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Dietary Reference Intakes: Minerals

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Introduction

The term Dietary Reference Intakes (DRIs) refers to a set of four nutrient-based reference values intended primarily for use in assessing and planning diets. The DRIs were developed by committees of American and Canadian scientists under the auspices of the Food and Nutrition Board of the National Academies' Institute of Medicine, and are intended to replace the former Recommended Nutrient Intakes (RNIs) in Canada and the former Recommended Dietary Allowances in the United States. To date, DRIs have been released for vitamins, minerals, macronutrients and energy[1-5]. This issue addresses the DRIs for minerals, and a subsequent issue will address the DRIs for vitamins.

Definition of the DRIs

***Estimated Average Requirement* (EAR):** The EAR is the average daily intake value estimated to meet the requirement, defined by a specified indicator or criterion of adequacy, of half the apparently healthy individuals in a life stage and gender group. For example, the EAR for selenium for adult men and women is 45 µg/d, based on maximizing activity of the enzyme glutathione peroxidase[3]. At that intake level, one would expect half the members of a group to meet their requirement (i.e., maximal glutathione peroxidase activity) and the other half to have sub-maximal values, indicating their requirement was not met. Accordingly, the EAR is *not* an intake goal for individuals.

***Recommended Dietary Allowance* (RDA):** The RDA is the average daily dietary intake level that is sufficient to meet or exceed the nutrient requirements of nearly all (97 to 98 percent) apparently healthy individuals in a particular life stage and gender group. If the requirement distribution is normally distributed, the RDA is set by adding 2 standard deviations (SD) of the requirement distribution to the EAR. Continuing with the selenium example, the RDA of 55 µg/d was set by adding 2 SD to the EAR of 45 µg/d. If the requirement distribution is skewed, which is known to occur for iron[4], the RDA is set at the 97th to 98th percentile of the distribution. Because the EAR is associated with a low risk of inadequacy, it can be used as an intake goal for individuals.

***Adequate Intake* (AI):** If sufficient scientific evidence is not available to set an EAR (and therefore an RDA), an AI is provided as an intake goal for individuals. The AI is an intake value based on experimentally determined intake levels or approximations of observed mean nutrient intakes of a group (or groups) of healthy people assumed to have adequate intakes of the nutrient. It is expected to meet or exceed the amount needed to maintain a defined nutritional state or criterion of adequacy in essentially all healthy people in a life stage and gender group.

***Tolerable Upper Intake Level* (UL):** The UL is the highest average daily nutrient intake level that is 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 may increase. The UL is not a recommended intake, but is an amount that can be tolerated biologically. With few exceptions (e.g., folic acid in women who could become pregnant[2]), intakes above the RDA or AI have no established benefits for healthy individuals. However, the UL is not intended to apply to those receiving supervised medical treatment for deficiency states.

Focus on Calcium, Magnesium, Iron, Selenium and Zinc

***Calcium*[1]:** Although some evidence exists for associations between calcium intake and the reduced risks of hypertension and colon cancer, the AI for calcium was determined based on the associations between calcium intake and bone mass. Specifically, it was estimated based on desirable rates of calcium retention as determined from balance studies, factorial estimates of requirements, and data on changes in bone mineral density (BMD) and bone mineral content (BMC). During growth, and particularly in the adolescent growth spurt, calcium intake is thought to contribute to maximizing peak bone mass. Thus, AIs for children and adolescents are 500 mg (1-3 yr), 800 mg (4-8 yr) and 1,300 mg (9-18 yr). The AI is increased for adults over age 50, when higher calcium intakes have been shown to reduce the rate of aging bone loss. The recommended intake during pregnancy and lactation remains at the age-appropriate level, in contrast to previous recommendations. Recent research indicates that adaptive changes in maternal calcium metabolism during pregnancy meet fetal needs, while during lactation, bone is lost irrespective of dietary calcium intake and is regained following weaning. The UL for calcium is based on the risk of hypercalcemia and renal insufficiency (milk-alkali syndrome). Intakes of most North Americans over the age of 8 are below the AI.

***Magnesium*[1]:** The magnesium requirement was based on the amount needed to maintain balance. Although evidence is beginning to accumulate to suggest a role for magnesium in chronic disease prevention (e.g., cardiovascular disease, hypertension, osteoporosis, diabetes mellitus), the data were not adequate to set a requirement on these grounds. Instead, the need for additional research was identified. Intake data suggest that many age/sex groups have magnesium intakes lower than current recommendations, although the health impact is not clearly established at present. The UL is based on risk of diarrhea with supplemental magnesium salts, and doesn't apply to magnesium in food.

***Iron*[4]:** Iron requirements were set by factorial modeling, based on the amount needed to maintain function with minimal stores (described as serum ferritin of ~15 ng/ml), assuming consumption of an omnivorous diet containing heme iron. Iron bioavailability is low in plant-based diets, and requirements of vegetarians may be higher by a factor of 1.8. In women of reproductive age, menstrual iron losses vary greatly, and the RDA is set high enough to meet the needs of those with the heaviest losses. These losses, and therefore iron requirements, are lower in oral contraceptive users. Iron needs are very high during pregnancy (RDA = 27 mg/d) and iron status relates importantly to pregnancy outcome. During lactation, however, the RDA is only 9 mg/d, reflecting lactational amenorrhea during breastfeeding. Human breast milk is low in iron, and after 6 months of age, infants are at risk of developing anemia. Accordingly, the RDA for infants age 6-12 months is 11 mg/d. Finally, endurance athletes (especially runners) may have increased iron needs (30-70%) because of iron losses from footstrike hemolysis and GI blood loss. The UL for iron was set based on GI side effects with elemental iron. It does not apply to those being treated for iron deficiency under medical supervision.

***Selenium*[3]:** The selenium requirement is based on the amount needed to maximize activity of plasma glutathione peroxidase, a selenium-containing protein that acts as an oxidant defense enzyme. Research is currently ongoing to determine whether selenium, in amounts greater than those needed to maximize glutathione peroxidase activity, protects against prostate cancer[6,7]. The UL was set based on risk of selenosis (symptoms include hair and nail brittleness and loss, GI disturbances and nervous system abnormalities).

***Zinc*[4]:** The zinc requirement was set by factorial modeling of the amount needed to maintain zinc balance. Zinc absorption is strongly inhibited by phytates, and the requirement may be up to 50% higher for vegetarians (especially vegans) because of low bioavailability. Long term heavy alcohol consumption also reduces absorption and increases urinary loss, so requirements would be increased. The UL was set based on reduced copper status with high zinc intakes.

Summary and Conclusions

The Dietary Reference Intakes reflect the current state of an evidence-based approach to human nutrient requirements and recommended intakes. New paradigms include an increased recognition of the role of nutrients in chronic disease prevention, and explicit recognition of the risks of excess (i.e., Upper Levels are now provided). Harmonization of recommendations between Canada and the United States may lead to more consistent information for consumers.

Table 1. Recommended Intakes and Upper Levels of Minerals for Adults (≥19 yrs of age)

Mineral	RDA/AI* Male	RDA/AI* Female	Upper Level	Food Sources[1]
Calcium (mg/d)	1000* (≤50) 1200* (≥51)	1000* (≤50) 1200* (≥51)	2500	Dairy products, canned salmon or sardines with bones, fortified orange juice, fortified soy beverage, almonds, blackstrap molasses
Phosphorus (mg/d)	700	700	4,000	Meat, fish, poultry, milk, eggs, processed foods
Iron (mg/d)	8	18 (≤50) 8 (≥51)	45	Meat, fish and poultry contain well-absorbed heme iron. Sources of non-heme iron include whole grain and enriched breads and cereals, breakfast cereal, legumes
Magnesium (mg/d)	420	320	350[3]	Legumes, nuts, whole grains, dark green vegetables
Selenium (µg/d)	55	55	400	Organ meats, seafood, poultry, meat, brazil nuts
Zinc (mg/d)	11	8	40	Red meats, certain seafood (oysters), whole grains
Chromium (µg/d)	35* (≤50) 30* (≥51)	25* (≤50) 20* (≥51)	ND[2]	High-bran cereals, meat, fish, poultry, beer and red wine
Copper (mg/d)	0.9	0.9	10	Organ meats, seafood, nuts, seeds, cocoa products, whole grains
Fluoride (mg/d)	4.0*	3.0*	10	Fluoridated drinking water, tea, seafood
Iodine (µg/d)	150	150	1,100	Iodized salt, dairy products, processed foods containing iodized salt, seafood
Manganese (mg/d)	2.3*	1.8*	11	Grain products, tea, vegetables
Molybdenum (µg/d)	45	45	2,000	Legumes, grain products, nuts
Arsenic	Not set[4]	Not set[4]	ND[2]	Meat, fish and poultry, grains, dairy products
Boron (mg/d)	Not set[4]	Not set[4]	20	Fruit-based beverages and products, nuts, tubers, legumes
Nickel (mg/d)	Not set[4]	Not set[4]	1.0[3]	Nuts, legumes, grain products, meat, poultry, vegetables
Silicon	Not set[4]	Not set[4]	ND[2]	Beer, coffee, water, grain products, vegetables
Vanadium (mg/d)	Not set[4]	Not set[4]	1.8	Grain products, mushrooms, shellfish, prepared foods

* Values with an asterisk represent an AI rather than an RDA.

[1] For more information about food sources of nutrients, go to http://www.nal.usda.gov/fnic/foodcomp/Data/SR14/wtrank/wt_rank.html

[2] ND = not determined. The absence of a UL should not be interpreted as meaning that high intakes are safe; it simply means data were not available to identify a UL.

[3] The UL for magnesium applies only to intake from supplements or pharmacologic agents, and does not include intake from food and water. The UL for nickel applies only to excess nickel intake as soluble nickel salts, and not to intake through a normal diet.

[4] A functional role in healthy humans has not been clearly established for arsenic, boron, nickel, silicon or vanadium.

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