Chromium intake, absorption and excretion of subjects consuming self-selected diets[1,2]

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ABSTRACT Chromium (Cr) content of the self-selected diets of 10 adult males and 22 females was determined. Each subject collected duplicate food and beverage samples on a daily basis for seven consecutive days. The 7-day average intake for males was 33 ± 3 μg (mean ± SEM), range 22–48 μg, and intake for females was 25 ± 1, range 13–36. Mean Cr intake per 1000 cal was approximately 15 μg. Approximately 90% of the diets analyzed were below the minimum suggested safe and adequate daily intake for Cr of 50 μg. Chromium absorption was inversely related to dietary intake; absorption at a dietary Cr intake of 10 μg was approximately 2% and, with increasing intake to 40μg, Cr absorption decreased to 0.5%. These data demonstrate that the average daily intake of chromium from self-selected diets is well below the minimum suggested safe and adequate intake and that Cr absorption, at levels found in typical US diets, is inversely related to dietary intake. *Am J Clin Nutr* 1985;41:1177–1183.

KEY WORDS Chromium absorption, chromium excretion, chromium intake, trace elements, dietary chromium

Introduction

Chromium is an essential nutrient that functions in carbohydrate, lipid and nucleic acid metabolism. Insufficient dietary intake leads to signs and symptoms similar to those associated with maturity-onset diabetes and cardiovascular disease (1).

The widespread tendency toward increased consumption of highly processed foods such as refined sugar which is not only low in Cr but also stimulates urinary Cr losses, may result in a marginal intake of chromium and depletion of chromium stores. The long-term effects of this suboptimal intake of chromium may be related to the decrease in tissue chromium with age and the increased incidence of diabetes and atherosclerosis observed in developed countries (2).

In 1980 the recommended or suggested safe and adequate intake for Cr was established at 50 to 200 μg for adults (3). In this study, the dietary Cr intake, urinary Cr excretion and Cr absorption of normal free-living subjects are reported. Dietary intake of Cr is also correlated with intake of other nutrients.

Materials and Methods

Subjects

Thirty-two subjects (ten males, mean wt 81.1 ± 3.4 kg, and twenty-two females, mean wt 59.5 ± 1.6 kg), ranging in age from 25 to 65 years, participated in the study. The experimental details of the study were approved by the Human Nutrition Study Committee, United States Department of Agriculture. Before the start of the study, subjects were informed of the purpose of the study and signed an informed consent form. All results are available to the participants.

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Food and beverage collection and analyses

Each subject collected a duplicate daily composite of all foods and beverages consumed during a period of seven days. Samples were collected in polyethylene containers, weighed and homogenized in a Waring blender equipped with a low-chromium steel blade (Brown and Sharp, Ground Flat Stock, Hill Chase Metals, Baltimore, MD) to minimize contamination. Homogenized samples were aliquoted into polyethylene tubes and frozen until analysis.

Immediately before use, samples were thawed, thoroughly mixed, and weighed in triplicate into borosillicate glass tubes. Samples were freeze-dried and subsequently ashed 16 h in a muffle furnace, stepwise to 480°. Fifty microliters of deionized H_2O, 50μl ultrex HNO_3, and 100 μl 50% H_2O_2 were added to ashed samples. Samples were dried in heating block and then dissolved in 10 ml of 0.1 N isothermal HCl and analyzed for chromium by method of standard additions using a Perkin-Elmer 5000 atomic absorption spectrophotometer and Perkin-Elmer HGA 500 furnace with pyrolytically coated tubes. Furnace conditions are described in **Table 1.**

A standard addition curve was run for each diet sample to account for matrix differences between diet composites. National Bureau of Standards standard reference material (SRM) bovine liver (SRM 1577) was analyzed as a check on the accuracy of the method. Under our conditions, a mean ± SD for the chromium content of bovine liver (SRM 1577) of 0.082 ± 0.02 μg/g for 9 determinations was obtained (certified value, 0.088 ± 0.012). In addition, a low-chromium purified rat diet with Cr concentration similar to that of most diet samples was assayed with each set of food samples as an internal control. Chromium content of the purified rat diet (0.050 ± 0.009 μg/g) was verified using gas chromatography stable isotope dilution mass spectrometry (4). A composite human diet sample (5) was also run as a check on the accuracy of analyses. Chromium content of the composite sample as determined by graphite furnace atomic absorption was 92 ± 6 ng/g, which was similar to that obtained by stable isotope dilution mass spectrometry, 85 ± 4 ng/g.

Dietary intake values for nutrients other than Cr were calculated from the nutrient data base from the tape version of USDA Handbook 456 (6), the tape version of sections 1-7 of USDA Handbook 8 with supplementary items from sections 8 and 9 and materials supplied by the food industry. Imputed nutrient values for the recipes provided by the subjects were determined from the nutrient data base and used in the calculation of nutrient intakes.

Statistical analyses were performed by repeated measure analysis of variance, and correlation coefficients (Pearson Product moment) were determined according to the statistical procedures of the SAS Institute Inc (Cary, NC). Individual mean comparisons were identified by Duncan's multiple-range test.

Urine sample collection

Twenty-four hour urine samples were collected in 4 L plastic bottles during the same time period as food collections. Urinary chromium concentration was determined by method of standard additions on non-ashed, non-diluted samples (25 μl) as described (7, 8). Daily aliquots, 10%, of mixed urine samples were combined for samples collected seven consecutive days, aliquots were then mixed and four ml aliquots used for Cr analysis. Total weekly urinary Cr excretion divided by seven is defined as the 7-day average Cr excretion.

Results

The distribution of the dietary chromium intake for all subjects is shown in **Figure 1.** The majority of the daily diet samples contained between 10 and 40 μg of Cr. The solid vertical line represents the minimum daily suggested safe and adequate intake for chromium which is 50 μg (3). More than 90 percent of the daily diets were below this recommended or suggested safe and adequate intake. There were almost as many samples containing less than 10 μg as there were samples containing at or above the suggested minimum Cr intake of 50 μg. Mean daily Cr intake for the ten male subjects was 33 ± 3 μg (range 13–89 μg) and 25 ± 1 μg (range 8–72 μg) for the 22 females (**Table 2**). Mean caloric intake for the males was 2340 ± 165 calories and 1619 ± 75 for the females. Chromium intake per 1000 calories for the males was approximately 14 μg and slightly higher, 16 μg, for the females. Therefore, a caloric intake of more than 3000 calories would be required to obtain the suggested minimum Cr intake from self-selected foods.

The correlation of Cr intake with intake of other nutrients is presented in **Table 3.** Foods high in potassium, fat, saturated fat and sodium also tended to be high in Cr (p

TABLE 1
Furnace program for analysis of ashed food samples

	Step 1	Step 2	Step 3	Step 4*	Step 5
Temp °C	100	130	1100	2700	2700
Ramp (sec)	15	10	15	0	1
Hold (sec)	20	10	20	4	4

* Internal flow = 50 ml/min.

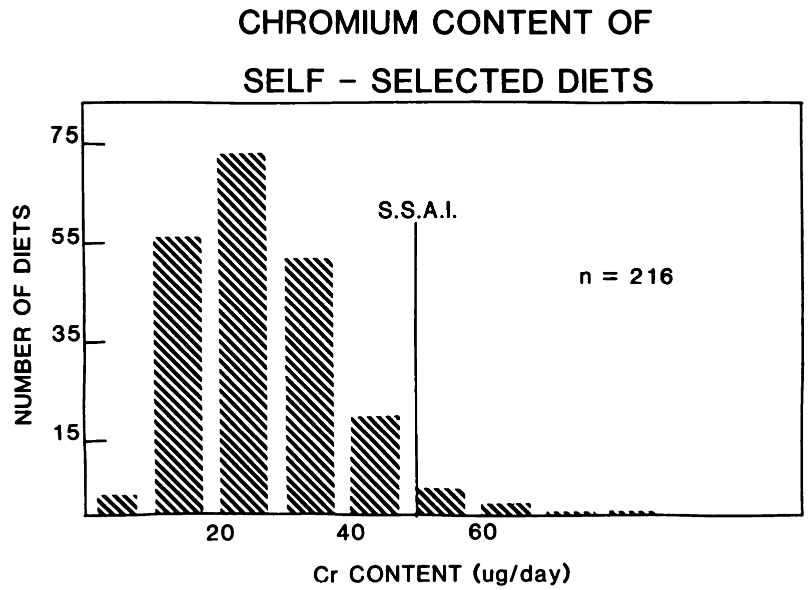

FIG 1. Frequency distribution of dietary Cr intake. Diets from 10 males and 22 females were collected for 7 consecutive days and analyzed for Cr. SSAI stands for the suggested safe and adequate intake.

< 0.001). Intakes of oleic acid, phosphorous, vitamin B_6, copper, protein and total carbohydrate also correlated with intake of Cr ($p < 0.01$). Intake of other trace elements, eg zinc and iron, did not correlate significantly with Cr intake.

Absorbed chromium is excreted primarily in the urine and only small amounts are lost in hair, perspiration and bile (9, 10). Therefore urinary Cr excretion can be used as a fairly accurate estimation of the amount of Cr absorbed. Mean 7-day average urinary Cr excretion for the males and females was the same, 0.19 ± 0.01 μg. Daily urinary Cr excretion was relatively constant, regardless of intake (**Fig 2**). This apparent anomaly can be explained by plotting Cr intake vs percent absorption (**Fig 3**). Percent Cr absorption was obtained by dividing absorbed Cr (total urinary Cr excreted) by total dietary intake times 100. The percent of the dietary Cr absorbed was inversely related to the amount of Cr in the diet. For example, when the daily dietary Cr intake was 10 μg, approximately 2% of the Cr was absorbed and at a Cr intake of 40 μg, only 0.4–0.5% of the Cr was absorbed. Therefore when dietary intake of Cr was below 40 μg, approximately 0.2 μg of Cr were absorbed and excreted in the urine as shown in Figure 2. Data in Figures 2 and 3 are primarily based on the average of 7-day urinary Cr samples since these values should give a more realistic value for urinary excretion than values computed for individual days. Data from selected individual days are also included (open circles) to approximate effects when daily Cr intake was above 40 or below 10 μg since none of the subjects had 7-day average dietary Cr intakes above or below these values. Line drawn in Figure 3 is derived only from the weekly samples.

Urinary Cr excretion for males and females was nearly identical, however, dietary Cr

TABLE 2
Chromium content of self-selected diets

Mean chromium intake (μg/day)		
Men	Women	All subjects
33 ± 3* (10)	25 ± 1 (22)	28 ± 1 (32)
Mean chromium μg/1000 calories		
Men	Women	All subjects
14	16	15

* Mean ± SE. Duplicate food samples were collected for 7 days for 10 male and 22 female subjects, total of 216 diet composites. Number in parentheses denotes number of subjects.

TABLE 3
Correlation of chromium intake with other nutrients

Parameter	Correlation coefficient
Potassium	0.66*
Energy	0.61*
Fat	0.60*
Saturated fat	0.59*
Sodium	0.58*
Oleic acid	0.57†
Phosphorus	0.51†
Vitamin B_6	0.51†
Copper	0.51†
Ash	0.50†
Protein	0.47†
Total carbohydrate	0.47†
Linoleic acid	0.44
Cholesterol	0.42
Pantothenic	0.37
Calcium	0.36
Ascorbic acid	0.36
Vitamin B_{12}	0.35
Riboflavin	0.34
Starch	0.27
Pentose	0.26
Thiamin	0.26
Iron	0.25
Folic acid	0.25
Lactose	0.25
Maltose	0.24
Vitamin A	0.22
Sucrose	0.18
Niacin	0.18
Fiber	0.15
Zinc	0.12
Reducing sugars	0.10
Cellulose	0.07
Fructose	0.05
Sorbitol	0.05
Hemicellulose	0.01
Lignin	0.01
Galactose	0.10
Glucose	−0.09
Pectin	−0.09

* Significant correlation at $p < 0.001$ level.
† Significant correlation at $p < 0.01$–$p \leq 0.001$.

intake of females was lower than that of males due to lower caloric intake. Therefore, Cr absorption for females was significantly greater than that for males, 0.93 ± 0.06 and 0.64 ± 0.05%, respectively.

Discussion

Reported Cr contents of diets have decreased in past decades (**Table 4**) due to increased awareness of contamination and improved instrumentation. Many of the studies listed in Table 4 also determined the intake of a number of other elements, in addition to Cr, and under these conditions the reported Cr intake values would be anticipated to be too high. For example, if conditions are not optimized for Cr and stainless steel collection vessels, blender blades, etc are used, erroneously high values for dietary Cr intake would be observed. Chromium leaching from stainless steel into foods is well documented (11–13). Determination of Cr as well as other elements but, using neutron activation under conditions that are not optimized for Cr, may also lead to erroneously high results (14).

In our study, conditions were optimized for Cr during the collection, homogenization and analysis steps. Samples were collected in plastic jars, homogenized in the same jars using low Cr blender blades and analyzed under conditions that lead to verifiable Cr values. Standard Reference Material (Bovine liver SRM-1577), certified for its Cr content, was analyzed and found to contain Cr within the certified range. In addition, a rat diet and a human diet composite sample of verified Cr concentrations (using gas chromatography mass spectroscopy) were used as internal controls. Other standard reference materials such as brewers yeast (SRM-1569), orchard leaves (SRM-1571) and citrus leaves (1572) were also analyzed, however, these values are not used since Cr contents of these materials are much higher than that found in foods. Using standard reference materials with certified values much higher or lower than the samples to be analyzed may lead to "false optimism" regarding actual concentration of samples to be analyzed and adds little or may even detract from the validity of the results.

In this study dietary Cr correlated significantly with intake of potassium, fat, saturated fat, and sodium as well as oleic acid, phosphorous, vitamin B_6, copper, protein, and total carbohydrates. It is interesting to note that copper is the only trace element that correlated with Cr intake. Gibson and Scythes (15) also reported a correlation between intake of Cr and Cu.

The observation that urinary Cr excretion was not related to dietary Cr intake (Fig 2) was an unexpected result, particularly in light of our previous work which demonstrated

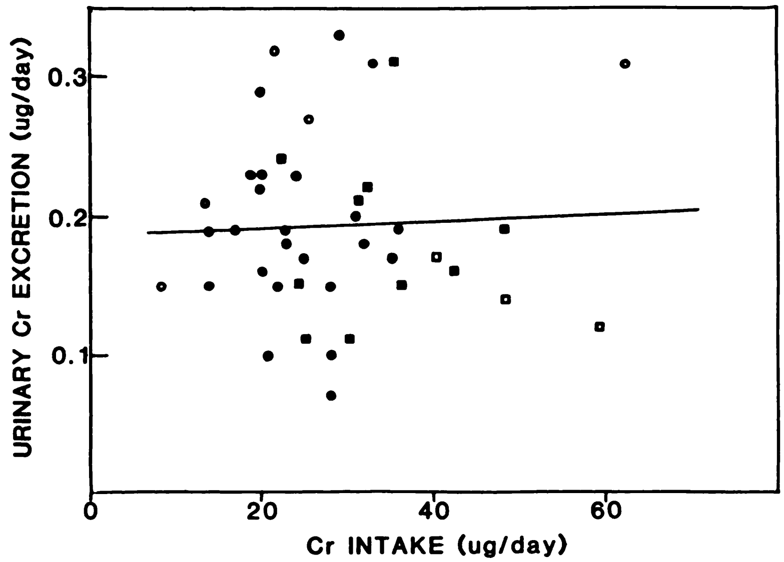

FIG 2. Urinary Cr excretion of adult subjects at varying Cr intakes. Solid symbols denote 7-day average values and open symbols daily values (■, □) males; (●, ○) females.

that an approximate 4-fold increase in Cr intake, due to Cr supplementation, led to an approximate 4-fold increase in urinary Cr excretion (7, 16). However, the data reported in this study pertain to daily Cr intakes of approximately 40 μg or less. Increased Cr absorption with decreased dietary intakes of less than approximately 40 μg (Fig 3) appears to be the reason for the relatively constant urinary Cr excretion. This is the first report of an effect of dietary Cr on Cr absorption. Increased Cr absorption with decreased intake represents a highly efficient means to ensure relatively constant amounts of absorbed Cr. Chromium absorption, at intakes from foods contributing more than 40 μg per day needs to be established. Increased dietary intake above basal levels due to supplemental chromium chloride leads to comparable increases in urinary Cr excretion (7, 16). The effects

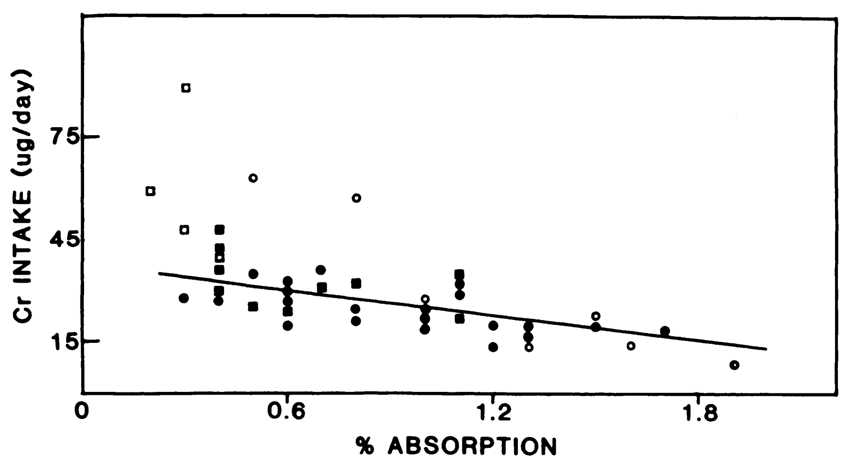

FIG 3. Chromium absorption of adult subjects at varying Cr intakes. Solid symbols denote 7-day average values and open symbols daily values; (■, □) males; (●, ○) females. Line was drawn using only the 7-day average values.

TABLE 4
Reported dietary Cr intakes

Cr intake (μg/day)	Country	Diet	Reference
78	USA	College	Schroeder et al, 1962 (17)
102	USA	Hospital	Deutsch et al, 1963 (18)
130–140	Japan	Self-selected	Murakami et al, 1965 (19)
52	USA	Nursing home	Levine et al, 1968 (20)
200–290	USA	Nutrition diet study	Tipton et al, 1969 (21)
170	Japan	Self-selected	Soman et al, 1969 (22)
150	India	Self-selected	Soman et al, 1969 (22)
231	USA	School lunch	Murphy et al, 1971 (23)
123	USA	Hospital	Schroeder 1971 (24)
282	Canada	Self-selected (representative)	Meranger and Smith, 1972 (25)
39–190	New Zealand	Self-selected	Guthrie, 1973 (26)
149	Italy	Self-selected	Clemente et al, 1977 (27)
77	USA	College	Walker and Page, 1977 (28)
62	West Germany	Self-selected	Schelenz, 1977 (29)
190	Sweden	Self-selected	Abdulla and Svensson, 1979 (30)
62, 89	USA	Nutrition diet study	Kumpulainen et al, 1979 (11)
29	Finland	Self-selected (calculated)	Koivistoinen, 1980 (31) Kumpulainen et al, 1980 (32)
240	Belgium	Hospital and self-selected	Buchet et al, 1983 (33)
56	Canada	Self-selected	Gibson and Scythes, 1984 (15)
24.5	England	Self-selected (elderly subjects)	Bunker et al, 1984 (34)
28	USA	Self-selected	This study

of Cr intakes above basal levels due to high Cr foods on Cr absorption and excretion need to be determined.

In summary, dietary Cr intake from self-selected diets appears to be approximately half of the minimum suggested safe and adequate intake. Chromium absorption, at intakes found in most diets, is inversely related to dietary Cr intake and urinary Cr excretion, under normal dietary conditions, appears to be relatively constant.

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