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Introduction to Dietary Reference Intakes

The term Dietary Reference Intakes (DRIs) refers to a set of at least four nutrient-based reference values, each of which has special uses. The development of DRIs expands on the periodic reports called Recommended Dietary Allowances, which have been published since 1941 by the National Academy of Sciences. This comprehensive effort is being undertaken by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (DRI Committee) of the Food and Nutrition Board, Institute of Medicine, the National Academies, with the active involvement of Health Canada. See Appendix A for a description of the overall process and its origins.

WHAT ARE DIETARY REFERENCE INTAKES?

The reference values, collectively called the Dietary Reference Intakes (DRIs), include the Recommended Dietary Allowance (RDA), the Adequate Intake (AI), the Tolerable Upper Intake Level (UL), and the Estimated Average Requirement (EAR).

A requirement is defined as the lowest continuing intake level of a nutrient that, for a specified indicator of adequacy, will maintain a defined level of nutriture in an individual. The chosen criterion of nutritional adequacy is identified in each nutrient chapter; note that the criterion may differ for individuals at different life stages. Hence, particular attention is given throughout this report to the choice and justification of the criterion used to establish requirement values.
This approach differs somewhat from that used by the World Health Organization, Food and Agriculture Organization, and International Atomic Energy Agency (WHO/FAO/IAEA) Expert Consultation on *Trace Elements in Human Nutrition and Health* (WHO, 1996). That publication uses the term *basal requirement* to indicate the level of intake needed to prevent pathologically relevant and clinically detectable signs of a dietary inadequacy. The term *normative requirement* indicates the level of intake sufficient to maintain a desirable body store or reserve. In developing RDAs and AIs, emphasis is placed instead on the reasons underlying the choice of the criterion of nutritional adequacy used to establish the requirement. They have not been designated as basal or normative.

Unless otherwise stated, all values given for RDAs, AIs, and EARs represent the quantity of the nutrient or food component to be supplied by foods from a diet similar to those consumed in Canada and the United States. If the food source of a nutrient is very different (as in the diets of some ethnic groups) or if the source is supplements, adjustments may have to be made for differences in nutrient bioavailability. When this is an issue, it is discussed for the specific nutrient in the section “Special Considerations.”

RDAs and AIs are levels of intake recommended for individuals. They should minimize the risk of developing a condition that is associated with the nutrient in question and that has a negative functional outcome. The DRIs apply to the apparently healthy general population. Meeting the recommended intakes for vitamin C, vitamin E, selenium, and carotenoids would not necessarily provide enough for individuals who are already malnourished, nor would they be adequate for certain disease states marked by increased requirements. Qualified medical and nutrition personnel must tailor recommendations for individuals who are known to have diseases that greatly increase requirements or who are at risk for developing adverse effects associated with higher intakes. Although the RDA or AI may serve as the basis for such guidance, qualified personnel should make necessary adaptations for specific situations.

**CATEGORIES OF DIETARY REFERENCE INTAKES**

Each type of Dietary Reference Intake (DRI) refers to average daily nutrient intake of individuals over time. In most cases, the amount taken from day to day may vary substantially without ill effect.
**Recommended Dietary Allowance**

The Recommended Dietary Allowance (RDA) is the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) apparently healthy individuals in a particular life stage and gender group (see Figure 1-1). The RDA is intended to be used as a goal for daily intake by individuals. The process for setting the RDA is described below; it depends on being able to set an Estimated Average Requirement (EAR). That is, if an EAR cannot be set, no RDA will be set.

**Estimated Average Requirement**

The Estimated Average Requirement (EAR) is the daily intake value that is estimated to meet the requirement, as defined by the specified indicator of adequacy, in half of the apparently healthy individuals in a life stage or gender group (see Figure 1-1). A normal or symmetrical distribution (median and mean similar) is usually assumed for nutrient requirements. At this level of intake, the other half of a specified group would not have its nutritional needs met. The general method used to set the EAR is the same for all of the nutrients in this report. The specific approaches, provided in Chapters 5 through 8, differ because of the different types of data available.

**Method for Setting the RDA**

The EAR is used in setting the RDA as follows. If the standard deviation (SD) of the EAR is available and the requirement for the nutrient is normally distributed, the RDA is defined as equal to the EAR plus 2 SDs of the EAR:

\[ \text{RDA} = \text{EAR} + 2 \text{SD}_{\text{EAR}}. \]

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1 The definition of EAR implies a median as opposed to a mean, or average. The median and average would be the same if the distribution of requirements followed a symmetrical distribution and would diverge as a distribution became skewed. Three considerations prompted the choice of the term EAR: data are rarely adequate to determine the distribution of requirements, precedent has been set by other countries that have used EAR for reference values similarly derived (COMA, 1991), and the type of data evaluated makes the determination of a median impossible or inappropriate.
If data about variability in requirements are insufficient to calculate an SD, a coefficient of variation \((CV_{\text{EAR}})\) of 10 percent will ordinarily be assumed and used in place of the SD. Because

\[
CV_{\text{EAR}} = \frac{SD_{\text{EAR}}}{\text{EAR}}, \text{ and}
\]

\[
SD = (\text{EAR} \times CV_{\text{EAR}});
\]

the resulting equation for the RDA is

\[
RDA = \text{EAR} + 2 \times 0.1 \times \text{EAR}, \text{ or}
\]

\[
RDA = 1.2 \times \text{EAR}.
\]

If the nutrient requirement is known to be skewed for a population, other approaches will be used to find the ninety-seventh to ninety-eighth percentile to set the RDA.

The assumption of a 10 percent CV is based on extensive data on the variation in basal metabolic rate (FAO/WHO/UNA, 1985; Garby and Lammert, 1984), which contributes about two-thirds of the daily energy expenditure of many individuals residing in Canada.
and the United States (Elia, 1992) and on the similar CV of 12.5 percent estimated for the protein requirements in adults (FAO/WHO/UNA, 1985). If there is evidence of greater variation, a larger CV will be assumed. In all cases, the method used to derive the RDA from the EAR is stated.

For vitamins C and E, and selenium, there are very few direct data on the requirements of children. Thus, EARs and RDAs for children are based on extrapolations from adult values. The method is described in Chapter 3.

Other Uses of the EAR

Together with an estimate of the variance of intake, the EAR may also be used in the assessment of the intake of groups or in planning for the intake of groups (Beaton, 1994) (see Chapter 9).

Adequate Intake

If sufficient scientific evidence is not available to calculate an EAR, a reference intake called an Adequate Intake (AI) is provided instead of an RDA. The AI is a value based on experimentally derived intake levels or approximations of observed mean nutrient intakes by a group (or groups) of apparently healthy people. In the judgment of the DRI Committee, the AI for children and adults is expected to meet or exceed the amount needed to maintain a defined nutritional state or criterion of adequacy in essentially all members of a specific, apparently healthy population, because it is set using presumably healthy populations. Examples of defined nutritional states include normal growth, maintenance of normal circulating nutrient values, or other aspects of nutritional well-being or general health.

The AI is set when data are considered to be insufficient or inadequate to establish an EAR on which an RDA would be based. For example, for young infants for whom human milk is the recommended sole food source for most nutrients in the first 4 to 6 months, the AI is based on the daily mean nutrient intake supplied by human milk for apparently healthy, full-term infants who are fed exclusively human milk.

Similarities Between the AI and the RDA

Both the AI and the RDA are to be used as a goal for individual intake. In general, the values are intended to cover the needs of nearly all persons in a life stage group. (For infants, the AI is the
mean intake when infants in the age group are consuming human milk. Larger infants may have higher needs, which they meet by consuming more milk.) As with RDAs, AIs for children and adolescents may be extrapolated from adult values if no other usable data are available.

**Differences Between the AI and the RDA**

There is much less certainty about the AI value than about the RDA value. Because AIs depend on a greater degree of judgment than is applied in estimating the EAR and subsequently the RDA, the AI may deviate significantly from the RDA, if it could have been determined, and may be numerically higher than the RDA, if it were known. For this reason, AIs must be used with greater care than RDAs. Also, the RDA is always calculated from the EAR, using a formula that takes into account the expected variation in the requirement for the nutrient (see previous section “Estimated Average Requirement”).

**Tolerable Upper Intake Level**

The *Tolerable Upper Intake Level* (UL) is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects in almost all individuals in the specified life stage group (see Figure 1-1). As intake increases above the UL, the risk of adverse effects increases. The term *tolerable intake* was chosen to avoid implying a possible beneficial effect. Instead, the term is intended to connote a level of intake that can, with high probability, be tolerated biologically. The UL is not intended to be a recommended level of intake, and there is no established benefit for healthy individuals if they consume a nutrient in amounts exceeding the recommended intake (the RDA or AI).

The UL is based on an evaluation conducted using the methodology for risk assessment of nutrients (see Chapter 4). The need for setting ULs grew out of the increased fortification of foods and the use of dietary supplements by more people and in larger doses. The UL applies to chronic daily use. As in the case of applying AIs, professionals should avoid very rigid application of ULs and first assess the characteristics of the individual or group of concern such as source of nutrient, physiological state of the individual, length of sustained high intakes, and so forth.

For vitamin C and selenium, the UL refers to total intakes—from food, fortified food, and nutrient supplements. In other instances
(e.g., vitamin E), it may refer only to intakes from supplements, food fortificants, pharmacological agents, or a combination of the three. For some nutrients, such as β-carotene and other carotenoids, there may be inconsistent and insufficient data on which to develop ULs. This indicates the need for caution in consuming amounts greater than the recommended intakes; it does not mean that high intakes pose no risk of adverse effects.

The safety of routine, long-term intake above the UL is not well documented. Although members of the general population should be advised not to routinely exceed the UL, intake above the UL may be appropriate for investigation within well-controlled clinical trials. Clinical trials of doses above the UL should not be discouraged as long as subjects participating in these trials have signed informed consent documents regarding possible toxicity and as long as these trials employ appropriate safety monitoring of trial subjects.

**Determination of Adequacy**

In the derivation of the EAR or AI, close attention has been paid to the determination of the most appropriate indicators of adequacy. A key question is, Adequate for what? In many cases, a continuum of benefits may be ascribed to various levels of intake of the same nutrient. One indicator may be deemed the most appropriate to determine the risk that an individual will become deficient in the nutrient, while another may relate to reducing the risk of chronic degenerative disease such as common neurodegenerative diseases, cardiovascular disease, cancer, diabetes mellitus, cataracts, or age-related macular degeneration.

Each EAR or AI is described in terms of the selected criterion or outcome. The potential role of vitamin C, vitamin E, selenium, and β-carotene and other carotenoids in the reduction of disease risk was considered in developing the EARs for this group of nutrients. With the acquisition of additional data relating intake to chronic disease or disability, the choice of the criterion for setting the EAR may change. These nutrients, their role in health, and the types of evidence considered are discussed in Chapter 2.
ed in later reports. If data are too sparse to distinguish differences in requirements by life stage or gender group, the analysis may be presented for a larger grouping.

Infancy

Infancy covers the period from birth through 12 months of age and is divided into two 6-month intervals. The first 6-month interval was not subdivided further because intake is relatively constant during this time. That is, as infants grow, they ingest more food; however, on a body weight basis their intake remains the same. During the second 6 months of life, growth velocity slows, and thus total daily nutrient needs on a body weight basis may be less than those during the first 6 months of life.

For a particular nutrient, average intake by full-term infants who are born to presumably healthy, well-nourished mothers and exclusively fed human milk has been adopted as the primary basis for deriving the Adequate Intake (AI) for most nutrients during the first 6 months of life. The value used is thus not an Estimated Average Requirement (EAR); the extent to which intake of human milk may result in exceeding the actual requirements of the infant is not known, and ethics of experimentation preclude testing the levels known to be potentially inadequate. Therefore, the AI is not an EAR in which only half of the group would be expected to have their needs met.

Using the infant fed human milk as a model is in keeping with the basis for estimating nutrient allowances for infants developed in the last Recommended Dietary Allowances (NRC, 1989) and Recommended Nutrient Intake (Health Canada, 1990) reports. It also supports the recommendation that exclusive human milk feeding is the preferred method of feeding for normal full-term infants for the first 4 to 6 months of life. This recommendation has also been made by the Canadian Paediatric Society (Health Canada, 1990), the American Academy of Pediatrics (AAP, 1997), and the Food and Nutrition Board report Nutrition During Lactation (IOM, 1991).

In general, for this report, special consideration was not given to possible variations in physiological need during the first month after birth or to the variations in intake of nutrients from human milk that result from differences in milk volume and nutrient concentrations during early lactation. Specific Dietary Reference Intakes (DRIs) to meet the needs of formula-fed infants are not proposed in this report. The previously published RDAs and RNIs for infants have led to much misinterpretation of the adequacy of human milk because of a lack of understanding about the derivation of these
values for young infants. Although they were based on the composition of human milk and the volume of intake, the previous RDA and RNI values allowed for lower bioavailability of nutrients from nonhuman milk.

Ages 0 through 6 Months. To derive the AI value for infants ages 0 through 6 months, the mean intake of a nutrient was calculated based on the average concentration of the nutrient from 2 to 6 months of lactation, using consensus values from several reported studies (Atkinson et al., 1995) and an average volume of milk intake of 0.78 L/day as reported from studies of full-term infants by test weighing, a procedure in which the infant is weighed before and after each feeding (Butte et al., 1984; Chandra, 1984; Hofvander et al., 1982; Neville et al., 1988). Because there is variation in both of these measures, the computed value represents the mean. It is expected that infants will consume increased volumes of human milk as they grow.

Ages 7 through 12 Months. There is no evidence for markedly different nutrient needs during the period of infants’ growth acceleration and gradual weaning to a mixed diet of human milk and solid foods from ages 7 through 12 months. The basis of the AI values derived for this age category was the sum of the specific nutrient provided by 0.60 L/day of human milk, which is the average volume of milk reported from studies in this age category (Heinig et al., 1993), and that provided by the usual intakes of complementary weaning foods consumed by infants in this age category (Specker et al., 1997). This approach is in keeping with the current recommendations of the Canadian Paediatric Society (Health Canada, 1990), the American Academy of Pediatrics (AAP, 1997), and Nutrition During Lactation (IOM, 1991) for continued human milk feeding of infants through 9 to 12 months of age with appropriate introduction of solid foods.

One problem encountered in trying to derive intake data in infants was the lack of available data on total nutrient intake from a combination of human milk and solid foods in the second 6 months of life. Most intake survey data do not identify the milk source, but the published values indicate that cow milk and cow milk formula were most likely consumed.

Toddlers: Ages 1 through 3 Years

The greater velocity of growth in height during ages 1 through 3 compared with ages 4 through 5 provides a biological basis for dividing this period of life. Because children in the United States and
Canada from age 4 onwards begin to enter the public school system, ending this life stage prior to age 4 seemed appropriate. Data are sparse for indicators of nutrient adequacy on which to derive DRIs for these early years of life. In some cases, DRIs for this age group were derived from data extrapolated from studies of infants or of adults aged 19 years or older.

*Early Childhood: Ages 4 through 8 Years*

Because major physiological changes in velocity of growth and in endocrine status occur during ages 4 through 8 or 9 years (the latter depending on onset of puberty in each gender), the category of 4 through 8 years is appropriate. For many nutrients, a reasonable amount of data are available on nutrient intake and various criteria for adequacy (such as nutrient balance measured in young children aged 5 through 7 years) that can be used as the basis for the EARs for this life stage group.

*Puberty/Adolescence: Ages 9 through 13 Years and 14 through 18 Years*

Recognizing that current data support younger ages for pubertal development, it was determined that the adolescent age group should begin at 9 years. The mean age of onset of breast development (Tanner Stage 2) for white females in the United States is $10.0 \pm 1.8$ (standard deviation) years; this is a physical marker for the beginning of increased estrogen secretion (Herman-Giddens et al., 1997). In African-American females, onset of breast development is earlier (mean 8.9 years $\pm 1.9$). The reason for the observed racial differences in the age at which girls enter puberty is unknown. The onset of the growth spurt in girls begins before the onset of breast development (Tanner, 1990). The age group of 9 through 13 years allows for this early growth spurt of females.

For males, the mean age of initiation of testicular development is 10.5 to 11 years, and their growth spurt begins 2 years later (Tanner, 1990). Thus, to begin the second age category at 14 years and to have different EARs for females and males for some nutrients at this age seems biologically appropriate. All children continue to grow to some extent until as late as age 20; therefore, having these two age categories span the period 9 through 18 years of age seems justified.

*Young Adulthood and Middle Ages: Ages 19 through 30 Years and 31 through 50 Years*

The recognition of the possible value of higher nutrient intakes during early adulthood on achieving optimal genetic potential for
peak bone mass was the reason for dividing adulthood into ages 19 through 30 years and 31 through 50 years. Moreover, mean energy expenditure decreases during this 30-year period, and needs for nutrients related to energy metabolism may also decrease. For some nutrients, the DRIs may be the same for the two age groups. However, for other nutrients, especially those related to energy metabolism, EARs (and RDAs) are likely to differ.

**Adulthood and Older Adults: Ages 51 through 70 Years and Greater than 70 Years**

The age period of 51 through 70 years spans active work years for most adults. After age 70, people of the same age increasingly display variability in physiological functioning and physical activity. A comparison of people over age 70 who are the same chronological age may demonstrate as much as a 15- to 20-year age-related difference in level of reserve capacity and functioning. This is demonstrated by age-related declines in nutrient absorption and renal function. Because of the high variability in functional capacity of older adults, the EARs for this age group may reflect a greater variability in requirements for the older age categories. This variability may be most applicable to nutrients for which requirements are related to energy expenditure.

**Pregnancy and Lactation**

Recommendations for pregnancy and lactation may be subdivided because of the many physiological changes and changes in nutrient needs that occur during these life stages. In setting EARs for these life stages, however, consideration is given to adaptations to increased nutrient demand, such as increased absorption, and to greater conservation of many nutrients. Moreover, some nutrients may undergo net losses due to physiological mechanisms regardless of the nutrient intake. Thus, for some nutrients, there may not be a basis for EAR values that are different during these life stages than they are for other women of comparable age.

**Reference Weights and Heights**

The reference weights and heights selected for adults and children are shown in Table 1-1. The values are based on anthropometric data collected from 1988–1994 as part of the Third National Health and Nutrition Examination Survey (NHANES III) in the United States.
The median heights for the life stage and gender groups through age 30 were identified, and the median weights for these heights were based on reported median Body Mass Index (BMI) for the same individuals. Since there is no evidence that weight should change as adults age if activity is maintained, the reference weights for adults ages 19 through 30 years are applied to all adult age groups.

The most recent nationally representative data available for Canadians (from the 1970–1972 Nutrition Canada Survey [Demirjian, 1980]) were reviewed. In general, median heights of children from 1 year of age in the United States were greater by 3 to 8 cm (1 to 2 1/2 inches) than those of children of the same age in Canada measured two decades earlier (Demirjian, 1980). This could be explained partly by approximations necessary to compare the two data sets, but more likely by a continuation of the secular trend of increased heights for age noted in the Nutrition Canada Survey when it compared data from that survey with an earlier (1953) national Canadian survey (Pett and Ogilvie, 1956).

Similarly, median weights beyond age 1 year derived from the recent survey in the United States (NHANES III, 1988–1994) were also greater than those obtained from the older Canadian survey (Demirjian, 1980). Differences were greatest during adolescence—from 10 to 17 percent higher. The differences probably reflect the

### TABLE 1-1 Reference Heights and Weights for Children and Adults in the United States

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Median Body Mass Index, kg/m²</th>
<th>Reference Height, cm (in)</th>
<th>Reference Weight, kg (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male, female</td>
<td>2–6 mo</td>
<td>–</td>
<td>64 (25)</td>
<td>7 (16)</td>
</tr>
<tr>
<td></td>
<td>7–12 mo</td>
<td>–</td>
<td>72 (28)</td>
<td>9 (20)</td>
</tr>
<tr>
<td></td>
<td>1–3 y</td>
<td>–</td>
<td>91 (36)</td>
<td>13 (29)</td>
</tr>
<tr>
<td></td>
<td>4–8 y</td>
<td>15.8</td>
<td>118 (46)</td>
<td>22 (48)</td>
</tr>
<tr>
<td>Male</td>
<td>9–13 y</td>
<td>18.5</td>
<td>147 (58)</td>
<td>40 (88)</td>
</tr>
<tr>
<td></td>
<td>14–18 y</td>
<td>21.3</td>
<td>174 (68)</td>
<td>64 (142)</td>
</tr>
<tr>
<td></td>
<td>19–30 y</td>
<td>24.4</td>
<td>176 (69)</td>
<td>76 (166)</td>
</tr>
<tr>
<td>Female</td>
<td>9–13 y</td>
<td>18.3</td>
<td>148 (58)</td>
<td>40 (88)</td>
</tr>
<tr>
<td></td>
<td>14–18 y</td>
<td>21.3</td>
<td>163 (64)</td>
<td>57 (125)</td>
</tr>
<tr>
<td></td>
<td>19–30 y</td>
<td>22.8</td>
<td>163 (64)</td>
<td>61 (133)</td>
</tr>
</tbody>
</table>


*b Calculated from body mass index and height for ages 4 through 8 and older.
secular trend of earlier onset of puberty (Herman-Giddens et al., 1997), rather than differences in populations. Calculations of BMI for young adults (e.g., a median of 22.6 for Canadian women compared with 22.8 for U.S. women) resulted in similar values, indicating greater concordance between the two surveys by adulthood.

The reference weights chosen for this report were based on the most recent data set available from either country, recognizing that earlier surveys in Canada indicated shorter stature and lower weights during adolescence compared with those from surveys in the United States.

Reference weights are used primarily when setting the EAR or Tolerable Upper Level Intake (UL) for children or when relating the nutrient needs of adults to body weight. For the 4- to 8-year-old age group on an individual basis, a small 4-year-old child can be assumed to require less than the EAR and a large 8-year-old will require more than the EAR. However, the RDA or AI should meet the needs of both.

SUMMARY

Dietary Reference Intakes (DRIs) is a generic term for a set of nutrient reference values that includes the Recommended Dietary Allowance, Adequate Intake, Tolerable Upper Intake Level, and Estimated Average Requirement. These reference values are being developed for life stage and gender groups in a joint U.S. and Canadian activity. This report, one volume in a series, covers the DRIs for vitamin C, vitamin E, selenium, and β-carotene and the other carotenoids.

REFERENCES


