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Multicountry Estimation of Dietary Boron Intake

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ABSTRACT

Dietary Reference Intakes are not yet established for boron (B), a naturally occurring trace element in the human diet. Estimated dietary B intakes provide useful information for planning and assessing diets in healthy populations. The countries selected for this study represent a wide variety of dietary patterns and have adequate nutrient databases (with the exception of B) and food consumption data. Large-scale nationwide survey data were provided by the US (1989–1991) and Germany (1985–1989). Survey data from rural agricultural communities of Mexico and Kenya were provided by the Human Nutrition Collaborative Research Support Program (1983–1986). A B nutrient database was created to include B concentrations for the foods consumed in each country. It incorporates B analytical data from various sources in the US, Finland, UK, Italy, Japan, and China. Each person's average daily B intake was estimated by linking the B database with the survey food records. Average dietary intake estimates were then generated for various age and sex groups. The estimates for adults in the US, Germany, Mexico and Kenya, respectively, are 1.11, 1.72, 2.12, and 1.95 mg B/d for males and 0.89, 1.62, 1.75, and 1.80 mg B/d for females. Foods that are major contributors to the B intake of each country were also identified.

Index Entries: Boron; nutrient intakes; United States, Germany, Mexico, Kenya, food consumption surveys.

INTRODUCTION

Dietary Reference Intakes are not yet established for boron (B), a naturally occurring trace element in the human diet. Dietary B intake data for humans are sparse, because B is not included in most nutrient

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databases. When the Codex Alimentarius Committee on Special Dietary Uses set out to create an international recommended daily intake level for the probable essential element, B, they lacked sufficient dietary intake data needed for the task. This research hopes to fulfill the need by providing estimations of B intake based on food consumption surveys from the US, Germany, Mexico, and Kenya.

Our primary objectives were to create a B nutrient database, estimate dietary B intake, and identify foods that make a major contribution to that intake. This research represents the first four countries in an ongoing series of multicountry B intake studies. It was important to represent a wide variety of dietary patterns. Therefore, we selected two large industrialized nations and two rural agricultural communities for the study. This article reports dietary intakes and major food sources of B as reflected in the survey data from each country.

METHODS

The process of compiling data for estimating the intake of a nutrient by a population has been discussed in the literature *(1–3)*. We employed many of the same methods that have been utilized for estimating the intakes of other nutrients, such as folate *(2)* and vitamin E *(3)*. It is a multistep process that generally involves conducting a food consumption survey to identify the foods and their amounts consumed by the population; developing a food composition database for the nutrient content of those foods; calculating the intake of the nutrient by the population; and determining what foods are major contributors of the nutrient to the diet.

Food Consumption Surveys

The US, Germany, Mexico, and Kenya were selected for this research, because they represent a wide variety of dietary patterns and have adequate food consumption survey data and nutrient databases, with the exception of B. Large-scale nationwide survey data were provided by the US and Germany. Surveys from Mexico and Kenya were regional, conducted in rural agricultural communities.

The US Department of Agriculture's Continuing Survey of Food Intakes by Individuals, 1989–1991 (CSFII) was carried out as a multistage, multistratified sample covering the 48 conterminous United States. In this survey, food records were collected for 1–3 consecutive days (one 24-h recall interview and 2 d of food diaries) *(4–6)*. Our B intake estimates for 14,239 individuals include all CSFII survey respondents age 4 and older.

The German National Consumption Study (Nationale Verzehrs-Studie, NVS) was sponsored by the German Federal Minister for

Research and Technology. This survey was conducted from 1985 to 1989 as a multistage, multistratified random sample based on the German population of the former Federal Republic of Germany (FRG, including West Berlin). All participants were given a 7-d food diary in which to record their food intake. The final data set includes 4–7 d of food consumption records for 23,209 persons age 4 and older *(7)*.

The surveys from Mexico and Kenya were conducted during 1983–1986 as part of the Human Nutrition Collaborative Research Support Program (CRSP), supported by the US Agency for International Development *(8)*. These surveys were conducted in rural areas where mild to moderate malnutrition was believed to exist. The Mexican Solis Valley is still predominantly agricultural, producing maize, wheat, rice, beans, and squash. About half of the men commute weekly to work in Mexico City *(9)*. Embu, Kenya is an agricultural area that grows maize, legumes, and vegetables for its own consumption *(10)*. In each community, 2-d dietary records were obtained monthly across 1 yr from approx 250 households. The quantitative data on food preparation and consumption were obtained by questioning and observing the lead female during each 48-h period. Our B consumption estimates for individuals age 7 and older include data for 641 persons in the Mexican Solis Valley and 728 persons in Embu, Kenya.

Development of a B Nutrient Database

All four countries have food composition data for most common nutrients, with the exclusion of B. Therefore, it was necessary to develop a B nutrient database for the foods consumed in each country.

One of the first steps in the creation of a nutrient database is to compile a list of the foods consumed by the population. From the survey data for each country, we generated reports listing each food and its total amount consumed for use in identifying foods for which B values would be particularly critical. Priority for the assignment of B concentrations was given to foods representing the greatest amounts (by weight) consumed in each survey.

The next step involves an investigation into the state of existing nutrient data. We utilized the analytical B nutrient database that was previously developed for the purpose estimating B intake. That database was created by gathering and reviewing all available analytical data on the B content of foods *(11)*.

B concentrations were assigned to the survey foods by comparing their nutrients and ingredients to those in the analytical B database and imputing the B content for foods lacking specific analytical data. Each country's nutrient database and supporting documentation were used for these comparisons and calculations. The 1989–1991 CSFII data contain recipe files that were used to calculate the B content of many US mixed dishes. The German NVS data lacked a recipe database, but much of the data were reported at the ingredient level. When required, recipes for mixed German dishes were obtained from personal contacts or from literature. For the Nutrition CRSP surveys of Mexico and Kenya, the World Food Dietary Assessment Program (WFDAP) was utilized. In that program, the country-specific survey foods are crossreferenced to the appropriate foods or combinations of foods (recipes) in the WFDAP international nutrient database *(12)*.

Daily Dietary B Intake

The average daily B intake for each person was estimated by linking the B nutrient database to the individual food consumption records from each survey. Descriptive statistics for each country were then generated for various age and sex groups, which were selected according to the Food and Nutrition Board's life-stage groups for Dietary Reference Intake Values *(13)*.

Major Contributors of B in the Diet

A report of the total weight and total B consumed for each food in each country was generated in order to assess the contribution of B from individual foods. In cases where there were multiple listings for the same or similar food (such as various forms of orange juice), the data for those foods were combined. The condensed list was then sorted in descending order of B contribution, and the percent contribution to total dietary B was calculated for each food.

RESULTS AND DISCUSSION

The data presented here are based on the most current available analytical values and imputed values for foods for which we had no data. B intake for the US may be underestimated by approx 5% as a result of zero B values in the database for some foods. For Germany, the potential underestimation is approx 3%. However, the negative bias is probably far less, because B concentrations were assigned to most foods expected to be high in B. In the Mexico and Kenya dietary surveys, this error does not exist because we imputed values for all foods for which we had no data. However, the use of imputation probably reintroduces some error.

Table 1 shows the medians, means, and standard deviations for daily B intake by age and sex category. Without exception, the mean intakes are higher in all sex and age categories of Germany, Mexico, and Kenya than in the US.

Table 2 presents data on the major contributors of B to the diets of the US and Germany, and the percent of total B contributed by the top 15 foods. The top 15 foods for the US contribute only 35% of the total dietary B, whereas 60% of Germany's B intake is from its top 15

Table 1
Dietary B Intake in Four Countries (mg/d)

	United States			Germany			Mexico			Kenya		
Group	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**
School-age males and females												
4-8 y	0.70	0.80	0.43	1.12	1.17	0.47	1.24	1.29	0.40	1.52	1.56	0.40
9-13 y	0.77	0.86	0.45	1.25	1.33	0.56	1.19	1.20	0.29	1.52	1.78	0.85
14-18 y	0.75	0.84	0.49	1.29	1.41	0.61	1.65	1.73	0.30			
Males ≥19 y	0.96	1.11	0.69	1.51	1.72	0.91	2.01	2.12	0.69	1.91	1.95	0.57
19-30 y	0.86	1.04	0.77	1.43	1.61	0.79	1.88	1.89	0.56	1.96	2.03	0.58
31-50 y	0.96	1.10	0.64	1.54	1.75	0.95	2.09	2.18	0.71	1.92	1.94	0.57
51-70 y	1.05	1.19	0.70	1.56	1.79	0.96	2.30	2.36	0.81	1.83	1.98	0.63
> 70 y	1.00	1.11	0.66	1.50	1.72	0.92						
Females ≥19 y	0.75	0.89	0.57	1.48	1.62	0.76	1.67	1.75	0.48	1.75	1.80	0.49
19-30 y	0.66	0.80	0.56	1.39	1.54	0.73	1.63	1.71	0.49	1.77	1.87	0.45
31-50 y	0.74	0.87	0.58	1.52	1.66	0.80	1.71	1.78	0.48	1.71	1.77	0.51
51-70 y	0.84	0.97	0.59	1.54	1.67	0.76						
> 70 y	0.81	0.92	0.52	1.35	1.48	0.74						

contributors. Coffee is the number one contributor of dietary B in the US, at 6.54% of total intake. Wine was the top contributor in the German diet at 15.40%.

Table 3 shows the top 15 major contributors of B in the diets of Mexico and Kenya. In contrast to the nationwide surveys of the US and Germany, the surveys of Mexico and Kenya represent a small number of people with access to fewer food choices. In these areas, the top 15 foods contribute a much larger percentage (94%) of total dietary B. In both Mexico and Kenya, such staples as corn (tortillas, maize) and beans are the top contributors, constituting approx 69% of dietary B intake. These initial findings could prove useful in developing survey tools, such as food frequency questionnaires, for future analyses of B intake.

In the more developed countries, many of the top contributors to dietary B are beverages. Six of the top US foods are beverages: coffee, milk, orange juice, wine, apple juice, and cola drinks. Together, these contribute 22% of total dietary B. In Germany wine, coffee, mineral water, apple juice, and orange juice are among the top contributors, representing 29% of the dietary B. In contrast, the only beverages of Kenya's top 15 contributors are milk and tea, which contribute only 2% of dietary B.

Table 2
Major Contributions of B in the Diets of the US and Germany

	United States			Germany		
Rank	Food	Percent of total boron	Cumulative percent of boron	Food	Percent of total boron	Cumulative percent of boron
1	Coffee	6.54	6.54	Wine	15.40	15.40
2	Milk	4.67	11.20	Apples	8.79	24.20
3	Orange juice	3.18	14.39	Bread	5.80	30.00
4	Peanut butter	3.05	17.43	Potatoes	5.50	35.50
5	Wine	2.79	20.22	Coffee	5.10	40.60
6	Pinto beans	2.36	22.58	Mineral water	4.75	45.35
7	Apple juice	2.27	24.85	Oranges	2.45	47 80
8	Cola drinks	2.06	26.91	Fruit tarts	2.35	50.15
9	Peaches	1.63	28.54	Apple juice	2.03	52.18
10	Bananas	1.62	30.16	Orange juice	1.83	54.01
11	Grapes	1.32	31.48	Onions	1.74	55.75
12	Oranges	1.24	32.71	Bananas	1.35	57.10
13	Potato chips	1.12	33.83	Honey	1.30	58.40
14	Raisins	0.95	34.78	Grapes	1.13	59.52
15	Apples	0.70	35.48	Hazelnut-nougat spread	1.12	60.64

In Mexico, maguey drink accounts for 11% of dietary B. Combined with a small contribution from milk, these two beverages account for 12% of B intake in Mexico.

CONCLUSIONS

The range of average B intakes was found to be relatively small between countries, within about 1 mg/d for any given age/sex group. Average intakes for all groups in all countries are within 1.6 mg of each other. We had expected greater differences between countries because of the wide variety of diets that were represented. However, B is present in so many foods that even though the major sources differ, the average amount of B consumed is rather consistent.

Many beverages are major contributors of B in the more developed countries, whereas corn (tortillas, maize) and beans alone contribute

Table 3
Major Contributions of B in the Diets of Mexico and Kenya

	Mexico			Kenya		
Rank	Food	Percent of total boron	Cumulative percent of boron	Food	Percent of total boron	Cumulative percent of boron
1	Tortillas	56.05	56.05	Maize	35.32	35.32
2	Beans	12.64	68.70	Kidney beans	34.08	69.40
3	Fermented maguey drink	10.78	79.48	Bananas	5.05	74.45
4	Cactus	4.12	83.60	Mangos	3.62	78.07
5	Potatoes	2.23	85.83	Potatoes	3.31	81.38
6	Avocados	1.84	87.67	Leaf, medium	2.78	84.17
7	Tomatoes	0.97	88.64	Kale	2.19	86.36
8	Lambsquarter	0.92	89.56	Papaya	1.52	87.88
9	Milk	0.91	90.47	Leaf, cowpea	1.39	89 27
10	Eggs	0.78	91.24	Milk	1.01	90.28
11	Bread	0.68	91.92	Taro	0.84	91.12
12	Zucchini squash	0.65	92.57	Sweet potatoes/yams	0.65	91.76
13	Onions	0.60	93.17	Cassava	0.62	92.38
14	Rice	0.47	93.65	Tea	0.58	92.96
15	Plantain	0.40	94.04	Avocados	0.57	93.53

almost 70% in the rural communities of Mexico and Kenya. In the diverse diets of the US and Germany, the top 15 contributors represent only 35 and 60% of dietary B, respectively. In both Mexico and Kenya, however, 94% comes from the top 15 foods. These initial findings could prove useful in developing survey tools for future analyses of B intake. Where such a large percentage of B comes from so few foods, the use of food frequency questionnaires would be an economical method by which to survey B intake in these regions.

Conclusions are limited by the need for more analytical research on the B content of foods. This includes the development of standardized analytical methods that take into account interferences in various food matrices. Additional testing of foods from the individual countries is needed, because B, like all food nutrients, varies with different soils, growing conditions, and plant varieties. The current B nutrient database serves to identify gaps in the analytical data and will be useful in prioritizing future analytical research according to the foods most widely consumed in each country. Our dietary B intake estimates provide the customary consumption data that are necessary for the determination of recommended daily intake levels.

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