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Iron absorption from typical Latin American diets[1-3]

A Acosta, M Amar, SC Cornbluth-Szarfarc, E Dillman, M Fosil, R Gongora Biachi, G Grebe, E Hertrampf, S Kremenchuzky, M Layrisse, C Martínez-Torres, C Morón, F Pizarro, C Reynafarje, A Stekel, D Villavicencio, and yH Zuniga

ABSTRACT The availability and daily absorption of iron was determined by the extrinsic-label method in typical lower middle to lower class diets consumed in regions of Argentina, Brazil, Chile, Mexico, Peru, and Venezuela. Differences in iron absorption from meals up to 7-fold, could be attributed to the varying contents of absorption enhancers, eg, in meat, and of inhibitors in tea, vegetables, and wheat or maize bread. The total iron available in the diets from four countries did not meet the physiological requirements for normal subjects but deficient subjects fulfilled their requirements absorbing from 1.0 to 2.1 mg/day. In five diets heme iron (6 to 24% of the total) provided 34 to 73% of the iron absorbed. These data suggest that such absorption and utilization studies may be used to correlate the prevalence of iron deficiency in a population with certain diets and to guide fortification programs. *Am J Clin Nutr* 1984;39:953–962.

KEY WORDS Dietary iron absorption, Latin American diets

Introduction

The introduction of the extrinsic tag method to measure the absorption of heme and nonheme iron from a food (1–3) paved the way for the measurement of the absorption of these iron compounds from a meal (2, 4–12) and from a complete diet (10, 12–16) and permitted the evaluation of the role that these diets may play in the development of iron deficiency and iron-deficiency anemia.

The United Nations University and Instituto Venezolano de Investigaciones Científicas in Venezuela started a program in 1979 called "Prevention of iron deficiency in Latin America by iron fortification." The first task of the program was the determination of the quantity of iron that is absorbed from diets consumed in countries and regions of Latin America and the second task, depending on the results obtained in the first, would be the study of food vehicles, and types of iron salt that would be suitable for the establishment of an iron fortification program for each country or area. Herein, we provide the results of the first task study carried out on typical diets consumed by lower middle and lower class subjects in Argentina, Brazil, Chile, Mexico, Peru, and Venezuela.

Materials and methods

A protocol was prepared in advance by the Caracas Laboratory to ensure that each participant would follow

[1] From the Hospital de Especialidades CM "La Raza," IMSS, Mexico (AA, ED, yHZ); Instituto de Nutrición y Technología de los Alimentos (INTA), Oniversidad de Chile, Santiago de Chile (MA, EH, FP, AS); Departamento de Nutrição, Facultade de Saúde Pública, Universidade de São Paulo, Brasil (SCC-S); FUNDACREDESA, Caracas, Venezuela (MF); Hospital O'Haran, Universidad de Yucatán, Mexico (RGB); Universidad Católica de Chile, Santiago de Chile (GG); Comision Nacional de Energía Atomica, Argentina (SK); Laboratorio de Fisiopatologiá, Instituto Venezolano de Investigaciones Científicas Caracas, Venezuela (ML, CM-T); Instituto de Endocrinología y Metabolismo de Salta, Argentina (CM); Universidad Nacional Mayor de San Marcos, Lima, Perú (CR, DV).

[2] Supported by United Nations University and Instituto Venezolano de Investigaciones Científicas, Caracas, Venezuela.

[3] Address reprint requests to: Dr M Layrisse, Instituto Venezolano de Investigaciones Científicas, Apartado 1827, Caracas 1010A, Venezuela.

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a similar protocol regarding the selection of typical diets, the number and characteristics of the subjects to be tested for iron absorption, the methods used to determine the hematological blood profile in terms of iron deficiency, and the method for the determination of iron absorption. Since not all participants had laboratory facilities to perform the tests, the Caracas Laboratory acted as a reference laboratory to assist some laboratory participants to perform the tests. In addition, some of the participants spent several weeks at the Reference Laboratory for training. The protocol for this study was approved by the Committee for the Protection of Human Subjects of Scientific Research (Instituto Venezolano de Investigaciones Científicas).

Diets

Each participating laboratory identified in its own country the typical diet that is consumed by the lower middle or lower economic segment of the population. The characteristics of each diet consumed by adults (**Table 1**) and the segment of the population identified with the diet, are described herein.

Argentina

The characteristics of the diet were obtained using a questionnaire directed to 231 people from the lower socioeconomic segment of the population living in Salta province, which represents about 43% of the total population of the province (662,870). The main dish is a stew (guiso) composed of vermicelli, potatoes, tomatoes, beans, squash, onion, pepper, and beef meat, which is eaten in different proportion at lunch and supper. Wheat bread eaten at each meal was used as the food vehicle to carry the extrinsic radioiron. The iron absorption from an afternoon snack was estimated from that measured at breakfast.

Brazil

Dietary survey was carried out by Fundação Instituto Brasileiro de Geografia e Estatistica (17), as that consumed by a lower class segment of the population with an income per family of less than $170/month, which represents 33% of the total population of Sao Paulo State (25 million). Beans and rice are the principal foods. Sugar, which is consumed at each meal, was taken as the food vehicle for the extrinsic radioiron label.

Chile

The typical diet was selected from nutritional studies performed on the different socioeconomic classes in the city of Santiago (18, 19). This diet is consumed by the lower middle and lower socioeconomic classes of the population representing about 50% of the city's population of 4.3 million. The main food article is wheat eaten as bread and as vermicelli, beef meat is eaten at lunch, eggs at supper, and an apple is consumed in the last two meals. The radioactive iron was added to a wheat dough for each meal. The iron absorption from an afternoon snack was calculated from the absorption measured at breakfast.

Mexico

The diet was chosen from a questionnaire survey of 50 housewives belonging to laborers' families from the city of Merida, Yucatan State. The total population of this state is about 500,000 and about 37% belong to this lower middle socioeconomic stratum. The outstanding characteristic of this diet is the consumption of meat in relatively large proportions at each meal. The radioactive iron was added to maize in different preparations in each meal as the extrinsic label.

Peru

The diet was not taken from a dietary survey for a given population. It rather represents the average daily diet that is consumed by the employers (nursing assistants) at a public hospital in Lima. It may be observed in Table 1 that this diet contains typical food preparations such as queque, made of wheat flour and sugar, and chicha morada prepared by boiling 5 g of mulberry maize in 100 ml of water plus 10 g of sugar. Fish is eaten twice a day. The radioactive iron used as the extrinsic label was mixed with queque at breakfast, with chicha morada at lunch, and with mashed potatoes at supper.

Venezuela

The diet tested was obtained from the dietary survey carried out in Carabobo State by Proyecto Venezuela (20). The daily dietary intake was obtained from a survey of 163 families living in Carabobo State. The diet chosen is consumed by the lower socioeconomic segment of the population, which represents 40% of the State's population (1 million). Maize and black beans are consumed at two meals, animal proteins are consumed at lunch as egg and at supper as beef meat. Maize dough was used as a food vehicle to carry the radioactive iron at breakfast and supper, and mashed black beans at lunch.

Subjects tested

One hundred fifty-six subjects 11 men and 21 women from Argentina, eight men and 20 women from Brazil, 10 men and 20 women from Chile, four men and 16 women from Mexico, one man and 14 women from Peru, and nine men and 22 women from Venezuela consented to participate in this study. They were in apparent good health and the low Hb values present in some of them did not interfer with their daily work. The subjects tested in Argentina, Brazil, Chile, Mexico, and Peru were from the same locality and same socioeconomic level as where the diet is consumed. The blood Hb concentration (21), serum iron concentration (22), unsaturated iron-binding capacity (23), and serum ferritin concentration (24) were tested in each case. Different methods were used in Chile samples for the determination of iron and ferritin in the serum (25, 26).

Preparation of radioactive material

The extrinsically labeled food was prepared by mixing the radioactive iron with the food vehicle according to the technique previously described (1–3).

The reference dose of iron ascorbate was prepared

TABLE 1
Daily food intake in typical Latin American diets

Country	Breakfast		Lunch		Supper		Afternoon snack	
	Uncooked food		Uncooked food		Uncooked food		Uncooked food	
	g		g		g		g	
Argentina								
Tea	2	Wheat bread	60	Wheat bread	60	Wheat bread	60	
Sugar	35	Banana	160	Vermicelli	20	Sugar	35	
Wheat flour	50	Vermicelli	40	Vermicelli	20	Tea	2	
		Beef meat	130	Beef meat	20			
		Potato	170	Potato	30			
		Tomato	30	Tomato	20			
		Oil	30	Oil	10			
		Carrot, squash onion, pepper	70	Carrot, squash onion, pepper	30			
		Beverage	160					
Brazil								
Sugar	9	Sugar	9	Sugar	9			
Coffee	6	Coffee	6	Coffee	6			
Margarine	8	Oil	20	Oil	18			
Wheat flour	55	Rice	59	Rice	61			
		Beans	44	Beans	44			
		Meat	54	Egg	60			
		Onion	18	Onion	5			
		Tomato	9					
Chile								
Wheat flour	100	Wheat flour	50	Wheat flour	100	Wheat flour	100	
Sugar	10	Beef meat	80	Vermicelli	80	Sugar	10	
Margarine	5	Rice	10	Eggs	57	Margarine	5	
Tea		Vermicelli	10	Oil	10	Tea		
		Potato	80	Apple	100			
		Onion	10					
		Oil	5					
		Pumpkin	50					
		Onion	10					
		Apple	150					
		Carrot	10					
Mexico								
Egg	100	Pork meat	200	Turkey meat	150			
Sausage pork	100	Watermelon	150	Onion	50			
Pepper	30	Pepper	40	Pepper	20			
Maize (Pime)	125	Maize	125	Maize (Salbute)	125			
Beans	50	Beans	100	Rice (Orgeat)	200 ml			
Wheat bread	50	Rice (Orgeat)	200 ml					
Coffee and milk	250 ml	Rice	60					
Peru								
Milk	254 ml	Rice	80	Rice	95			
Wheat flour	90	Beans	60	Beans	60			
Sugar (queque)	15	Sugar	10	Sugar	10			
Margarine	10	Oil	10	Oil	10			
		Fish (Lisa)	100	Fish (Lisa)	100			
		Bacon	3	Bacon	5			
		Onion	20	Onion	20			
		Tomato	20	Tomato	20			
		Plantain	120	Potato	90			
		Chicha morada		Milk	30			
				Maize flour	15			
Venezuela								
Maize flour	85	Egg	35	Maize flour	85			
White cheese	15	Rice	60	Wheat paste	40			
Margarine	5	Black beans	40	Black beans	40			
Milk powder	200 ml	Tomato	20	Tomato	20			
Coffee	5	Plaintain	90	Hamburger	80			
Sugar	20	Onion	10	Onion	10			
		Redpepper	5	Redpepper	5			
		Garlic	2.5	Garlic	2.5			
		Oil	15	Oil	15			
		Beverage	120	Beverage	120			

following the detailed information described in the agreed protocol, which is essentially the same as previously published (27).

Iron absorption

Each meal was administered in the morning after an overnight fast. No food or drink was allowed for 3 h after the administration of the radioactive material. The extrinsic label, ^{55}Fe or ^{59}Fe, was mixed with the food vehicle in each meal. Approximately 0.7 μCi of ^{59}Fe or 2 μCi of ^{55}Fe were used in each test. All meals were given in the morning and the terms breakfast, lunch, and supper are used here only to identify the type of meal. Breakfast was given on day 1 and lunch on day 2, blood was drawn 15 days after the administration of the breakfast and lunch to determine the hematological characteristics of the subject and to measure the radioactivity in the blood samples. The subjects were fed with the supper on day 15 and with the reference dose of iron ascorbate on the day 16. Blood was drawn again on day 30 to measure the radioactivity. Duplicate 10-ml samples together with the radioactive food and reference dose standard were prepared for radioactive counting following the technique of Dern and Hart (28, 29). The blood samples from Chile were processed according to the method of Eakins and Brown (30). Radioactivity was measured in a liquid scintillation spectrometer. Triplicate standards of the food administered were counted simultaneously with the blood samples. The iron absorption from the food was calculated from the ^{59}Fe and ^{55}Fe activity in the subjects' blood using an estimate of blood volume based on sex, weight, and height (31); no correction was made to determine the total iron utilization.

Determination of heme and nonheme iron content in meat

The total iron content of various kinds of meat (beef, pork, turkey and fish) was determined by the digestion method (32) and the non-heme iron by the method of Torrance and Bothwell (33). The heme iron content was estimated from the difference between the total iron and nonheme iron content of each meat.

Statistical analysis

The mean and SE of the values for the iron absorption and ferritin concentration were calculated using logarithms and the results returned to the original units by taking the antilog (34).

Results and discussion

Table 2 shows the nutrient content of the Latin American diets. With the exception of Brazil the diets contain an adequate amount of ascorbic acid to meet the normal requirements; however, this amount is not enough to promote an increase in absorption of nonheme iron present in vegetable foods as has been reported using larger quantity of ascorbic acid (13, 35, 36). The richest diet in terms of nutrients and promoters of iron absorption is from Yucatan, Mexico, where meat is eaten three times a day and the diet contains 3100 cal, 87 g of animal protein, 3 mg of heme iron, and 29 mg of nonheme iron. In the second category are the diets from Peru and Argentina; in the former fish is eaten twice a day and the diet contains 2400 cal, 39 g of animal protein, 0.9 mg of heme iron, and 18 mg of nonheme iron; the latter diet contains meat which is eaten twice a day, 2000 cal, 30 g of animal protein, 4 mg of heme iron, and 13 mg of nonheme iron. In the third category are Chile and Venezuela; the former diet contains meat which is eaten once a day, 2100 cal, 27 g of animal protein, 1 mg of heme iron, and 16 mg of nonheme iron; the latter contains meat eaten once a day, 2200 cal, 22 g of animal protein, 1 mg of heme iron, and 16 mg of nonheme iron. In the fourth category is the Brazilian diet which contains a small amount of meat eaten once a day, 1700 cal, 10 g of animal protein, 1 mg of heme iron, and 15 mg of nonheme iron.

Table 3 shows the hematological characteristics and iron absorption results of the subjects tested for each Latin American diet. Anemia was considered to be present in those men with blood Hb values less than 13 g/100 ml (36) and in those women with values less than 11 g/100 ml and those with values between 11 and 11.9 g/100 ml who also showed a transferrin saturation less than 16%. Subjects with iron deficiency were identified when one of the following variables were identified: *1*) transferrin saturation less than 16%; *2*) serum ferritin concentration below 12 ng/ml; and *3*) absorption of the reference dose of iron ascorbate equal to or more than 40%. According to these criteria, anemia was present in 9% of the subjects tested, iron deficient erythropoiesis in 12% as indicated by the transferrin saturation, iron depletion in 15% by the serum ferritin concentration, and 21% by the absorption of the reference dose (27, 37–39). The total number of iron deficient subjects as determined by one or more of the methods was 27%. Konijn et al (40) found that practically all iron-deficient subjects could be identified from their low values for either transferrin saturation or serum ferritin con-

TABLE 2
Nutritional content of the Latin American diets

Country	Meal	Total food* (energy)	Protein*		Fat*	Carbohydrate*	Ascorbic acid*	Heme iron†	Nonheme iron*
			Animal	Vegetal					
		kcal	*g*	*g*	*g*	*g*	*mg*	*mg*	*mg*
Argentina	Breakfast	280	0.0	5.0	0.5	65.0	0.00	0.00	0.90
	Lunch	1044	26.0	15.4	36.5	137.7	28.75	3.16	9.04
	Snack	208	0.0	6.0	0.6	71.0	0.00	0.00	1.12
	Supper	389	4.1	8.5	11.0	60.0	0.00	0.48	2.83
	Total	2021	30.1	34.9	48.6	333.7	28.75	3.64	13.89
Brazil	Breakfast	279	0.0	2.9	8.8	47.4	0.00	0.00	1.86
	Lunch	730	10.0	15.4	22.4	88.6	2.00	1.10	7.37
	Supper	671	0.0	22.1	24.3	90.1	0.00	0.00	5.98
	Total	1680	10.0	40.4	55.5	226.1	2.00	1.10	15.21
Chile	Breakfast	342	0.0	6.4	4.8	70.0	0.00	0.00	2.60
	Lunch	597	17.8	9.7	11.1	101.4	11.80	1.00	4.67
	Snack	342	0.0	6.4	4.8	70.0	0.00	0.00	2.60
	Supper	808	0.0	25.2	16.5	310.2	25.80	0.00	6.14
	Total	2089	17.8	47.7	37.2	551.6	37.60	1.00	16.01
Mexico	Breakfast	1315	22.1	30.1	66.6	131.0	0.60	0.54	12.16
	Lunch	1250	35.0	34.5	32.0	172.3	6.20	1.22	12.36
	Supper	544	30.1	7.9	11.6	66.0	5.60	1.28	4.77
	Total	3109	87.2	72.5	110.2	369.3	12.40	3.04	29.29
Peru	Breakfast	530	0.0	17.1	16.7	78.4	2.40	0.00	2.34
	Lunch	954	19.6	20.0	16.0	164.7	30.60	0.43	7.68
	Supper	939	19.6	24.2	18.2	159.4	22.60	0.43	8.60
	Total	2423	39.2	61.3	50.9	402.5	55.6	0.86	18.62
Venezuela	Breakfast	582	0.0	17.2	13.0	100.2	0.00	0.00	1.41
	Lunch	717	4.3	15.1	20.7	86.3	29.10	0.00	6.91
	Supper	915	17.2	21.6	22.2	136.2	17.40	1.23	7.16
	Total	2214	30.3	37.8	67.2	322.7	21.20	1.23	15.48

* The nutrient content of the diets were calculated from the table nutrient content used in each country.
† The percentage of heme iron content from animal food was determined by the method of Torrance and Bothwell (33). The percentage of heme iron content was 57% in beef meat, 53% in turkey, 34% in pork, and 24% in fish (Lisa).

centration or both, being below 16% and 16 ng/ml, respectively. Of the subjects tested here 22% were iron deficient according to the latter.

The proportion of iron-deficient subjects was not the same in the different groups. It was high in Peru (63%) and Argentina (41%), moderate in Venezuela (23%), Chile (20%) and Brazil (18%), and practically nonexistent in Yucatan Mexico (only one of 19 subjects).

Iron absorption

Table 3 shows the mean nonheme iron absorption from the meals of each diet. The absorption is, in general, very low between 1 and 4% in most meals; however, since the proportion of iron-deficient subjects vary between the groups of subjects tested, the absorption of each meal was calibrated multiplying the mean absorption observed by the ratio between the composite mean absorption from the reference dose of all individual tested and the mean absorption from the reference dose for a given meal. **Table 4** shows the calibrated nonheme iron absorption from each meal. The results of the iron absorption from breakfast are a clear demonstration of the complexity of factors present in a meal that may affect the absorption of the nonheme iron pool. Four diets contained wheat bread at breakfast, which is practically the only source of nonheme iron; however, their absorption shows that when this bread is accompanied by tea with the meal, such as in Argentina and Chile, the

TABLE 3
The mean nonheme iron absorption from typical Latin American diets

Country	No. of subjects male/female	Age	Hb	Serum iron concentration	Serum transferrin saturation	Serum ferritin concentration	Iron absorption (%)			Iron ascorbate
							Breakfast	Lunch	Supper	
			g/100 ml	μg/100 ml	%	μg/ml				
Salta, Argentina	11M/21F	29 ± 1*	14.5 ± 0.2	128 ± 10	32 ± 2	31 ± 1	1.1 ± 1.3	3.2 ± 1.3	3.5 ± 1.3	18.8 ± 1.2
Sao Paulo, Brazil	8M/20F	34 ± 2	11.7 ± 0.3	111 ± 34	32 ± 2	24 ± 1	2.9 ± 1.2	2.5 ± 1.3	1.2 ± 1.3	17.9 ± 1.2
Santiago, Chile	10M/20F	30 ± 1	14.0 ± 0.2	84 ± 5	28 ± 2	49 ± 1	1.9 ± 1.2	4.0 ± 1.2	1.8 ± 1.2	23.3 ± 1.2
Yucatan, Mexico	4M/16F	31 ± 2	13.5 ± 0.2	122 ± 12	30 ± 3	56 ± 2	0.9 ± 1.3	3.5 ± 1.2	2.7 ± 1.3	16.0 ± 1.2
Lima, Peru	1M/14F	+	13.4 ± 0.3	89 ± 8	25 ± 2	8 ± 1	2.5 ± 1.1	7.1 ± 1.2	11.4 ± 1.3	20.2 ± 1.3
Carabobo, Venezuela	9M/22F	26 ± 2	12.6 ± 0.2	97 ± 2	27 ± 2	27 ± 1	5.4 ± 1.2	3.1 ± 1.2	3.7 ± 1.2	17.3 ± 1.2

* Mean ± SE.
† Not registered.

TABLE 4
Calibration of the nonheme iron absorption from the typical Latin American diets according to the reference dose*

Country	Iron absorption (%)			Reference dose of iron ascorbate
	Breakfast	Lunch	Supper	
Argentina	1.1	3.2	3.5	18.8
Brazil	3.1	2.6	1.3	
Chile	1.5	3.2	1.5	
Mexico	1.1	4.1	3.7	
Peru	2.3	6.6	11.4	
Venezuela	5.9	3.4	4.0	
Variation in absorption (times)	5	3	8	

* The calibration of nonheme iron absorption was made by multiplying the mean observed absorption data by the ration of A/B where A is the composite mean of the reference dose of all individuals and B the mean absorption of the reference dose for the given meal.

absorption is very low, 1.1 and 1.5%, respectively, while in Peru and Brazil where the bread is taken with coffee and milk, respectively, the iron absorption is about twice that observed in Argentina and Chile. These data confirm previous observations made by Disler et al (41, 42). In Venezuela and Mexico wheat bread at breakfast is replaced by maize bread but the cooking preparation is completely different in the two countries. In Venezuela the "arepa" is made from maize flour free of the germ and pericarp of the grain, while the Mexican "tortilla" is prepared by boiling whole maize in water containing quick lime (about 6 g of quick lime per 100 g of maize). In a preliminary study (43) it was observed that in the iron absorption from "arepa" made from maize free of pericarp and germ, the iron absorption was about twice the absorption from Mexican "tortilla."

The variation in iron absorption from the lunches and suppers of the Latin American diets is due in large part to variations in the quantities of animal tissue proteins contained in the meals and the amount of vegetable foods containing iron inhibitors. A significant absorption enhancing effect of tissue animal proteins was observed in eight of the lunch or supper meals as compared with breakfast or the other meals from the same study. It was noticed that 100 g of fish

had a strong enhancing effect on the absorption of nonheme iron from the Peruvian lunch and supper, containing 7 and 8 mg of iron, respectively. The relatively low absorption from Chilean supper can be attributed to the inhibitory effect of eggs.

In some meals the large intake of vegetable foods containing strong inhibitors may moderate or even hinder the iron absorption enhancing effect of meat. This is possibly the case in the Brazilian lunch and Venezuelan supper in which 54 and 80 g of meat, respectively, were not sufficient to enhance the absorption of 6 mg of nonheme iron.

The iron absorption enhancing effect of beef and fish meat on vegetable foods was first demonstrated in 1969 (44); this observation has since been confirmed in many studies (1, 6, 10–13, 45–47). Although a dose of 100 or more g of beef or fish meat enhanced the absorption of about 3 to 4 mg of vegetal iron, the effect of a smaller amount of these tissue proteins may be neutralized by the inhibiting effect of vegetable or other foods (47).

Iron absorption from diet meals in normal and iron-deficient subjects

The percentage of iron absorption from Latin American diets represents for each meal a mean of the absorption by normal subjects and the absorption by subjects with various degrees of iron deficiency. It is expected, therefore, that the mean iron absorption from each meal, by normal subjects, would be about 20 to 60% less than that calculated from the combined results of normal and iron-deficient subjects. **Table 5** shows the mean iron absorption from normal and iron-deficient subjects tested with each diet. It may be noted that the nonheme iron absorption by iron deficients is from 2- to 5-fold higher than that observed in normal subjects. As only one iron-deficient subjects was tested with the Mexican diet, the mean iron absorption was calculated for normal subjects only. Since heme iron absorption is not affected by vegetable foods (2, 45), the absorption of this iron compound was determined according to previous observations in which the iron absorption from veal muscle containing 95% of heme iron and from a reference dose of iron ascorbate was tested in 58 subjects in the first study (45) and in all subjects in the second (2). The mean ratio between these two variables was 0.89. The correlation coefficient assuming a normal distribution of these variables was 0.61, highly statistically significant at the level of $p < 0.001$ and the correlation coefficient calculated by the nonparametric regression shows a Spearman correlation of 0.56 which is highly statistically significant at the level of $p < 0.00001$. Accordingly the iron absorption from iron was calculated from the equation $Y - 14.30 + 0.31 \times X$, where Y is the heme iron absorption and X is the reference dose absorption. The equation is more exact than the ratio mentioned before because it reproduces more accurately the relationship between these absorption variables, being the absorption of heme iron equal or moderately higher than the absorption of the reference dose in normal subjects while it is the other way in iron-deficient subjects.

Purified ferritin and hemosiderin given alone have very low iron absorption, which increases several fold when these compounds are integrated into liver or muscle. The absorption is reduced by about one-half when these animal foods are administered with vegetable foods (48, 49). Strictly speaking specific experiments should be performed in order from different meats. However, since ferritin and hemosiderin iron belong to the nonheme pool, we judge that the iron absorption from this source would be very similar to that of vegetal iron, which is of course also nonheme. On this basis, values of absorption of vegetal iron from each meal will be used to estimate the absorption from ferritin and hemosiderin present in the meat of the same meal. Similar estimates will be made for the iron present in this form in eggs and milk.

The results shown in Table 5 indicate that the heme and nonheme iron absorption of iron-deficient subjects were increased from two to five times compared to normal subjects and the absorption of heme iron in normal and iron-deficient subjects were also from two to five times higher than that observed from nonheme iron.

TABLE 5
The mean of heme and nonheme iron absorption from Latin American diets consumed by normal and iron-deficient subjects

Country	Type of iron compound	Iron absorption (%)									
		Normal					Iron deficient				
		No subjects	Breakfast	Lunch	Supper	Reference dose	No subjects	Breakfast	Lunch	Supper	Reference dose
Argentina	Nonheme	20	0.6	1.6	1.8	10.7	12	2.9	8.0	11.0	48.0
	Heme			17.6	17.6				29.1	29.1	
Brazil	Nonheme	23	2.6	2.2	1.1	14.2	5	4.8	4.1	4.7	51.6
	Heme*			18.7					30.3		
Chile	Nonheme	23	1.3	2.7	1.3	16.9	7	6.4	14.1	4.9	66.7
	Heme			11.5					34.9		
Mexico	Nonheme	11	0.9	3.5	2.6	15.0					
	Heme		18.6	18.6	18.6						
Peru	Nonheme	5	0.9	5.7	6.5	7.9	10	4.4	7.9	15.2	32.4
	Heme			16.7	16.7				24.3	24.3	
Venezuela	Nonheme	22	3.9	2.2	3.3	12.8	9	11.8	7.0	4.8	36.3
	Heme				18.3					25.5	

Iron availability from the diet in normal and iron-deficient subjects

Figure 1 shows the mean iron availability from the Latin American diets tested in both normal and iron-deficient subjects. It may be seen that in general, the low heme iron content in these diets accounts for 6 to 7% of the total iron in the normal cases of Brazil, Chile, and Venezuela and this form of iron represents about 23 to 34% of the total iron available. The total iron utilization by normal subjects from Argentina, Brazil, Chile, and Venezuela, does not meet the physiological iron requirements for men (0.8 to 1.0 mg) (50), and even less for women during their reproductive age in which 50% require about 1.4 mg of iron, for 90% the requirement is about 2.2 mg, because of their excessive menstrual blood loss (51). The iron availability of these diets, increases more than twice when subjects become iron deficient.which would allow an improvement in their iron balance and prevent the development of iron deficiency anemia in most subjects. The bioavailable nutrient density of iron was calculated in each diet (**Table 6**). It was observed that the diets from Brazil,

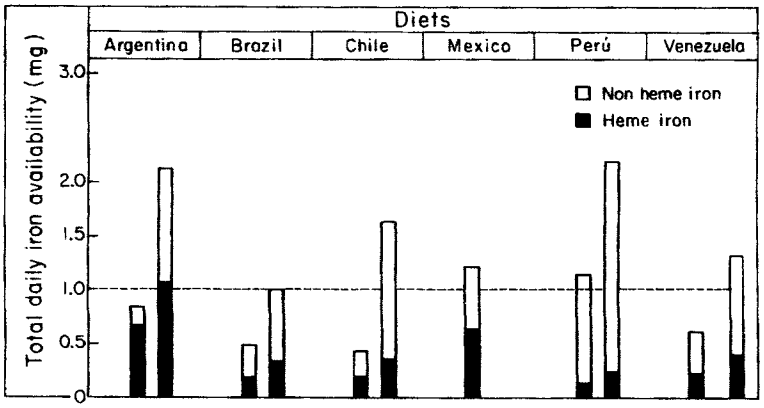

FIG 1. Total daily iron availability from Latin American diets. *First column*, normal subjects; *second column*, iron-deficient subjects.

TABLE 6
Bioavailable nutrient density of iron from Latin American diets

Country	Total food energy	Total iron absorption (mg) calculated from absorption		Bioavailable nutrient density	
		A of 40% of the reference dose	B iron-deficient subjects	A	B
	kcal			*mg/1000 kcal*	
Argentina	2021	2.19	2.63	1.08	2.30
Brazil	1680	0.88	1.14	0.52	0.68
Chile	2089	1.13	1.89	0.54	0.90
Mexico	3109	2.82		0.91	
Peru	2423	2.74	2.25	1.13	0.91
Venezuela	2214	1.52	1.38	0.68	0.62
Total				0.81	0.87

Chile, and Venezuela absorb less than 1 mg of iron per 1000 cal calculated either from the absorption of iron-deficient subjects tested for each diet or by the method of Halberg (39) in which the absorption of nonheme and heme iron from each meal is extrapolated to that expected if the subjects absorb 40% of the reference dose of iron ascorbate.

It is expected, therefore, that a certain proportion of the population that consumes the deficient diets in terms of iron absorption mentioned before, should develop various degrees of iron deficiency and iron-deficiency anemia, especially women whose excessive menstrual blood loss demands a higher efficiency of iron absorption from their diets in order to balance their iron loss. Unfortunately, we only have information from the population that consumes the Carabobo diet tested here. This diet shows that 8% of the women had anemia and 32% of the women and 10% of men had iron deficiency as indicated by their levels of serum ferritin (52).

The diets studied here are restricted to a given area of a country and are not representative of foods that are consumed by the total population belonging to the same socioeconomic level. It will be necessary, therefore, to carry out additional iron absorption studies from diets consumed in other areas in order to obtain sufficient information to assess the possible prevalence of nutritional iron deficiency in the country and guide the effort to establish iron fortification programs to prevent such deficiency.

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