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Fecal Nickel Excretion by Healthy Adults

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Nickel was measured by atomic absorption spectrometry in three-day collections of feces from healthy hospital workers (age 22–65) who had lived for more than a year in Hartford, Connecticut. None of the 10 subjects (4♂, 6♀) had occupational exposure to nickel. Fecal nickel averaged 3.3 μg/g (wet weight); SD, ±0.8; and range, 2.1 to 4.4 μg/g. Corresponding figures on a dry-weight basis were 14.2 μg/g; SD, ±2.7; and range, 10.8 to 18.7 μg/g. The fecal excretion of nickel averaged 258 μg/day (SD, ±126; range, 80 to 540 μg/day). Fecal excretion is evidently the major route for elimination of nickel from the human body. Comprehensive evaluations of environmental or occupational exposures to nickel should also include analyses of nickel in serum, urine, and hair.

Additional Keyphrases: *normal values • nickel metabolism • trace metals • atomic absorption spectrometry • Ni content of serum, urine, sweat, hair*

To provide reliable indices of environmental and occupational exposures to nickel, previous papers from this laboratory have reported concentrations of nickel in serum (*1–3, 5*), urine (*1, 2*), and hair (*4*) from healthy adult subjects who had lived longer than a year in Hartford, Connecticut. Normal values for fecal nickel are reported here.

Materials and Methods

The 10 subjects (4♂, 6♀) were healthy clinical laboratory workers, medical students, and physicians, whose ages averaged 32.3 years (range, 22 to 65 years), and who were not occupationally exposed to nickel. The subjects ingested their usual diets throughout the period of the study, and they abstained from any medications or alcoholic beverages. The subjects all had regular bowel habits, with one defecation each morning. Feces were collected in acid-washed plastic containers for three consecutive days. We took cautions to avoid nickel contamination, as previously described (*6*). The fecal samples for the three-day period were pooled; weighed; transferred into a 2-liter plastic jar containing 500 ml of distilled, demineralized water; reweighed; and homogenized by shaking the plastic jar violently for 3 h on an apparatus for shaking paint cans. Sets of four samples of each homogenate were taken for nickel analyses. The four samples—which weighed 0.50, 1.00, 2.00, and 3.00 g, respectively—were transferred to 125-ml Erlenmeyer flasks. Twenty-five milliliters of water was added to each flask, and the samples were digested with nitric, sulfuric, and perchloric acids (*1*).

Nickel in the digested samples was measured by the method of Nomoto and Sunderman (*1*), with minor modifications reported by Sunderman (*6*). In this method, nickel is chelated at pH 2.5 with ammonium pyrrolidone dithiocarbamate, and the Ni-APDC complex is extracted into methylisobutylketone. Nickel in the methylisobutylketone extract was measured by atomic absorption spectrometry at 232 nm, with a Model 403 atomic absorption spectrophotometer (Perkin-Elmer Corp., Norwalk, Conn. 06852), with acetylene–air flame, "high-solids" burner, and a 10-inch strip-chart recorder. Instrumental parameters were: (*a*) nickel lamp current, 20 mA; (*b*) entrance slit, position no. 3; (*c*) recorder response, position no. 3; and (*d*) recorder scale expansion, 1.0 *A* full-scale. Under these conditions, peak heights of the recorder signals were linearly related to nickel concentrations in standard solutions containing from 40 to 4000 ng of Ni per sample. The peak heights of the recorder signals were also linearly related to the weights of the four samples in each set of analyses of fecal homogenates. The recovery of 1 μg of nickel added to 1-g samples of five fecal homogenates averaged 100.3% (range, 95 to 105%).

Two 1-g samples of each fecal homogenate were transferred into tared evaporating dishes and were placed in desiccator jars containing 200 ml of anhydrous sulfuric acid. The samples were kept in the desiccator jars at 25°C for at least two weeks, until they had dried to constant weight. Measurements of nickel were calculated as: (*a*) micrograms of Ni per gram of feces (wet weight, as defecated); (*b*) micrograms of Ni per gram of feces (dry weight); and (*c*) micrograms of Ni per day.

Results

Nickel in the three-day collections of feces from the 10 healthy subjects averaged 3.3 μg/g wet weight (SD, ±0.8; range, 2.1 to 4.4). On a dry-weight basis, the corresponding figures were 14.2 μg/g (SD, ±2.7; range, 10.8 to 18.7). Fecal excretion of nickel averaged 258 μg/day (SD, ±126; range, 80 to 540).

Discussion

Schroeder et al. (*7*) reported that the usual daily oral

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Table 1. Nickel in Specimens from Healthy Inhabitants of Hartford

Specimen	No. subjects	Mean ± SD	Range	Units	References
Serum	80(37♂,43♀)	2.6 ± 0.9	0.8–5.2	μg/liter	(1,2,3,5)[a]
Urine	50(24♂,26♀)	2.2 ± 1.2	0.7–5.2	μg/liter	(1,2)[a]
		2.6 ± 1.4	0.5–6.4	μg/day	
Feces	10(4♂,6♀)	3.3 ± 0.8	2.1–4.4	μg/g (wet)	Present study
		14.2 ± 2.7	10.8–18.7	μg/g (dry)	
		258 ± 126	80–540	μg/day	
Sweat	5♂	49 ± 18	33–81	μg/liter	[b]
Hair	20(13♂,7♀)	0.22 ± 0.08	0.13–0.51	μg/g (dry)	(4)

[a] Includes unpublished observations of F. W. Sunderman, Jr.
[b] Unpublished observations of D. C. Hohnadel and F. W. Sunderman, Jr.

intake of nickel by adults ranges from 300 to 600 μg. Wide variations in nickel ingestion, from 240 to more than 1000 μg/day, may occur (*7–13*).

Most ingested nickel is not absorbed and is excreted in the feces (*12–14*). Schroeder et al. (*7*) stated that there appears to be physiological regulation of intestinal absorption of nickel. The concentration of nickel in serum and the excretion of nickel in urine are maintained within relatively normal ranges in healthy adults (Table 1) (*15*), and nickel homeostasis is altered in diseases such as myocardial infarction (*15*). As indicated in Table 1, the mean daily excretion of nickel in feces of the 10 healthy subjects (258 μg/day) was approximately 100 times greater than the mean daily excretion of nickel in urines of 50 comparable healthy subjects (2.6 μg/day). Similarly, the mean concentration of nickel in feces (14.2 mg/kg, dry weight) was about 500 times greater than the mean concentration of nickel in sera of 80 comparable healthy subjects (30.2 μg/kg, dry weight), computed on the basis that serum solids in man total 86.1 g/liter (*16*).

The only previous comparable measurements of the excretion of nickel in feces of healthy subjects are the data of Nodiya (*12*). From nickel analyses in three-day collections of feces, Nodiya (*12*) found the fecal excretion of nickel by 10 male Russian students to average 258 μg per day (SD, ±23). The range of values we found (80 to 540 μg/day) was substantially wider than the range found by Nodiya (219 to 278 μg/day). This difference may be explained by the fact that all of the Russian students ingested the same school diet, whereas our subjects ingested varied diets, prepared in their own homes.

From our study and Nodiya's studies (*12*), we conclude that fecal excretion is the major route for elimination of nickel from the human body. Hence, comprehensive evaluations of environmental or occupational exposures to nickel should include analyses of nickel in feces, as well as analyses of serum, urine, and hair (*2, 4*). From preliminary data that are cited in Table 1, it may be noted that appreciable losses of nickel also occur in the sweat. This observation may account for the diminished concentrations of serum nickel that have been reported by Szadkowski et al. (*17*) in blast-furnace workers who were chronically exposed to extreme heat. The only other known route for the excretion of appreciable amounts of nickel is in women's milk, as has been reported by Stovbun et al. (*18*) and Medvedeva (*19*).

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