DIETARY INTAKES OF METALS AND MINERALS: RESULTS FROM THE FDA'S TOTAL DIET STUDY

Jean A.T. Pennington, Ph.D., R.D.

The Food and Drug Administration
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Food and Drug Administration's (FDA) Total Diet Study is a yearly program that monitors the levels of various organic and elemental contaminants and nutritional elements in the United States (U.S.) food supply and estimates the intakes of these substances in representative diets of specific age-sex groups (1,2). The yearly data provided by the Total Diet Study allow for the identification of changes and trends in the levels of contaminants and nutrients in the food supply and thereby assist in identifying potential public health problems.

Through the Total Diet Study, typically consumed foods are purchased in specified cities and sent to the Total Diet Laboratory in Kansas City, MO, where they are prepared for consumption and analyzed for the contaminants and nutrients of concern. The foods collected and the age-sex group diets developed from these foods are updated periodically as food consumption data become available from national food consumption surveys. When the Total Diet Study began in 1961, it was based on data from the 1955 USDA Household Food Consumption Survey. The program was updated when data from the 1965 USDA Household Food Consumption Survey became available, and it was again updated in 1982 when data from the 1977-78 USDA Nationwide Food Consumption Survey and the NHANES II (the Second National Health and Nutrition Examination Survey, 1976-80) became available.

Two other major changes were made to the Total Diet Study during the 1982 revision. The number of age-sex groups was expanded from three (adult males, infants, and 2-year-old children) to eight. The current program includes infants, 2-year-old children, teenage girls and boys, adult men and women, and older men and women. The second major change was the analysis of individual foods, rather than food commodity groups. In the current program, there are 234 foods which include traditional meat, fruit, vegetable, grain, and dairy products plus fast foods, mixed dishes, alcoholic beverages, desserts, and commercially prepared infant foods (3).

The Total Diet Study foods are purchased four times per year, once from each of the four regional areas of the U.S. Each of the four yearly collections consists of the purchase of each food from supermarkets in three cities. Three portions of each food (from the three cities within a region) are composited and test samples of each composite are then analyzed.

The elements that have been routinely analyzed in the Total Diet Study include the toxic elements lead, arsenic, cadmium, and mercury and the nutritional elements sodium, potassium, calcium, phosphorus, magnesium, iron, zinc, copper, manganese, selenium, and iodine. Portions of foods from one of the four yearly collections are routinely sent to the FDA Winchester Engineering Analytical Center in Boston, MA, where they are analyzed for radionuclides including strontium-90, cesium-137, iodine-131, ruthenium-106, and potassium-40. In a special study of one of the 1984 Total Diet Study collections, portions of foods from the Total Diet Laboratory in Kansas City were sent to the Division of Contaminants Chemistry, Center for Food and Applied Nutrition in Washington, DC, where they were analyzed for aluminum, molybdenum, nickel, cobalt, vanadium, and strontium.

The analytical methods used for these elemental analyses include:

- beta-counting of yttrium-90 for strontium-90;
- gamma-ray spectroscopy for cesium-137, iodine-131, ruthenium-106, and potassium-40;
- dry ash-graphite furnace atomic absorption spectrometry or dry ash anodic stripping voltammetry procedure for cadmium and lead;
- atomic absorption spectrometry with rapid hydride evolution for arsenic and selenium;

- flameless atomic absorption spectrometry for mercury;
- inductively coupled plasma emission spectroscopy for sodium, potassium, calcium, phosphorus, magnesium, iron, zinc, copper, manganese, aluminum, molybdenum, nickel, cobalt, vanadium, and strontium; and
- colorimetry method for iodine.

Last year at the Nutrient Databank Conference in Athens, GA, the results for the nutritional elements for the first two years of the revised Total Diet Study program (1982-84) were presented. These results (4,5) indicated that:

- levels of calcium, magnesium, iron, zinc, copper, and manganese were less than 80% of the Recommended Dietary Allowance (RDA) or below the low end of the Estimated Safe and Adequate Daily Dietary Intake (ESADDI) range for some or all age-sex groups;
- those most at risk of low intakes were young children, teenage girls, adult women, and older women;
- non-discretionary sodium intakes exceeded the upper ESADDI range for two age-sex groups;
- iodine was considerably above the RDA for all age-sex groups; and
- levels of potassium, phosphorus, and selenium were adequate for all groups.

Currently the nutritional element results for the first four years of the revised Total Diet Study (1982-86) are being evaluated to compare the yearly levels of these elements in the food supply and in daily diets to determine if any trends or changes are occurring. Of particular interest are the intakes of sodium and iodine.

The intake levels of radionuclides have remained within safe levels during the years of analyses as have the levels of the toxic elements lead, arsenic, cadmium, and mercury (6,7). The results of the special study on aluminum, molybdenum, nickel, cobalt, vanadium, and strontium have provided information on elements not traditionally evaluated in dietary studies. Of these six elements, three (molybdenum, nickel, and vanadium) are considered essential, but only for molybdenum has an ESADDI been established. These and other trace elements are of interest because it is possible that the balance between adequate or safe levels and toxic levels of these substances may be upset by the use of supplements or by changes in agricultural or manufacturing practices, food additive use, or nutrient fortification practices. For example, an increase in the intake of one trace element (as through supplementation) may affect the absorption or metabolism of one or more other trace elements.

Intakes of aluminum are of interest because of the known toxic effects of aluminum from drugs and dialysis fluids. Previous estimates of dietary aluminum intake are old and are based on older analytical methods for this element. In connection with this analysis of Total Diet Study foods, an extensive database on the aluminum content of foods was developed by compiling literature data (8). To this was added the results from the Total Diet Study (9). The results indicate that few foods are naturally high in aluminum, the exceptions being tea, spices, herbs, and some subtropical plants and leafy vegetables from Nigeria and South America that are able to concentrate this element. Aluminum may migrate to foods if aluminum utensils and aluminum wrap are used; however, to be of practical significance, the foods must be acidic and heated or stored for long periods. Migration is probably not a major source of dietary aluminum. The most impressive source of dietary aluminum is that from foods which contain aluminum additives such as processed cheese and baked goods made with aluminum-containing baking powder. For example, a one-ounce serving of cheddar cheese contains only 0.005 mg of aluminum, while a one-ounce serving of processed American cheese containing an aluminum additive may contain 11.5 mg of this element. Baking powders without aluminum additives contain no measurable amount of this element; such baking powders will not contribute to the aluminum content of baked products. Baking powders with aluminum additives may contain 2,300 mg of aluminum per 100 g (69 mg of aluminum per teaspoon); muffins, pancakes, cornbread, etc. made from these baking powders may

contain 3-18 mg of this element per serving.

The daily intakes of aluminum for the eight age-sex groups included in the Total Diet Study (2-14 mg/day) were considerably lower than most values previously reported (18-36 mg/day). By food group, the major sources of aluminum were grains and grain products; milk, yogurt, and cheese; and desserts. By individual foods, the major sources of aluminum were American processed cheese, cornbread, yellow cake with white icing, cream substitute, flour tortillas, blueberry muffins, chocolate cake with chocolate icing, pancakes, and fish sticks.

The levels of molybdenum (10) found in the Total Diet Study diets (50-126 ug/day) met the ESADDI's for infants (40-80 ug/day) and 2-year-old children (50-100 ug/day), but were below the 150-500 ug ESADDI range established by the National Research Council for teenagers and adults. The two major food group sources for molybdenum were grains and grain products and legumes. For infants and young children, the milk, yogurt, and cheese group was also a major source. The individual foods with the highest concentrations of molybdenum were legumes, liver, breakfast cereals, and grain products.

Nickel intakes for the eight age-sex groups ranged from 69 to 162 ug/day (10). The major contributors to nickel intake were mixed dishes and soups; vegetables; legumes; grains and grain products; and desserts. Individual foods with the highest nickel concentrations were legumes, foods containing chocolate, canned foods, and grain products.

Cobalt intakes ranged from 3 to 12 ug/day (10). Major contributors to cobalt intakes were meat, fish, and poultry; vegetables; desserts; and grains and grain products. For infants, the milk, yogurt, and cheese group was the major source of cobalt. Individual foods with the highest cobalt concentrations were liver, breakfast cereals, and foods containing chocolate.

Vanadium intakes ranged from 6 to 18 ug/day (10). Vanadium was obtained primarily from grains and grain products. Fruits and fruit juices were major contributors to vanadium intake for infants and young children, while beverages were a major contributor for adult males and females and older males. Individual foods high in vanadium included breakfast cereals, fruit juices, fish sticks, several vegetables, several sweet items, wine, and beer. Previous reports indicate that vanadium may be introduced into foods during processing.

Strontium intakes ranged from 490 to 1,390 ug/day (10). Strontium was obtained primarily from grains and grain products; vegetables; and mixed dishes and soups. Milk, yogurt, and cheese were major sources of strontium for infants and 2-year-old children, while beverages were the major source for adult males. Strontium levels were highest in fried shrimp, some vegetables, pecans, breads, cheeses, some fruits, and chocolate powder.

The levels of aluminum, molybdenum, nickel, cobalt, vanadium, and strontium in Total Diet Study foods, commodity groups, and in age-sex group diets may serve as baseline data until more information becomes available. It is hoped that the Total Diet Study will be expanded to include some of these lesser known elements on a routine basis.

REFERENCES

1. Pennington, JAT, Gunderson EL. A history of the Food and Drug Administration's Total Diet Study, 1961 to 1987. J Assoc Off Anal Chem. In press.
2. Pennington, JAT, Gunderson EL. Appendices for A History of the Food and Drug Administration's Total Diet Study, 1961 to 1987. National Technical Information Service. Springfield, VA. PB 87151676/AS.
3. Pennington, JAT. Revision of the Total Diet Study food list and diets. J Am Diet Assoc 82:166-173, 1983.
4. Pennington, JAT. Update of the Total Diet Study: Selected Minerals in Foods Survey. Proceedings of the 11th National Nutrient Databank Conference. Athens, GA. June 29-July 2, 1986.

5. Pennington, JAT, Young, BE, Wilson, DB, Johnson, RD, Vanderveen, JE. Mineral content of foods and total diets: The Selected Minerals in Foods Survey, 1982 to 1984. J Am Diet Assoc 86:876-891, 1986.
6. Gartrell, MJ, Craun, JC, Podrebarac, DS, Gunderson, EL. Pesticides, selected elements, and other chemicals in adult Total Diet samples. J Assoc Off Anal Chem 69:146-161, 1986.
7. Gartrell, MJ, Craun, JC, Podrebarac, DS, Gunderson, EL. Pesticides, selected elements, and other chemicals in infant and toddler Total Diet samples. J Assoc Off Anal Chem 69:123-145, 1986.
8. Pennington, JAT, Jones, JW. Aluminum content of foods and diets. submitted.
9. Pennington, JAT, Jones, JW. Aluminum in American Diets, in Aluminum in Health, A Critical Review. Gitelman, HJ (ed). Marcel Dekker. NY. in press.
10. Pennington, JAT, Jones, JW. Molybdenum, nickel, cobalt, vanadium, and strontium in Total Diets. submitted.