

Prevalence of inadequate intake of vitamins and minerals in the Mexican population correcting by nutrient retention factors, Ensanut 2016

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Abstract

Objective. To estimate the usual intake and the prevalence of inadequacy of selected nutrients in the Mexican population and the potential effect that the nutrient retention factors (NRF) could have on these estimates. Likewise, document the methodology used in the analysis of the 24 hours of the mid-way National Health and Nutrition Survey 2016 (Ensanut MC 2016). **Materials and methods.** Dietary information from the Ensanut MC 2016 was analyzed with and without the use of NRFs. **Results.** Most nutrients evaluated showed a relevant inadequacy prevalence above 10% in all age groups. Likewise, we documented that, when NRFs were not applied, estimated intakes and prevalence were significantly underestimated in a range of 2% to 55.5%. **Conclusions.** We documented the relevance of the application of NRFs for adequate estimation of the prevalence of inadequate intake of selected nutrients in population studies.

Keywords: methodology; usual intake estimation; nutrient retention factors; 24-hour dietary recall; micronutrients; macronutrients

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Resumen

Objetivo. Estimar la ingesta habitual y la prevalencia de inadecuación de nutrimentos selectos en la población mexicana y el efecto potencial de los factores de retención de nutrimentos (FRN). Asimismo, describir la metodología utilizada en el procesamiento del recordatorio de 24 horas de la Encuesta Nacional de Salud y Nutrición de Medio Camino 2016 (Ensanut MC 2016). **Material y métodos.** Se analizó la información dietética de Ensanut MC 2016 con y sin utilización de FRN. **Resultados.** En los nutrimentos evaluados, las prevalencias de inadecuación fueron superiores al 10% en todos los grupos de estudio. La no consideración de los FRN causó la subestimación en las prevalencias de inadecuación en un rango de 2% a 55.5%. **Conclusión.** Se documenta la relevancia de la aplicación de FRN para la adecuada estimación de las prevalencias de inadecuación en estudios poblacionales.

Palabras clave: metodología; estimación de la ingesta usual; factores de retención de nutrientes; recordatorio de 24 horas; micronutrientes; macronutrientes

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Several international groups have previously worked on the development and validation of instruments and methodologies to improve accuracy and reliability when collecting dietary information.^{1,2} However, other methodological aspects need to be considered, such as the use of dietary factors, particularly nutrient retention factors (NRFs), which improve accuracy in dietary intake estimations. In relation to NRFs, it is known that in order to appropriately estimate dietary intake, Food Composition Databases (FCDs) require information on food in both raw and cooked forms. However, in several FCDs, most food items are presented only in their raw form, with few food items in their cooked versions.³⁻⁶ Due to the above, NRFs, which account for the proportion in which a nutrient remains in the cooked form of the food in relation with the quantity in its raw form, have been developed for corrections in recipe calculations and nutrient estimates when using the raw form of cooked food items (in those cases in which such data are not available in the FCDs). Nevertheless, most studies do not clarify the source of their NRF compilations or whether these were considered in nutrient intake estimates.⁷⁻⁹ If not considered, they may represent an important source of overestimation in dietary intake estimates, especially for thermolabile vitamins (such as vitamin C, thiamin and folate, among others) and water-soluble minerals (such as zinc and magnesium).

Due to the above, the objective of this article was to estimate usual intake of selected vitamins and minerals by the Mexican population, as well as the prevalence of nutrient inadequacy and the potential effect that the nutrient retention factors may have on these estimates. Finally, this article also intends to document the methodology used in the analysis of the 24-hour dietary recall (24HR) of the mid-way National Health and Nutrition Survey 2016 (Ensanut MC 2016).

Materials and methods

Design and study population

The current study used dietary information from Ensanut MC 2016, a nationally representative probabilistic multistage stratified cluster survey of 29 795 individuals from 9 474 randomly selected households, constructed to make distinctions between urban and rural areas, as well as among four geographic regions.^{10,11} This survey was carried out between May and October 2016, including information for 24HR in a random subsample of ~15% of participants (n=4 341).

For this study, we included individuals with complete diet information, from which pregnant or lactating women (n=85) and preschool children (n=535) were

excluded, as were implausible values for main macronutrients and micronutrients (n=79; first dietary recall n=75; secondary dietary recall n=4). Our final sample included 3 646 individuals, of whom 1 081 were schoolchildren (aged 5-11 years; mean=8.51 years), 1 228 were teenagers (aged 12-19 years; mean=15.63 years), and 1 337 were adults (aged ≥20 years; mean=47.09 years).¹⁰ Around 8% of participants had a second dietary recall (3.98% of schoolchildren; 10.99% of teenagers; and 8.45% of adults) to estimate within-person variance estimates to adjust nutrient intake distributions¹² (figure 1).

The Research, Ethics and Biosafety Committees of the Mexican National Institute of Public Health (*Instituto Nacional de Salud Pública*, INSP) approved the protocol for Ensanut MC 2016. Written informed consent was obtained from all study participants aged ≥18 years, as well as from the father, mother, or guardian of participants under 18 years. Informed assent was also collected for children and adolescents between 5 and 17 years.

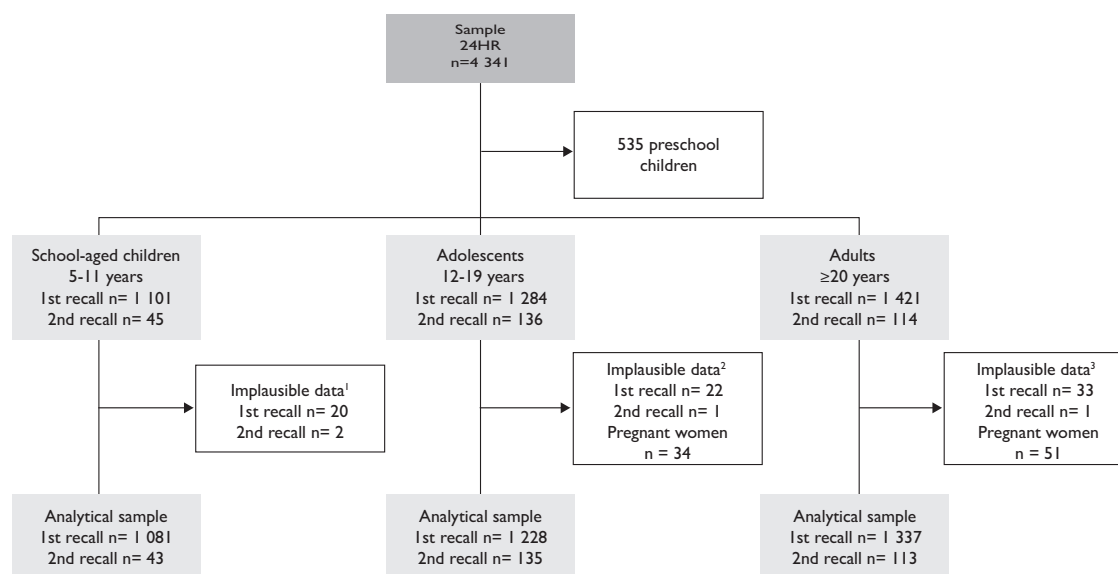
Diet information

A standardized 24HR was applied for data collection through an automated software* of an adapted version of the original method designed by the United States Department of Agriculture.¹³ This method was selected for capturing more accurate information from the interviewees through five iterative steps that complement each other in order to improve the memory in relation to food intake and thus, reduce underreporting. In Mexico, it is identified as the Automated Software utilized for the multiple-pass 24HR (MP-24HR). This method was complemented with information regarding the type of foods consumed (food preparations or food-items), place and activity while consuming the reported foods, cooking method applied, waste fractions, and whether food recipes were prepared at home or bought in a food stand, supermarket, restaurant or others. The information above is briefly described in figure 2; more details about the adapted method are described elsewhere.¹⁴ Previously trained and standardized personnel applied the MP-24HR.

Data editing and processing

Information obtained from the MP-24HR was edited and processed in four main phases that make up a series of iterative processes:

* Angulo Estrada JS, Espinosa Montero J, Gaytan Colin MA, González de Cossio Martínez T, González Romero J, Gutiérrez JP, et al. *Recor-datorio 24 horas de 5 pasos (R24H5)*. Programa de computación. Cuernavaca, Morelos: Instituto Nacional de Salud Pública, 2013.



1 Implausible values in energy, fiber and nutrients: energy=12, macronutrients=14, vitamins and minerals=8

2 Implausible values in energy, fiber and nutrients: energy=13, macronutrients=19, vitamins and minerals=7

3 Implausible values in energy, fiber and nutrients: energy=24, macronutrients=22, vitamins and minerals=9

FIGURE 1. ANALYTICAL SAMPLE OF THE 2016 ENSANUT MC 24-HOUR DIETARY RECALL (24HR)

Phase 1. Processing-review and correction of context information. Coding errors regarding mealtime and detailed food records were reviewed and corrected (steps 3 and 4 of figure 2). For step 3 of the multiple pass 24HR, the coding of mealtime, place and activity was verified. For the 24HR's step 4, regarding food details, information on reported foods and recipes was reviewed and corrected (such as: name coding, type of food, raw and net weights, portions prepared, leftovers, cooking methods, etc.) and when new foods were identified (foods not previously compiled in the food composition database), these were included, and their nutritional information was obtained and added to the Mexican Food Database (BAM, Spanish acronym). Coding errors in food items and preparations were also corrected (e.g. the quick list included "fried fish" with the type code 3, "standardized recipe", which is when the person didn't know in detail the preparation of the recipe; however, for some reason, the interviewer selected "raw fish" in the list catalogue). Those cases which were clearly errors were corrected by selecting the correct option from the list, in this case the "fried fish, standardized recipe" option. Inconsistencies for food details were also corrected when possible.

Phase 2. Processing - Estimation of grams of food consumed. Grams of food consumed were estimated based on a database with 14 types of household measures (such

as: small piece, medium piece, large piece, teaspoon, measuring cup, etc.) constructed from standardized measurements obtained in a field workshop with kitchen scales. Implausible values for each food-item in terms of grams consumed were identified according to a reference based on its specific distribution by age and sex. It is worth noting that this is an iterative process, so when implausible values were identified, information for those individuals was reviewed again in phase 1. Afterwards, the data were processed in four stages:

- 1) Processing - Imputation of grams of salt and condiments used in recipes. Since salt and seasoning measurement in the field is complex, our approach was through a workshop with trained nutritionists who measured the amounts of salt or condiments used in recipes frequently reported by the Mexican population. This information was used for imputation in recipes in general (in both disaggregated and standardized recipes).
- 2) Processing - Estimation of net grams consumed. For every food item reported in its raw weight (when applicable), the edible portion factor was multiplied to obtain net weights. For beverages, we applied density factors when necessary to convert their volume in milliliters into grams, using a food-matching approach based on the Food and Agri-

Steps	Description
1. Quick list	Unstructured design Main question: Can you tell me everything that you ate and drank yesterday, from the moment you woke up until you went to sleep? The interviewees provide a quick, unstructured list of all the food items consumed the day before, from the moment they woke up until they went to sleep, in the order that they remember it.
2. Commonly forgotten food items	Structured design Main question: In addition to what you already mentioned, did you drink or eat any of the following foods yesterday? (---Structured list is mentioned---) The previous list is complemented with another food list of commonly forgotten foods, grouped into a) alcoholic, non-alcoholic and energy drinks; b) snacks; c) cereal products (cookies, tortillas, bread, etc.); d) dressings; e) sweeteners.
3. Time and occasion (activities)	Structured design Main question: At what time did you consume each food or recipe? For each food or recipe, the following data are identified: 1) Meal Time (MT), defined as the time established by the interviewees, comprising a total of 14 MTs (four main meals such as breakfast, lunch, dinner and supper and 10 snacks). This section includes questions for every MT as to whether the foods were accompanied with other food items or drinks and if other ingredients were added. 2) Place of meal consumption: for each MT, the place where it was consumed (home, work, school, transport, restaurant, sports or recreational areas, or other) is identified. 3) Activities during meals: activities carried out during MT are identified, with eight main categories. Sections 2 and 3 allow the interviewee to remember other foods consumed.
4. Food detail cycle	Structured design Main question: Did you add any ingredients to (---name food in question---)? This step consists in identifying: 1) if it's a food or a recipe, 2) if the recipe was homemade or not, 3) type of food (drink or solid food), 4) food characteristics in relation to the food composition database, 5) grams used in standard measures or volume, 6) if its weight is in edible portion or not, 7) cooking method (raw, boiled, roasted, fried and baked), 8) food quantity served in plate, 9) food waste, 10) characteristics of bought foods (if it comes in packages, is processed or frozen).
5. Final probe	Unstructured design Information compiled in the final list is reviewed and additional details frequently forgotten in the recall of each MT are obtained. Also, specific information that was inadequately reported is corrected. Examples: identifying whether fried foods have fats or oils associated, whether desserts contain sweeteners, etc.

FIGURE 2. MULTIPLE-PASS 24-HOUR DIETARY RECALL DESCRIPTION (24HR), ADAPTED FOR MEXICO

culture Organization (FAO) and the international network of food data systems (INFOODS) density database, which was carried out by researchers from the INSP for the BAM.¹⁵

- 3) Cleaning information of grams of food consumed: Outliers in terms of grams of food consumed were defined and identified as >4 standard deviations above the average of each food-item, by age and sex. For outlier imputations, a random value between the 95-99th percentile was used (as in previous Ensanut), considering the characteristics of the food/recipe, mealtime, age group and sex,¹⁶ in order to keep those values in the upper tail of the

distribution, within plausible ranges. For missing data, imputations were made using the mean value according to the characteristics mentioned above. It is worth noting that, in all cases, ≤1% of observations were imputed.

Phase 3. Processing - Energy and nutrient estimations. Nutrient and energy estimations were carried out using the BAM—a compilation of the frequently consumed foods in the country—in its 18.1.1 version, made up of a total of 1978 foods, recipes, and beverages, being an indirect compilation from several food composition databases³⁻⁶ made for the Center for Nutrition and Health Research

of the INSP.* Additionally, in order to estimate potential nutrient losses by different cooking methods, we used an indirect compilation of NRFs made for BAM. For the NRF compilation, we mainly used the United States Department of Agriculture (USDA), Bergstrom's and Bognar's publications.¹⁷⁻¹⁹ In those cases where information was not available for reported food-items, we used the average value of the NRF compilation from the European Food Information Resource (EuroFIR), which is group-specific.²⁰ All the NRFs were applied at the ingredient level when the nutrient composition in the cooked version was not available, according to international recommendations made by EuroFIR.²¹ The NRFs used to adjust estimations of nutrient intake were for the following cooking methods: boiled, roasted, fried, baked, and stewed.

Phase 4. Energy and nutrient data cleaning. Regarding data editing, we prioritized nutrients identified as relevant based on the evidence in the area of nutrition in terms of their contents of dietary energy, fiber, carbohydrates, proteins, lipids, vitamin A, vitamin C, vitamin D, vitamin B12, iron, zinc and calcium. We added the energy, fiber, and nutrient content from foods/ingredients at individual level. For intake revision, we used as a reference for adequacy the equations developed by the Institute of Medicine (IOM), according to body mass index (BMI, normal weight, overweight or obese) and age group.²² The physical activity factor we considered for estimating energy requirements was light physical activity in school-aged children, adolescents and adult men; and in adult women, sedentary activity was considered (based on previous evidence of national surveys).¹⁴ For micronutrients, individual intake was divided by the estimated average requirement (EAR) of the Dietary Reference Intakes (DRI).²³⁻²⁶ For macronutrients, we used the ratio between individual intake contribution to dietary energy and the upper value of the acceptable contribution range (55% for carbohydrates and 30% for lipids). Finally, outliers were identified based on the ratio of each nutrient's intake to the average requirements for specific population groups. For both macro and micronutrients, based on each nutrient's ratio distribution, <-3 and >+3 standard deviation values were marked as outliers or implausible values by sex and age group, and these outliers were removed from analysis.

* Ramírez-Silva I, Barragán-Vázquez S, Rodríguez-Ramírez S, Rivera-Dommarco JÁ, Mejía-Rodríguez F, Barquera-Cervera S, Tolentino L, et al. Base de Alimentos de México (BAM): Compilación de la composición de los alimentos frecuentemente consumidos en el país. Versión 18.1.1. Disponible en: www.redpidieta.mx

Afterwards, a review of energy and nutrient estimates was carried out. When implausible values were identified, the case was revised again in phases 1 and 2 to correct the information. For the above, we reviewed the complete 24HR for selected cases, in order to search for possible errors in the estimations of grams of food consumed. This was done by comparing it to the energy and nutrient intake distributions according to the individual's age and sex. If errors in terms of grams of food consumed were identified, we proceeded to impute the food-specific mean value of intake by age and sex as described above.

On the other hand, in order to describe the effect of the use of NRFs, we selected the following micronutrients previously known to have varying degrees of loss due to cooking methods: vitamin A (μg of retinol equivalents), vitamin C (mg), vitamin D (international units), thiamin (mg), riboflavin (mg), niacin (mg), dietary folate equivalents (μDFE), vitamin B12 (μg), zinc (mg), calcium (mg) and magnesium (mg). Afterwards, using the methodology previously described, we estimated intakes of these micronutrients with and without NRFs. Values above 1.5 times the 99th percentile were imputed with a random value between the 95th and 99th percentiles, according to the individual's age and sex, as in the last Ensanut 2012.¹⁶

All the processes were performed using the Stata V.13.1 Software.*

Study variables

We estimated the usual dietary intake estimations with and without the application of NRF for vitamin A (μg of retinol equivalents), vitamin C (mg), vitamin D (international units), thiamin (mg), riboflavin (mg), niacin (mg), dietary folate equivalents (μDFE), vitamin B12 (μg), zinc (mg), calcium (mg), and magnesium (mg).

The prevalence of micronutrient inadequacy was calculated using as a reference the EARs cutoff from the DRIs for the nutrients mentioned above.²³⁻²⁶ We estimated the proportion of the population that was below the EAR for each specific vitamin and mineral by age group and sex, with and without NRFs.

Frequency of vitamin and mineral loss through cooking methods by food group

Average vitamin and mineral loss through cooking methods was calculated in order to provide information regarding the most affected food groups in the Ensanut

* StataCorp. 2011, College Station, TX: Stata Press.

MC 2016.* Food groups were obtained by selecting food items that represented 70% of those reported in Ensanut MC 2016. Selected foods were classified into 12 categories: vegetables, tubers, corn products, fish and seafood, cereals and breads, legumes, dairy products, fats and oils, fruits, cold meats, breakfast cereals, and meats and eggs. For each food group, frequency of reported cooking methods was obtained. Mean differences between estimated nutrient intake with and without NRFs were calculated and transformed into relative percentages for each nutrient.

Statistical analysis

The main characteristics of the study population were estimated considering the survey design, using the SVY module for complex samples of the Stata software V.13.1.

The usual intake of selected micronutrients was estimated by age groups, using the Iowa State University method,²⁷ through the PC-Side program version 1.0 (Iowa State University).[‡]

This method estimates the distribution of the usual intake of nutrients by removing the effect of intra-individual variability and leaving the variability of daily intake between individuals. Likewise, the inadequate prevalence of selected micronutrients was estimated with PC-Side using the age and sex specific EAR cutoffs of the IOM in two scenarios by age group: with and without NRFs.²²⁻²⁵ Because our age groups of interest differed from those of the EARs, we scaled the individual intake, as it has been previously described in terms of age and sex, in order to use a single cutoff within each group.²⁸ The scaling process consisted in selecting the group with the largest sample size within age and sex and scaling the individual intake for the rest of the groups. For example, in the adult group aged >20 years, there were two cutoffs for vitamin C according to sex, of which the group of females had a larger sample size; therefore, we selected the female cutoff and scaled the individual intake by males in order to be able to apply the same cutoff. The differences between groups (with and without NRFs) regarding mean usual intakes were analyzed with paired

T-test's; this was done using the Individual Usual Intakes obtained from PC-Side in Stata. Also, the differences in prevalence of nutrient inadequacy were calculated using the McNemar's test. P values <0.05 were considered statistically significant. All the statistical analyses were performed using the Stata software V.13.1.

Results

Our study population of the Ensanut MC 2016 included 3 646 participants with plausible 24HR information (figure 1), who together represented around 93.34 million Mexicans between the ages of 5-97 years, 51.15% of whom were female. Regarding geographic representation and general characteristics, most participants were from urban areas (74.94%), and approximately half lived in the Central region and in Mexico City (33.59%, Central region; 16.28%, Mexico City; 30.72%, South, and 19.41%, North). Most were adults (65.65% adults, 18.42% adolescents, and 15.92% school-aged children) and there was a slight overrepresentation of low socioeconomic status (49.12% with low vs. 29.53% with medium and 21.35% with high socioeconomic status).¹⁰

Usual intake

Significant differences were identified with respect to the mean usual intake of vitamins and minerals, based on the application of the NRFs (table I). For all age groups, differences in estimated usual intakes with and without NRFs were small for some nutrients, such as minerals, with differences ranging from 0.5% for calcium up to 2.9% for magnesium. However, differences in the usual intake of vitamins were relevant, ranging from 1.55% for vitamin D to 14% for folate and 34.4% for B12 (table I). By age group, differences in the usual intake of vitamins and minerals were similar to those mentioned above.

Prevalence of nutrient inadequacies

Two out of three school children had a lower calcium intake than recommended, and approximately one out of three had a lower intake of vitamin A. The prevalence of inadequacy (with NRFs) for other nutrients in school children ranged from 4.4 (thiamin) to 71.2% (calcium) and 100% (vitamin D). In adolescents, nutrients with the highest prevalence of inadequacy (with NRFs) –excluding vitamin D– were calcium, vitamin A and magnesium, followed by vitamin B12, folate, vitamin C, riboflavin, and thiamin. Adults had the highest prevalence of inadequacy (with NRFs) for most nutrients. All age groups had a vitamin D inadequacy of 100% (table II).

* Ramírez-Silva I, Rodríguez-Ramírez S, Barragán-Vázquez S, Castellanos A, Reyes-García A, Martínez-Piña A, *et al.* Prevalence of inadequate intake of vitamins and minerals in the Mexican population correcting by nutrient retention factors, ENSANUT 2016. Supplementary material. Figshare. Dataset. 2020. <https://doi.org/10.6084/m9.figshare.12328193>

‡ Department of Statistics. Center for Agricultural and Rural Development. Software for intake distribution estimation (PC-Side) version 1.02 [Internet]. Ames: Iowa State University, 2003. Available from: <http://www.side.stat.iastate.edu/pc-side.php>

Table I
USUAL INTAKE OF VITAMINS AND MINERALS AMONG THE MEXICAN POPULATION,
BY AGE GROUP AND USE OF NUTRIENT RETENTION FACTORS, 2016

Nutrient	Without NRF Mean ± SD	With NRF Mean ± SD	Nutrient	Without NRF Mean ± SD	With NRF Mean ± SD
School children			Adults		
Energy (Kcal)	1 761 ± 47		Energy (Kcal)	1 908 ± 54	
Calcium (mg)	829.3 ± 329.8	822.5 ± 315.4*	Calcium (mg)	823.7 ± 270.8	818.3 ± 271.2*
Magnesium (mg)	295.8 ± 75.9	287.2 ± 72.8*	Magnesium (mg)	365.7 ± 83.4	355.2 ± 83.4*
Zinc (mg)	9.0 ± 3.0	8.9 ± 2.9*	Zinc (mg)	8.7 ± 3.2	8.6 ± 3.2*
Vitamin A RAE (µg)	483.8 ± 68.0	469.6 ± 69.5*	Vitamin A RAE (µg)	592.7 ± 472.9	568.7 ± 438.5*
Vitamin C (mg)	77.9 ± 28.3	73.7 ± 29.8*	Vitamin C (mg)	105.0 ± 72.8	99.2 ± 71.4*
Vitamin D (IU)	123.0 ± 59.6	120.9 ± 55.6*	Vitamin D (IU)	96.5 ± 47.9	95.0 ± 54.1*
Thiamin (mg)	1.2 ± 0.4	1.1 ± 0.3*	Thiamin (mg)	1.3 ± 0.4	1.18 ± 0.40*
Niacin (mg)	14.2 ± 5.4	12.9 ± 4.9*	Niacin (mg)	15.5 ± 6.0	14.3 ± 5.8*
Riboflavin (mg)	1.5 ± 0.6	1.5 ± 0.6*	Riboflavin (mg)	1.4 ± 0.6	1.3 ± 0.6*
Folate DFE (µg)	574.6 ± 269.4	526.1 ± 275.8*	Folate DFE (µg)	561.5 ± 295.6	488.1 ± 325.5*
Vitamin B12 (µg)	3.66 ± 1.83	3.12 ± 1.79*	Vitamin B12 (µg)	2.6 ± 1.7	2.3 ± 1.6*
Adolescents			All age groups		
Energy (Kcal)	2 184.1 ± 64		Energy (Kcal)	1 903 ± 602	
Calcium (mg)	913.1 ± 434.2	909.0 ± 436.5*	Calcium (mg)	834.0 ± 336.6	829.5 ± 336.2*
Magnesium (mg)	367.2 ± 143.5	357.1 ± 143.6*	Magnesium (mg)	350.2 ± 118.2	340.06 ± 116.5*
Zinc (mg)	11.0 ± 2.8	10.9 ± 3.0*	Zinc (mg)	9.0 ± 3.4	8.9 ± 3.4*
Vitamin A RAE (µg)	468.1 ± 247.8	455.2 ± 247.5*	Vitamin A RAE (µg)	553.1 ± 352.3	533.2 ± 327.7*
Vitamin C (mg)	113.6 ± 69.8	104.4 ± 66.1*	Vitamin C (mg)	102.6 ± 67.4	96.8 ± 65.1*
Vitamin D (IU)	124.3 ± 59.6	120.2 ± 59.7*	Vitamin D (IU)	104.9 ± 48.7	100.6 ± 46.9*
Thiamin (mg)	1.4 ± 0.5	1.3 ± 0.5*	Thiamin (mg)	1.3 ± 0.5	1.1798 ± 0.5*
Niacin (mg)	17.3 ± 6.0	15.868 ± 5.6*	Niacin (mg)	15.3 ± 6.5	14.1 ± 6.2*
Riboflavin (mg)	1.5 ± 0.7	1.5 ± 0.7*	Riboflavin (mg)	1.4 ± 0.7	1.4 ± 0.7*
Folate DFE (µg)	603.4 ± 391.5	547.0 ± 356.3*	Folate DFE (µg)	566.7 ± 377.9	497.1 ± 375.0*
Vitamin B12 (µg)	3.2 ± 1.4	2.1 ± 1.4*	Vitamin B12 (µg)	2.7 ± 1.8	2.4 ± 1.7*

NRF: nutrient retention factors
 DFE: dietary folate equivalents

RAE: retinol active equivalents
 SD: standard deviation

IU: international units
 *p<0.05

Regarding the prevalence of nutrient inadequacies with and without NRFs by age groups, we identified that, as with the usual intake estimations, the differences were small for some nutrients such as calcium, zinc, vitamin A and D. For vitamin C and magnesium, the differences were approximately 3-6%. Thiamin, niacin, vitamin B12 and folate were the most affected nutrients, with differences of up to 55.5% in the prevalence of inadequacy. Globally, the prevalence of nutrient inadequacies was underestimated when NRFs were not applied, with all differences being statistically significant except for vitamin D (table II).

Percent nutrient loss per food group

The intake of vitamins and minerals depends in part on the amount of food consumed, but it also depends on the way the food item is cooked. Figure 3A shows the proportion of cooking methods reported in the preparation of some of the main food items of the Ensanut MC 2016: 73% of vegetables, 96% of tubers, 94.7% of meats and eggs, 89% of fish and shellfish, 84% of legumes, 58% of sausages, and 43% of breakfast cereals were consumed in a cooked form (boiled, roasted, fried or baked). Figure 3B shows the average percentage of nutrient loss for some

Table II
PREVALENCE OF INADEQUATE INTAKE OF VITAMINS
AND MINERALS AMONG THE MEXICAN POPULATION
BY AGE GROUP AND USE OF NUTRIENT RETENTION
FACTORS, 2016

Nutrient	Without NRF % I ± SE	With NRF % I ± SE
School children		
Calcium (mg)	70.7 ± 0.05	71.2 ± 0.05*
Magnesium (mg)	4.21 ± 0.04	5.0 ± 0.04*
Zinc (mg)	12.3 ± 0.09	12.5 ± 0.1*
Vitamin A RAE (μg)	28.6 ± 0.1	29.00 ± 0.16*
Vitamin C (mg)	8.51 ± 0.11	11.35 ± 0.11*
Vitamin D (IU)	100 ± 0	100 ± 0
Thiamin (mg)	2.6 ± 0.04	4.4 ± 0.1*
Niacin (mg)	8.8 ± 0.1	12.5 ± 0.1*
Riboflavin (mg)	4.56 ± 0.05	5.6 ± 0.06*
Folate DFE (μg)	3.3 ± 0.07	7.92 ± 0.10*
Vitamin B12 (μg)	8.0 ± 0.102	13.12 ± 0.097*
Adolescents		
Calcium (mg)	72.9 ± 0.02	73.5 ± 0.02*
Magnesium (mg)	32.58 ± 0.02	35.9 ± 0.02*
Zinc (mg)	11.7 ± 0.1	11.7 ± 0.1*
Vitamin A RAE (μg)	65.7 ± 0.03	67.49 ± 0.03*
Vitamin C (mg)	19.18 ± 0.07	23.81 ± 0.06*
Vitamin D (IU)	100 ± 0	100 ± 0
Thiamin (mg)	13.8 ± 0.04	20.7 ± 0.04*
Niacin (mg)	12.3 ± 0.07	18.6 ± 0.1*
Riboflavin (mg)	20.89 ± 0.03	23.38 ± 0.03*
Folate DFE (μg)	19.3 ± 0.04	25.07 ± 0.04*
Vitamin B12 (μg)	17.4 ± 0.06	26.2 ± 0.05*
Adults		
Calcium (mg)	57.2 ± 0.02	58.0 ± 0.02*
Magnesium (mg)	16.37 ± 0.16	23.16 ± 0.12*
Zinc (mg)	46.0 ± 0.02	48.2 ± 0.02*
Vitamin A RAE (μg)	59.1 ± 0.02	60.68 ± 0.02*
Vitamin C (mg)	36.78 ± 0.03	40.88 ± 0.02*
Vitamin D (IU)	100 ± 0	100 ± 0
Thiamin (mg)	16.1 ± 0.06	28.8 ± 0.04*
Niacin (mg)	26.3 ± 0.05	35.2 ± 0.03*
Riboflavin (mg)	30.16 ± 0.03	33.49 ± 0.02*
Folate DFE (μg)	15.45 ± 0.1	32.47 ± 0.05*
Vitamin B12 (μg)	45.0 ± 0.01	51.0 ± 0.01*

NRF: nutrient retention factors

IU: International Units

%I: inadequacy prevalence

*p<0.05

RAE: retinol active equivalents

DFE: dietary folate equivalents

SE: standard error

food groups, identifying vegetables, meats and eggs, fish and seafood and legumes as the most affected groups.

Discussion

We identified a high prevalence of inadequate intake of minerals and vitamins in the Mexican population, in some cases above 10%, in the various study groups. In the different groups analyzed, the highest prevalence of inadequacy was found for calcium, vitamin A and vitamin D. Likewise, adolescents had the highest prevalence of inadequacy for magnesium, while adults had it for vitamin C, vitamin B12 and zinc. Additionally, when NRFs were not applied, the inadequacy prevalence (ranging from 2% to 55.5%) was significantly underestimated, particularly for folate, vitamin B12, vitamin C, magnesium, thiamin, niacin. Also, we documented the procedures used for estimating the dietary intake in the Mexican population of the Ensanut 2016.

Comparing these findings with those of other studies in Mexico (without NRFs), we identified that the prevalence of inadequacy in 2016 was higher in the different age groups analyzed for most vitamins and minerals than that documented by the Ensanut 2012 (for both males and females).^{16,28} The highest difference in inadequacy prevalence in mineral intake observed between 2012 and 2016 was identified in adults (-16.2 to 38%), followed by adolescents (-14.6 to 2.2%) and school-aged children (1.1 to 8.5%).^{16,28,29} However, the highest prevalence difference was observed for zinc in adults, with a difference of 38%.²⁸ Regarding vitamin inadequacies, adults had the greatest prevalence differences (ranging from -36.13 to 28.8%), followed by adolescents (-40.53 to 19.79%) and school-aged children (-16.0 to 13.2%).¹⁶ Nonetheless, it is worth noting that in folate we observed a lower prevalence of inadequacy with respect to the Ensanut 2012.

The above is probably due to the facts that the food composition database was updated and the NRFs were not applied in the Ensanut 2012. This is also consistent with the folate inadequacies reported by Orjuela and colleagues for the Ensanut 2012 after corrections were made to the food composition database; the inadequacies were considerably lower than those originally reported (approximately 4-11.5% in school children, 4.8 to 32.7% in adolescents, and 9.9 to 28.6% in adults).³⁰ Also, with respect to other nutrients, in recent years the availability and accessibility of processed and ultra-processed foods has increased; most of these are high in energy density and low in nutrients and have displaced natural foods with high nutritional value, such as fruits and vegetables.^{31,32}

Calcium and vitamin D were the nutrients with the highest prevalence of inadequacy across all age groups.

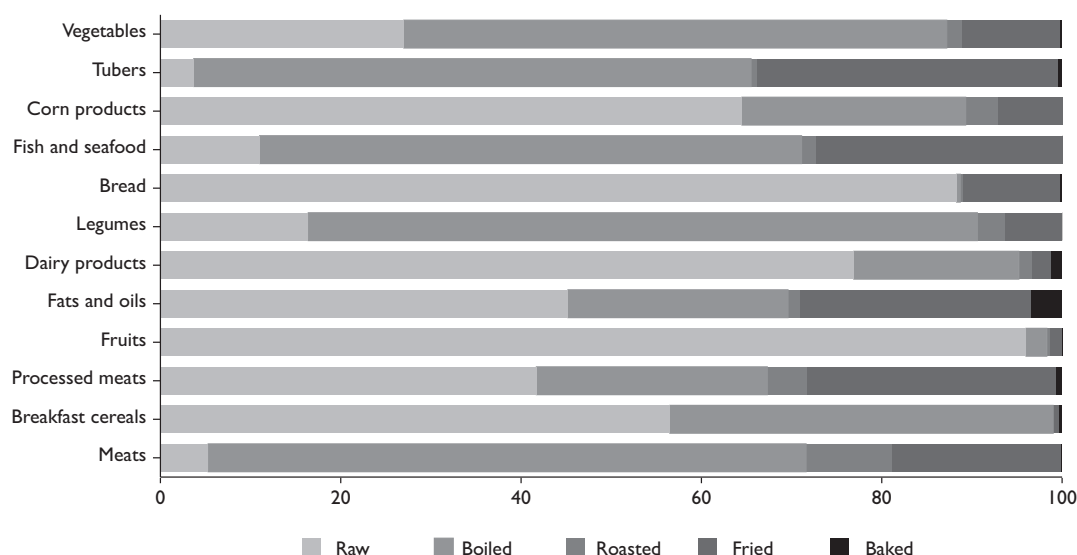


FIGURE 3A. PROPORTION OF COOKING METHODS USED FOR THE MAIN FOOD GROUPS BY THE MEXICAN POPULATION

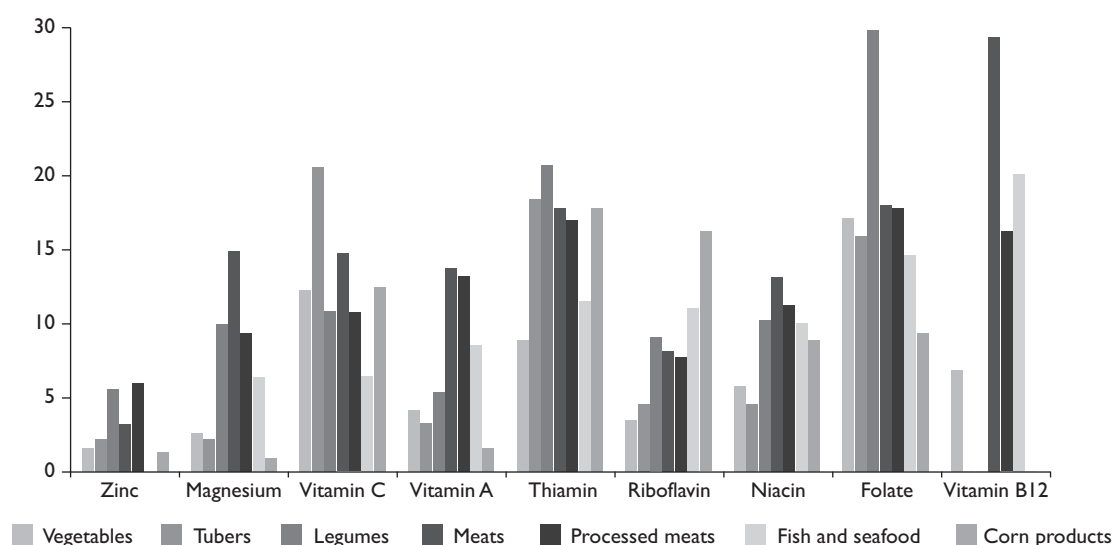


FIGURE 3B. PERCENTAGE OF MEAN VITAMIN AND MINERAL LOSS IN MAIN FOOD GROUPS BY COOKING METHOD AMONG THE MEXICAN POPULATION

However, estimates for vitamin D should be taken with caution, since the synthesis in the skin by sun exposure is another important source. For instance, Flores and colleagues documented, through 25-hydroxyvitamin D concentrations (<50 nmol/L), that 36.6% of schoolchildren, 8% of adolescents and 9.8% of adults in Mexico had vitamin D deficiency.^{33,34}

Moreover, we observed a relatively high prevalence of inadequacy in vitamin A and zinc intake as well. In this regard, almost 50% of Mexican adults in 2016 had an inadequate intake. Finally, prevalence of inadequacy

for the intake of vitamin C, folate and other B group vitamins was particularly relevant among adolescents and adults.

Regarding the potential limitations of this study, the within-person variability was adjusted with information from <10% of participants for adults and school-aged children. However, we also estimated results using the nutrient-specific intra-individual variability coefficients of the Ensanut 2012 by age group and found no significant differences; we also identified that the intra-individual variabilities in 2012 and 2016 were highly

comparable. Therefore, failure to consider the original variability adjustment for 2016 would have derived in greater measurement error.¹²

Also, vitamin and mineral supplements were not considered, and therefore, nutrient intake may be underestimated. Although there is no information about the proportion of Mexicans that consumed supplements in 2016, it is expected to be similar to that reported in the 2012 survey, which was ranged between 8.3% and 16.7%.³⁵ However, the potential contribution of these supplements to nutrient intake is unknown. The fact that there is no direct compilation of NRFs in Mexican foods constitutes a limitation for the NRF analysis. Also, we were not able to find a suitable NRF match for approximately 16.1% of the foods reported. Although most foods with missing NRFs were not relevant in terms of their contribution to micronutrient intake (e.g. pork rind, *acociles*, sugar, chocolate, mustard, condiments, and *mole*). In general, it is worth noting that information of NRFs is still limited; however, not considering them could lead to a greater measurement error.

It should be noted that NRFs take into consideration mainly the variables of heat and surrounding medium (i.e. diffusion into cooking water or into fats). Vitamin losses are also due to pH conditions and to oxygen, which are hard to quantify in population studies (at both the collection of dietary information and the bromatological analysis levels). However, minerals tend to be more stable to pH and oxygen, their main losses being due to blanching and to diffusion into cooking water.¹⁸ Nonetheless, this information is still not available for estimation in food intake.

The strengths of this study include the fact that it is one of the first to document the potential impact of the use of NRFs in the prevalence of nutrient inadequacy in a population study. Another important aspect is that our estimates on the distributions of usual intake were adjusted considering within-person variability using the PC-SIDE software, and that the findings are derived from a probabilistic survey representative of the Mexican population. Although the use of NRFs is expected to be included as part of the diet estimation methodology, few dietary studies describe their application.^{36,37} A large proportion of food items are cooked for human consumption; however, most food composition databases provide nutritional information only on their raw forms. Experimental studies in this area have shown that the analytical calculation compared to the indirect calculation through NRFs has a high correlation.¹⁸ Given the above and the findings of this study, the use of NRFs is recommended in order to adequately identify population groups at risk of inadequate nutrient intake. Also, it is important to report the use of NRFs (or to clarify

that they were not used, as is the case of some previous studies) in the dietary information methodology for identifying potential limitations and the reliability of reported intakes.^{10,28}

In sum, a high prevalence of nutrient inadequacy in the Mexican population was identified in all age groups for most nutrients analyzed, identifying a possible detriment in diet quality. Likewise, the methodology for the analysis of the 24HR from mid-way Ensanut 2016 was documented, as was the relevance of the application of NRFs in dietary intake estimations for identifying population groups at risk of inadequate nutrient intake, especially for thiamin, niacin, riboflavin, vitamin C, B12 and folate. These findings provides relevant information for designing nutrition and health policies in Mexico.

Declaration of conflict of interests. The authors declare that they have no conflict of interests.

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