Iron, zinc, copper and magnesium deficiencies in Mexican adults from the National Health and Nutrition Survey 2006

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Mejía-Rodríguez F, Shamah-Levy T, Villalpando S, García-Guerra A, Méndez-Gómez Humarán I. Iron, zinc, copper and magnesium deficiencies in Mexican adults from the National Health and Nutrition Survey 2006. Salud Publica Mex 2013;55:275-284.

Abstract
Objective. To describe the prevalence of serum iron and zinc deficiencies and low serum concentrations (LSC) of copper and magnesium in Mexican adults. **Materials and methods**. Blood samples from subjects (≥20 years, both genders) participating in the 2006 National Health and Nutrition Survey were used to measure the serum concentrations of s-ferritin, soluble-transferrin-receptor (s-TfR), zinc, copper, and magnesium. **Results**. The prevalence of s-ferritin≤12ug/L was 18.1 and 3.6% while s-TfR>6mg/L was 9.5 and 4.4%, for females and males, respectively. The prevalence of zinc deficiency was 33.8% females and 42.6% males; LSC of copper were 16.8 and 18.2%, and 36.3 and 31.0% for magnesium, for females and males, respectively. **Conclusions**. The prevalence of deficiencies in iron (in females), and zinc are still high in the adult population. LSC of copper and magnesium are published for the first time and show significant prevalence of deficiencies. Corrective actions are necessary in order to diminish these nutritional deficits in the Mexican population.

Key words: Minerals; iron; zinc; copper; magnesium; Mexico

Mejía-Rodríguez F, Shamah-Levy T, Villalpando S, García-Guerra A, Méndez-Gómez Humarán I. Deficiencias de hierro, zinc, cobre y magnesio en adultos mexicanos. Encuesta Nacional de Salud y Nutrición 2006. Salud Publica Mex 2013;55:275-284.

Resumen
Objetivo. Describir la prevalencia de deficiencias de hierro y zinc y valores bajos (VB) de cobre y magnesio en adultos mexicanos. **Material y métodos**. Se utilizaron muestras de sangre de individuos (≥20 años, ambos sexos) de la Encuesta Nacional de Salud y Nutrición 2006 para medir concentraciones séricas de s-ferritina, receptor soluble de transferrina (s-TfR), zinc, cobre y magnesio. **Resultados**. La prevalencia de s-ferritina≤12ug/L fue de 18.1 y 3.6%, s-TfR>6mg/L de 9.5 y 4.4% para mujeres y hombres, respectivamente. Para zinc fue de 33.8% mujeres y 42.6% hombres. Para VB de cobre fue 16.8 y 18.2%; y magnesio 36.3 y 31.0% en mujeres y hombres, respectivamente. **Conclusiones**. Las prevalencias de deficiencia de hierro (mujeres) y zinc aún son altas en la población adulta. VB de cobre y magnesio se publican por primera vez en una muestra representativa de adultos y muestran prevalencias importantes. Son necesarias medidas correctivas para combatir estos problemas en la población mexicana.

Palabras clave: minerales; hierro; zinc; cobre; magnesio; México

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Received on: May 17, 2012 • **Accepted on:** February 1, 2013
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Deficiency of micronutrients such as iron, iodine, and vitamin A, are globally the most frequent. Some reports estimate that more than two thousand million persons suffer from these nutritional deficiencies worldwide.[1,2,3]

Iron deficiency during pregnancy is linked to increased maternal morbidity and mortality.[4] Women of childbearing age from middle- and low-income countries are prone to iron deficiency anemia.[5] Low serum concentrations (LSC) of copper are linked to a decreased activity of some metalloenzymes[6] reducing iron ions to facilitate its absorption and transport.[7] It has also been associated with a decreased immune response,[8] osteoporosis, hypercholesterolemia, and glucose intolerance.[9-11] In adult males, a zinc to copper ratio >1 is associated with decreased immune response and higher mortality in HIV positive individuals.[12] LSC of magnesium is less common, but it produces hypokalemia; a condition affecting the electrolyte equilibrium of the body.[13-15] In developing countries, micronutrient deficiencies frequently coexist with inflammation and infection, impeding the interpretation of iron and zinc deficiencies. C-reactive protein or alpha 1-acid glycoprotein should be measured simultaneously to avoid confounding effects of inflammation.[16,17]

In Mexico, information about mineral deficiencies in adults from probabilistic surveys is limited to the prevalence of iron and zinc deficiencies in women of childbearing age, reported in the 1999 Mexican National Nutrition Survey (ENN 99)[18] which found a prevalence of iron and zinc deficiencies, of 40 and 30% respectively.[19] Reports from other countries found a LSC of copper of 17 and 8.6% in Iranian females and males,[11] respectively, and 5.9% in Chilean females.[20]

Information on the national prevalence of these deficiencies is required in order to consider redesign of ongoing or new interventions to accelerate the reduction of micronutrient deficiencies. The aim of this study is to describe the magnitude and distribution of iron and zinc deficiencies, and LSC of copper and magnesium and the inflammation status using protein C reactive (PCR) in Mexican adults.

Materials and methods

Population and methods

Data for the present analysis were from a sample of 30% of male and female adults who were older than 20 years, participating in the 2006 Mexican National Health and Nutrition Survey (ENSANUT 2006); with available measurements of the serum concentrations of s-ferritin, soluble transferrin receptor (s-TfR), zinc, copper, magnesium and C reactive protein (PCR). The power of the subsample allowed for distinctions at the national and regional level. Pregnant women and those with no biochemical determinations were excluded from the analysis. The final number of subjects was 3 421 female and 1 989 males.

Survey design

ENSANUT 2006 is a Mexican nationwide survey representative of both rural and urban areas from four regions of the country. The study used a stratified cluster sample design.[21]

Blood sample collection, preparation and storage

Fasting blood samples were drawn from an antecubital vein and centrifuged; serum was separated, stored in cryovials kept in liquid nitrogen, and transported to the nutrition laboratory at INSP in Cuernavaca, Mexico.[22]

Methods for determination of micronutrients

S-Ferritin, soluble transferrin receptor, and C-reactive protein

Iron levels were approximated using measures of s-ferritin and soluble transferrin receptor (s-TfR). The deficiency of body iron stores was defined as s-ferritin ≤12ug/L and tissue iron deficiency as by s-TfR concentrations >6mg/L.[23] Serum concentrations of C-reactive protein (PCR) were measured by nephelometry using an ultrasensitive, monoclonal antibody and the manufacturer protocol was followed.

Determinations of serum iron, zinc, copper, and magnesium concentrations

Measurements of serum iron, zinc, copper, and magnesium concentrations were measured using an inductively coupled plasma optical emission spectrometer, following the procedure described by Tietz *et al*.[24] Zinc deficiency was defined as serum zinc <70ug/dL in females and < 74ug/dL in males,[25] LSC of serum copper <70ug/dL in men and <80ug/dL in women,[26] and LSC of serum magnesium <1.823mg/dL (<0.75 mmol/L).[26] The controls for measurements are expressed as follows: mean±SD (coefficient of variation=%). S-ferritin 74.6±3.67µg/L, (c.v.=4.4%); s-TfR 2.32±0.13mg/L, (c.v.=5.6%); PCR 1.2±0.05mg/dL, (c.v.=2.2%); zinc 76.1±1.3ug/dL, (c.v=11.5%); copper 99.3±27.7ug/

dL, (c.v.=5.6%) and magnesium 1564±27.2mg/dL (c.v.=11.7%).

Anemia

Anemia was defined as hemoglobin concentration <120 g/L in non-pregnant women and <130 g/L in men[23], adjusting for altitude above sea level, as by Cohen and Haas.[27] Iron deficiency anemia (IDA) was defined when an abnormal Hb value coexisted with at least one iron status indicator below the cut-off values, s-ferritin ≤ 12 ug/L or s-TfR >6 mg/L.[28] Both venous and capillary blood was obtained from each subject.

Dietary intake of micronutrients

Dietary intakes data collection have been described in detail elsewhere.[29] Inadequate intake was defined when it was below the cutoff of Estimated Average Requirement (EAR). For iron intake was <16 mg/day and copper <0.7mg/day; zinc <11mg/day (females) and <12mg/day (males) and magnesium <280mg/day (females) and <215mg/day (males).[30] We did not consider bioavailability in the assessment of mineral intake.

Definition of variables

Demographic and socioeconomic information was collected using *ad hoc* questionnaires.[18] Selected variables including age, sex, body mass index (BMI),[31] indigenous status (any member spoke an indigenous language), socioeconomic status (SES, index was constructed using a principal components analysis),[32] area and region of residence, and affiliation to food assistance programs such as *Oportunidades* and the milk distribution program *Liconsa*.

Statistical analysis

Distribution of variables was described using means, medians, frequencies or proportions stratified by sex. Prevalence of mineral deficiencies or LSC and 95% confidence intervals were calculated.[33] Multiple logistic regression models were constructed to test whether prevalence of iron deficiency anemia, IDA or prevalence of zinc deficiency changed with inflammation (PCR>6 mg/L), adjusting for age group, sex and interaction sex-age group. Other logistic regression models were constructed to estimate predictors of the prevalence of the following micronutrient deficiencies or LSCs (in females): iron, zinc, copper and magnesium, adjusting for affiliation to food assistance programs, age, SES, micronutrient dietary intake, enhancers and inhibitors of mineral bioavailability, and excluding cases with PCR concentration >6 mg/L.

All analyses were adjusted for the study design, considering the Primary Sample Unit (PSU), the strata defined for the survey, and their corresponding calibrated weights. Analyses were done using Stata Versión 12 (StataCorp. 2011 Stata Statistical Software: Release 12. College Station, Tx: Stata Corp LP).

Ethical aspects

The study protocol was approved by the Ethics, Biosecurity, and Research Boards of the National Institute of Public Health (INSP), Cuernavaca, Mexico. Anthropometric measurements and blood samples were obtained after participants had signed an informed consent letter.

Results

This analysis included 3 421 non-pregnant females and 1 989 males who represented about 59 million people older than 20 years. About 70% of the sample (sexes combined) was overweight or obese. Females (44.8%) and males (37.6%) had 6 years and (15.8 and 28.3%) had more than 12 years of schooling. Only 8.8% of females and 6% of males (6%) spoke an indigenous language, while 26.2 and 20.6% lived in rural areas (table I).

In table II are shown the medians and interquartile ranges (p25, p75) for serum concentrations of s-ferritin, s-TfR, iron, zinc, copper, and magnesium.

Iron nutritional status

The prevalence of iron deficiency (table III) based on s-ferritin was lower in males (2-7%) than in females in all age groups. It was higher in females aged 20 to 50 years (19.3-26.9%) and decreased to a half in older than 50 years (8.0-9.4%). The prevalence was 2-fold higher in the South region (21.6%) compared with Mexico City (12.1%), (table III). The prevalence of tissue iron deficiency as determined by high concentrations of s-TfR was higher in female aged 20-49 years (9.6-13.5%) than in those older than 50 years (4.8-5.1%). It was higher in the Center region (11.4%) compared with Mexico City (9.6%), (table III). The prevalence of tissue iron deficiency were similar in males by age group and by urban or rural area of residence, although it was higher in Mexico City (12.2%) compared with other regions (1.3-2.8%). No differences were found when controlling for PCR.

The total prevalence of anemia by Hb values was 13.6% in females and 6% in males. No differences were

Table I
Characteristics of the population. Mexico, ENSANUT 2006

Characteristics	Females: Estimated N (thousands)	Females: mean	Females: (95% CI)	Males: Estimated N (thousands)	Males: mean	Males: (95% CI)
Weight (kg)	34 151.8	66.1	(65.1-66.8)	23 573.2	75.3	(74.0-76.7)
Height (cm)	33 763.5	151.9	(151.5-152.4)	23 470.8	165.9	(165.1-166.7)
PCR (mg/L)	33 976.4	4.8	(4.5-5.1)	23 415.2	3.4	(3.0-3.8)
Vitamin C (dietary, mg)	33 496.5	102.1	(96.3-108.1)	23 261.5	100.3	(92.2-108.4)

	Females: n	Females Expanded: Estimated N (thousands)	Females Expanded: (%)	Males: n	Males Expanded: Estimated N (thousands)	Males Expanded: (%)
Age (years)						
20 to 29	722	7 934.7	23.2	398	5 296.7	22.5
30 to 39	1 062	8 911.0	26.1	472	5 430.4	23.0
40 to 49	737	7 394.8	21.7	401	4 465.8	18.9
50 to 64	538	5 741.1	16.8	430	5 115.7	21.7
>65	362	4 170.2	12.2	288	3 264.6	13.9
PCR						
<6 mg/L	2 511	25 671.4	75.6	1 691	20 307.3	86.8
≥6 mg/L	889	8 309.4	24.4	285	3 095.0	13.2
BMI (kg/m^2)						
<18.5	36	457.1	1.4	29	251.1	1.1
18.5-24.9	857	8 587.7	25.5	619	7 664.3	32.8
25-29.9	1 240	12 922.4	38.3	854	10 276.7	44.0
>30	1 251	11 737.7	34.8	472	5 178.0	22.2
Socioeconomic status						
Low	1 469	12 228.7	35.6	857	7 677.2	32.6
Middle	1 231	11 714.3	34.5	631	7 226.5	30.7
High	709	10 063.6	29.6	497	8 633.3	36.7
Schooling (years)						
None	431	4 936.6	14.5	224	2 164.5	9.2
6	1 668	15 258.7	44.8	866	8 827.6	37.6
9	898	8 528.6	25.0	455	5 811.6	24.8
12	263	3 018.3	8.9	235	2 845.8	12.1
> 16	154	2 333.4	6.9	201	3 802.0	16.2
Literacy						
Literate	2 958	29 280.2	86.0	1 773	21 490.5	91.5
Illiterate	458	4 770.6	14.0	214	2 005.9	8.5
Indigenous status						
Indigenous	378	2 987.7	8.8	185	1 423.2	6.0
Non-indigenous	3 041	31 148.5	91.3	1 803	22 148.7	94.0
Area						
Urban	2 276	25 198.6	73.8	1 390	18 718.0	79.4
Rural	1 145	8 953.2	26.2	599	4 855.3	20.6
Region						
North	576	5 630.8	16.4	409	4 300.2	18.2
Center	1 430	10 500.4	30.7	670	5 824.3	24.7
Mexico City	126	5 841.2	17.1	91	4 727.2	20.1
South	1 289	12 179.3	35.7	819	8 721.6	37.0
Food assistance program						
Oportunidades	1 390	9 803.7	28.7	61	278.4	1.2
Liconsa	184	3 048.3	9.0	95	1 947.9	8.3

Table II
Median and interquartile range of s-ferritin, (s-TfR), iron, zinc, copper and magnesium. Mexico, ENSANUT 2006

	s-ferritin (ug/L) Median (p 25, p 75)	*s-TfR (mg/L) Median (p 25, p 75)*	*Serum iron (ug/dL) Median (p 25, p 75)*	*Zinc (ug/dL) Median (p 25, p 75)*	*Copper (ug/dL) Median (p 25, p 75)*	*Magnesium (mg/dL) Median (p 25, p 75)*
Females						
Age (years)						
20 to 29	27.4 (10.5-49.7)	3.7 (2.7-4.7)	93.1 (68.1-133.8)	89.1 (73.3-111.8)	90.4 (80.9-110.0)	1.8 (1.7-2.1)
30 to 39	30.5 (14.5-60.7)	3.5 (2.7-4.5)	90.9 (66.0-132.0)	89.4 (66.0-115.5)	94.4 (81.5-114.8)	1.9 (1.7-2.1)
40 to 49	37.8 (15.7-85.7)	3.4 (2.7-4.6)	90.3 (69.5-116.7)	85.5 (61.2-114.3)	100.9 (89.4-121.2)	1.9 (1.8-2.2)
50 to 64	82.7 (43.9-130.8)	3.3 (2.8-4.2)	82.6 (65.4-118.2)	77.1 (56.7-112.3)	101.3 (90.4-123.8)	2.0 (1.8-2.2)
>65	72.8 (34.4-140.0)	3.5 (2.9-4.3)	91.3 (66.3-115.2)	66.7 (53.3-106.0)	103.6 (84.4-120.3)	2.1 (1.8-2.2)
Area						
Urban	41.0 (17.8-87.9)	3.5 (2.7-4.4)	89.6 (67.3-122.1)	82.5 (61.1-113.4)	99.4 (84.4-116.9)	1.9 (1.7-2.2)
Rural	41.1 (18.1-80.6)	3.5 (2.7-4.6)	92.6 (62.9-120.6)	85.6 (68.5-108.6)	101.6 (83.8-121.2)	2.0 (1.8-2.2)
Region						
North	51.9 (22.4-101.4)	3.3 (2.5-4.4)	92.4 (75.6-113.1)	90.0 (62.6-125.3)	97.0 (81.8-115.2)	1.8 (1.7-2.0)
Center	39.3 (16.4-77.3)	3.5 (2.8-4.7)	91.0 (66.1-122.4)	82.4 (65.2-104.0)	102.6 (85.0-123.6)	1.9 (1.8-2.2)
Mexico City	52.3 (22.7-93.4)	3.9 (3.1-4.6)	75.5 (56.9-112.5)	78.4 (57.8-109.5)	95.2 (83.3-108.0)	1.9 (1.7-2.1)
South	34.0 (14.4-79.0)	3.3 (2.6-4.2)	104.8 (78.8-140.0)	86.6 (64.9-137.5)	107.4 (93.9-128.2)	2.2 (2.0-2.3)
National	41.1 (17.9-86.5)	3.5 (2.7-4.5)	90.2 (66.8-121.7)	82.7 (62.5-112.3)	99.6 (83.9-117.1)	1.9 (1.7-2.2)
Males						
Age (years)						
20 to 29	106.1 (59.1-166.7)	3.1 (2.7-3.9)	93.0 (70.3-116.6)	89.0 (62.2-110.1)	79.8 (68.0-100.0)	1.9 (1.8-2.1)
30 to 39	119.5 (72.7-178.7)	3.2 (2.7-4.0)	101.1 (77.6-130.9)	99.6 (68.3-163.0)	85.2 (77.9-99.0)	1.9 (1.7-2.1)
40 to 49	118.6 (69.2-204.1)	3.2 (2.6-4.2)	108.8 (82.3-142.5)	83.9 (62.9-111.1)	83.4 (71.7-100.1)	2.0 (1.8-2.2)
50 to 64	141.8 (83.7-210.3)	3.0 (2.6-3.8)	97.7 (70.7-133.6)	72.3 (58.4-95.5)	90.3 (76.5-106.3)	2.1 (1.8-2.3)
>65	104.4 (57.9-194.1)	3.4 (2.7-4.2)	95.2 (67.9-135.1)	84.3 (60.7-111.1)	91.5 (78.3-109.5)	2.0 (1.7-2.2)
Area						
Urban	123.4 (73.8-196.7)	3.2 (2.7-4.1)	99.4 (71.3-126.8)	85.0 (63.1-115.5)	84.3 (74.4-102.8)	1.9 (1.7-2.2)
Rural	98.1 (60.3-168.1)	3.1 (2.6-3.7)	108.5 (85.0-142.9)	82.5 (61.2-114.2)	91.5 (77.2-117.4)	2.1 (1.9-2.4)
Region						
North	137.9 (84.4-202.6)	3.1 (2.5-3.9)	98.2 (78.9-118.1)	87.3 (65.3-139.3)	82.2 (71.0-97.4)	1.9 (1.7-2.2)
Center	127.6 (70.3-192.1)	3.0 (2.6-3.6)	103.1 (78.6-142.5)	79.5 (60.7-117.8)	92.6 (78.2-117.0)	2.1 (1.9-2.4)
Mexico City	136.4 (87.1-207.7)	3.6 (3.1-5.2)	78.0 (63.9-108.7)	73.8 (60.6-111.1)	80.4 (74.4-91.6)	1.9 (1.7-2.0)
South	96.6 (57.1-161.9)	3.1 (2.6-3.9)	134.7 (99.4-159.1)	90.6 (71.3-115.3)	99.0 (81.8-116.9)	2.2 (2.1-2.4)
National	118.2 (69.2-189.4)	3.2 (2.7-4.0)	99.8 (72.1-128.3)	85.0 (62.3-115.3)	85.2 (74.5-103.8)	2.0 (1.8-2.2)

found when controlling for PCR in both males and females, although the prevalence was 12.8% without inflammation and 13.8% with inflammation in females; in males was 8.2% without inflammation and 5.7% with inflammation (data not shown).

The total prevalence of IDA was 28.5% in females and 10% in males. No differences were found when controlling for PCR in both males and females. IDA after adjusting by PCR, the prevalence was 26.8% without inflammation and 29.2% with inflammation in females; in males was 8.3% without inflammation and 10.4% with inflammation. The prevalence of IDA remained constant in female of all age groups. As for males, the prevalence was 1.5% at 20 to 29, 7.2% at 30 to 39, 8.5% at 40 to 49, 10.6% at 50 to 64.9 years of age, and 19.9% in older than 65 years of age (data not shown). Daily dietary intake of iron was approximately 9 mg/day for females and 10 mg/day for males. Prevalence inadequate intake of

Table III

Prevalence of iron deficiency as assessed by serum-ferritin* and TfR)‡ and deficiencies of zinc,§ copper,# and magnesium&. Mexico, ENSANUT 2006

	s-ferritin				s-TfR				Zinc				Copper				Magnesium			
		Expanded				Expanded				Expanded				Expanded				Expanded		
	n	N (Millions)	%	(95%CI)	n	N (Millions)	%	(95%CI)	n	N (Millions)	%	(95%CI)	n	N (Millions)	%	(95%CI)	n	N (Millions)	%	(95%CI)
Females																				
Age (years)																				
20 to 29	711	7.9	26.9	(21.5-32.4)	710	7.8	9.6	(6.1-13.0)	373	4.3	19.3	(12.5-26.1)	220	3.2	20.9	(10.3-31.4)	220	3.2	40.2	(29.0-51.3)
30 to 39	1 061	8.9	19.8	(15.7-23.9)	1 057	8.8	11.1	(8.1-14.1)	601	5.2	30.6	(23.6-37.7)	325	3.5	23.4	(12.4-34.3)	325	3.5	36.0	(24.8-47.1)
40 to 49	738	7.4	19.3	(15.4-23.2)	735	7.4	13.5	(10.0-17.0)	440	4.4	33.1	(25.2-41.1)	285	3.6	15.2	(7.1-23.3)	285	3.6	39.7	(30.4-49.0)
50 to 64	530	5.7	8.0	(4.7-11.4)	529	5.7	4.8	(1.2-8.4)	298	3.6	42.3	(32.8-51.7)	301	3.6	8.4	(3.6-13.2)	301	3.6	34.0	(24.2-43.7)
>65	359	4.1	9.4	(4.0-14.8)	359	4.2	5.1	(0.7-9.6)	220	2.9	51.7	(40.4-63.0)	221	2.9	16.8	(8.8-24.8)	221	2.9	31.2	(19.7-42.8)
Area																				
Urban	2 262	25.1	18.1	(15.6-20.6)	2 261	25.1	8.8	(6.9-10.6)	1 217	15.4	36.1	(30.5-41.7)	1 021	14.2	17.6	(13.3-21.8)	1 021	14.2	38.4	(32.8-44.0)
Rural	1 137	8.9	18.0	(14.1-21.9)	1 129	8.8	11.5	(8.0-15.0)	715	5.0	26.9	(19.5-34.2)	331	2.5	12.4	(5.6-19.2)	331	2.5	24.3	(15.3-33.3)
Region																				
North	566	5.6	16.0	(11.8-20.1)	567	5.6	9.4	(5.8-12.9)	405	4.1	30.9	(24.2-37.6)	405	4.1	24.3	(17.2-31.4)	405	4.1	47.4	(38.9-55.8)
Center	1 427	10.5	18.6	(14.4-22.7)	1 422	10.4	11.4	(8.6-14.2)	1 045	7.3	30.5	(24.1-36.9)	538	3.8	9.7	(5.4-14.0)	538	3.8	32.6	(23.9-41.4)
Mexico City	125	5.8	12.1	(6.5-17.7)	125	5.8	9.6	(4.2-14.9)	121	5.6	41.3	(28.4-54.2)	117	5.6	18.6	(10.2-27.1)	117	5.6	46.2	(35.2-57.3)
South	1 281	12.1	21.6	(18.6-24.5)	1 276	12.0	7.8	(5.5-10.2)	361	3.4	32.0	(23.9-40.2)	292	3.2	12.3	(4.8-19.8)	292	3.2	9.5	(5.9-13.1)
National	3 399	34.0	18.1	(16.0-20.2)	3 390	33.9	9.5	(7.8-11.1)	1 932	20.4	33.8	(29.2-38.5)	1 352	16.7	16.8	(13.0-20.6)	1 352	16.7	36.3	(31.3-41.3)
Males																				
Age (years)																				
20 to 29	397	5.3	3.7	(-0.1-7.5)	397	5.3	6.1	(1.1-11.1)	172	2.9	42.4	(28.5-56.3)	172	2.9	33.9	(19.9-47.9)	172	2.9	33.7	(21.3-46.0)
30 to 39	469	5.4	2.0	(0.6-3.4)	463	5.4	4.0	(1.0-6.9)	194	2.5	31.8	(19.1-44.5)	194	2.5	14.0	(5.9-22.1)	194	2.5	39.7	(20.7-58.7)
40 to 49	398	4.4	2.8	(0.6-5.1)	397	4.4	4.8	(1.4-8.2)	197	2.5	45.0	(32.5-57.5)	198	2.5	21.1	(11.1-31.0)	198	2.5	23.9	(15.0-32.8)
50 to 64	429	5.1	3.5	(1.2-5.8)	427	5.1	2.8	(0.3-5.2)	215	2.8	52.2	(41.9-62.5)	215	2.8	10.3	(4.4-16.3)	215	2.8	27.2	(18.0-36.3)
>65	286	3.2	7.0	(2.5-11.5)	283	3.2	4.0	(0.4-7.7)	146	2.0	39.9	(25.0-54.7)	146	2.0	7.7	(1.6-13.8)	146	2.0	30.4	(14.2-46.6)
Area																				
Urban	1 381	18.6	3.9	(2.3-5.5)	1 371	8.8	4.9	(2.9-6.9)	697	11.0	42.7	(35.8-49.5)	698	11.0	19.1	(13.5-24.6)	698	11.0	32.8	(24.5-41.0)
Rural	598	4.9	2.2	(1.0-3.3)	596	4.8	2.1	(0.9-3.3)	227	1.7	42.4	(24.5-60.4)	227	1.7	12.5	(5.4-19.5)	227	1.7	19.0	(11.9-26.0)
Region																				
North	404	4.2	2.5	(0.8-4.2)	402	4.2	1.3	(0.3-2.4)	298	3.0	40.4	(32.5-48.4)	299	3.0	24.2	(16.6-31.9)	299	3.0	39.3	(30.0-48.5)
Center	667	5.8	2.1	(0.7-3.5)	663	5.8	2.5	(1.2-3.9)	343	2.8	42.7	(29.2-56.3)	343	2.8	15.2	(6.2-24.2)	343	2.8	20.8	(13.6-28.0)
Mexico City	90	4.7	4.7	(-0.1-9.5)	90	4.7	12.2	(5.1-19.4)	87	4.6	51.1	(37.0-65.1)	87	4.6	20.5	(9.6-31.4)	87	4.6	45.0	(28.6-61.5)
South	818	8.7	4.4	(2.4-6.5)	812	8.7	2.8	(1.3-4.2)	196	2.4	29.0	(20.7-37.4)	196	2.4	9.5	(3.6-15.4)	196	2.4	5.1	(1.0-9.2)
National	1 979	23.4	3.6	(2.2-4.9)	1 967	23.3	4.4	(2.7-6.0)	924	12.7	42.6	(36.2-49.0)	925	12.7	18.2	(13.3-23.0)	925	12.7	31.0	(23.7-38.3)

* s-Ferritin deficiency <12 ug/L
‡ Soluble transferrin receptor (s-TfR) deficiency >6 mg/L
§ Zinc deficiency <65 ug/dL
\# Copper deficiency <70 ug/dL in men and <80ug/dL in women
& Magnesium deficiency<1.823 mg/dL

iron below the EAR was 88.2% for females and 76.6% for males (data not shown).

In a multiple logistic regression model, high socioeconomic status (OR=0.64, 95%CI: 0.42-0.97; $p<0.05$), older age (OR = 0.97, 95%CI: 0.96-0.99; $p< 0.001$), meat intake (OR=0.0997, 95CI%: 0.995-0.999; $p<0.05$) and the food assistance program *Oportunidades* (OR=0.73; 95CI%: 0.53-1.02; $p=0.063$) had a protective effect for the risk of iron deficiency by s-ferritin; no association was found with dietary iron, zinc, PCR, vitamin C, or phytates (data not shown).

Zinc nutritional status

The prevalence of zinc deficiency was higher in females >65 (51.7%) relative to the age group 20-29 years (19.3%). The prevalence was higher in urban females (36.1%) compared with their rural counterparts (26.9%), and in those living in Mexico City (41.3%) compared with the ones who lived in the Center region (30.5%), (table III). In males, the prevalence of zinc deficiency varied inconsistently by age group (31.8 to 52.2%). The prevalence was similar in rural (42.2%) and in urban (42.7%) males. The highest prevalence was seen in the Mexico City region (S1.1) and the lowest in the South region (29.0%), (table III). The prevalence of zinc deficiency did not change with PCR concentrations ($p=0.551$).

The median of the daily intake of zinc was below the EAR and the prevalence of inadequate consumption was 90.3% for females and 83.5% for males (data not shown). In a multiple logistic regression model age (OR= 1.03, 95%CI 1.01-1.04; $p<0.001$), males (OR= 1.43, 95%CI 0.99-2.07; $p=0.059$), and dietary fiber (OR= 1.03, 95%CI 0.999-1.000; $p=0.053$) increased the risk for zinc deficiency. No association was found with PCR concentrations, dietary iron, zinc, vitamin C, phytates, or affiliation with *Oportunidades* or *Liconsa* food assistance programs (data not shown).

Copper and magnesium nutritional status

The prevalence of LSC of copper were lower in females (8.4-23.4%) compared with males (7.7-33.9%); the prevalence for magnesium was higher in females (31.2-40.2%) than in males (23.9-39.7%). The prevalence of LSC of these two minerals was higher in urban compared with rural areas in both males and females. The highest prevalence was seen in the North and Mexico City regions and the lowest in the South region (table III).

In a multiple logistic regression model with LSC of magnesium as dependent variable there were no significant predictors. In contrast, in the model having LSC of copper as dependent variable, only copper intake was protective (OR=0.15, 95%CI 0.03-0.80, $p=0.03$), data not shown. The median of copper dietary intake was 0.9-0.97 mg/day in both genders. The median of magnesium intake in female was 91-106 mg/day and in male 109-128 mg/day (table IV). Prevalence for daily intake of copper below the EAR was 28.6% for female and 15.9% for males. For magnesium the prevalence was 64.2% for female and 25.2% for males (data not shown).

Discussion

The present study demonstrates that younger women have a higher prevalence of iron deficiency than older women and adults, as indicated by low s-ferritin and by high serum s-TfR concentrations. This finding suggests that iron requirements are not met by young women, likely secondary to iron losses from menstruation and reproductive cycles resulting in a high prevalence of iron deficiency. This hypothesis is also supported by the low prevalence of iron deficiency found in men in the same age groups.

In the ENN 99,[34,35] iron status was evaluated by a different method, the percentage of transferrin saturation (PST),[19] whereas in the ENSANUT 2006 it was estimated by s-ferritin and s-TfR concentrations, thus comparisons are not possible.

In our study, we found a protective association between participation in the *Oportunidades* or *Liconsa* programs and the risk for iron deficiency. This evidence suggests that the fortified foods distributed by both programs are playing a role in reducing anemia.[36,] Nevertheless, the program *Oportunidades* offers other benefits that may contribute to reduce iron deficiency, as is the case of cash transfer which play a role in the increase in the familiar income that allows greater food availability with high nutritional content in the *Oportunidades* homes.

The prevalence of zinc deficiency in Mexican population represents a high public health risk according to the IZiCG (≥20%).[25] The prevalence of zinc deficiency in women 12-49 years of age (27.8%) was lower than reported in ENN 99 (30.9%),[19] the difference is so small. We were unable to find associations between being beneficiary of *Oportunidades* or *Liconsa* and the prevalence of zinc deficiency, given the apparent lack of association among beneficiaries, it will be necessary to further examine the effectiveness of the current strategies for zinc fortification of foods and supplements distributed by both programs. Among other causes of zinc deficiencies, it is possible that phytate and total fiber may play a role, because the molar ratio phytate/zinc is (6:1) in

Table IV

Daily dietary intake* of iron, zinc, copper, and magnesium in adult men and women. Mexico, ENSANUT 2006

Characteristics	Iron (mg/d)		Zinc (mg/d)		Copper (mg/d)		Magnesium (mg/d)	
	Females Median (p 25, p 75)	Males Median (p 25, p 75)	Females Median (p 25, p 75)	Males Median (p 25, p 75)	Females Median (p 25, p 75)	Males Median (p 25, p 75)	Females Median (p 25, p 75)	Males Median (p 25, p 75)
Age (years)								
20 to 29	9.6 (7.2-13.0)	12.2 (9.6-16.3)	6.8 (4.8-8.5)	8.5 (6.5-11.2)	0.90 (0.65-1.20)	1.13 (0.82-1.46)	97.9 (74.2-132.6)	128.2 (92.3-171.4)
30 to 39	10.4 (7.4-13.7)	11.4 (8.6-16.1)	7.2 (5.1-9.1)	8.1 (5.9-11.1)	0.97 (0.71-1.29)	1.09 (0.86-1.46)	109.6 (80.4-145.5)	117.7 (87.7-166.4)
40 to 49	9.8 (7.2-13.1)	11.5 (8.4-17.1)	6.8 (4.8-8.9)	8.4 (5.9-11.2)	0.94 (0.70-1.22)	1.11 (0.81-1.51)	106.6 (78.9-138.8)	128.5 (96.3-167.0)
50 to 64	9.2 (6.5-12.3)	10.8 (8.0-14.4)	6.3 (4.5-8.6)	7.4 (5.6-10.3)	0.91 (0.69-1.21)	1.07 (0.78-1.46)	105.5 (76.3-136.5)	128.4 (98.2-159.9)
>65	8.0 (5.2-10.7)	10.0 (7.6-12.8)	5.8 (3.8-7.2)	7.3 (4.9-8.4)	0.77 (0.54-1.00)	0.97 (0.69-1.16)	91.0 (62.1-124.7)	109.1 (80.8-136.8)
BMI (kg/m^2)								
<18.5	14.2 (10.8-15.0)	10.2 (6.7-17.7)	9.1 (6.6-10.2)	8.1 (4.8-11.0)	1.02 (0.78-1.23)	1.01 (0.62-1.52)	86.7 (73.1-139.7)	111.5 (62.3-198.1)
18.5-24.9	10.0 (6.8-13.0)	11.5 (8.6-16.0)	6.6 (4.9-8.7)	8.0 (5.7-10.5)	0.92 (0.64-1.25)	1.09 (0.81-1.46)	101.6 (73.6-139.8)	124.6 (88.3-167.9)
25-29.9	9.7 (7.1-13.0)	11.3 (8.3-15.4)	6.5 (4.7-8.8)	7.7 (5.9-10.4)	0.91 (0.69-1.23)	1.08 (0.78-1.41)	105.7 (78.3-141.8)	127.2 (94.0-162.5)
>30	9.2 (6.7-12.2)	10.5 (8.2-15.6)	6.6 (4.7-8.4)	7.9 (5.9-10.8)	0.91 (0.65-1.15)	1.06 (0.82-1.48)	101.0 (73.8-128.4)	116.0 (95.1-154.9)
Socioeconomic status								
Low	9.4 (6.5-13.1)	11.6 (8.0-15.4)	6.1 (4.1-8.3)	7.2 (5.2-9.4)	0.88 (0.61-1.19)	1.02 (0.76-1.34)	108.2 (73.1-140.3)	124.6 (93.9-169.2)
Middle	9.3 (7.2-12.7)	11.3 (8.2-15.5)	6.6 (4.7-8.6)	7.8 (5.9-10.4)	0.94 (0.67-1.23)	1.06 (0.78-1.42)	103.2 (76.8-137.2)	120.2 (91.3-158.6)
High	10.0 (7.1-12.5)	11.0 (8.6-15.7)	7.3 (5.3-9.1)	8.6 (6.5-11.5)	0.92 (0.71-1.23)	1.13 (0.86-1.50)	101.9 (74.5-131.9)	122.8 (89.3-161.3)
Indigenous status								
Indigenous	11.0 (7.1-15.0)	11.9 (8.3-16.2)	6.8 (4.4-9.2)	6.6 (5.3-9.3)	0.94 (0.65-1.32)	0.98 (0.80-1.28)	113.5 (79.2-160.2)	122.3 (96.4-164.4)
Non-indigenous	9.4 (6.9-12.6)	11.3 (8.4-15.5)	6.6 (4.8-8.6)	7.9 (5.9-10.6)	0.91 (0.66-1.21)	1.08 (0.80-1.45)	102.9 (74.7-135.3)	122.8 (91.5-163.0)
Area								
Urban	9.6 (7.0-12.6)	11.1 (8.4-15.2)	6.8 (5.0-8.7)	8.0 (6.0-10.6)	0.92 (0.68-1.22)	1.08 (0.81-1.46)	101.9 (74.6-133.9)	120.6 (90.4-157.9)
Rural	9.8 (6.6-13.5)	12.1 (8.4-16.6)	6.1 (3.8-8.4)	7.4 (5.2-10.1)	0.88 (0.62-1.20)	1.07 (0.76-1.37)	108.97 (76.3-148.4)	131.3 (98.4-178.2)
Region								
North	10.3 (7.0-13.1)	12.1 (8.6-17.5)	6.8 (5.0-9.9)	8.4 (6.1-11.4)	0.91 (0.65-1.20)	1.08 (0.79-1.47)	101.1 (74.9-134.2)	114.9 (91.3-156.9)
Center	9.4 (6.6-12.7)	13.2 (8.7-17.3)	6.5 (4.5-8.4)	8.8 (6.5-11.8)	0.87 (0.64-1.16)	1.20 (0.81-1.54)	104.3 (73.6-142.0)	133.3 (103.0-179.4)
Mexico City	9.3 (7.0-11.9)	10.5 (8.6-12.8)	6.6 (4.9-8.5)	7.7 (5.7-9.4)	0.94 (0.70-1.25)	1.02 (0.82-1.37)	99.7 (74.2-126.7)	112.8 (81.9-147.7)
South	9.6 (7.0-13.2)	11.0 (7.9-15.2)	6.5 (4.7-8.7)	7.4 (5.3-9.8)	0.93 (0.66-1.23)	1.04 (0.78-1.37)	106.9 (76.5-139.3)	122.6 (93.6-162.5)

* Semi-quantitative Food Frequency Questionnaire
Iron Estimated Average Requirement (EAR)=16 mg/d
Zinc EAR= women 11mg/d, men 12mg/d
Copper EAR= 0.7mg/d
UL=8.0mg/d
Magnesium EAR= women 280mg/d, men 215mg/d

the Mexican diet,[37] in our study total fiber resulted a risk factor. Other cause may be the low dietary intake of zinc, because the intake was only half of the EAR for females (6.8 mg/d) and about ¾ of the EAR for males (8.1 mg/d).

Our analysis presents for the first time LSC of copper and magnesium in Mexican adult population. Although the prevalence was high, the scarce availability of population-based investigations precludes comparisons between studies. In focal studies, LSC copper was 17% in Iran[11] and 5.9-8.6% in Chile.[20] A contradiction in our study was that the median copper intake exceeded the EAR,[30] and cannot explain the high prevalence of copper LSC, it is possible that a high intake of antagonists, such as phytate and fiber, could reduce copper bioavailability.

The prevalence of LSC of magnesium in this survey is almost twice the prevalences reported in other countries (14.5%).[38] LSC of magnesium was associated with an insufficient dietary intake, although we did not consider bioavailability of this mineral.[26] Both factors may contribute to the high prevalence of LSC of magnesium in Mexico. A study in South Mexico City found a magnesium intake three fold above ours; however its focal nature may explain the difference.[39] Ames *et al*,[40] suggest that in humans, LSC of magnesium has been associated with colorectal and other cancers, hypertension, osteoporosis, diabetes, and the metabolic syndrome.

Dietary copper deficiency may play a role in the genesis of iron deficiency,[41] however, in this case the association was not significant between dietary copper and iron deficiency by s-ferritin (p=0.63). High dietary intake of phytates[42,43] negatively affects iron, zinc, and copper absorption. Likewise, a high intake of tannins reduces iron absorption up to 50%. However, in our study, phytate was not associated with a risk for iron and zinc deficiencies and LSC of copper; but this may explain the lack of improvement of the prevalence of zinc deficiency.

An inconsistency in our study was that no differences were found in IDA when controlling for PCR in males and females, because values of PCR and ferritin increased in these circumstances and may not reflect actual state of iron deficiency. So the prevalence of IDA was overestimated in people without inflammation in total prevalence of IDA.[16,17]

The lack of association between dietary intakes of iron, zinc, copper and magnesium on the deficiencies or LSC of these minerals may be due to a lack of precision of a semi-quantitative food frequency questionnaire.[26] A better estimation of LSC of magnesium is erythrocyte magnesium, as serum magnesium reflects the recent intake of this mineral. Likewise, Milne[44] recommends the use of more sensitive indicators than serum copper concentrations for measuring copper deficiency (erythrocyte superoxide dismutase and platelet cytochrome-c oxidase). However, some of them are not feasible for large epidemiological studies as is the case of ENSANUT 2006.

Our study confirms a high prevalence of iron deficiency in female and zinc deficiency in both sexes. Data on LSC of copper and magnesium in Mexico are published here for the first time, reporting a high prevalence. We conclude that it is necessary to reexamine the nutritional interventions aimed at decreasing the prevalence of zinc deficiency because apparently there is no change in the prevalence in women 12-49 years of age. Likewise, LSC of copper and magnesium should be examined their adverse effects and to decide about the pertinence to include them as part of the strategies to reduce the prevalence of micronutrient deficiencies in Mexico.

Declaración de conflicto de intereses: Los autores declararon no tener conflicto de intereses.

References

1. Ramakrishnan U. Prevalence of micronutrient malnutrition worldwide. Nutr Rev 2002;60:S46-S52.
2. Freire W. La anemia por deficiencia de hierro: estrategias de la OPS/OMS para combatirla. Salud Publica Mex 1998;40(2):199-205.
3. Stoltzfus RJ. Iron-deficiency anemia: reexamining the nature and magnitude of the public health problem. Summary: implications for research and programs. J Nutr 2001;131(2):697S-701S.
4. Brabin BJ, Hakimi M, Pelletier D. An analysis of anemia and pregnancy-related maternal mortality. J Nutr 2001;131:604S-615S.
5. Dallman P. Iron. Present knowledge in nutrition. 6th edition. International Life Sciences Institute. ILSI. North America. 1990.
6. Wang J, Pantopoulos K. Regulation of cellular iron metabolism. Biochem J 2011;434:365-381.
7. Zidar BL, Shadduck RK, Zeigler Z, Winkelstein A. Observations on the anemia and neutropenia of human copper deficiency. Am J Hematol 1977;3:177-185.
8. Chandra RK, Grace A, Goldsmith Award lecture. Trace element regulation of immunity and infection. J Am Coll Nutr 1985;4(1):5-16.
9. Klevay LM, Canfield WK, Gallagher SK, Henriksen LK, Lukaski HC, Bolonchuk W, *et al.* Decreased glucose tolerance in two men during experimental copper depletion. Nutr Rep Int 1986;33:371-382.
10. Klevay LM. Metabolic interactions among dietary cholesterol, copper, and fructose. Am J Physiol Endocrinol Metab 2010;298(1):138-139.
11. Mir E, Hossein-nezhad A, Bahrami A, Bekheirnia MR, Javadi E, Afshar Naderi A, *et al.* Adequate Serum Copper Concentration Could Improve Bone Density, Postpone Bone Loss and Protect Osteoporosis in Women. Iranian J Publ Health 2007; suppl Osteoporosis:24-29.
12. Lai H, Lai S, Shor-Posner G, Ma F, Trapido E, Baum MK. Plasma zinc, copper, copper:zinc ratio, and survival in a cohort of HIV-1-infected homosexual men. J Acquir Immune Defic Syndr 2001;1;27(1):56-62.
13. Nachimuthu S, Balamuthusamy S, Irimpen A, Delafontaine P. Calcific constrictive pericarditis with refractory hypokalemia in a patient with Gitelman's syndrome. Am J Med Sci 2009;337:74-76.
14. Kasifoglu T, Akalin A, Cansu DU, Korkmaz C, Saudi J. Hypokalemic paralysis due to primary hyperaldosteronism simulating Gitelman's syndrome. Kidney Dis Transpl 2009;20:285-287.
15. Akinci B, Celik A, Saygili F, Yesil S. A case of Gitelman's syndrome presenting with extreme hypokalaemia and paralysis. Exp Clin Endocrinol Diabet 2009;117:69-71.
16. Calò LA, Pagnin E, Ceolotto G, Davis PA, Schiavo S, Papparella I, *et al.* Silencing regulator of G protein signaling-2 (RGS-2) increases angiotensin II signaling: insights into hypertension from findings in Bartter's/Gitelman's syndromes. J Hypertens 2008;26:938-945.
17. Thurnham D, Northrop-Clewes. Infection and the etiology of anemia. En: Nutritional Anemia. Kraemer K, Zimmermann MB, eds. Sight and Life Press 2007:231-256.
18. Rivera-Domarco J, Shamah-Levy T, Villalpando-Hernández S, González de Cossío T, Hernández-Prado B, Sepúlveda J. Encuesta Nacional de Nutrición 1999. Estado nutricio de niños y mujeres de México.

Cuernavaca, Morelos, México: Instituto Nacional de Salud Pública, 2001.
19. Villalpando S, García-Guerra A, Ramírez CI, Mejía F, Matute G, Shamah T, *et al*. Iron, zinc, and iodide status in Mexican children under 12 years and women 12-49 years of age. A probabilistic national survey. Salud Publica Mex 2003; 45:520-529.
20. Cediel DG, Olivares GM, Araya QM, Letelier CMA, López de Romana ED, Pizarra AF. Efecto de la inflamación subclínica sobre el estado nutricional de hierro, cobre y zinc en adultos. Rev Chil Nutr 2009; 36(1): 8-14.
21. Resano-Pérez E, Méndez-Ramírez I, Shamah-Levy T, Rivera Juan A, Sepúlveda-Amor J. Methods of the National Nutrition Survey 1999. Salud Publica Mex 2003;45(3):558-64.
22. Villalpando S, Gaytán MA, González Herrera O, Morales Ruán MC, Gómez Acosta LM, García Guerra A. Toma de muestras sanguíneas. En: Shamah- Levy T, Villalpando- Hernández S, Rivera-Dommarco J. Manual de Procedimientos para Proyectos de Nutrición. Cuernavaca, México. Instituto Nacional de Salud Pública 2006:109-148.
23. World Health Organization/United Nations University/UNICEF. Iron deficiency anemia: assessment, prevention, and control. Ginebra, Organización Mundial de la Salud, 2001 (WHO/NHD/01.3).
24. Tietz NW (Ed): Clinical Guide to Laboratory Tests, 3rd ed. W. B. Saunders, Philadelphia, PA 1995:142-145.
25. International zinc Nutrition Consultative Group (IzincG). Technical Document # 1. Assessment of the risk of zinc deficiency in populations and options for its control. Hotz C and Brown KH (eds). Food Nutr Bull 2004;25:S94-S203.
26. Gibson R. Cap 23. Assessment of calcium, phosphorus, and magnesium status. In: Principles of nutritional assessment. Nueva York (NY): Oxford University Press, 2005.
27. Cohen JH, Haas JD. Hemoglobin correction factors for estimating the prevalence of iron deficiency anemia in pregnant women residing at high altitudes in Bolivia. Pan Am J Public Health 1999;6(6):392-399.
28. Cogswell ME, Looker AC, Pfeiffer CM, Cook JD, Lacher DA, Beard JL, Lynch SR, and Grummer-Strawn LM. Assessment of iron deficiency in US preschool children and nonpregnant females of childbearing age: National Health and Nutrition Examination Survey 2003-2006. Am J Clin Nutr 2009;89:1334-42.
29. Rodríguez-Ramírez S, Mundo-Rosas V, Jiménez-Aguilar A, Shamah-Levy T. Methodology for the analysis of dietary data from the Mexican National Health and Nutrition Survey 2006. Salud Publica Mex 2009;51 suppl 4:S523-S529.
30. Bourges H, Casanueva E, Rosado JL. Recomendaciones de Ingestión de Nutrimentos para la población Mexicana. Bases Fisiológicas. Tomo 1. México: Medica Panamericana, 2005.
31. World Heal Organization. Physical status: The use and interpretation of anthropometry. Geneva: WHO, 1995.
32. Brofman M, Guiscafre H, Castro V, Castro R y Gutiérrez G. La medición de la desigualdad: una estrategia metodológica, análisis de las características socioeconómicas de la muestra. Arch Invest Med (Méx) 1988;19:351-360.
33. Sharon L Lohr. Chap 9. Variance estimation in complex Surveys. In: Sharon L Lohr. Sampling: desing and analysis. Duxbury Press, 1999.
34. Shamah-Levy T, Villalpando-Hernández S, García-Guerra A, Mundo-Rosas V, Mejía-Rodríguez F, Domínguez-Islas CP. Anemia in Mexican women: Results of two national probabilistic surveys. Salud Publica Mex 2009;51 suppl 4:S515-S522.
35. Shamah-Levy T, Cuevas-Nasu L, Mundo-Rosas V, Morales-Ruán C, Cervantes-Turrubiates L, Villalpando-Hernández S. Health and nutrition status of older adults in Mexico: Results of a national probabilistic survey. Salud Publica Mex 2008;50:383-389.
36. Shama-Levy T, Villalpando-Hernandez S, Rivera-Dommarco JA, Cuevas-Nasu L. Capítulo 4: Impacto en Oportunidades en el estado de nutrición y anemia de niños y mujeres en edad fértil: Componente rural. Neufeld L, Garcia-Guerra A, Fernandez-Gaxiola AC, Rivera-Dommarco JA. Capítulo 5: Impacto de Oportunidades en alimentación y nutrición en niños y mujeres en zonas Urbanas. En: González de Cossio T, López Acevedo G, Rivera Dommarco J, Rubio Soto GM. Nutrición y Pobreza: Política Pública Basada en videncia. México: Banco Mundial: SEDESOL, 2008.
37. WHO. Zinc. In: Vitamin and mineral requirements in human nutrition: report of a joint FAO/WHO expert consultation. Bangkok, Thailand: World Health Organization, 2005:230-245.
38. Schimatschek HF, Rempis R. Prevalence of hypomagnesemia in an unselected German population of 16,000 individuals. Magnes Res 2001;14(4): p. 283-90.
39. Hernández-Avila M, Romieu I, Parra S, Hernández-Avila J, Madrigal H, Willett W. Validity and reproducibility of a food frequency questionnaire to assess dietary intake of women living in Mexico City. Salud Publica Mex 998;40:133-140.
40. Ames BN. Low micronutrient intake may accelerate the degenerative diseases of aging through allocation of scarce micronutrients by triage. PNAS 2006; 103 (47): 17589-17594.
41. Knovich MA, Il'yasova D, Ivanova A, Molnar I. The association between serum copper and anemia in the adult Second National Health and Nutrition Examination Survey (NHANES II) population. Br J Nutr 2008;99(6):1226-1229.
42. Barquera S, Hernández-Barrera L, Campos-Nonato I, Espinosa J, Flores M, Barriguete JA, *et al*. Energy and nutrient consumption in adults: Analysis of the Mexican National Health and Nutrition Survey 2006. Salud Publica Mex 2009;51 suppl 4:S562-S573.
43. Barquera S, Rivera JA, Espinosa-Montero J, Safdie M, Campirano F, Monterrubio EA. Energy and nutrient consumption in Mexican women 12-49 years of age: Analysis of the National Nutrition Survey, 1999. Salud Publica Mex 2003;45 suppl 4:S530-S539.
44. Milne DB. Copper intake and assessment of copper status. Am J Clin Nutr 1998;67 Suppl 5:1041S-1045S.