Iron deficiency anemia in Tarahumara women of reproductive-age in Northern Mexico

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Monárrez-Espino J, Martínez H, Greiner T.
Iron deficiency anemia in reproductive-age Tarahumara women of Northern Mexico.
Salud Publica Mex 2001;43:392-401.
The English version of this paper is available at: http://www.insp.mx/salud/index.html

Abstract

Objective. To determine the prevalence of iron deficiency anemia (IDA) among Tarahumara women of reproductive age. **Material and Methods**. A cross-sectional survey was conducted in a representative sample of 481 women aged 12-49 years, residents of Guachochi Municipality, Chihuahua, from June to September 1998. The hemoglobin (Hb) level was measured in capillary blood using the Hemocue technique, and the serum ferritin level in capillary serum spotted on filter paper, in a sub-sample of women. Central tendency and dispersion measures were estimated; the Chi-squared test was used to test differences in proportions and ANOVA and Bonferroni's test for differences in means. **Results**. Prevalence of anemia (mean Hb±*S.D.*) was 16.1% (140±16 g/l) and 25.7% (129±12 g/l) for non-pregnant and pregnant women, respectively. Pregnant women in the 3rd trimester and those who were breast-feeding their children during the first 6 months after delivery had the highest prevalence of anemia (38.5% and 42.9%, respectively). Iron deficiency was responsible for most of the anemia found in this sample. **Conclusions**. This study provides relevant information for the development of intervention programs to treat and prevent IDA in this ethnic group. The English version of this paper is available too at: http://www.insp.mx/salud/index.html

Key words: anemia, iron deficiency; Tarahumara women; Mexico

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El texto completo en inglés de este artículo está disponible en: http://www.insp.mx/salud/index.html

Resumen

Objetivo. Determinar la prevalencia de anemia ferropriva en mujeres tarahumaras de edad fértil. **Material y métodos**. Se realizó un estudio transversal en una muestra representativa de 481 mujeres, de edades entre 12 a 49 años, residentes del municipio de Guachochi, Chihuahua, de junio a septiembre de 1998. El nivel de hemoglobina (Hb) se midió en sangre capilar mediante la técnica del Hemocue, además, en un subgrupo se midió el nivel de ferritina en suero capilar sobre papel filtro. Se obtuvieron medidas de tendencia central y de dispersión, se hicieron pruebas de ji cuadrada para diferencias de proporciones, además de ANOVA y prueba de Bonferroni para diferencias de medias. **Resultados**. La prevalencia de anemia ($\bar{X}$ Hb±*DE*) fue de 16.1% (140±16 g/l) y 25.7% (129±12 g/l) para no embarazadas y embarazadas, respectivamente. Las embarazadas en el tercer trimestre y las que estaban lactando durante los primeros seis meses del postparto mostraron las más altas prevalencias de anemia (38.5% y 42.9%, respectivamente). La deficiencia de hierro fue responsable de la mayoría de los casos de anemia encontrada en esta muestra. **Conclusiones**. Este estudio provee información relevante para desarrollar programas de intervención para tratar y prevenir la anemia ferropriva en este grupo étnico. El texto completo en inglés de este artículo está también disponible en: http://www.insp.mx/salud/index.html

Palabras clave: anemia ferropriva; mujeres tarahumaras; México

This study was financially supported by the Swedish Mission Council through the International Maternal and Child Health Section, Uppsala University, and ITESM, Campus Chihuahua.

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Received on: September 14, 2000 • **Accepted on:** April 9, 2000

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Iron deficiency is the most common nutritional disorder in the world, it affects particularly women of reproductive age and preschool children in tropical and sub-tropical zones, and constitutes a major health issue in many developing countries. Iron is essential in the production of hemoglobin (Hb), which participates in the delivery of oxygen from the lungs to the body tissues, in electron transport in cells, and in the synthesis of iron enzymes that are required to use oxygen for the production of cellular energy.[1]

Anemia, defined as the reduction of Hb concentration in the blood, is due, in many developing countries, primarily to the lack of bio-available dietary iron.[2] Although there are other causes of nutritional anemia, including folate or vitamin B-12 deficiency, iron deficiency is a common cause of anemia in areas with a high prevalence of anemia. Other non-nutritional causes of anemia include malaria, hemorrhage, inherited disorders and various chronic diseases.[3]

The normal physiologic iron losses among menstruating women and the substantial increase in iron requirements during the 2nd-3rd trimesters of pregnancy make it inevitable for many women to develop anemia if they do not receive supplemental iron.[4] In developing countries, anemia is often aggravated by repeated and closely-spaced pregnancies, as well as by intestinal parasites, mostly hookworm.[5]

Iron balance is dependent on the body's iron stores, absorption and losses. At least two-thirds of body iron is functional iron, found mainly as Hb circulating in the red blood cells. Most of the remaining is storage iron, mainly as serum ferritin (SF) to be mobilized when needed.[6]

There are three major stages in the development of iron deficiency:[7] iron depletion is a reduction in the SF level, with no evidence of functional consequences;[8,9] iron deficient erythropoiesis occurs when the needs of the erythroid marrow for iron are no longer met with a subsequent rise in erythrocyte protoporphyrin and serum transferrin receptor levels; and finally, iron deficiency anemia (IDA), the most severe form associated with functional consequences. IDA is diagnosed when the Hb concentration is lower than the level considered normal for the person's age, sex and physiological status (i.e. below a statistically defined threshold of 2 S.D. from the mean for a healthy population).[10] The restriction in Hb production causes distortion of erythrocytes with microcytosis and hypochromia.

Well-documented consequences of anemia include diminished learning ability, reduced work capacity, increased morbidity from infections, and greater risk of death associated with pregnancy and childbirth.[11-14] Infants born to anemic mothers are more predisposed to low birth weight and prematurity.[15,16] Furthermore, some studies have also supported the hypothesis of an association between iron deficiency without anemia and poorer performance on tests of cognitive development in children.[17-19]

At the World Summit for Children, Mexico made a commitment to achieve by the year 2000 a reduction of one-third in the prevalence of IDA in women of reproductive age, as compared to the prevalence in 1990. In 1991, a plan of action was drawn up to reach this goal and specific programs were assigned to different institutions. Unfortunately, these programs have not yet reached some marginalized areas of the country, often inhabited by indigenous groups such as the Tarahumara.

The Tarahumara women

The Tarahumara are the most numerous indigenous minority of Northern Mexico, with nearly 80 000 inhabitants,[20] and are one of the most isolated and socially deprived ethnic communities in North America. Their children have low immunization coverage and high rates of infant mortality, infant malnutrition, and various infectious diseases.[21-23] Although the local authorities are attempting to deal with some of these problems, women's health is still neglected. Health care for them has been limited to trying to provide some prenatal care during pregnancy and family planning.

Women play a central role in the Tarahumara household as they are involved basically in all domestic tasks including fetching fuel, carrying water, and the care of the children. Their productive sphere includes herding, making handcrafts for sale, and agricultural labor. They usually join the men in weeding, harvesting, and sowing, even while carrying infants on their backs. It is common to see women performing tasks such as hoeing maize or even ploughing with oxen. These activities frequently demand a high physical energy expenditure that can be better achieved by those with better nutritional and health status.

However, information concerning the health of these women is scarce and usually based on hospital records. No population-based data are available. Their high fertility rates, closely spaced pregnancies, low levels of education, along with other ecological and demographic factors, make Tarahumara women very vulnerable to IDA and its consequences.

The aim of the present study was to provide detailed population-based data to establish the frequency, severity, and distribution of IDA among these indigenous women. This information is needed to design pertinent interventions to improve the Tarahumara women's nutritional status that can be translated into lower health risks.

Material and Methods

A cross-sectional survey was conducted during the Summer of 1998, in the most predominantly indigenous municipality of Chihuahua State, Mexico. It focused on reproductive-age (12-49 years) Tarahumara women (able to speak the indigenous language), who were permanent residents of Guachochi municipality.

Although this municipality occupies only 10% of the Tarahumara territory, it is inhabited by one-third of the total Tarahumara population.[20] It comprises 4 350 km^2 with an average altitude of 2 200 m above sea level. It has a temperate humid forest climate with a mean annual temperature of 11 ºC (max. 32 ºC; min. –12 ºC), and a mean annual rainfall of 827 mm.[24]

A brief gynecological clinical history to evaluate reproductive health risks and a short questionnaire focusing on basic demographic and educational indicators were utilized. To evaluate the use of iron supplements, women were asked if they had received iron tablets (shown to them) within the last 6 months prior to the interview and, if so, the prescribed schedule and duration of supplementation.

Local translator-guides were hired to reach isolated communities and to interview women who did not speak Spanish. Anthropometrical measurements were also taken, but were reported separately.[25]

The aims of the study were explained to all potential participants. Verbal informed consent was obtained from all women who agreed to participate. Participation required accepting a finger-prick for capillary blood, to determine Hb and SF levels. As Hb determination took only a few minutes, all women found to be anemic received an iron supplementation treatment. The study was approved by Uppsala University Ethics Committee and by the local health authority (Secretariat of Health, Guachochi). When possible, traditional authorities were also asked for cooperation.

Sample design

The sample size estimation was based on the 25% prevalence of anemia found among indigenous women, reported by the National Nutrition Survey (NNS) carried out in 1988.[26] Specifying a confidence level of 95% and a 15% relative precision of the estimate, the required sample size was 485 women, according to the formula described by Lemeshow and associates.[27]

A sample frame from which to draw a probabilistic sample could not be established, because there is no census for the Tarahumara population and there are no cartographic data to use in distinguishing between the indigenous and non-indigenous households. Logistic constraints included the fact that more than half of Tarahumara women in the municipality reside in nearly 1 000 communities with <50 inhabitants each. These localities, inhabited mostly by indigenous peoples, are widely scattered throughout mountains that are difficult to access.

Multistage proportional sampling was used; the population was grouped according to the number of people living in each locality. From the estimated 6 500 Tarahumara women aged 12-49 years living in the municipality, approximately 53%, 24% and 23% lived in localities with <50, 50-99, and ≥100 persons, respectively.

The relatively small number of localities with 50-99 and ≥100 persons (108 and 39, respectively) allowed the drawing of a systematic sample. The localities were listed with the number of households in alphabetical order, the cumulative frequency of households, and the range of households between the previous and the current locality. Then, a random number was chosen and the predetermined sampling interval was added consecutively. The localities sampled were those found within the range where the number was located. Once in the field, eight houses were randomly selected from the inhabited Tarahumara households in each selected locality, and all reproductive-age women in them were included in the sample. In the localities with 50-99 persons, 115 women living in 95 households from 20 localities were selected; and in those localities with ≥100 persons, 111 women living in 85 households from 12 localities were similarly sampled.

In communities with <50 persons, quota sampling was used. As most of these small villages surround the bigger ones, a random sample from the surrounding localities with ≥50 persons was drawn, and all reproductive-age women found were sampled until the quota was reached. A total of 255 women living in 207 households from 93 of these small localities were sampled.

Hemoglobin assessment

Hemoglobin was measured on capillary blood with a portable photometer (HemoCue AB, Box 1204, SE-262

23 Ängelholm, Sweden). This azide methemoglobin method has a correlation of 0.99 compared to the laboratory Hb determination,[28] and it has been proven to provide adequate prevalence estimates of anemia at population levels.[29]

The prevalence and severity of anemia was assessed based on the recommended Hb cut-off points at sea level: mild (100-119); moderate (80-99); and severe (<80 g/l).[30] It was necessary to adjust these cut-off points, as several factors can affect the Hb concentration, including pregnancy and altitude.

During the 2nd and 3rd trimesters of pregnancy, a physiological plasma expansion occurs, and therefore the Hb cut-off for mild anemia must be lowered by 10 g/l (i.e. <110 g/l) during these trimesters. However, for moderate and severe anemia the cut-offs remain unchanged.

Regarding altitude, a recently published exponential curve was utilized to determine the altitude-specific Hb cut-offs.[31] The use of this exponential model has shown a better fit to the data for women of childbearing age than previous models.[32-34] A Global Positioning System instrument was employed to measure the altitude in each of the sampled localities, and the corrected Hb cut-offs for the three degrees of anemia were calculated every 100 meters using the formulas proposed by Cohen and Hass:[31]

$$\text{Mean Hb (g/l)} = 120 + [\text{exponential}^{\,(0.00038\,(\text{altitude} - 1000))}]$$
$$\text{Hb cut-off} = \text{Mean Hb} - [(0.061)(\text{Mean Hb})(1.96)]$$

The Hb correction values derived were: 1 800-1 899 m=6g/l; 1 900-1 999 m=7g/l; 2 000-2 099 m=7g/l; 2 100-2 199 m=8g/l; 2 200-2 299 m=9g/l; 2 300-2 399 m=10g/l; 2 400-2 499 m=11g/l; and 2 500-2 599 m=12g/l.

Serum ferritin assessment

In adults, SF is regarded as one of the best tools to evaluate iron deficiency.[35,36] However, there are important logistical and practical constraints in evaluating SF in remote settings, such as the need to freeze the samples for storage and transportation, and the low acceptability of venous puncturing to the population.

A laboratory method that does not require a venous puncture or sample freezing, and that can use serum from capillary blood spotted on filter paper, has been recently published.[37] After developing the field technique to obtain suitable capillary serum samples that allowed the use of this methodology,[38] the last 171 surveyed women were sampled. The method requires 20 µl of capillary serum to be spotted on filter paper. A capillary specimen was taken from a finger using a disposable lancet. After wiping away the first drop and taking the next for the Hemocue®, a capillary tube was filled with free-flowing blood. This was a 75 x 1 mm standard microhematocrit tube (contents ≈75 µl), which was sealed at one end, and centrifuged on site. The electricity source for the microcentrifuge run was a car battery that had a converter to transform 12-v direct current to 110-v alternating current. At least 20 µl of serum were obtained after spinning at 4 500 rpm for five min. The tube was broken just above the cell layer without spillage. The volume of serum left in the tube was then measured in mm, each being equivalent to one µl. A syringe with a cut-off needle that fitted exactly into the microtube was held to make it airtight, and the serum was then expelled from the end of the capillary tube onto the filter paper (Whatman 1®). The samples were air-dried, placed in polyethylene bags at room temperature and sent to the University of California at Davis for analysis. Serum was released from the filter paper by enzyme digestion, and the SF level was determined using radioimmunoassay, following the method described by Ahluwalia *et al*.[37]

Because recent infections lead to spuriously high SF values,[39,40] measurement of armpit temperature and a series of questions to identify possible infectious diseases in the two weeks before the interview were included. Ferritin values of women with temperatures over 37.5 ºC or with a recent history of infection (urinary, respiratory or gastrointestinal) were considered to be possibly falsely high.

Statistical analysis

Data were captured and analyzed in the SPSS computer software. Box plot graphs, and means (*s.d.*) for Hb were presented to describe the Hb distribution. Analyses were stratified according to the women's reproductive status, age group, number of inhabitants in the locality, use of contraception method, and ability to speak Spanish.

The mean (*SD*) and 95% confidence intervals for SF levels were calculated for pregnant and non-pregnant women, with and without possible infection. To determine the prevalence of depleted iron stores, a cut-off point of SF<12 µg/l was used, corresponding to the 5th percentile of the SF reference distribution for women, was used.[41] As SF was not normally distributed, a logarithmic transformation was done and the correlation between Hb and logarithm SF (Log SF) was plotted.

The proportion of women who received iron supplementation, including the prescribed duration and schedule, was tabulated stratifying by size of the locality.

Pearson chi[2] tests were used to detect differences between categorical variables. ANOVA and Bonferroni were used to identify mean differences. The level at which differences were considered statistically significant was 0.05.

Results

A total of 481 women from 387 households were surveyed (1.24 women per household). From the households where two women were surveyed (n=71), neither woman was anemic in 62%, one was anemic and the other was not in 29%, and both were anemic in 9% of the households.

The mean altitude (range) in the 125 sampled localities was 2 237 meters above sea level (1 840-2 500); for those with <50, 50-99, and ≥100 households, it was 2 180 m (1 840-2 420), 2300 m (2 100-2 500), and 2 298 m (2 020-2 460), respectively.

Table I presents the mean Hb±*SD* and prevalence of anemia by level of severity, stratifying by physiological status, age group, use of contraception method, size of the locality, and ability to speak Spanish. The overall prevalence of anemia (mean Hb±*SD*) among non-pregnant and pregnant women was 16.1% (140.2±16.1 g/l) and 25.7% (129.3±12.6 g/l), respectively. The prevalence of mild, moderate, and severe anemia was 12.1%, 2.9%, and 1.1% for non-pregnant women, and 17.1%, 8.6%, and 0% for pregnant women, respectively. Anemia was worse in women aged 20-39 years. Those aged 40-49 years had a significantly higher mean Hb (145.6 g/l), and the lowest prevalence of overall anemia. Though not statistically different, women using an intrauterine device (IUD) had a lower mean Hb (141.7 g/l) than hormonal contraceptive users (146.5 g/l). Women living in localities with ≥100 persons showed a significantly lower mean Hb (137.7 g/l) than those with <100 persons (141 g/l), and the prevalence of moderate and severe anemia were statistically higher in the bigger localities. Spanish-speaking women tended to be associated with a higher Hb mean and a lower prevalence of mild and moderate anemia (p<0.10).

Figure 1 presents the Hb distribution, the mean Hb, and the severity of anemia by chronology of physiological events during the women's reproductive life. Low mean Hb, and high prevalence of anemia were important among pregnant women in the 3rd trimester, and particularly among those lactating their babies during the first six months after delivery, when the prevalence of moderate and severe anemia reached 17.1%. The best status was seen among pre-menarcheal and postmenopausal or hysterectomized women.

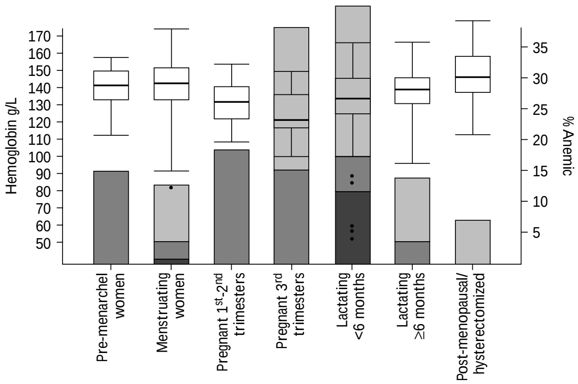
Table I
Distribution of hemoglobin* and severity of anemia‡ among non-pregnant Tarahumara women of Northern Mexico, 1998

	n	$\overline{X}$ *Hb (SD) g/l*	*Prevalence of anemia* Mild	Moderate	Severe
Pregnant women	35	129.3 (12.6)§	17.1	8.6	–
Non-pregnant women	446	140.2 (16.1)	12.1	2.9	1.1
Age groups in years					
12-19	108	138.7 (13.6)	15.7	2.8	–
20-29	141	137.7 (17.7)	14.2	4.3	2.1
30-39	101	140.6 (16.5)	10.9	4.0	1.0
40-49	96	145.6 (14.5)§	6.3	–	1.0
Use of contraception					
Intrauterine device	76	141.7 (13.2)	9.2	–	2.6
Hormonal method#	24	146.5 (13.2)	12.5	–	–
Size of the locality					
<100 persons	342	141.0 (14.6)§	12.6	1.2	0.6
≥100 persons	104	137.7 (20.0)	10.6	8.7&	2.9&
Able to speak Spanish					
Yes	333	141.0 (15.6)	11.1	2.4	1.2
No	113	138.0 (17.1)	12.5	4.4	0.9

* Non-altitude-adjusted hemoglobin
‡ Using altitude-adjusted cut-offs
§ Statistically different Hb mean (p<0.05); ANOVA and Bonferroni were used
# Includes oral contraceptives and injectable methods
& Statistically different proportion (p<0.05); Pearson X^2 was used

The mean SF was 16.0 and 9.9 µg/l for non-pregnant and pregnant women, respectively, when possibly infected women were included in the analysis. When women with possible infection were excluded (n=25), there was a decrease in the mean SF of 0.5 µg/l for non-pregnant and 0.4 µg/l for pregnant women. Conversely, the prevalence of iron depletion (SF<12 µg/l) increased 2.7% in non-pregnant and 2.6% in pregnant women (Table II).

Table III presents the relationship between anemia and depleted iron stores. Over half of the women had depleted iron stores, whether anemic or not. The proportions of iron depletion in women with anemia tended to be higher than in those without it, although this difference was not statistically significant.



n	20	234	22	13	35	104	53
$\bar{X}$ Hb	140.2	142.0	132.0	124.8	125.5	138.0	146.6
DE	13.4	14.7	11.4	13.8	27.4	11.8	13.6

• Each point indicates a value <90 g/l

Mild* Moderate Severe

* The cut-off value was set 10 g/l lower in women pregnant in the 2nd and 3rd trimesters

FIGURE 1. DISTRIBUTION OF NON-ALTITUDE-ADJUSTED HEMOGLOBIN AND SEVERITY OF ANEMIA IN TARAHUMARA WOMEN OF NORTHERN MEXICO, 1998

Table II

SERUM FERRITIN MEAN AND PREVALENCE OF DEPLETED IRON STORES, WITH AND WITHOUT POSSIBLE INFECTION IN NON-PREGNANT AND PREGNANT TARAHUMARA WOMEN OF NORTHERN MEXICO, 1998

	n	$\bar{X}$ *SFµ/l (95% CI)*	*% SF<12µ/l**
Including women with possible infection‡			
Non-pregnant	155	16.0 (12.2-19.7)	59.4
Pregnant	16	9.9 (6.8-12.9)	68.8
Excluding women with possible infection			
Non-pregnant	132	15.5 (11.5-19.5)	62.1
Pregnant	14	9.5 (6.5-12.6)	71.4

Serum ferritin: SF
* The generally accepted SF cut-off point iron depletion in adult women
‡ Temperature >37.5 ºC or history of infection (urinary, respiratory, gastrointestinal) within 2 wk. prior to the interview

Five of the 7 anemic women (Hb values between 121 and 127 g/l) in whom no iron depletion was found had SF values close to the cut-off (12.3-16.2 µg/l). The remaining two had SF values of 41.1 and 70.9 µg/l,

Table III

RELATIONSHIP BETWEEN PREVALENCE OF ANEMIA AND IRON DEPLETION, MEASURED AS SERUM FERRITIN <12µ/L, BY PREGNANCY STATUS AMONG TARAHUMARA WOMEN OF NORTHERN MEXICO, 1998

	Anemic			*Non-anemic*		*Total*	
	n	*%*	*p-value**	*n*	*%*	*n*	*%*
Non-pregnant	23			132		155	
SF <12µ/l	16	69.6	0.28	76	57.6	92	59.4
SF≥ 12µ/l	7	30.4		56	42.4	63	40.6
Pregnant	3			13		16	
SF <12µ/l	3	100	0.19	8	61.5	11	68.8
SF≥12µ/l	0	-		5	38.5	5	31.2

Serum ferritin: SF
* Pearson X^2 was used

and reported muscle/bone pain and respiratory tract infection respectively in the morbidity recall, respectively.

Table IV shows that the majority of women were not given iron-containing supplements within six months before the survey, irrespective of size of their community. The proportion that had received iron tended to be higher in communities with ≥100 persons ($p<0.10$), and pregnant women were more likely to have received iron supplementation ($p<0.05$). The supplement contained 75µg of elemental iron per tablet. Three tablets per day was the prescribed dosage schedule for almost half of the supplemented women, and the most common duration of supplementation prescribed was ≤1 month.

Discussion

This is the first survey of anemia carried out at population level among reproductive-age women in the Tarahumara population. Indeed, in the NNS, carried out by the Ministry of Health in 1988, there were no indigenous women sampled in the northern region of the country, where Chihuahua State is located.[26] Although it was not possible to obtain a probabilistic sample due to the lack of a reliable sampling frame, we consider that the sampling strategy used in this study gives a fair estimate of the prevalence of anemia in this group.

The results of this survey can be compared to those obtained by the 1988 NNS. Nationwide, the prevalence of anemia (non-altitude-adjusted mean Hb±*S.D.*)

Table IV
IRON SUPPLEMENTATION BY NUMBER OF INHABITANTS IN THE LOCALITY AMONG REPRODUCTIVE-AGE TARAHUMARA WOMEN OF NORTHERN MEXICO, 1998

	Number of inhabitants in the locality		
	<100 n (%)	*≥100 n (%)*	*Total n (%)*
Iron supplementation within the last six months			
No supplement received	345 (93.2)	98 (88.3)	443 (92.1)
Received supplementation	25 (6.8)	13 (11.7)*	38 (7.9)
Schedule of the iron supplementation‡			
Three tablets per day	11 (44.0)	6 (50.0)	17 (45.9)
One tablet per day	13 (52.0)	5 (41.7)	18 (48.6)
One tablet per week	1 (4.0)	1 (8.3)	2 (5.5)
Prescribed duration of the iron supplementation			
One month or less	9 (36.0)	6 (50.0)	15 (40.6)
One to two months	8 (32.0)	3 (25.0)	11 (29.7)
More than two months	8 (32.0)	3 (25.0)	11 (29.7)
Iron supplementation by physiological state			
Pregnant	5 (17.8)	4 (57.1)§	9 (25.7)
Non-pregnant	19 (5.5)	9 (8.6)	28 (6.3)

* Statistically different proportion ($p<0.10$); Pearson χ^2 was used
‡ Tablets in the health care centers visited in the municipality (Secretariat of Health, Mexican Institute of Social Security) contained 75μg of elemental iron
§ Statistically different proportion (p0.05); Pearson χ^2 was used

was 24.8% (130±18 g/l) and 22.9% (123±15 g/l) for non-pregnant and pregnant indigenous women, respectively, compared to 16.1% (140±16 g/l) and 25.7% (129±12 g/l) found among Tarahumara women. The higher proportion of anemia among non-pregnant women at the national level cannot be easily explained, especially because dietary data are not available. That pregnant Tarahumara women presented a slightly higher prevalence of anemia could be due to a lower intake of iron supplements during pregnancy.

No clear tendency for women within the same household to have similar iron status was found, as indicated by the fact that in households where two women were sampled (18.3% of the total households), only in 9% of them both women were anemic.

Among non-pregnant women, those aged 20-39 years showed the highest prevalence of moderate and severe anemia. This is expected, as these women are at the peak of their reproductive lives. The lower prevalence of anemia among women aged 40-49 may be explained by the fact that half of them were post-menopausal.

Although the difference did not reach statistical significance (p=0.12), mean Hb was higher among women who used hormonal contraception compared to IUD users, as it has been reported elsewhere.[42,43] However, the lack of dietary and socioeconomic data limit the interpretation of this result; for instance, women using hormonal contraceptives might have a better diet or a better socioeconomic status, then the differences found could be related to their better diet or overall health. The same argument is valid for the lower proportions of anemia found among women who spoke Spanish.

The proportion of women who used contraception was 38%, similar to that reported at the national level for the period 1987-92 for women with no schooling (38.2%), but almost three times as many Tarahumara women used IUD as women at the national level.[44]

Contrary to what might have been expected, the mean Hb among non-pregnant women was significantly higher and the prevalence of moderate and severe anemia significantly lower, in women living in localities with <100 persons, than in those living in localities with ≥100 persons, these differences could not be explained by differences in the number of menstruating days, nor in the proportion of lactating women in the first six months. There were in fact significantly more monolingual women and slightly fewer iron-supplemented women in the smaller localities. No significant trends were found for women in the smaller localities to use IUD less often and hormonal contraceptives more often than in the larger localities. All these factors could have only a marginal effect, if any, in explaining the differences. Hookworm and other parasitic diseases, not evaluated in this survey, are known causes of anemia and could perhaps explain part of the differences found. One would expect higher infection rates in smaller localities, as these are found in the more deprived and marginalized settings, but since all women in this sample are living under rather deprived circumstances, parasitic diseases could be more prevalent in areas where the population density is higher and transmission rates greater. Dietary intakes of *haem* iron in these women were not measured. Meat is expensive and traditionally eaten only in ceremonial occasions, but may be more widely eaten in the better-off and larger communities.

However, perhaps the factors that could best explain this difference are those that influence non-*hae-*

me iron absorption. For example, women in smaller villages might eat more wild plants and fruits with high contents of ascorbic acid, a powerful enhancer of non-*haeme* iron absorption.[45] Alternatively, women in larger communities might drink more coffee, which contains tannins; these phenolic compounds inhibit iron absorption.[46] Cultural explanations should also not be ruled out. For instance, it might be possible that women living in small localities drink more "tesgüino" than those in the larger localities. This traditional Tarahumara beer is a thick, nutritious brew made from fermented corn prepared in iron containers. There is evidence that extrinsic iron from the surface of cooking vessels used to brew traditional alcoholic beverages, as do some Southern African tribes, can add up to 100 mg to the daily iron intake.[47] Further research to clarify this issue is needed.

Although the prevalence of anemia among non-pregnant women, particularly in those living in the smaller localities, does not appear to be very high, pregnant women and women during the first six months of lactation have serious difficulties maintaining a normal Hb level. Based on these cross-sectional data, pregnancy appears to have a dramatic impact on the Hb and anemia levels of these women, lasting into the first months of lactation, after which marked improvement occurs, presumably in part due to lactation amenorrhoea. The extremely high prevalence of severe anemia among lactating women during the first six months after delivery (11.4%) was not due to the cut-off point used, as the cut-offs for moderate and severe anemia were similar among pregnant and non-pregnant women. It is possible that high blood losses at delivery contributed to this, especially considering that 73% of the Tarahumara children are born at home without any health care attention.[48] The high prevalence of anemia found among lactating women, suggests that it may be necessary to supplement mothers with daily iron several months after delivery, in addition to other preventive measures.

The fact that the SF sub-sample was not randomly selected might certainly bias the estimates; however, there were no significant differences in characteristics between the SF sampled and non-sampled women, including Hb levels and prevalence of anemia.

The study by Ahluwalia *et al*, measured venous blood iron under laboratory conditions; they reported a very high correlation between SF in filter paper and the conventional SF analytical technique (r=0.99; p=0.0001), with a perfect sensitivity and specificity, even for samples stored up to four weeks.[37] Moreover, this method was validated under field conditions with capillary serum, using a very similar field technique to the one utilized in this survey. A strong correlation was found between the capillary dried serum spot and the traditional SF method (r=0.86; p=0.0001), and a sensitivity and specificity of 80% and 96.8%, respectively.[49]

Some authors have found that determination of ferritin in capillary serum may lead to 5-7% overestimation, as compared to venous serum values.[50] However, this would not have had a substantial impact on our conclusions. Also, the use of plasma (serum with anticoagulant) leads to higher within- and between-sample variation;[51] to avoid these problems, serum without anticoagulant was utilized.

Some SF values may also be falsely high due to recent infections, as serum apoferritin is an acute-phase reactant protein that increases in response to infection.[35] This limits the interpretation of SF in situations where the incidence of infection is high.[3] To control for this situation, it is common to assess C-reactive protein, another acute-phase reactant protein that increases in response to infection. However, as a filter paper method adapted for field use to test for C-reactive protein is not available, a 2-week morbidity recall and raised armpit temperature was used to control for infection.

When possibly infected women were excluded from the analysis (n=25), a slight decrease was observed in the mean SF of 0.5 μg/l for non-pregnant and 0.4 μg/l for pregnant women. Conversely, the prevalence of SF<12 μg/l increased 2.7% in non-pregnant and 2.6% in pregnant women, respectively, but no statistically significant difference in mean SF or in the proportions of SF<12 μg/l was found when a possible infection was considered. For these reasons, it was decided to include the whole sub-sample for the analysis of the relationship between anemia and iron depletion.

In this sub-sample, a highly significant but modest positive correlation between Log SF and Hb was found (r=0.31; p=0.000). Most women were iron-depleted, whether anemic or not. The majority of the anemia was related to iron deficiency in both non-pregnant and pregnant women. This is consistent with the common finding that for every case of IDA found in a population, there are at least two cases of non-anemic iron deficiency.[3] However, not all anemic women showed iron depletion. This may be related to the cut-off points used or due to the existence of an inflammatory response; from the seven anemic women in which no iron depletion was found, five had Hb and SF values lying very close to the cut-off points for both anemia and iron depletion, and the other two had histories of inflammatory processes in the morbidity recall.

It was found that only 7.9% of the surveyed women had received iron supplementation within six months prior to the interview. Iron supplements were taken slightly more often (p=0.07) in the localities with ≥100 inhabitants (11.7%), compared to those with <100 persons (6.8%). The Mexican Technical Norm for Prenatal Consultation, states that all women should receive iron supplementation during the last trimester of pregnancy,[51] yet in this study, 57.1% of the pregnant women living in localities with ≥100 inhabitants received iron supplements, but only 17.8% in localities with <100 persons. The fact that nearly half the supplemented women received three high-dose tablets per day and each tablet contains 25% more iron than recommended, suggests a delay in implementing more modern single-dose per-day supplementation schedules.[52] This could cause more side effects, leading to compliance problems, as well as being a waste of economic resources. Furthermore, when anemic women were asked about the reason for iron prescription, it was found that iron supplements were being used as a treatment for weakness, dizziness, pallor, or other signs and symptoms related to anemia in non-pregnant women, but diagnoses were rarely confirmed. These findings point to the need to improve not only the coverage, but also the quality of health care, especially for those women living in small localities. In particular, lower-dose treatment schedule should be initiated for prophylaxis throughout pregnancy and for the first six months after delivery.

In Mexico, where most deliveries occur in hospitals, it has been calculated that, among hospital deliveries, 25% of the maternal deaths are due to hemorrhage during the delivery period.[53] Although the maternal mortality rate in this ethnic group has never been determined, the relatively high prevalence of anemia among pregnant women reported here, along with the poor prenatal care coverage, and the fact that 3 out of 4 children are born at home with no health care whatsoever,[48] pose significant risks for the mother and baby during the perinatal period. Improving the mothers' Hb status prior to the delivery will thus diminish their risk of dying during delivery. Iron deficiency undoubtedly contributes to the high morbidity and mortality among Tarahumara women of childbearing age, potentially impairing work performance and active learning capacity as well.

For many years, protein-energy malnutrition among infants belonging to this ethnic group has been recognized as a public health problem, and has been a major focus of attention by governmental and non-governmental organizations. In response, several interventions, including feeding programs, have been carried out. However, much less has been done to identify or treat other common forms of malnutrition. We hope that these findings encourage governmental and non-governmental organizations to focus on the problem of IDA among these women.

Acknowledgments

The authors want to thank Nutritionist Andrea Gerger for her help in data collection and Prof. Bo Lönnerdal (UC-Davis) for his laboratory assistance.

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