Instead, the distribution of intakes must be examined to determine the proportion of the population below the EAR. For thiamin, less than 1% of the group has intakes below the EAR of 0.5 mg day⁻¹, indicating that thiamin is not likely to be a problem nutrient for this group. The same is true for vitamin C. For magnesium, about 5% of the group has intakes below the EAR, which is higher than the commonly accepted prevalence of inadequacy of about 2–3%. Note that mean magnesium intake is not only above the EAR of 110 mg day⁻¹, but also substantially above the RDA of 130 mg day⁻¹. Nonetheless, the prevalence of inadequacy is higher than desirable. Calcium does not have an EAR, so the AI is the only DRI available for assessing intakes. For this group of children, mean calcium intake exceeded the AI, implying that the prevalence of inadequacy is likely to be low. However, because the calcium AI was not based directly on intakes of a healthy population (but rather on maximum calcium retention), this assessment involves assuming that the AI is at least as high as it would have been if based on observed intakes of a healthy group of children. Finally, no assessment is possible for iron, because the DRIs for iron have not yet been set. Even though the mean intake is above the 1989 RDA, no

Table 2 Evaluation of a hypothetical group's diet. CSFII* data for children 4–8 years old

Nutrient	Mean intake	Requirement	Prevalence of inadequacy†	UL	Prevalence of excessive intakes‡
Thiamin (mg)	1.44	0.5 (EAR)	< 1%	None set	Unknown
Magnesium (mg)	212	110 (EAR)	5%	110	Unknown (supplements only)
Calcium (mg)	838	800 (AI)	Low	2500	< 1%
Vitamin C (mg)	96	22 (EAR)	< 1%	650	< 1%
Iron (mg)	14	10 (1989 RDA)	Unknown (no DRIs yet)	None (no DRIs yet)	Unknown

UL – Tolerable Upper Intake Level; EAR – Estimated Average Requirement; AI – Adequate Intake; RDA – Recommended Dietary Allowance.

* CSFII is the US Department of Agriculture's Continuing Survey of Food Intake of Individuals, 1994–1996.

† Percentage of intakes below the EAR or above the UL. The intake distribution must be adjusted to remove the effect of day-to-day variation before these assessments are made.

assessment of the prevalence of inadequacy can be offered.

Table 2 also gives the estimated prevalences of intakes that are above the UL, and thus at risk of adverse effects. For these five nutrients, three have a UL: magnesium (for pharmacological agents only), calcium and vitamin C. The percentage of the group above the calcium and vitamin C ULs is low (less than 1%). The prevalence of excessive intakes of magnesium cannot be evaluated from these data because intakes from supplements are not included. An accurate evaluation could only be undertaken if magnesium from supplements was known, and was reported as a separate variable that did not contain magnesium intake from food and fortificants.

Recommendations for research to enhance use of the DRIs

In several parts of the IOM report¹, the Subcommittee on Interpretation and Use of Dietary Reference Intakes was able to provide only general guidelines for application of the DRIs in dietary assessment. By highlighting areas where much research is still needed, the Subcommittee hoped to increase the chance that research on these topics will be undertaken.

Increased knowledge in any of the areas listed below would be beneficial in enhancing use of the DRIs for dietary assessment.

Research to improve estimates of nutrient requirements

Even for nutrients for which an EAR is available, the estimated EARs and RDAs are often based on just a few experiments with very small sample sizes. For nutrients with an AI for age groups older than infants, new research and data that allow replacement of the AIs with EARs and RDAs will greatly aid the assessment of nutrient adequacy. In addition, information on the distribution of requirements is needed so that the appropriate method for

assessing the prevalence of inadequacy for groups can be determined (EAR cut-point vs. full probability approach).

Research on adverse health effects should be undertaken to allow ULs to be set for all nutrients, and to generate information on ways to identify and conceptualise the risk of exceeding the UL.

Research to improve the quality of dietary intake data

The estimation and amelioration of bias (such as under- or overreporting of food intake) is a relatively unexplored field. Efforts in the management of bias during data analysis are very preliminary and far from satisfactory at present. This is seen as a high-priority area waiting for new initiatives and innovative approaches.

Advances in behavioural research to determine why people underreport food intake would allow the development of improved dietary data collection tools that would not trigger this behaviour. Such information would also help in the derivation of statistical tools to correct the bias associated with this phenomenon.

Better ways to quantify the intake of supplements are needed. A large proportion of the population in the USA and Canada consumes dietary supplements. Using intakes from food sources only in dietary assessment is certain to result in a faulty estimate of nutrient inadequacy, as well as inaccurate estimates of the percentage of the population with intakes above the UL.

Food composition databases need to be updated to include the forms and units that are specified by the DRIs. Chemical methodology to facilitate analysis of various forms of certain nutrients (e.g., α -tocopherol vs. γ -tocopherol) may be required for comparison with the DRIs.

Research to improve statistical methods for using DRIs to assess intakes of groups

Methods for developing standard errors for prevalence estimates should be investigated. Some sources of variance (primarily associated with intake data) can

Table 3 Uses of DRIs for assessing the intakes of individuals and groups

For an individual	For a group
<i>EAR</i> : use to examine the possibility of inadequacy	<i>EAR</i> : use to estimate the prevalence of inadequate intakes within a group
<i>RDA</i> : usual intake at or above this level has a low probability of inadequacy	<i>RDA</i> : do not use to assess intakes of groups
<i>AI</i> : usual intake at or above this level has a low probability of inadequacy	<i>AI</i> : mean usual intake at or above this level implies a low prevalence of inadequate intakes*
<i>UL</i> : usual intake above this level places an individual at risk of adverse effects from excessive nutrient intake	<i>UL</i> : use to estimate the percentage of the population at risk of adverse effects from excessive nutrient intake

EAR – Estimated Average Requirement; RDA – Recommended Dietary Allowance; AI – Adequate Intake; UL – Tolerable Upper Intake Level.

* When the AI for a nutrient is not based on mean intakes of healthy populations, this assessment is made with less confidence.

currently be quantified, but many (such as those associated with requirement estimates) cannot. Without a standard error estimate, it is not possible to determine if an estimated prevalence of $X\%$ is significantly different from zero or if the prevalence estimates for two groups differ significantly from each other or from zero.

Ways to assess the performance of models to estimate prevalence of inadequacy should be investigated. A detailed investigation of the effect of violating assumptions for the EAR cut-point method discussed in the IOM report¹ is a high research priority. This would best be done using well-designed, well-planned and well-implemented simulation studies. Results of such studies would permit recommendations of the best assessment approach to use for each nutrient and would provide an estimate of the expected bias in prevalence estimates when the conditions for application of the cut-point method are not ideal.

Summary: using the DRIs for assessing intakes

Table 3 provides a brief summary of appropriate uses of the DRIs for dietary assessment. For complete details, the IOM report¹ should be consulted.

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