Deficient Dietary Iron Intakes among Women and Children in Russia: Evidence from the Russian Longitudinal Monitoring Survey

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ABSTRACT

Objectives. This study evaluated the iron sufficiency of the Russian diet.

Methods. Data were obtained from 24-hour dietary recalls conducted in 4 rounds (1992 through 1994) of a nationally representative longitudinal survey of 10 548 women and children. Iron bioavailability was estimated via algorithms adjusting for enhancers (heme, vitamin C) and inhibitors (tannins in tea, phytates in grains) consumed at the same meal.

Results. Dietary iron intakes were deficient in the most vulnerable groups: young children and women of reproductive age. Poverty status was strongly associated with deficiency. After adjustment for enhancers and inhibitors, estimated bioavailable iron intakes at 3% to 4% of total iron were inadequate in all women and children.

Conclusions. These dietary data suggest that Russian women and children are at high risk of iron deficiency. Grain products rich in phytates, which inhibit absorption, were the major food source of iron in Russia. High intakes of tea and low consumption of vitamin C also inhibited iron bioavailability. Since changes in eating behavior could potentially double iron bioavailability, educational programs should be explored as a strategy for improving iron nutriture. (*Am J Public Health.* 1998;88:576–580)

Introduction

In present-day Russia, the iron sufficiency of diets may be lower than desirable as a consequence of reduced purchasing power and subsequent changes in food consumption patterns.[1] Since the liberalization of price policies, there has been a sharp increase in the price of all consumer goods, especially food products. The consumer price index rose 900% between January 1991 and January 1992, while household incomes increased by only 354%.[2] Meats, fruits, and vegetables, which enhance iron absorption, may be less affordable to large segments of the population. The consumption of antagonists to iron absorption is also of concern, because the Russian diet is traditionally rich in compounds such as phytates (from grains and seeds) and tannins (from black tea) that inhibit iron uptake.

The iron content of the Russian diet and the bioavailability of dietary iron are evaluated in this report, since these are the primary determinants of iron nutriture in healthy individuals. This analysis focuses on the dietary iron intakes of Russian women and children, 2 groups particularly vulnerable to deficiency because their requirements are high. Children require iron for growth, during which they must increase their total iron stores commensurate to their increase in body mass.[3] Iron deficiency in children can result in impaired mental development and may have long-term deleterious effects on cognitive and behavioral performance.[4] In their reproductive years, women have relatively high requirements as a result of menstrual losses. During pregnancy and lactation, iron requirements are further increased owing to the transfer of iron to the fetus and placenta, losses during delivery, and breast-milk requirements.

Methods

Study Population

Data for this analysis were drawn from rounds 1 through 4 of the Russian Longitudinal Monitoring Survey (August through October 1992, December 1992 through March 1993, July through September 1993, and October 1993 through February 1994, respectively). The survey was designed to monitor social, economic, and health conditions in Russia using interviewer-administered questionnaires, 24-hour dietary recalls, and anthropometric measurements. The sample was based on a probability distribution of 7200 households throughout Russia. Round-specific weighting factors based on age, gender, and area of residence (urban vs rural) were used in calculating mean intakes. The weights accounted for sampling and design factors, as well as changes in participation rates over time. A total of 6485 households (89.5% of the target), including 10 548 women and children, participated in round 1; 6675 women and children participated in all 4 rounds and were included in this analysis. Mean intakes

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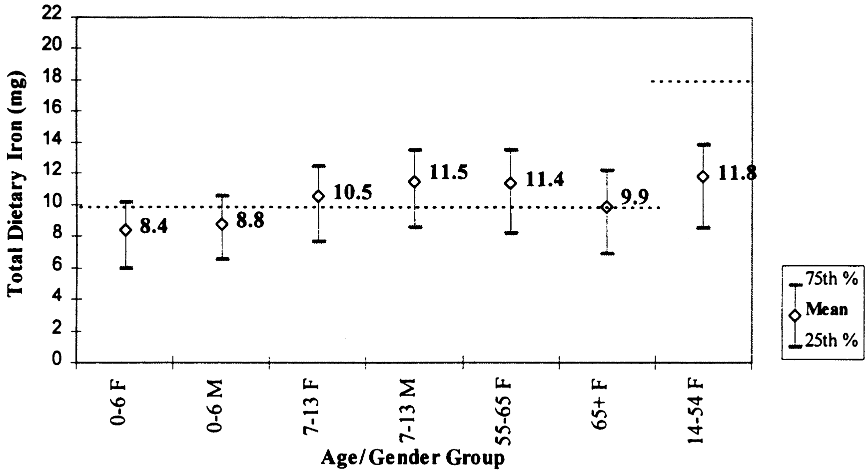

FIGURE 1—Mean intakes of total dietary iron in all age/gender groups, 1993/94 (F = female; M = male).

in this subgroup were slightly higher than means for all subjects participating in each round; thus, estimates of deficiency based on this analysis are conservative.

Dietary Assessment

Interviewers visited study households and obtained 24-hour dietary recalls using a menu-driven computer program (Glukala) designed by the Russian Center for Preventive Medicine. Interviewers were trained to capture consumption in sufficient detail for coding with a nutrient database of 642 food items. Reported food intakes were converted to nutrients via revised Russian food composition tables[5] based on the data of Skurichin and Volgarev.[6] Because the original tables contained surprisingly high iron levels for a number of fruits and vegetables, iron values were compared with alternate data sources, namely the US Department of Agriculture (excluding foods fortified with iron), the German Federal Food Code, the Russian Institute of Nutrition, and the Russian Center for Preventive Medicine. Iron content values of 365 foods were changed because of large discrepancies; values were revised if the percentage agreement between Glukala and an alternate source was less than 75% or more than 125%.

Mean daily intakes of total, heme, and bioavailable iron were estimated on the basis of 24-hour dietary recalls conducted in each round. Because requirements vary with rate of growth, menstrual losses, and pregnancy, iron intakes were estimated for 7 age and gender groups: boys and girls 0 to 6 years of age and 7 to 13 years of age, women of reproductive age (14 to 54 years), older women (55 to 65 years), and elderly women (> 65 years). Data from rounds 1 (fall 1992) and 2 (winter 1992/93) and from rounds 3 (summer 1993) and 4 (winter 1993/94) were merged to represent intakes during these 2 subsequent years. Combining 2 rounds of data collected in each year helped to reduce the influence of seasonal variation when assessing temporal changes in intakes and provided a more informative picture of year-round intakes for each individual. Mean intakes were also calculated separately for each round (data not shown); conclusions based on individual rounds did not differ meaningfully from those based on the merged data.

As a means of assessing the iron sufficiency of diets, mean total iron intakes were compared with Russian recommended intakes for each age and gender group.[7] When Russian recommendations were not available, intakes were compared with US recommended allowances.[3] Bioavailable intakes were compared with estimated metabolic requirements for optimal growth and maintenance of stores. Major sources of total and bioavailable iron in the Russian diet were identified by ranking food groups based on the percentage of the population's iron intakes contributed by each group. The Eurocode food coding system[8] was used in creating food groups.

Stratified analyses were used to assess whether variation in dietary iron intakes was associated with several sociodemographic variables, including household income. In addition, linear regression models were used to assess the statistical significance of associations between sociodemographic factors and iron consumption after adjustment for the other variables in the model (urban vs rural residence, household income, education level, nutritional status, smoking status, and household size). Repeated measures analyses of variance and *t* tests were used to determine whether changes in iron intakes over time were statistically significant. SAS statistical software (SAS Institute Inc, Cary, NC) and SUDAAN (Research Triangle Institute, Research Triangle Park, NC) was used for all analyses.

Iron Bioavailability

Because the Russian diet is rich in whole grains and black tea, which inhibit iron absorption, it is important to estimate the effect of these products on bioavailability. The method used to estimate the combined effect of enhancers and inhibitors on iron absorption is summarized subsequently; additional details are available elsewhere.[9] The algorithm was derived on the basis of data from several clinical studies but has not been validated biochemically. Despite the lack of validation, it has been used to provide an indicator of the impact of the high concentration of inhibitors in the Russian diet on iron bioavailability.

Because of differences in absorption of heme and nonheme iron, the amounts of each type of iron absorbed from each meal or snack were estimated separately and totaled. Meat iron (including fish and poultry) was estimated to be 40% heme and 60% nonheme; the quantity of meat in mixed dishes was estimated from official recipes. The first bioavailability adjustment, based on the work of Monsen and others,[10,11] used average absorption rates for heme and nonheme iron and accounted for the effect of enhancers. The absorption rate for heme iron was estimated to be a constant 23%. Nonheme absorption, which ranged from 3% to 8% depending on the concurrent consumption of enhancing factors, was estimated as follows: (1) for consumption of fewer than 75 units, percentage of nonheme absorption = $3 + 8.93 \times \ln[(\text{Enhancing Factors} + 100)/100]$, and (2) for consumption of more than 75 units, percentage of nonheme absorption = 8 (where 1 enhancing factor unit = 1 g meat, fish, or poultry or 1 mg vitamin C consumed in the same meal).

The second adjustment took into account the effect of inhibitors. Nonheme iron availability was reduced by an additional 40% for subjects consuming more then 225 g of tea with a meal.[12] By means of algorithms based on clinical studies conducted by Hallberg et al.[13] nonheme absorp-

TABLE 1—Estimated Mean Intakes and Temporal Change in Heme and Bioavailable Dietary Iron (mg/day) Based on 24-Hour Dietary Recalls

	Heme Iron				Bioavailable Iron					
					Adjustment 1			Adjustment 2		
	Mean Heme Iron Intakes, mg/d		Temporal Change in Intakes,		Bioavailable Iron Intakes Adjusted for Enhancers		Temporal Change in Intakes,	Bioavailable Iron Intakes Adjusted for Phytates/Tea		Temporal Change in Intakes,
Gender and Age Group, y	1992/93, Mean (SD)	1993/94, Mean (SD)	Mean % (P^b)	Estimated Required Range[a]	1992/93, Mean (SD)	1993/94, Mean (SD)	Mean % (P^b)	1992/93, Mean (SD)	1993/94, Mean (SD)	Mean % (P^b)
Children										
Girls 0–6 (n = 386)	0.81 (0.76)	0.77 (0.77)	−5 (.42)	0.4–1.5	0.91 (0.42)	0.96 (0.41)	6 (.02)	0.33 (0.23)	0.32 (0.23)	−3 (.51)
Boys 0–6 (n = 360)	0.84 (0.79)	0.81 (0.77)	−4 (.63)	0.4–1.5	0.91 (0.42)	0.99 (0.43)	8 (.00)	0.34 (0.24)	0.34 (0.25)	−1 (.93)
Girls 7–13 (n = 495)	1.12 (0.97)	1.03 (1.25)	−8 (.16)	1.0–2.8	1.12 (0.46)	1.09 (0.43)	−3 (.23)	0.44 (0.28)	0.42 (0.36)	−5 (.16)
Boys 7–13 (n = 523)	1.23 (1.00)	1.16 (1.01)	−6 (.21)	1.0–2.0	1.15 (0.46)	1.14 (0.45)	−1 (.76)	0.48 (0.29)	0.46 (0.29)	−5 (.22)
Women										
14–54 (n = 5161)	1.33 (1.14)	1.21 (1.22)	−9 (.00)	1.7–4.8	1.19 (0.51)	1.14 (0.47)	−4 (.00)	0.51 (0.32)	0.47 (0.34)	−8 (.00)
55–65 (n = 814)	1.02 (1.06)	0.96 (1.10)	−6 (.18)	0.6–0.9	1.01 (0.48)	0.99 (0.44)	−2 (.24)	0.42 (0.30)	0.40 (0.31)	−6 (.08)
>65 (n = 909)	0.82 (0.92)	0.76 (1.02)	−8 (.11)	0.6–0.9	0.91 (0.43)	0.87 (0.39)	−4 (.00)	0.35 (0.26)	0.32 (0.29)	−8 (.01)

Note. Adjustment 1 accounts for concurrent consumption of enhancers (heme and vitamin C). Adjustment 2 accounts for concurrent consumption of enhancers and inhibitors (heme, vitamin C, phytates, and tea). Note that this algorithm, which combines data from 2 clinical studies, has not been validated biochemically.

[a] Estimate of iron required for maintenance and growth in each age and gender group (Fairbanks and Bentley[16]).

[b] Based on a *t* test of the difference in intakes in 1992/93 vs 1993/94.

tion was again reduced to account for the antagonistic effect of phytates. Reductions ranged from 0% to 85%, depending on the amount of phytate-containing foods consumed in each meal.[9] Reference sources were used in estimating the phytate content of specific foods, since no data on phytates were available in the Russian data sources.[14,15]

Because the algorithm combining inhibitor and enhancer effects has not been validated, intakes adjusted for enhancers only (based on clinical studies by Monsen and others[10,11]) were used to identify major food sources of bioavailable iron and to analyze the relationship between dietary iron intakes and sociodemographic factors. This was done to avoid incorrectly identifying food sources of iron or overestimating the effects of sociodemographic factors as a result of inaccuracies in the algorithm.

Results

Total Iron Intakes

Mean total iron intakes in 2 groups—women of reproductive age (14 to 54 years) and young children (0 to 6 years of age)—were well below recommended levels (Figure 1). In 1993/94, mean intakes among young children (0 to 6 years of age) represented 84% to 88% of the recommended 10-mg allowance. Among women of reproductive age, mean total iron intakes were only 66% of the level recommended for nonpregnant/nonlactating women. This large shortfall resulted primarily from the higher intake recommendation for this group; in absolute terms, mean intakes in this group were higher than those among older women or children. Mean intakes among older children (7 to 13 years of age) and elderly women (>65 years of age) were comparable to recommendations. Between 1992/93 (data not shown) and 1993/94, total iron intakes declined by 5% to 9% (*t*-test $P < .05$) in women and by 3% to 5% in older children ($P < .05$ for girls). This temporal trend may be an indicator of increasing risk of deficiency in these groups. Intakes among younger children changed by less than 2% (not significant) over the same period.

Heme Iron

As with total iron, mean intakes of both heme and nonheme iron were highest among women of reproductive age (14 to 54 years) and lowest among young children (0 to 6 years of age) and women more than 65 years old (Table 1). Elderly women had the lowest concentration of heme intakes (7.6% of total iron), while women 14 to 54 years of age had the highest concentration (10.8%). The small difference in heme and total iron intakes of boys and girls does not appear to indicate a meaningful gender bias in iron or meat intakes. Over time, heme iron consumption declined 4% to 10% among all groups, again suggesting an increased risk of deficiency; this decline was significant ($P < .05$) among women of reproductive age.

Bioavailable Iron

Estimates of iron available for absorption are also shown in Table 1. Age and gender differences were similar to those for total iron: women 14 to 54 years of age had the highest intakes of available iron, and elderly women and young children had the lowest.

Before the impact of inhibiting factors was taken into account, estimated bioavailable intakes represented 9% to 11% of total iron. At this stage, mean intakes fell within the range of estimated metabolic requirements[16] (Table 1). After adjustment for inhibitors, however, estimates of mean

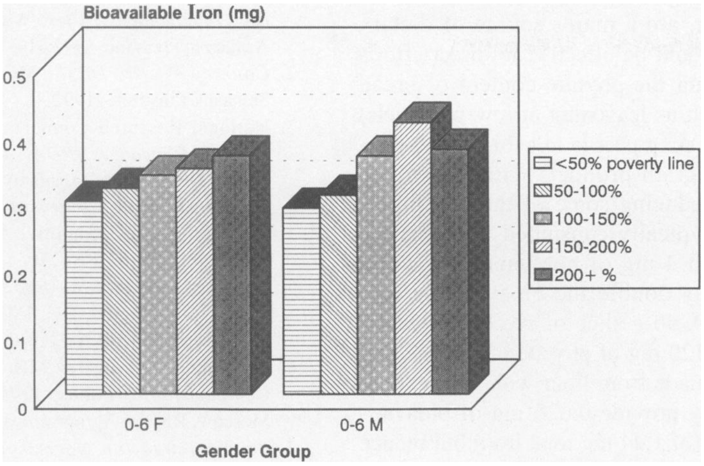

FIGURE 2—Intakes of bioavailable iron estimated from dietary intake in children 0 through 6 years of age, by poverty level (percentage of poverty line), 1993/94 (F = female; M = male).

bioavailable iron intakes were substantially below minimal metabolic requirements for each age and gender group. For example, the mean bioavailable intake of 0.47 mg in women 14 to 54 years of age (in 1993/94) represented as little as 20% and not more than 67% of the estimated metabolic requirement (0.7 to 2.3 mg[16]) for menstruating women. Because no safety factors were included in the values for metabolic requirements, these shortfalls suggest a high risk of deficiency for all women and children.

Adjusting for inhibitors had a dramatic effect, reducing mean intakes of bioavailable iron to 3% to 4% of total dietary iron consumption. The impact of tea alone (data not shown) was significant for some age and gender groups. However, the most dramatic reduction predicted was the result of phytate consumption.

Food Sources of Total and Available Iron

Iron intakes in the Russian diet were concentrated in a small number of food groups. Twenty-five food groups provided 93% to 96% of total dietary iron intakes in all 4 rounds. The top 5 sources of total iron (wheat breads, other wheat products, rye products, beef, and potatoes, roots, and tubers) provided more than half (53%) of the population's total dietary iron consumption. Grains alone (primarily wheat and rye) provided 35% of total iron.

Enhancer-adjusted bioavailable iron intakes were even more concentrated: the top 5 food groups (rye products, wheat breads, beef, meat products, and other wheat products) provided 64% of intakes. As with total iron, grains were the most important source of bioavailable iron (providing 51% of intakes), followed by beef and other meats (23%). Meats, as a result of their high heme iron content, were relatively more important sources of bioavailable iron than of total iron. Still, more than half of the available iron was consumed in nonmeat foods.

Iron Intakes and Economic Status (Poverty)

As illustrated in Figure 2, households with incomes below the poverty line tended to have low iron intakes. Poverty was a statistically significant ($P < .05$) predictor of total, heme, and bioavailable iron intakes in multivariate models for most age and gender groups. The disparity between poorer and wealthier households was more evident for intakes of both heme and bioavailable iron than for total iron (data not shown), indicating that meat consumption was an important influence on the disparity in bioavailable intakes. This disparity was especially apparent for young children and younger women; differences in bioavailable iron intakes among the highest and lowest income groups ranged from 18% to 31%. However, among elderly women, who had the lowest intakes, iron consumption was poor regardless of income. The disparity in mean bioavailable iron intakes of the lowest and highest income groups was only 7%, suggesting that meat consumption in elderly women was universally low regardless of income.

Discussion

Ongoing economic upheaval in Russia may pose a serious threat to the iron nutriture of women and children. Based on recommended daily allowances, total iron intakes appear to be inadequate in young children and women of reproductive age. When both enhancers and inhibitors were taken into account, estimates of bioavailable iron intakes for women and children of all ages were well below metabolic requirements, reflecting the high concentration of inhibitors to iron absorption in the Russian diet.

Four rounds of the survey provide consistent evidence of insufficient dietary intakes. Given the high risk of deficiency suggested by these data, it seems important to collect biochemical and clinical data to monitor iron status in Russian women and children. The proportion of the population at risk of deficiency cannot be determined from dietary intakes alone. Because individuals generally adapt to poor dietary intakes by increasing their rate of absorption and by using body stores to maintain equilibrium,[17] individual rates of absorption and losses may differ greatly from predicted values. Thus, biochemical measures of iron status are necessary to determine the prevalence of deficiency.

The lack of biochemical measures notwithstanding, these nationally representative dietary data strengthen and support the results of other, more limited studies. A number of smaller surveys conducted since 1990 indicate that a substantial proportion of Russian women—perhaps more than 20%—are deficient according to biochemical indices including hemoglobin levels and transferrin saturation (A. Baturin, written communication, July 1995). Anemia of pregnancy is thought to exist in 20% to 25% of Russian women (A. Baturin, written communication, July 1995) and in up to 30% to 50% of women in regions such as Siberia.[18] No recent data on iron status in children are available (A. Baturin, written communication, July 1995).

Because of the composition of the Russian diet, adjustments for the combined effect of inhibitors and enhancers were critical in evaluating iron sufficiency. However, the lack of biochemical validation is an important shortcoming. The algorithms used to estimate availability were developed on the basis of absorption rates in iron-replete subjects; iron-deficient individuals would absorb a larger proportion of ingested iron. While increased absorption in individuals with low iron stores may help to delay deficiency, chronically inadequate dietary intakes prevent repletion. In the long run, inadequate intakes also lead to depletion in individuals with initially normal stores. By estimating habitual bioavailable iron intakes using assumptions based on iron-replete individuals, we sought to identify individuals likely to have low iron stores or to be at risk of depleted stores in the future.

Another potential shortcoming of these data is that they do not include information on the use of iron-containing supplements. This is unlikely to affect the validity of our findings, because the use of supplements is believed to be uncommon, with the possible exception of a few pregnant women in urban areas (A. Baturin, written communication, July 1995). The infrequent use of vitamin and mineral supplements may be due to the lack of awareness of the problem of nutrient deficiency in Russia, as well as expense and limited availability (A. Baturin, written communication, July 1995). It seems reasonable to assume that, at present, foods represent the sole source of iron for all but a small fragment of the Russian population.

The most significant finding in this analysis is the potent impact of meal composition on bioavailable iron in the Russian diet. Consumption of phytate-rich grains and black tea substantially reduces iron availability. Significant improvements in iron nutriture could be accomplished by changing eating behaviors to reduce the concurrent consumption of iron-rich foods and antagonists to iron absorption.

Based on our data, income appears to be another important determinant of dietary iron intakes. Average intakes of both total and bioavailable (adjusted for heme and vitamin C) iron were lower among poor households than among wealthy households. This discrepancy may reflect differences in purchasing power, particularly of meats, fish, fruits, and vegetables. Increased meat consumption will not be an option for many families and may be undesirable in view of other health risks. Optimizing absorption of nonheme iron is an important alternative.

Promotion of concurrent consumption of foods rich in vitamin C and iron-rich meals may improve iron absorption. We should point out, however, that in a recent study, supplemental ascorbic acid was shown to improve iron status much less than expected. Nonetheless, frequent consumption of locally available vitamin C–rich foods, such as black currants (fresh or in jellies), peppers (fresh or pickled), and cabbage, would be desirable irrespective of the impact on iron absorption, considering the importance of this essential nutrient.

Since grain products, and breads in particular, are a major source of dietary iron, it would be effective to direct efforts at reducing the phytate content of bread flour (such as leavening at low pH levels) or at educating people to avoid eating phytate-rich grain products with their main meals. Reducing some of the 120 mg of phytate typically consumed in a Russian meal with 4 mg of nonheme iron could potentially double the bioavailable iron content. A 40-g slice of rye bread, which contains 120 mg of phytate (or more if the bread is made from flour with high extraction), may provide 0.025 mg of bioavailable iron (of 1.44 mg total iron) but reduce the bioavailability of nonheme iron in the meal (4 mg) by 0.12 mg. Eliminating the phytate contributed by this slice of bread could increase bioavailable iron as much as a 20-g slice of beef. ☐

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