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New Approaches to Assessing Nutrient Intakes Using the Dietary Reference Intakes

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The Dietary Reference Intakes (DRI's) are new nutrient intake standards that are being set for the United States and Canada. There are currently four types of DRI's: Estimated Average Requirements (EAR), Recommended Dietary Allowances (RDA), Adequate Intakes (AI), and Tolerable Upper Intake Levels (UL). The EAR is the nutrient intake that would be adequate for about half the population, while intake at the RDA should be adequate for 97-98% of the population. When the data are insufficient to set an EAR and RDA, then an AI is set. The UL is the highest intake level that does not pose a risk of adverse effects. The EAR, AI, and UL may be used to assess intakes of both individuals and of groups of people. For individuals, the EAR is used to calculate the probability that intake is inadequate, the AI is used to decide if the probability of inadequacy is low, and the UL is used to determine if a risk of excess intake is present. For groups, the EAR is used to estimate the prevalence of inadequacy, the AI is used to decide if the prevalence of inadequacy is low, and the UL is used to estimate the prevalence of excessive intakes. Because this approach to setting and applying nutrient standards is new, research recommendations include improving estimates of risk, improving dietary data, and improving statistical methods.

INTRODUCTION

New nutrient intake standards for the United States and Canada are being set by the Food and Nutrition Board of the Institute of Medicine. These standards are called Dietary Reference Intakes (DRI's) and replace the former Recommended Dietary Allowances (RDAs) in the US (NRC, 1989) and the Recommended Nutrient Intakes (RNIs) in Canada (Health and Welfare Canada, 1990).

DEFINITIONS OF THE DRI' S

DRI is a collective term that includes four nutrient-based dietary reference values:

- Estimated Average Requirement (EAR): The average daily nutrient intake level estimated to meet the requirement of half the healthy individuals in a particular life stage and gender group. At this level of intake, 50% of people would have their needs met and 50% would not. A specific criterion of adequacy is established for each nutrient.
- Recommended Dietary Allowance (RDA): The average daily nutrient intake level sufficient to meet the requirement of nearly all (97 to 98%) healthy individuals in a particular life stage and gender group. Thus, the RDA is sufficient to meet the daily needs of most individuals. It is intended to serve as a goal for daily intake by individuals. If the requirements are normally distributed, the RDA can be calculated from the EAR as:

$$RDA = EAR + 2SD_{EAR}$$

Where SD_{EAR} is the standard deviation of the EAR. Fig 1 illustrates this relationship graphically. For most nutrients, the SD_{EAR} is between 10% and 20% of the EAR. Thus, the RDA is usually 20% to 40% higher than the EAR.

- Adequate Intake (AI): A recommended average daily nutrient intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adquate-it is set when an RDA cannot be determined. It can be used as the intake goal for an individual. Thus, a nutrient will have either an EAR/RDA, or an AI, but not both.
- 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 potential risk of adverse effects increases. It is neither a recommended intake nor a level that is desirable to attain.

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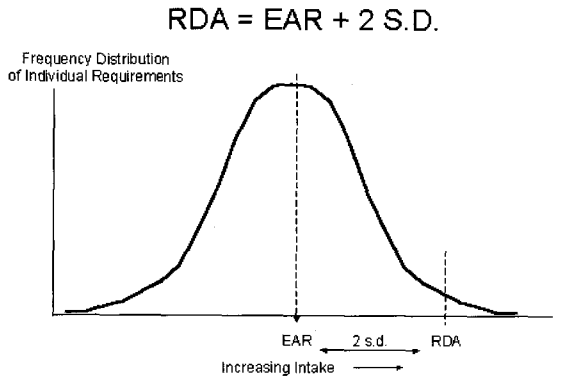

Fig 1. A hypothetical frequency distribution of individual requirements that could be used to determine the EAR and RDA for a nutrient.

Relationships among the four DRI's are shown graphically in Fig 2.

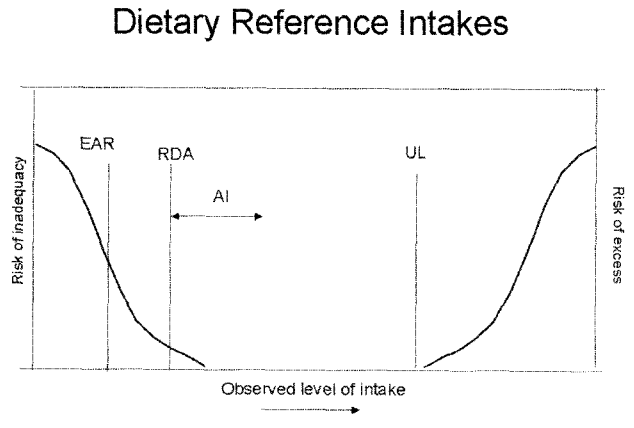

Fig 2. Relationship among the four Dietary Reference Intakes: Estimated Average Requirement (EAR), Recommended Dietary Allowance (RDA), Adequate Intake (AI), and Tolerable Upper Intake Level (UL).

NUTRIENTS WITH DRI' S

The new DRI's are being released in a series of reports from the Institute of Medicine (IOM, 1997, 1998, 2000b, 200[1]). To date, requirements for all vitamins and minerals except electrolytes have been set. A report on macronutrient requirements has just been released (IOM, 200[2]).

Most vitamins and minerals have an EAR and an RDA for persons over one year of age: phosphorus, magnesium, thiamin, riboflavin, niacin, vitamin B_6, folate, vitamin B_{12}, vitamin C, vitamin E, selenium, vitamin A, copper, iodine, iron, molybdenum, and zinc. For infants under one year of age, an AI is set based on the nutrient content of breast milk. In addition, AIs have been set for older age groups for the following nutrients: calcium, vitamin D, fluoride, pantothenic acid, biotin, choline, vitamin K, chromium, and manganese. Table 1 shows some examples of differences in recommended intakes for adult women between 1989 (former RDAs) and 1997-2001 (DRI's).

Table 1. Former RDAs versus new DRI's: Examples for adult women 31-50 years of age.

Nutrient	RDA from 1989	DRI (AI or RDA)
Calcium (mg)	800	1000
Folate (μg)*	180	400
Magnesium (mg)	280	320
Vitamin E (mg)*	8	15
Iron (mg)	15	18

* The unit for the 1989 folate RDA was micrograms, but the unit for the 1998 RDA is micrograms of Dietary Folate Equivalents (IOM, 1999). The unit for the 1989 vitamin E RDA was milligrams of alpha-tocopherol equivalents, while the unit for the 2000 RDA is milligrams of alpha-tocopherol (IOM, 2000b).

All vitamins and minerals that have an EAR/RDA or an AI also have a UL, with the following exceptions: thiamin, riboflavin, vitamin B_{12}, pantothenic acid, biotin, vitamin K, and chromium. Three minerals have a UL, but no EAR/RDA or AI: boron, nickel, and vanadium.

USES OF THE DRI' S

A subcommittee on uses and interpretation of the DRI's has been convened to provide guidance to health professionals on appropriate applications for the DRI's. The subcommittee decided to divide the applications into two broad categories: those related to assessing diets and those related to planning diets. Within each category, applications for individuals and those for groups of people would be addressed separately. The subcommittee published its first report, *Applications in Dietary Assessment*, in 2000 (IOM, 2000a). The report can be accessed at www.nap.edu. A similar report on applications in planning diets is expected by the end of 2002.

ASSESSING NUTRIENT INTAKES OF INDIVIDUALS

Three DRI's may be used to assess the diets of individuals:

- The EAR is used to calculate the probability of inadequacy.
- When a nutrient has an AI, rather than an EAR,

the probability of inadequacy cannot be calculated. However, usual intakes at or above the AI have a low probability of inadequacy.
- The UL may be used to determine if the intake is at risk of being excessive. Usual intakes above the UL place an individual at risk of adverse effects.

The EAR is particularly useful when trying to answer the question, "Does an individual's usual nutrient intake exceed his or her requirement?" This is a difficult question to answer because a person's true *requirement* is almost never known, and a person's usual (long-term average) *intake* is almost impossible to measure. However, we can estimate a person's requirement as the EAR (because it is the average requirement), and we can estimate a person's usual intake by observing (or having them report) their intake for one or more days. Because it is necessary to estimate both intake and requirement, the confidence of adequacy is affected by the variance of the EAR, the day-to-day variance in intake, and the number of days of intake data that were collected. All these factors should be considered when deciding the probability that the intake is greater than the requirement. An equation for performing this calculation is given in the assessment report (IOM, 2000a).

Table 2 gives the confidence of adequacy for a hypothetical adult male patient in a clinic. Because only three days of intake were collected, the confidence of adequacy for thiamin is only 85%, even though intake (1.3mg/d) is above the EAR (1.0mg/d) and also above the RDA (1.2mg/d). Calcium intake (1,200mg/d) is well above the AI (1000mg/d), but the confidence that intake is truly above the AI is only 86% because three days of intake do not reflect usual long-term intake. For iron, intake (8mg/d) is close to the EAR (8.1mg/d) but the confidence of adequacy is only 55% because intakes at the EAR have, by definition, about a 50% probability of inadequacy.

Table 2. An assessment of the diet of a hypothetical adult male patient with three days of observed intake*

Nutrient	Mean Intake Across 3 Days	Requirement	Confidence of adequacy
Thiamin (mg)	1.3	1.0 (EAR)	85%
Folate (μg)	200	320 (EAR)	5%
Calcium (mg)	1200	1000 (AI)	86%
Vitamin D (μg)	3	5 (AI)	Unknown
Iron (mg)	8	8.1 (EAR)	55%

*Adapted from IOM, 2000a

ASSESSING NUTRIENT INTAKES OF GROUPS

The same three DRI's that are used to assess intakes of individuals may also be used to assess the nutrient intakes of groups. However, the way they are used differs somewhat:

- The EAR is used to examine the prevalence of inadequate intakes in the group.
- When a nutrient has an AI, rather than an EAR, the prevalence of inadequacy cannot be calculated. However, if the mean intake of the group is at or above the AI, the prevalence of inadequacy can be assumed to be low.
- The UL is used to estimate the percent of a population potentially at risk of adverse effects.

The availability of an EAR for a nutrient provides a new tool for estimating the proportion of a group that has inadequate intakes (i.e., intake below their requirement). Such an estimate of the prevalence of inadequacy is useful in guiding nutrition policies and programs. A "full" probability approach to estimating the prevalence of inadequacy involves calculating the probability of inadequacy for each person in the group. The group prevalence of inadequacy is the average of these individual probabilities. A greatly simplified method of estimating these prevalences is also available: the EAR cut-point approach. With this approach, the prevalence of intakes below the EAR is used as an estimate of the group prevalence of inadequacy. Both approaches assume that intake and requirement are independent, which is thought to be true for most nutrients except energy. Additionally, the EAR cut-point approach assumes that the requirement distribution is symmetric (which is thought to be true for all nutrients except iron) and that the between-person variance in intakes is greater than the variance of requirements (which is generally true for large groups in the US and Canada, but may not be true for smaller groups or for other countries).

THE DAY-TO-DAY VARIATION IN INTAKES SHOULD BE REMOVED BEFORE ASSESSING GROUP INTAKES

When using either the full probability approach or the EAR cut-point approach to estimating the prevalence of inadequate intakes within a group, it is first necessary to remove the effect of day-to-day variation in intake. It was not possible to remove this variation from the estimates of individual intakes, but statistical methods are available for removing it for groups. Software is available from Iowa State University for performing these calculations (Carriquiry, 1999), or an approach described in a report from the National Research Council may be used (NRC, 1986). In either case, an estimate

of the day-to-day variation for the nutrient is needed, either by collecting at least two days of dietary data for a representative subsample of the group (the preferred method), or by using published information on day-to-day variation for a similar group.

The importance of making this adjustment is shown in Fig 3, which gives two hypothetical distributions of intakes. The dotted line is the observed distribution of one-day intakes, while the solid line is the adjusted distribution of intakes that better reflects usual intakes observed over many days. The usual intake distribution is narrower, and the tails are smaller. As a result, the proportion of the population with intakes below the EAR is much smaller for the adjusted distribution than for the one-day intake distribution. If the intake distribution had not been adjusted for day-to-day variation, the prevalence of inadequacy, using the EAR cut-point method, would have been substantially over-estimated for this group of people.

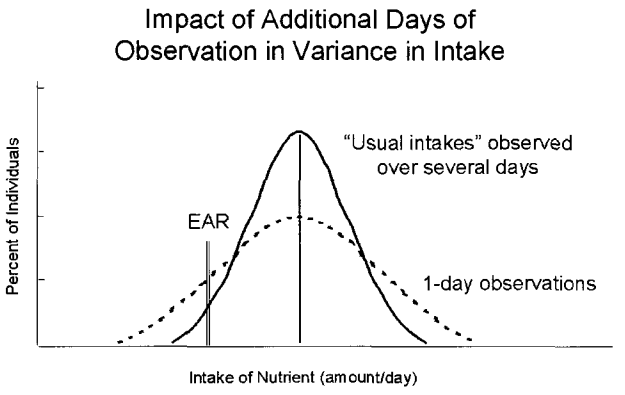

Fig 3. A hypothetical distribution of usual intake compared to the corresponding distribution of one-day observations of intake.

Table 3 shows how intakes for a group of children 4-8 years of age might be assessed. These data are taken from a national nutrition survey conducted in the US in 1994-96. The intake distributions have been adjusted to remove the effect of day-to-day variation as described above. For thiamin, magnesium, and vitamin C intakes, the prevalence of inadequacy was estimated as the proportion of children below the EAR. The prevalence was low for all three nutrients, implying that few children are at risk of nutrient inadequacy. Because iron requirements are not normally distributed, the EAR cut- point method cannot be used. However, the full probability approach may be used, along with tables of requirements published in the DRI report for micronutrients (IOM, 200[1]), to estimate a prevalence of inadequacy; in this example, the prevalence is less than 5%. For calcium, an EAR is not available, so it is not possible to calculate the prevalence of inadequacy. However, because the mean intake (838 mg/d) is greater than the AI (800 mg/d), a low prevalence of inadequacy can be assumed.

Table 3. An assessment of the prevalence of inadequate intakes for children 4-8 years of age using national survey data in the United States.*

Nutrient	Mean Intake	Requirement	Prevalence of inadequate intakes
Thiamin (mg)	1.44	0.5 (EAR)	< 1%
Magnesium (mg)	212	110 (EAR)	5%
Calcium (mg)	838	800 (AI)	Low
Vitamin C (mg)	96	22 (EAR)	< 1%
Iron (mg)	14	4.1 (EAR)	< 1%

* Adapted from IOM, 2000a

Table 4 continues the assessment of intakes for 4-8 year old children in the US by examining the prevalence of potentially excessive intakes for this group (defined as intakes above the UL). The prevalence of intakes at risk of adverse effects is less than 1% for calcium, vitamin C, and iron. The prevalence cannot be estimated for either thiamin or magnesium because no UL was set for thiamin, and the UL for magnesium refers only to intakes from non-food sources. The survey did not measure non-food sources of nutrients (such as dietary supplements), so it is not possible to evaluate the prevalence of excessive intakes.

Table 4. An assessment of the prevalence of excessive intakes for children 4-8 years of age using national survey data in the United States.[1)]

Nutrient	Mean Intake	UL	Prevalence of high intakes
Thiamin (mg)	1.44	None set	Unknown
Magnesium (mg)	212	110	Unknown[2)]
Calcium (mg)	838	2500	< 1%
Vitamin C (mg)	96	650	< 1%
Iron (mg)	14	40	< 1%

1) Adapted from IOM, 2000a
2) The magnesium UL applies only to intakes from supplements, so the prevalence of high intakes can only be determined if the dietary data are separated into intakes from foods and intakes from supplements.

NEW UNITS ARE BEING USED FOR SOME OF THE DRI'S

Three new units have been defined when setting DRI's for folate, vitamin A, and vitamin E. For folate, the new unit is the Dietary Folate Equivalent (DFE). One microgram of DFE is equal to one microgram of food folate, 0.5 micrograms of synthetic folic acid on an empty

stomach, and 0.6 micrograms of synthetic folic acid with food. Thus, the bioavailability of synthetic folic acid is up to two times greater than that of food folate.

For vitamin A, the new unit is micrograms of Retinol Activity Equivalents (RAE), which replaces the micrograms of Retinol Equivalents (RE) that was used in the past. The new unit was necessary because the availability of provitamin A carotenoids was decreased to only 50% of its former value. Vitamin E requirements are no longer expressed as milligrams of alpha-tocopherol equivalents because the other forms of tocopherols (for example, gamma- and beta-tocopherol) and tocotrienols are no longer believed to have vitamin E activity. Thus, vitamin E DRI's are given as milligrams of alpha tocopherol. Furthermore, the naturally-occurring form of alpha-tocopherol is assumed to be more bioavailable than the synthetic forms that are a mix of different stereoisomers of alpha-tocopherol. Conversion factors are available for the synthetic forms of vitamin E (IOM, 2000b).

RESEARCH RECOMMENDATIONS

In the Assessment Report (IOM, 2000a), several research recommendations are made:

- ***Research to improve estimates of risk:***
  - Obtain better estimates of requirement distributions to replace AIs.
  - Determine factors that alter requirements and ULs, so DRI's can be tailored to individuals and groups.
  - Develop ULs for all nutrients.
- ***Research to improve dietary data:***
  - Reduce bias in intake (over- and under-reporting).
  - Find better ways to quantify usual dietary supplement intake.
  - Update food composition tables to reflect the forms and units specified by the DRI's.
- ***Research to improve statistical methods:***
  - Find ways to more accurately estimate an individual's within-person variation in intake.
  - Develop methods for estimating the standard errors in prevalence estimates for groups.
  - More thoroughly evaluate the performance of the EAR cut-point method.

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