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Article

Dietary Sodium and Potassium Intake: Data from the Mexican National Health and Nutrition Survey 2016

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Abstract:
Population studies have demonstrated an association between sodium (Na) and potassium (K) intake and levels of blood pressure (BP) and cholesterol. The aim of this study was to describe the dietary intake and distribution of Na and K in Mexicans, and their association with metabolic risk outcomes. We analyzed a national survey that included 4,219 participants. Dietary information was obtained through a 24-hour recall. Foods and beverages were classified based on the degree of processing. BP and biomarkers in blood and urine were measured. The mean intake (mg/d) of Na was 1512 in pre-schoolchildren, 2844 in schoolchildren, 3743 in adolescents, and 3132 in adults. The mean intake of K was 1616 in pre-schoolchildren, 2256 in schoolchildren, 2967 in adolescents, and 3401 in adults. Processed and ultra-processed foods (UPF) contribute to sodium intake: 49% in preschool and schoolchildren, 47% in adolescents, and 39% in adults. Adults in the fourth quartile of sodium intake had lower serum concentrations of cholesterol (181.4 mg/dL) and HDL-c (35.5 mg/dL). The Mexican population has high Na and low K intakes. There is a relationship between Na sodium consumption and cholesterol, and LDL levels. UPF contributes to almost 40% of the sodium consumed by Mexicans.

Keywords: Sodium, potassium, national survey, Mexico

1. Introduction

Sodium (Na) and Potassium (K) are essential minerals for human homeostasis because they help maintain osmotic balance [1]. In the plasma membrane of cells, Na and K move against concentration gradients through constant pumping of Na-K ATPase. This ion exchange regulates cell volume and maintains homeostasis of tissues and organs [2].

Population studies have demonstrated an association between high dietary Na intake and high blood pressure (BP) [3], reduced renal function [4] and metabolic disorders [5]. Conversely, a low Na intake can lower BP in people who are sensitive to salt, increase the vascular insulin resistance, and improve blood levels of cholesterol and triglycerides [6].

The Institute of Medicine (IOM) established a maximum tolerable intake level (UL) of Na of 2.3 g / day [7], while the World Health Organization (WHO) recommends not exceeding 2 g / day [8]. Both organizations suggest that consuming less than these amounts is unlikely to cause adverse health effects for most people in the general population [9]. In a cohort conducted in Mexicans, the mean Na intake was 3.5 g/day [10]. In a study that examined sodium levels in 14 Latin American and Caribbean countries that included Mexico, the main dietary sources of Na were meat and processed meats, ready-to-eat cereals, yogurt and milk-based drinks, seasonings, and salty snacks [11].

The NOVA classification classifies foods according to the degree of their processing [12]. Processed and ultra-processed foods (UPF) are characterized by containing high amounts of Na [12]. According to the Centers for Disease Control and Prevention (CDC), up to 40% of daily sodium intake comes from UPF [13]. In Mexico, the purchase of these foods has increased during the last decades [14]; however, the contribution of these foods to daily sodium intake is unknown.

On the other hand, an increase in K intake has beneficial effects on cardiovascular health outcomes, such as lower BP and lower risk of renal disease [6,15]. However, K is among the four most common deficient nutrients in the diet [10,16], and an adequate intake (at least 3.5 g/day) [7,8] has been regarded as a protective factor against high BP and kidney failure [17]. In contrast, a low intake of K increases deleterious effect of Na on BP [18].

Adult K intake was found to be low (1.9 g/d) in a cohort based in Mexico City [10]. The WHO highlights the importance of implementing a surveillance system to measure and evaluate the patterns of salt consumption, as well as identify the main sources of Na consumption in the population, since this can inform the development of programs aimed at reducing Na consumption [19]. The effects of high sodium and low potassium intake on cardiovascular disease (CVD) are synergic, so the Na–K ratio may be a strong indicator for cardiovascular health outcomes [20,21]. The current evidence indicates that a ratio greater than 1.0 between Na and K results in an increase in BP [22].

In Mexico, the consumption of Na and K, as well as their food sources, have not been reported with nationally representative data. Therefore, the aim of this study was to describe the dietary intake and main food sources of Na and K in participants of the Mexican National Health and Nutrition Survey 2016 (ENSANUT-2016). A secondary objective was to describe the intake distribution of dietary Na and K in the Mexican population according to the NOVA classification. A third objective was to describe the association between Na and K intake with metabolic risk outcomes in adults.

2. Materials and Methods

2.1 Design and study population.

This cross-sectional study used data from the ENSANUT-2016, which is a probabilistic survey with national, regional (North, Center, Mexico City and South), and urban (with ≥2,500 inhabitants) and rural (<2,500 inhabitants) strata representativeness. The main objective of ENSANUT-2016 was to quantify the frequency and distribution of health and nutrition conditions in the Mexican population, as well as associated risk factors. The period of data collection was between May and October 2016. Details of the design, sampling size calculation, and methodology of this survey have been previously described elsewhere [23].

2.2 Estimating total sodium and potassium intake

Dietary information was obtained from a subsample of ≈26% participants of ENSANUT-2016. It included 4,305 subjects, of which 535 were pre-school children (1 to <5 years), 1,101 were school-age children (5 to <12 years), 1,284 were adolescents (12 to <20 years), and 1,421 were adults (> 20 years).

Trained interviewers obtained a multiple-pass 24-hour recall [24]. The recall was collected between Monday and Sunday to capture the intake variability between weekdays and weekends. Participants, particularly those younger than 15 years old, were assisted by the person who cooked and prepared their meals in the household. Those participants with extreme energy intake (outside three standard deviations of the log of energy intake-to-energy requirement ratio), were excluded from the study, as well as pregnant, lactating females, and all males ≥1 years old (n= 184) [25]. Energy and nutrient intakes were estimated using the Mexican Food Database (BAM for its Spanish acronym, version 1.1) [26].

Participants reported their dietary intake from the previous days as individual foods, custom recipes (individual ingredients that make up the recipe), and standard recipes (sets of default ingredients that make up a recipe when the informer was not able to provide one). For the present analysis, food recipes were disaggregated into their ingredients. The ENSANUT-2016 dataset does not include Na from salt added at the table but does include Na from salt used in preparations.

We classified all foods and beverages that were reported into 36 groups according to their nutritional profile; if they were frequently consumed by the population, these were considered in a single group (for example, tortilla). The groups are shown in supplementary table 1. We calculated the total Na and K intake and the contribution (percentage of total Na/k intake) of each food group, meal times, and ratio of sodium to potassium intake (sodium: potassium).

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Table 1. Sodium and potassium intake by sociodemographic characteristics and BMI in Mexican population. ENSANUT 2016.

	Pre-Schoolchildren		Schoolchildren		Adolescents		Adults	
	n= 528	N= 8,584,831	n= 1095	N= 16,144,480	n= 1240	N= 23,988,992	n= 1356	N= 87,921,191
	Mean (SE)	**95% CI**	**Mean (SE)**	**95% CI**	**Mean (SE)**	**95% CI**	**Mean (SE)**	**95% CI**
Total (n= 4,219; N=136,639,494)								
Sodium intake (mg/day)	1512.2 ± 68.6	(1377.1, 1647.2)	**2843.8 ± 236.1**	**(2379.0, 3308.6)**	**3743.2 ± 304.2**	**(3144.4, 4341.9)**	**3132.3 ± 171.9**	**(2794.0, 3470.7)**
Potassium intake (mg/day)	1615.7 ± 68.6	(1480.6, 1750.7)	**2255.7 ± 136.5**	**(1986.9, 2524.5)**	**2966.6 ± 180.3**	**(2611.7, 3321.5)**	**3400.6 ± 273.5**	**(2862.1, 3939.0)**
Na/K ratio	1.1 ± 0.1	(0.9, 1.2)	**1.4 ± 0.1**	**(1.1, 1.7)**	**1.3 ± 0.0**	**(1.3, 1.4)**	1.1 ± 0.0	(1.0, 1.2)
Sex								
Women (n= 2,312; N=72,673,426)								
Sodium intake (mg/day)	1494.8 ± 95.6	(1306.7, 1682.9)	2817.2 ± 425.6	(1979.5, 3655.0)	3286.6 ± 240.2	(2813.8, 3759.5)	2927.9 ± 217.2	(2500.3, 3355.5)
Potassium intake (mg/day)	1594.4 ± 93.0	(1411.3, 1777.6)	2052.2 ± 77.6	(1899.4, 2205.1)	2560.6 ± 138.5	(2288.0, 2833.1)	3250.5 ± 427.4	(2409.1, 4091.9)
Na/K ratio	1.0 ± 0.1	(0.9, 1.1)	1.6 ± 0.3	(1.0, 2.2)	1.4 ± 0.1	(1.2, 1.5)	1.1 ± 0.1	(1.0, 1.2)
Men (n=1,907; N=63,966,069)								
Sodium intake (mg/day)	1528.6 ± 109.7	(1312.5, 1744.6)	2867.2 ± 253.4	(2368.3, 3366.1)	4236.6 ± 567.5	(3119.5, 5353.7)	3383.7 ± 257.2	(2877.3, 3890.1)
Potassium intake (mg/day)	1635.8 ± 96.6	(1445.6, 1826.0)	2434.6 ± 236.4	(1969.2, 2900.0)	**3405.5 ± 329.3**	**(2757.1, 4053.9)**	3585.0 ± 325.7	(2943.7, 4226.3)
Na/K ratio	1.1 ± 0.1	(0.9, 1.4)	1.3 ± 0.1	(1.2, 1.4)	1.3 ± 0.1	(1.2, 1.5)	1.1 ± 0.1	(1.0, 1.2)
Area of residence								
Rural (n=2,227; N=37,106,754)								
Sodium intake (mg/day)	1439.1 ± 107.6	(1225.8, 1652.3)	2515.5 ± 243.5	(2032.9, 2998.1)	3498.7 ± 202.9	(3096.6, 3900.8)	3133.7 ± 375.8	(2389.0, 3878.5)
Potassium intake (mg/day)	1552.4 ± 100.4	(1353.5, 1751.3)	2193.2 ± 125.1	(1945.2, 2441.1)	2817.7 ± 135.3	(2549.5, 3085.9)	3626.9 ± 452.4	(2730.3, 4523.5)
Na/K ratio	1.0 ± 0.1	(0.9, 1.1)	1.3 ± 0.1	(1.1, 1.5)	1.3 ± 0.1	(1.2, 1.4)	1.0 ± 0.1	(0.9, 1.2)
Urban (n= 1,992; N=99,532,740)								
Sodium intake (mg/day)	1538.7 ± 84.6	(1371.7, 1705.7)	2978.9 ± 317.6	(2352.0, 3605.9)	3824.4 ± 398.5	(3037.9, 4610.9)	3131.8 ± 189.5	(2757.7, 3505.9)
Potassium intake (mg/day)	1638.7 ± 85.9	(1469.0, 1808.3)	2281.4 ± 185.6	(1915.1, 2647.7)	3016.1 ± 233.3	(2555.6, 3476.6)	3314.9 ± 337.7	(2648.4, 3981.5)
Na/K ratio	1.1 ± 0.1	(0.9, 1.3)	1.5 ± 0.2	(1.1, 1.9)	1.4 ± 0.1	(1.2, 1.5)	1.1 ± 0.1	(1.0, 1.2)
Socioeconomic Tertile								
Low (n=1,464; N=31,441,350)								
Sodium intake (mg/day)	1388.4 ± 112.4	(1166.7, 1610.2)	2368.8 ± 201.1	(1972.1, 2765.5)	2896.1 ± 144.7	(2610.7, 3181.6)	2854.5 ± 278.6	(2304.9, 3404.2)

Potassium intake (mg/day)	1483.7 ± 101.0	(1284.4, 1683.0)	2163.3 ± 250.4	(1669.3, 2657.3)	2701.7 ± 134.7	(2436.1, 2967.4)	3283.7 ± 261.1	(2768.6, 3798.8)
Na/K ratio	1.0 ± 0.1	(0.9, 1.2)	1.3 ± 0.1	(1.1, 1.4)	1.2 ± 0.0	(1.1, 1.3)	1.0 ± 0.1	(0.8, 1.1)
Medium (n=1,516; N=40,785,812)								
Sodium intake (mg/day)	1448.3 ± 108.6	(1234.3, 1662.2)	2958.1 ± 574.0	(1827.6, 4088.7)	4324.4 ± 772.5	(2802.8, 5846.0)	3264.8 ± 379.6	(2517.0, 4012.6)
Potassium intake (mg/day)	1637.2 ± 118.2	(1404.3, 1870.1)	1982.8 ± 116.5	(1753.3, 2212.4)	3423.6 ± 445.3	(2546.4, 4300.8)	3450.6 ± 486.4	(2492.6, 4408.7)
Na/K ratio	1.1 ± 0.2	(0.8, 1.4)	1.7 ± 0.4	(0.9, 2.5)	1.3 ± 0.1	(1.1, 1.5)	1.2 ± 0.1	(1.0, 1.3)
High (n=1,239; N=64,412,333)								
Sodium intake (mg/day)	1684.5 ± 126.3	(1435.7, 1933.3)	3053.3 ± 313.5	(2435.7, 3670.9)	**3707.6 ± 271.0**	**(3173.6, 4241.5)**	3186.0 ± 216.4	(2759.6, 3612.4)
Potassium intake (mg/day)	1692.7 ± 123.8	(1448.7, 1936.6)	2546.4 ± 264.9	(2024.6, 3068.3)	2745.9 ± 132.0	(2485.8, 3005.9)	3426.1 ± 463.0	(2513.8, 4338.4)
Na/K ratio	1.1 ± 0.1	(1.0, 1.3)	1.3 ± 0.1	(1.1, 1.4)	**1.5 ± 0.1**	**(1.3, 1.6)**	1.1 ± 0.1	(1.0, 1.3)
Body Mass Index [a]								
Normal (n=2,277; N=49,562,419)								
Sodium intake (mg/day)	1477.9 ± 70.7	(1338.6, 1617.1)	2533.5 ± 327.7	(1888.3, 3178.7)	2894.7 ± 121.6	(2655.2, 3134.1)	2898.6 ± 234.6	(2436.6, 3360.5)
Potassium intake (mg/day)	1576.3 ± 73.3	(1431.9, 1720.6)	1878.3 ± 77.0	(1726.8, 2029.9)	2380.0 ± 93.7	(2195.5, 2564.5)	3072.9 ± 285.5	(2510.8, 3635.0)
Na/K ratio	1.1 ± 0.1	(0.9, 1.2)	1.5 ± 0.2	(1.1, 1.9)	1.4 ± 0.1	(1.2, 1.5)	1.1 ± 0.1	(0.9, 1.3)
Overweight (n=949; N=35,937,427)								
Sodium intake (mg/day)	**1097.8 ± 128.3**	**(845.2, 1350.4)**	2376.3 ± 139.2	(2102.2, 2650.4)	2856.8 ± 138.7	(2583.6, 3129.9)	3110.9 ± 318.0	(2484.5, 3737.3)
Potassium intake (mg/day)	**1064.5 ± 153.1**	**(762.9, 1366.1)**	2103.3 ± 106.4	(1893.7, 2312.9)	2188.1 ± 108.7	(1973.9, 2402.2)	3163.4 ± 400.8	(2374.1, 3952.7)
Na/K ratio	1.1 ± 0.1	(0.8, 1.3)	1.2 ± 0.1	(1.1, 1.4)	1.4 ± 0.1	(1.3, 1.5)	1.1 ± 0.1	(1.0, 1.3)
Obesity (n=840 N=42,639,888)								
Sodium intake (mg/day)	**2194.8 ± 254.5**	**(1693.5, 2696.2)**	2720.2 ± 224.5	(2277.9, 3162.5)	3359.6 ± 375.0	(2620.7, 4098.4)	3287.1 ± 257.1	(2780.5, 3793.6)
Potassium intake (mg/day)	**2102.1 ± 131.4**	**(1843.1, 2361.0)**	2095.6 ± 168.8	(1763.1, 2428.1)	2653.8 ± 252.6	(2156.2, 3151.5)	3786.6 ± 511.3	(2779.3, 4793.9)
Na/K ratio	1.1 ± 0.2	(0.8, 1.5)	1.5 ± 0.1	(1.2, 1.7)	1.3 ± 0.2	(1.0, 1.6)	1.0 ± 0.1	(0.9, 1.2)

Bold numbers means statistically significant difference vs reference category ($p < 0.05$).
The reference category is the first row of each variable, except for the first variable where it is the first column.
a Body mass index (BMI): <25 kg/m2 (normal); 25-29.9 kg/m2 (overweight); ≥30 kg/m2 (obesity). For those under 19 years of age, the BMI for age was used according to the WHO child growth patterns.

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2.3 Food Classification Based on the Degree of Processing

Based on the NOVA food framework, foods and beverages reported in the 24HR interview were classified as: 1) unprocessed or minimally processed foods (those obtained directly from nature or altered in ways that do not introduce any additional substances but may involve removal of inedible parts); 2) processed culinary ingredients (substances derived from foods or nature through methods such as pressing, refining, grinding, milling, and drying and which are used in culinary preparations); 3) processed foods (those manufactured products made by adding sugar, fat, oil, salt and/or other culinary ingredients to minimally processed foods); and 4) ultra-processed foods (manufactured formulations made from substances derived from foods or synthesized from other organic sources, preservatives and additives) [12,27]. Details of the food and beverage subcategory of each NOVA group are described elsewhere [28].

2.4 Sociodemographic characteristics and Socio Economic Index

Trained personnel applied questionnaires to participants. The questionnaires were previously validated to collect sociodemographic characteristics. Age groups were classified as following: preschoolers (0 to 4.9 years), school age children (5 to 11.9 years), adolescents (12 to 19.9 years), and adults (older than 20 years). Sociodemographic characteristics such as: household characteristics, goods, and services available were used to create a socioeconomic status index (SES) using principal component analysis. The SES was classified into three categories using the 33% and 67% percentiles of the index as cutoff points to create the low, medium and high strata for SES [29].

2.5 Anthropometry

Trained personnel measured participants' weight, height, and waist circumference using international protocols [23]. Weight in kg and height in m^2 were used to calculate the Body Mass Index (BMI) and categorized according to the WHO criteria [30]. For participants <19 years, we used STATA macro to analyze survey anthropometric data. For adult participants (>19 years), we used the following classification: Normal BMI (18.5-24.9 kg/m2), overweight (25.0-29.9 kg/m2), obesity (≥30.0 kg/m2).Abdominal obesity was defined as a waist circumference of ≥80 and ≥90 cm for women and men, respectively [31].

2.6 Adult sample

Blood pressure (BP). BP was measured using a digital sphygmomanometer Omron HEM-907 XL following the protocol recommended by the American Heart Association [32]. Adults were classified with hypertension when they had a systolic BP ≥130 mmHg and/or a diastolic BP ≥85 mmHg and/or when they were under pharmacologic treatment for high BP.

Serum biomarkers. Blood samples were collected after ≥8 hours of fasting. Serum biomarkers were analyzed using the Syncron® Clinical UniCel DxC 600 system. Glucose, total cholesterol, triglycerides, HDL cholesterol (c-HDL), and LDL cholesterol (c-LDL) were analyzed by end-point coupled methods. Impaired fasting glucose was defined according to the American Diabetes Association classification [33]: Prediabetes (fasting glucose ≥100 y <126 mg/dL or HbA1c ≥5.7 and <6.5%) or survey finding (fasting glucose ≥126 mg/dL or HbA1c ≥6.5%).

Biomarkers in urine. An 11 ml spot urine sample was collected in a conical plastic tube. The sample was collected at the participant's home and was subsequently refrigerated (2-8ºC) for a maximum of 7 days. Afterwards, they were frozen at -70ºC until they were processed in the Mexican National Institute of Public Health (MNIPH) laboratory. Creatinine was measured by the Jaffé method and Na and K were measured through in-

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direct potentiometry with specific electrodes for the analyte and a Na glass electrode. Serum creatinine level was obtained from subjects to evaluate their kidney function alteration, which was calculated through the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [34] based on the Glomerular filtration rate (GFR, ml/min/1.73m2). It was categorized as follows: Normal (≥90); mildly reduced (60-89); moderately reduced (30-59); severely reduced (15-29) [34]. A spot urine sample was collected among adults that had a blood sample, also in the participant's household. Women on their menstrual period or those who reported transvaginal bleeding were excluded.

Chronic diseases. An adult participant was considered to have diabetes, hypertension, cardiovascular disease, and/or acute myocardial infarction/angina pectoris when they reported the diagnosis by a doctor.

2.7 Ethical considerations

All participants signed the informed consent approved by the Institutional Review Board of the National Institute of Public Health in Mexico. This study was a secondary data analysis. Ethics and Research Commissions of the MNIPH with the Commission number 1401, Bioethics registration 17 CEI00120130424, and COFEPRIS registration CEI 17 007 36 approved the original protocol.

2.8 Statistical Analysis

Means, standard deviations, and confidence intervals (CI 95%) of total Na and K intakes were estimated considering age group categories, socioeconomic index for the entire sample, academic level, residence area, BMI, BP, diabetes, cholesterol, c-LDL, c-HDL, triglycerides, and previous medical diagnosis. We also estimated means and percentage contribution of food groups and classified them by degree of processing and eating occasions, stratified by age group. The quartiles of Na and K intake were categorized by BMI, waist circumference, BP, lipids, glucose, previous medical diagnosis and smoking. We obtained the percentage and 95% CI of the population with a high sodium intake, a low potassium intake, as well as a ratio> 1.0 according to the sociodemographic characteristics.

Pearson's chi-squared tests were used to compare prevalences among strata and were carried out for multiple comparisons. A general $p<0.05$ value was considered to set the statistical significance. All the analyses were performed using the SVY module for survey design in STATA version 15 (College Station, TX, USA).[1]

3. Results

Data from 4,219 participants were analyzed, representing more than 136 million Mexicans. Table 1 shows Na and K intake according to age group and sociodemographic characteristics. The mean intake of Na in pre- schoolchildren was 1 512 mg (95% CI: 1 377, 1 647); in schoolchildren it was 2 844 mg (95% CI: 2 379, 3 309); in adolescents (the age group with the highest consumption) it was 3 743 mg (95% CI: 3 144, 4 341); and in adults it was 3 132 mg (95% CI: 2 794, 3 470). The mean intake of K in pre-schoolchildren was 1 616 mg (95% CI: 1 481, 1 751); in schoolchildren it was 2 256 (95% CI: 1 987, 2,525); in adolescents 2,967 mg (95% CI: 2,612, 3,322), and in adults (age group with the highest consumption) it was 3 401 mg (95% CI: 2 862, 3 939). The Na/K ratio was higher in children 1.4 (95% CI: 1.1, 1.7) and adolescents 1.3 (95% CI: 1.3, 1.4).

[1] Stata Corp. Release 14, vol. 1-4. College Station (TX): Stata Press.

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3.1 Food groups and mealtimes contribute to sodium and potassium intake

Table 2 shows the ten food groups that contribute the most to sodium and potassium intake in Mexicans, categorized by age groups. The foods groups that contributed the highest proportion to daily Na intake in preschool children were: Dairy (197 mg), processed meats (148 mg), and condiments (77 mg); in school-age children: Dairy (229 mg), processed meats (237 mg) and salty snacks (117 mg); in adolescents: Dairy (287 mg), processed meats (269 mg) and salty snacks (172 mg); and in adults: Red meat (197 mg), dairy (184 mg) and processed meat (179 mg). Also by age group, the food categories that contributed to a higher daily intake of K in pre-school children were: Dairy (397 mg), fruits (261 mg) and vegetables (169 mg); in school-age children they were: Vegetables (350 mg), dairy 324 mg), fruits (2798 mg) and corn tortillas (216 mg); in adolescents they were: Fruits (415 mg), vegetables (386 mg) and corn tortillas (363 mg); and in adults they were: Vegetables (702 mg), fruits (467 mg) and corn tortillas (401 mg).

Supplementary Table 2 shows the Na and K consumption categorized by six mealtimes in the Mexican population. In preschool children, school children, adolescents and adults, the fourth meal time (fourth time in the day) had the highest daily intake of sodium (446.6 mg, 1 103.4 mg, 1 104.4 mg and 1 114.6 mg, respectively) and K (411.3 mg, 706.9 mg, 922.0 mg and 1 208.8 mg, respectively).

Table 2. Dietary top ten food and beverage groups contributing to sodium and potassium intake in Mexican population: ENSANUT 2016

	Pre-Schoolchildren			Schoolchildren			Adolescents			Adults		
Sodium												
Ranking	**Food groups**	**mg/day**	**% Contribution**	**Food groups**	**mg/day**	**% Contribution**	**Food groups**	**mg/day**	**% Contribution**	**Food groups**	**mg/day**	**% Contribution**
1	Salt	399.3 ± 41.3	26.8 ± 1.5	Salt	1016.9 ± 216.2	28.1 ± 1.2	Salt	1186.2 ± 133.7	32.2 ± 2.3	Salt	1153.5 ± 104.7	36.5 ± 1.5
2	Cereals	253.6 ± 38.7	13.4 ± 1.6	Cereals	458.1 ± 43.3	16.0 ± 1.2	Cereals	641.7 ± 117.0	13.6 ± 1.4	Cereals	448.5 ± 60.5	12.5 ± 1.1
3	Dairy	196.8 ± 12.3	16.1 ± 1.3	Dairy	228.8 ± 20.0	10.2 ± 0.6	Dairy	287.1 ± 44.3	8.4 ± 1.0	Red meat	197.3 ± 40.6	5.9 ± 0.9
4	Processed meats	148.1 ± 28.1	7.6 ± 1.2	Processed meats	237.1 ± 34.7	7.9 ± 0.8	Processed meats	268.7 ± 43.5	6.6 ± 0.9	Dairy	184.0 ± 16.9	6.7 ± 0.5
5	Seasonings	76.6 ± 20.1	4.4 ± 1.0	Salty snacks	116.9 ± 19.3	4.1 ± 0.4	Salty snacks	172.3 ± 34.4	4.0 ± 0.6	Processed meats	178.6 ± 31.6	4.5 ± 0.6
6	Eggs	42.7 ± 3.7	3.3 ± 0.3	Red meat	105.4 ± 17.0	3.6 ± 0.5	Red meat	159.0 ± 31.8	4.7 ± 1.2	Seasonings	125.0 ± 44.2	3.5 ± 1.0
7	Salty snacks	45.5 ± 15.4	2.3 ± 0.6	Seasonings	104.1 ± 30.2	2.7 ± 0.5	Seasonings	89.02 ± 19.1	2.5 ± 0.4	Corn tortilla	95.5 ± 8.6	4.4 ± 0.4
8	Red meat	27.8 ± 8.4	1.7 ± 0.4	Corn tortilla	52.2 ± 4.8	2.9 ± 0.2	Corn tortilla	87.6 ± 9.4	3.5 ± 0.3	Eggs	68.0 ± 8.9	2.9 ± 0.4
9	Cereal based sweets	26.1 ± 6.1	1.8 ± 0.4	Eggs	51.6 ± 4.2	2.9 ± 0.3	Sweet bakery bread	80.3 ± 14.6	3.2 ± 0.6	Sweet bakery bread	63.4 ± 8.4	2.9 ± 0.4
10	Non cereal based sweets	26.5 ± 4.6	1.8 ± 0.2	R-to-E Cereals	51.1 ± 11.0	2.7 ± 0.4	Eggs	77.7 ± 9.1	2.7 ± 0.3	Cereals based sweets	60.3 ± 18.1	1.9 ± 0.6
Potassium												
Ranking	**Food groups**	**mg/day**	**% Contribution**	**Food groups**	**mg/day**	**% Contribution**	**Food groups**	**mg/day**	**% Contribution**	**Food groups**	**mg/day**	**% Contribution**
1	Dairy	396.7 ± 32.3	23.7 ± 1.7	Vegetables	350.3 ± 42.5	13.5 ± 0.9	Fruits	414.5 ± 67.7	11.7 ± 1.2	Vegetables	701.6 ± 124.8	17.7 ± 1.2
2	Fruits	260.7 ± 28.5	14.7 ± 1.2	Dairy	324.2 ± 29.1	15.6 ± 0.9	Vegetables	385.7 ± 46.7	13.2 ± 1.1	Fruits	467.0 ± 74.2	12.3 ± 0.8
3	Vegetables	168.7 ± 19.1	9.8 ± 0.8	Fruits	278.5 ± 22.3	12.1 ± 0.8	Corn tortilla	363.3 ± 38.9	13.8 ± 0.9	Corn tortilla	401.4 ± 35.7	13.9 ± 1.0
4	Yogurt and milk-based drinks	101.4 ± 14.5	5.9 ± 0.8	Corn tortilla	215.9 ± 19.9	10.8 ± 0.6	Dairy	360.4 ± 48.4	11.5 ± 0.9	Legumes	302.6 ± 38.1	9.3 ± 0.9
5	Corn tortilla	89.3 ± 9.1	6.4 ± 0.6	Legumes	149.8 ± 18.0	6.7 ± 0.5	Legumes	273.6 40.6	8.2 ± 0.8	Dairy	233.2 ± 26.6	7.9 ± 0.6
6	Legumes	81.4 ± 10.9	5.3 ± 0.6	Root vegetables	134.2 ± 34.1	4.2 ± 0.6	Red meat	161.4 ± 20.8	5.7 ± 0.4	Root vegetables	198.6 ± 47.8	4.5 ± 0.6
7	SSBs carbonated	75.6 ± 11.5	4.8 ± 0.8	Red meat	101.6 ± 11.7	4.8 ± 0.6	Cereals	100.2 ± 11.3	4.0 ± 0.4	Red meat	172.0 ± 24.3	5.9 ± 0.5
8	Root vegetables	59.4 ± 13.7	3.0 ± 0.5	Cereals	88.2 ± 6.7	4.5 ± 0.2	Salty snacks	98.2 ± 19.0	3.1 ± 0.5	Cereals	138.9 ± 27.7	4.2 ± 0.4
9	Cereals	55.8 ± 7.3	4.3 ± 0.5	Yogurt and milk-based drinks	82.1 ± 14.9	3.0 ± 0.4	Poultry	95.4 ± 23.7	3.4 ± 0.7	Coffee and tea	134.0 ± 36.9	3.5 ± 0.4
10	Poultry	45.2 ± 6.2	3.0 ± 0.4	Poultry	79.7 ± 11.4	3.3 ± 0.3	Root vegetables	88.7 ± 16.01	2.9 ± 0.4	Poultry	120.8 ± 21.1	4.2 ± 0.5

Salt refers to that reported in the preparations.

SSBs, Sugar-Sweetened Beverages. R-to-E Cereals, Ready to eat cereals.

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3.2 Contribution of sodium and potassium according to the NOVA classification

Figure 1 and 2 show the contribution of Na and K intake according to the NOVA classification in the Mexican population. Processed and ultra-processed foods and beverages contribute about 49% of the Na consumed in pre-school children and schoolchildren, 47% in adolescents, and 39% in adults (Figure 1). Conversely, the consumption of K is higher in foods and beverages that are unprocessed or minimally processed, since they contribute 68% in preschool children, 76% in schoolchildren, 75% in adolescents, and 83% in adults (Figure 2). The mean intake and contribution of Na and K according to the NOVA classification in the Mexican population are displayed in supplementary table 3.

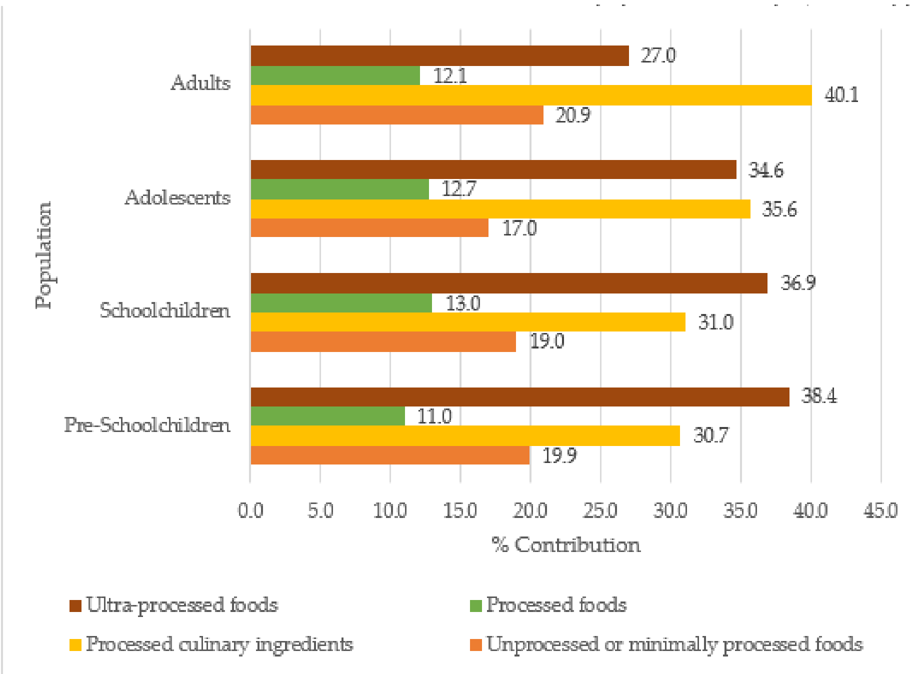

Figure 1. Sodium contribution (percentage) intake by NOVA classification in the Mexican population: ENSANUT 2016.

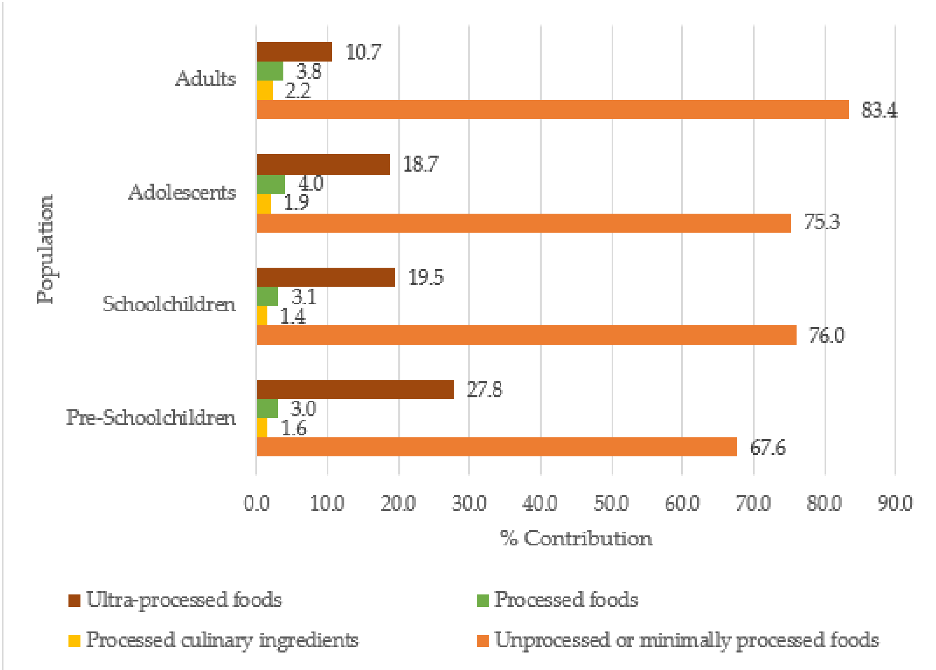

Figure 2. Potassium contribution (percentage) intake by Nova classification in the Mexican population: ENSANUT 2016.

3.3 Sodium and potassium intake: Health risk

Table 3 shows the proportion of participants with high Na and K consumption, as well as a Na:K ratio greater than 1.0. In preschool children, the northern region (55.4%, CI95%: 38.6-71.0. p <0.005) had a higher proportion of children with a Na: K ratio greater than 1 compared to the southern region. Furthermore, it showed a higher proportion of children who had insufficient K intake with low SES (82.0% CI95%: 71.2-89.4. p <0.005), as well as those who were overweight (97.9% CI95%: 90.3-99.6). p <0.005). Among schoolchildren, a higher proportion of children with high Na consumption was observed in urban areas (84.8% CI95%: 79.5-89.0. p <0.005), high SES (87.2% CI95%: 79.9-92.1. p < 0.005), as well as those with obesity (88.0% CI95%: 80.0-93.1. p <0.005). Insufficient K consumption was observed among children with a normal BMI (76.5% 95% CI: 70.8-81.4. p <0.005). In addition, those who had a Na: K ratio greater than 1 were from an urban area (64.7%. CI95%: 58.5-70.4. p <0.005), as well as the northern region (67.1%. CI95%: 56.8-76.0. p <0.005). Among adolescents, a higher proportion of high Na consumption was observed in the northern region (89.5% CI95%: 78.1-95.3. p <0.005), as well as those with overweight (82.4% CI95%: 75.8-87.5. P < 0.005) and obesity (86.8% 95% CI: 72.7- 94.2. p <0.005). Likewise, those with a higher proportion of insufficient K consumption were found in the northern region (76.9% 95% CI: 52.2-91.0. p <0.005). Among adults, a higher proportion of people with high SES consumed high amounts of Na (70.6% 95% CI: 60.7-78.9. p <0.005).

3.4 Sodium and potassium intake: Cardiovascular health

Table 4 shows the quartiles of Na and K intake in adults according to nutritional status and clinical characteristics. Adults in the fourth quartile of sodium intake (5049.6 mg / day) had lower serum concentrations of cholesterol (181.4 mg / dL) and HDL-c (35.5 mg / dL) than adults in the first quartile (cholesterol 202.5 mg / dL and HDL-c 40.8 mg / dL) (p <0.005). Adults who were in the fourth quartile showed lower levels of HDL-c (34.3 mg/ dL) compared to those in the first quartile (41.6 mg/ dL) (p <0.005). Participants in the third quartile of K intake (2 166.5 mg/ day) had higher serum concentrations of LDL-c (123.5 mg/ dL) compared to those in the first quartile (104.9 mg/ dL) (p <0.005).

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Table 3. Percent of population with high sodium and insufficient potassium intake and sodium: potassium ratio in Mexican population. ENSANUT 2016.[1, 2, 3]

	Pre-Schoolchildren			Schoolchildren			Adolescents			Adults		
	High Na	**Insufficient K**	**Na:K**	**High Na**	**Insufficient K**	**Na:K**	**High Na**	**Insufficient K**	**Na:K**	**High Na**	**Insufficient K**	**Na:K**
Total (n=4219; N=136,639,494)												
Age	73.6 (66.9, 79.4)	73.3 (66.2, 79.4)	41.5 (34.6, 48.8)	**82.1 (78.1, 85.6)**	67.1 (61.5, 72.3)	**61.1 (56.3, 65.8)**	81.6 (76.3, 85.9)	**58.0 (49.1, 66.3)**	**62.5 (52.6, 71.5)**	**64.1 (57.1, 70.5)**	65.6 (56.7, 73.5)	45.7 (38.6, 53.0)
Sex												
Women	74.8 (67.0, 81.2)	71.9 (61.6, 80.2)	44.8 (35.3, 54.7)	80.9 (75.4, 85.4)	66.8 (59.8, 73.2)	59.5 (53.3, 65.5)	79.4 (70.5, 86.2)	62.1 (49.5, 73.3)	60.5 (44.2, 74.7)	60.9 (51.0, 70.0)	69.7 (55.0, 81.3)	45.1 (35.0, 55.6)
Men	72.5 (61.9, 81.1)	74.7 (64.5, 82.8)	38.4 (28.6, 49.2)	83.2 (77.0, 88.0)	67.4 (59.0, 74.9)	62.6 (54.8, 69.7)	84.0 (76.8, 89.3)	53.5 (42.0, 64.7)	64.8 (52.6, 75.3)	68.0 (58.6, 76.1)	60.4 (49.5, 70.4)	46.4 (37.3, 55.8)
Area of residence												
Rural	71.8 (63.3, 79.0)	80.5 (72.8, 86.5)	40.3 (31.4, 49.9)	75.6 (69.9, 80.5)	67.1 (59.7, 73.8)	52.5 (46.0, 58.9)	79.3 (73.5, 84.1)	54.0 (45.6, 62.2)	60.2 (53.7, 66.4)	65.6 (56.1, 74.0)	61.5 (47.9, 73.6)	37.8 (27.7, 49.1)
Urban	74.3 (65.49,81.5)	70.7 (61.4, 78.6)	41.9 (33.1, 51.3)	**84.8 (79.5, 89.0)**	67.1 (59.7, 73.8)	**64.7 (58.5, 70.4)**	82.4 (75.5, 87.7)	59.3 (47.8, 69.8)	63.3 (50.0, 74.8)	63.5 (54.5, 71.6)	67.1 (55.8, 76.7)	48.7 (39.6, 57.8)
Region												
North	73.2 (58.7, 84.1)	70.8 (50.9, 85.1)	55.4 (38.6, 71.0)	81.4 (71.0, 88.6)	75.4 (59.3, 86.6)	67.1 (56.8, 76.0)	89.5 (78.1, 95.3)	76.9 (52.2, 91.0)	58.2 (26.5, 84.3)	70.8 (53.5, 83.6)	52.4 (30.3, 73.6)	45.8 (26.7, 66.2)
Center	70.4 (55.9, 81.7)	69.2 (55.7, 80.0)	39.1 (26.9, 53.0)	85.0 (79.2,89.4)	64.7 (55.3, 73.0)	65.8 (57.1, 73.6)	81.2 (72.2, 87.7)	**47.9 (36.4, 59.5)**	67.0 (55.2, 77.0)	71.3 (62.2, 78.9)	68.4 (55.4, 79.0)	47.2 (37.0, 57.7)
Mexico City and State of Mexico	78.3 (63.1, 88.4)	70.2 (49.5, 85.0)	43.2 (26.0, 62.1)	88.5 (76.1, 94.9)	70.5 (56.9, 81.3)	70.5 (59.0, 79.8)	**72.3 (56.8, 83.9)**	67.9 (55.4, 78.2)	75.3 (57.6, 87.3)	58.8 (44.7, 71.7)	77.0 (64.5, 86.1)	60.3 (46.5, 72.6)
South	75.4 (65.6, 83.1)	81.1 (71.5, 88.0)	**35.2 (26.1, 45.6)**	77.2 (68.9, 83.8)	63.3 (53.4, 72.2)	**49.3 (40.8, 57.7)**	80.9 (73.5, 86.5)	53.2 (41.1, 64.9)	54.5 (42.7, 65.7)	55.3 (42.0, 67.8)	66.8 (52.3, 78.6)	38.4 (27.3, 50.8)
Socioeconomic tertile												
Low	70.5 (60.5, 78.9)	82.0 (71.2, 89.4)	38.0 (28.2, 49.0)	75.7 (68.8, 81.5)	71.2 (61.7, 79.2)	58.8 (50.7, 66.5)	75.2 (67.1, 81.9)	61.7 (51.3, 71.2)	58.1 (49.2, 66.6)	49.5 (35.6, 63.5)	64.4 (50.8,76.0)	37.3 (26.3, 49.9)
Medium	71.4 (59.0, 81.3)	74.3 (62.4, 83.5)	39.2 (27.3, 52.5)	81.0 (73.9, 86.6)	72.0 (64.4, 78.5)	59.2 (51.1, 66.9)	83.7 (75.7, 89.5)	52.2 (38.6, 65.5)	63.2 (48.3, 76.0)	64.1 (53.0, 73.8)	63.4 (48.0, 76.5)	48.5 (35.8, 61.4)
High	78.7 (66.1, 87.5)	**65.4 (51.7, 76.9)**	47.0 (34.2, 60.1)	**87.2 (79.9, 92.1)**	60.4 (49.9, 70.0)	64.2 (55.6, 72.0)	83.1 (73.0, 89.9)	60.6 (45.2, 74.1)	64.1 (44.4, 80.0)	**70.6 (60.7, 78.9)**	67.2 (52.0, 79.5)	47.9 (36.8, 59.2)
BMI [a] (kg/m²)												
Normal	72.3 (65.1, 78.5)	74.9 (67.0, 81.4)	41.8 (34.3, 49.7)	78.5 (72.8, 83.3)	76.5 (70.8, 81.4)	59.1 (53.2, 64.8)	68.1 (61.0, 74.5)	69.0 (62.8, 74.5)	60.3 (52.3, 67.8)	60.8 (47.6, 72.6)	70.8 (57.1,81.6)	45.4 (33.7, 57.8)
Overweight	71.2 (29.6, 93.6)	**97.9 (90.3, 99.6)**	41.6 (14.0, 75.7)	84.7 (75.4, 90.9)	**60.3 (48.7, 70.8)**	60.2 (48.4, 70.9)	**82.4 (75.8, 87.5)**	75.7 (65.5, 83.6)	70.1 (60.6, 78.1)	61.7 (51.5, 71.0)	73.0 (59.7, 83.1)	47.9 (37.9, 58.1)
Obesity	100	40.3 (11.0, 78.8)	68.4 (28.8, 92.1)	**88.0 (80.0, 93.1)**	66.6 (49.4, 80.2)	61.5 (48.1, 73.3)	**86.8 (72.7, 94.2)**	81.5 (58.1, 93.3)	50.6 (19.4, 81.3)	68.0 (56.7, 77.4)	56.4 (41.7, 70.0)	44.0 (32.0, 56.8)

Bold numbers means statistically significant difference vs reference category (p <0.05), using logistic regression models.

The reference category is the first row of each variable; except for the first variable (age), in wich is the first column.

Data represents percent's and confidence intervals (95%), also was adjusted for the survey design.

*Self-report of previous medical diagnosis of the described diseases.

a Body mass index (BMI): <25 kg/m2 (normal); 25-29.9 kg/m2 (overweight); ≥30 kg/m2 (obesity). For those under 19 years of age, the BMI for age was used according to the WHO

1, For those ≤ 18 the references of adequate intake by age and sex (AI) for sodium and potasium were used: National Academies of Sciences, Engineering, and Medicine 2019. Dietary Reference Intakes for Sodium and Potassium. Washington, DC: The National Academies Press; For those over 18 years old the references of potassium and sodium intake were used; Source: WHO. Guideline: Potassium intake for adults and children. Geneva, World Health Organization (WHO), 2012 and WHO. Guideline: Sodium intake for adults and children. Geneva, World Health Organization (WHO), 2012.

2, High sodium was considered when sodium intake was above: 800 mg (1 to 3 years old), 1000 mg (4 to 8 years old), 1200 mg (9 to 13 years old), 1500 mg (14 to 18 years old), 2000 mg (19 years old or older); Insufficient potassium was considered when sodium intake was under: 2000 mg (1 to 3 years old), 2300 mg (4 to 8 years old), 2500 mg (9 to 13 males 9 to 13 years old), 2300 mg (9 to 18 females 9 to 13 years old), 3000 mg (males 14 to 18 years old), 3510 mg (19 years old or older).

3, Na:K >1.0

Na, Sodium; K, Potassium.

Table 4. Nutritional status and clinical characteristics according to quartiles of sodium and potassium intake in adults: ENSANUT 2016

Sodium Intake Quartiles (mg/day)	**First**		**Second**		**Third**		**Fourth**		**p**	***n***
Quartile, Mean, 95% CI	**801.8**	**(761.9, 841.7)**	**1578.93**	**(1517.6, 1649.2)**	**2438.4**	**(2381.6, 2494.9)**	**5049.6**	**(4579.4, 5519.8)**	**-**	**1,356**
BMI (kg/m²), mean (95% CI)	28.7	(27.2, 30.2)	28.5	(27.2, 29.8)	28.7	(27.0, 30.3)	28.2	(27.1, 29.4)	0.966	1,294
Waist circumference (cm).Women, mean (95% CI)	96.4	(91.4, 101.3)	93.5	(88.9, 98.2)	94.2	(90.2, 98.2)	94.1	(90.8, 97.4)	0.853	554
Men, mean (95% CI)	98.562	(89.8, 107.3)	95.0	(90.9, 99.1)	98.1	(93.8, 102.5)	97.3753	(92.0, 102.8)	0.749	356
SBP (mm Hg), mean (95% CI)	123.2	(119.7, 126.8)	128.3	(119.6, 136.9)	120.5	(117.1, 123.9)	122.1	(117.2, 127.0)	0.373	901
DBP (mm Hg), mean (95% CI)	73.7	(71.3, 76.2)	76.4	(73.1, 79.7)	73.4	(70.9, 75.8)	72.1	(69.6, 74.6)	0.259	901
eGFR (mL/min/1.73 m²), mean (95% CI)	116.6	(110.6, 122.5)	113.7	(107.4, 120.1)	123.3	(108.2, 138.4)	112.4	(108.3, 116.5)	0.486	922
Glucose (mg/dL), mean (95% CI)a	107.4	(101.4, 113.4)	115.8	(96.0, 135.5)	109.9	(98.0, 121.7)	101.0	(95.9, 106.0)	0.185	922
Cholesterol (mg/dL), mean (95% CI)a	202.5	(189.0, 216.0)	193.5	(178.4, 208.6)	184.4	(172.8, 196.1)	**181.4**	**(173.6, 189.1)**	0.058	922
HDL-c (mg/dL), mean (95% CI)a	40.8	(38.1, 43.6)	**35.7**	**(31.6 39.8)**	38.9	(35.2, 42.6)	**35.5**	**(33.2, 37.8)**	**0.026**	922
LDL-c (mg/dL), mean (95% CI)a	123.6	(110.1, 137)	115.3	(108.3, 122.3)	111.9	(102.3, 121.4)	**106.6**	**(98.8, 114.3)**	0.156	865
TG (mg/dL), mean (95% CI)a	197.8	(176.3, 219.3)	361.5	(79.9, 643.1)	218.8	(153.4, 284.3)	220.5	(170.3, 270.6)	0.547	922
Diabetes[a] (%)										
Prediabetes	24.6	(17.4, 33.6)	27.79	(15.0, 45.6)	32.92	(21.7, 46.6)	28.46	(16.5, 44.6)	0.548	926
Previous diagnosis	12.31	(7.9, 18.8)	8.107	(4.6, 13.8)	7.305	(4.2, 12.4)	6.175	(3.3, 11.2)		
Survey finding	9.9	(3.7, 24.2)	15.3	(3.7, 46.4)	9.1	(2.4, 28.6)	3.7	(1.3, 9.9)		

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High blood pressure[b] (%)										
Elevated	11.5	(6.7, 19.2)	11.8	(4.9, 25.7)	18.3	(8.6, 34.9)	15.3	(8.4, 26.4)	0.213	901
Stage 1	23.7	(13.3, 38.6)	20.8	(9.6, 39.4)	21.7	(11.1, 38.0)	9.8	(5.5, 17.0)		
Stage 2	7.9	(4.5, 13.5)	25.6	(10.4, 50.6)	8.4	(4.6, 15.0)	11.4	(4.4, 26.5)		
Previous diagnosis	13.2	(8.7, 19.6)	9.7	(5.6, 16.3)	9.3	(4.5, 18.3)	16.7	(8.0, 31.6)		
Coronary Heart Disease (%)	0.7	(0.1, 3.4)	1.5	(0.6, 4.2)	1.9	(0.6, 5.7)	4.1	(0.7, 21.7)	0.385	926
Cerebro-vascular Disease (%)	0.0		0.5	(0.1, 3.3)	0.1	(0.0, 1.1)	0.9	(0.1, 6.0)	0.580	916
Smoking (%)										
Never	43.2	(32.0, 55.1)	65.8	(51.5, 77.8)	54.9	(40.8, 68.2)	31.8	(21.3, 44.5)	**0.002**	926
Current smoker	20.1	(11.4, 33.1)	6.4	(3.6, 11.1)	13.7	(7.0, 25.2)	30.9	(18.4, 46.9)		
Ex-smoker	36.7	(26.2, 48.7)	27.8	(17.4, 41.3)	31.4	(20.2, 45.3)	37.3	(24.8, 51.8)		

Potasium Intake Quartiles (mg/day)	**First**		**Second**		**Third**		**Fourth**		**p**	***n***
Quartile, Mean, 95% CI	**965.4**	**(921.1, 1009.7)**	**1552.2**	**(1510.6, 1593.7)**	**2210.9**	**(2166.5, 2255.5)**	**5039.5**	**(4338.9, 5740.1)**	**-**	**1,356**
BMI (kg/m²), mean (95% CI)	28.3	(27.1, 29.5)	27.4	(26.4, 28.5)	29.4	(28.2, 30.6)	28.6	(27.3, 29.9)	0.096	1,294
Waist circumference (cm), mujeres, mean (95% CI)	98.2	(93.5, 102.9)	93.6	(89.4, 97.7)	96.6	(93.0, 100.3)	**92.1**	**(88.9, 95.4)**	0.143	554
Men, mean (95% CI)	91.4	(87.5, 95.3)	95.7	(91.3, 100.0)	**98.4**	**(94.8, 102.1)**	**98.2**	**(93.4, 103.1)**	0.056	356
SBP (mm Hg), mean (95% CI)	122.0	(117.8, 126.2)	122.4	(116.8, 127.9)	122.3	(119.6, 125.0)	123.7	(118.6, 128.8)	0.959	901
DBP (mm Hg), mean (95% CI)	73.9	(70.6, 77.2)	74.5	(71.7, 77.2)	74.4	(72.1, 76.7)	72.8	(70.5, 75.2)	0.758	901
eGFR (mL/min/1.73 m²), mean (95% CI)	115.2	(112.0, 118.4)	117.6	(110.4, 124.7)	118.0	(113.1, 122.8)	115.3	(107.2, 123.4)	0.819	922
Glucose (mg/dL), mean (95% CI)[a]	118.0	(98.0, 138.0)	102.0	(97.1, 106.9)	105.9	(99.2, 112.6)	106.7	(97.5, 115.9)	0.289	922
Cholesterol (mg/dL), mean (95% CI) [a]	181.8	(172.1, 191.6)	187.9	(176.9, 198.8)	**198.7**	**(187.8, 209.5)**	184.1	(174.7, 193.6)	0.112	922
HDL-c (mg/dL), mean (95% CI) [a]	41.6	(39.3, 43.9)	39.9	(33.3, 46.5)	40.1	(37.7, 42.4)	**34.3**	**(32.4, 36.1)**	**0.000**	922
LDL-c (mg/dL), mean (95% CI) [a]	104.9	(95.7, 114.1)	112.7	(104.2, 121.2)	**123.5**	**(113.5, 133.5)**	108.7	(101.4, 115.9)	**0.036**	865
TG (mg/dL), mean (95% CI) [a]	225.6	(145.9, 305.2)	224.9	(113.0, 336.9)	235.3	(160.9, 309.8)	258.7	(145.3, 372.1)	0.969	922
Diabetes[a] (%)										
Prediabetes	24.7	(14.8, 38.3)	29.3	(16.8, 46.0)	24.8	(14.9, 38.4)	31.5	(20.4, 45.2)	0.505	926

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Previous diagnosis	9.2	(5.3, 15.5)	9.8	(5.8, 16.0)	12.3	(7.5, 19.5)	5.0	(2.8, 8.9)		
Survey finding	17.8	(4.5, 50.0)	5.4	(2.5, 11.4)	5.2	(1.5, 16.9)	8.0	(2.6, 22.2)		
High blood pressure[b] (%)										
Elevated	10.1	(4.9, 19.6)	9.4	(5.0, 16.8)	20.3	(10.4, 35.8)	15.9	(8.7, 27.5)	0.754	901
Stage 1	24.5	(9.3, 50.6)	22.9	(11.8, 39.8)	19.3	(10.6, 32.4)	12.7	(7.6, 20.6)		
Stage 2	8.9	(4.2, 18.1)	12.7	(5.1, 28.2)	11.0	(5.9, 19.5)	14.8	(6.5, 30.1)		
Previous diagnosis	9.1	(5.1, 15.6)	13.7	(8.1, 22.3)	13.3	(7.9, 21.6)	13.2	(6.3, 25.6)		
Coronary Heart Disease (%)	1.0	(0.3, 3.5)	0.7	(0.1, 4.6)	3.2	(1.2, 7.9)	3.2	(0.6, 16.8)	0.496	926
Cerebro-vascular Disease (%)	0.7	(0.1, 5.3)	0.0	0	0.2	(0.0, 1.6)	0.7	(0.1, 4.6)	0.699	916
Smoking (%)										
Never	58.2	(42.3, 72.5)	50.8	(36.7, 64.7)	45.4	(33.7, 57.7)	42.5	(30.7, 55.2)	0.691	926
Current smoker	17.8	(8.9, 32.2)	20.2	(10.8, 34.5)	22.4	(12.9, 36.0)	19.6	(10.3, 34.0)		
Ex-smoker	24.1	(15.5, 35.4)	29.1	(19.6, 40.8)	32.2	(22.1, 44.2)	37.9	(26.7, 50.7)		

*Data adjusted for the survey design.

a Body mass index (BMI): <25 kg/m² (normal); 25-29.9 kg/m² (overweight); ≥30 kg/m² (obesity).

b Blood pressure (mm Hg): normal (<120/80); elevated (systolic between 120-129 and diastolic <80); stage 1 (systolic between 130-139 or diastolic between 80-89); stage 2 (systolic at least 140 or diastolic at least 90).

c Diabetes classification: prediabetes (fasting glucose ≥100 y <126 mg/dL or HbA1c ≥5.7 and <6.5%); survey finding (fasting glucose ≥126 mg/dL or HbA1c ≥6.5%).

d High total cholesterol levels: ≥200 mg/dL.

e High LDL-c levels: ≥100 mg/dL.

f Low HDL-c levels (hypoalphalipoproteinemia): <40 mg/dL.

g High triglycerides levels: ≥150 mg/dL.

Bold numbers indicate statistically significant difference between first quartile and other quartiles (p <0.05).

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4. Discussion

This study shows that the Na dietary intake in Mexicans exceeds the WHO recommendation (2 g/day) for pre schoolchildren, schoolchildren, adolescents, and adults. The main sources of dietary Na are salt, cereals, dairy, and processed and red meats, while the main sources of dietary K are vegetables, dairy fruits and tortillas and legumes. In addition, all age groups consume insufficient amounts of K according to the WHO and IOM recommendations. Processed and ultra-processed foods and beverages are the foods that contribute the most Na to the diet, while minimally processed or unprocessed foods contribute the most K to the diet. In addition, it was found that adults who consume higher amounts of Na and K (> 5g) have a lower lipid profile (cholesterol and LDL-c).

The results show that Na consumption is high at all ages. This is similar to Latin American and the Caribbean countries, where the average Na consumption is close to 3.4 g/ day [35], observing higher consumption in Brazil, Chile and Colombia (> 4.7 g/ day). It is even similar to worldwide Na consumption (about 3.95 g/ day) [36]. Potassium consumption is low in this population according to recommendations from international organizations [7,8]. Globally, it has been shown that the consumption of this nutrient has increased in recent years, falling slightly above expectations (3.7 g/ day) [37]. However, in countries such as Brazil, slightly low potassium consumption has been identified, similar to the adult population in this study [38]. The consumption of both nutrients may be due in a large extent to modified nutritional behavior [39–41]. Most countries have experienced a change in their traditional diets, shifting towards a western diet, which is characterized by increased consumption of processed foods [42] and decreased consumption of fruits and vegetables [43]. If this nutrient consumption is maintained, it will continue to contribute to the main cause of mortality in Mexico and the years of life lost, also worsening years of life lost due to disability [44].

Our study showed that processed and ultra-processed foods and beverages contribute the most to dietary Na, while minimally processed or unprocessed contribute the most K. This is expected since the higher the degree of processing, the greater the amount of critical nutrients that are added (such as sodium), while the lower the processing, the greater the amount of fiber due to the natural state of the product [12].

A study carried out in Canada found that the population that consumed a proportion of processed foods in their diet had a higher Na content and a lower K content; the opposite was observed in a diet that consisted of either minimally processed or unprocessed foods. [45]. Similarly, a study in Australia found that a higher quintile of processed food consumption contributes more Na and less K, compared to a lower quintile that contributes more K and less Na [46]. Furthermore, this study showed that foods that are minimally processed contribute more than 50% of dietary K. If this is transposed in Mexico, our consumption of processed and ultra-processed foods will increasing [14]. If this trend continues, K intake in our population will continue to decrease and it is probable that Na: K ratio will increase, affecting cardiovascular risk [47]. This is expected because at a higher degree of processing, more sodium is added to food and beverages, contrary to minimally processed foods [12,27]. However, the studies that link NOVA classification with some event in health or quality of the diet do not use added salt, since this would contribute greatly to culinary foods and would be the first source of sodium in the diet [48,49]. However, in this study, we include this source of Na (salt in preparations) within the culinary ingredients in the NOVA classification, however processed and ultra-processed foods provide between 40-50% of Na.

In addition, this study showed that clinical characteristics in lipids such as HDL-c, LDL-c and cholesterol were lower in people who consumed more Na compared to those who consumed less Na. These results are consistent with a review by Gradual et al who showed that Na consumption was lower in people who had high levels of cholesterol, triglycerides and LDL-c, compared to those with high Na intake [15].

Our results also demonstrated a relationship between higher sodium consumption (fourth quartile) and cholesterol and LDL-c levels, compared to people who consumed less sodium (first quartile). This finding adds to the literature since it has been shown that decreasing sodium intake increases serum concentrations of undesirable lipids [15]. Furthermore, this has been observed in developed countries such as Denmark where salt intake is negatively associated with HDL-c but positively associated with triglycerides. According to this study, the direction of the association between sodium intake and blood lipids is opposite to the direction of the association between obesity and blood lipids [50].

Our results showed a consumption of Na 1 512 mg/day and K 1 616 mg /day for *pre-schoolchildren*. In Mexicans the amount of Na is high for the age, however, the Japanese population (2 300 mg) [51], Poland (1 220 mg) [52] and Australia (3 400 mg) [53] consume more Na. For K consumption, it is higher in Japan (1 700 mg) [51] and lower in Poland (947 mg) [52] and Australia (1 119 mg) [53]. This may be due to cultural differences between countries. Also, the consumption of processed foods may be greater in developing countries. Mexico exceeds amounts recommended by the WHO and the IOM probably due to poor diet quality [54].

In *schoolchildren,* Na consumption exceeds the WHO recommendation, while K consumption was below the recommended level; the Na / K ratio was 1.4 (95% CI 1.1, 1.7). These results coincide with those obtained in Indonesian children between 9 and 12 years, who had a high Na consumption (>2 300 mg / day) and a low K consumption (<2 500 mg/day) [55]. On the other hand, in Spanish children between 9 and 13 years old, Na consumption was close to 2 500 mg/day, while K consumption was 2 800 mg/day [56]. Guatemalan children (6-11 y) reported a low consumption of Na (831 mg/day), as well as a low consumption of K (1 364 mg/day) [57].

The main food groups that contribute to Na consumption in this population group are salt, cereals, dairy products, processed meats, salty snacks, red meats, and seasonings. Food groups such as dairy, vegetables, fruits, as well as corn tortillas and root vegetables contribute the most Na to the diet. These results are consistent with those obtained by Grimes et al, since they showed that in Australian children between 4 and 12 years, the main food groups that contributed to a high Na intake in the diet were cereals, as well as meat, poultry, condiments or seasonings, and flavoring sauces. While the consumption of K, this population showed that milk products and dishes, as well as vegetables, fruits, meats and cereals contribute most of the consumption of this nutrient [58]. On the other hand, Cuadrado et al., showed that the main food sources that contributed Na to the diet in Spanish children between 7 and 11 years old were meats and meat products, cereals, grains and legumes, as well as pre-cooked and ready-to-eat meals [48]. This may also be due to the fact that non-basic foods that are high in fat and sugar, animal products, and milk and dairy derivatives were found to contribute 22% to total dietary energy in schoolchildren [42].

In *adolescents,* the mean dietary Na intake was higher and the mean dietary K intake was below the levels recommended by international agencies. These results were consistent with international studies; for example, Portuguese adolescents showed a high mean dietary Na intake (3 500 mg/day) while the mean dietary K intake was low (2 150 mg/day) [59]. Furthermore, adolescents in Morocco reported consuming more than 2 134 mg/day [57], while adolescents in China reported consuming a median consumption of dietary Na of 4 300 mg/day while consuming 1 600 mg/day of dietary K [60]. In this population group, the main sources of foods that contributed Na were salt, cereals, dairy products, processed meats, salty snacks and red meat. The main food sources that contributed a high K intake were fruits, vegetables, corn tortillas, dairy, legumes, and red meat [61]. These results were consistent with that of American adolescents since the main food sources that contributed to high Na intake were mixed dishes - pizza, mixed-Mexican dishes, as well as mixed avocado-sandwiches, as well as breads, rolls and tortillas [61]. On the other hand, the main food sources that contributed to K consumption were milk, white potatoes, fruits, 100% juices, poultry and mixed-Mexican dishes [62]. This may be because this population group is the one that consumes the least fruits and vegetables compared to adults and those under 12 years of age. In addition, adolescents have been identified to have a Western diet pattern, which is characterized by high processed food and salt intake [42].

Mexican *adults* have a high Na intake (3 132 mg / day), as well as a low K intake (3,400 mg/day). The previous results were consistent with previous studies obtained from the SALMEX cohort in Mexico City [10]. This study showed that the estimated Na intake was high (2 600 mg/day), while the (urinary) K intake was low (1 982 mg/day) [10]. A study carried out in China showed that Na consumption in the adult population was above 4 100 mg/day, while K consumption was between 1 500 and 1 600 mg / day [63]. A study carried out with Australian adults showed that the median K intake was high, since it was above 3 000 mg/day [64]. Another study carried out with American adults showed that the mean population consumption was close to 3 500 mg/day, while the mean K consumption was close to 2 800 mg/day [65]. Our results did not show a high proportion between Na: K; however, other countries have shown that these proportions are above two [63,64], which was related to diastolic and systolic pressure. Mexican adults have shown to have the highest potassium consumption in the population. However, this is not sufficient to comply with the WHO recommendations. Potassium consumption is higher than in other countries, probably because consumption of non-basic foods (14%) in the adult diet is lower than that of minors [42].

Our results showed that the food groups that most contribute to Na consumption are salt, cereals, red meat, dairy, processed meats, as well as seasonings, while the food groups that contribute the most to K consumption are vegetables, fruits, corn tortillas, legumes, dairy, as well as root vegetables. These results are slightly consistent with those obtained in a subsample of the SALMEX cohort [66]. For instance, this study showed that processed meats, savory breads, sweet bakery goods, natural cheeses, as well as tacos and breakfast cereals, were the main sources of Na in the diet [66]. This may be due to the fact that our results have national coverage and there is a greater variety of food consumption in different regions. A study conducted with Chinese adults showed that the main source of Na distribution was salt (69%), as well as soy sauce (8%) and processed food (6%) [67]. However, the Mexican diet is different from this population; it has higher mortality rates attributed to a high Na intake compared to Mexico [44]. In addition to the above, our results are consistent with a study conducted with Australian adults, in which the main sources of K consumption were vegetables, meat, poultry, fruits, and milk products [64].

Finally, the mealtimes that contributed the most to higher consumption of Na and K was the fourth mealtime and breakfast (first mealtime). These results contradict the results obtained from a study with the Japanese population, since dinner was the main mealtime that contributed most. This may be since the meal times in the first years of life are prepared at home and heavy meals are usually eat at these times. The main food groups that contributed Na to the diet were cereals, dairy products and processed meats. These data were consistent with a study from Australian, since their main source of Na was cereals and cereal products, milk products and meat-poultry dishes [53]. On the other hand, the main sources of K consumption in our study were dairy products, fruits and vegetables, as well as yogurt and milk based beverages. These were also consistent with Australia: milk products, fruits products/ dishes, vegetables products/ dishes and cereals [53]. These foods also contributed the most K to the diet in the Polish population [53]. This may be because the first stages of consumption (in early childhood) involve dairy products and also, according to the complementary feeding scheme, some of the first foods consumed are cereals, vegetables and fruits [68].

The main strengths of this study are that it is based on a representative sample, it includes all age groups nationwide, and is the first to identify the main dietary sources of Na and K, meal times, and mean intakes. The detailed dietary intake data were collected at the brand level for each food consumed and Na values were updated with analytical data on Mexican foods. In addition, we measured cardio metabolic risk biomarkers with a high precision. The main limitation of this study is that the instrument was not designed for the main objective of this study. Therefore, sodium intake may be underestimated. However, the population-based information generated in this investigation is essential to help design, evaluate, and reformulate strategies to reduce Na intake and increase K intake in Mexico. On the other hand, Na intake is a combined sum of Na present in natural food (approximately 10%), Na added by the consumer when cooking and at the table (approximately 36%) and that present in processed food as added during the manufacturing process (approximately 54%). Hence, dietary assessments would tend to grossly underestimate total salt intake since this study did not consider some of the main sources of sodium added at the table.

5. Conclusions

Our results show that a high proportion of the Mexican population, including most age and gender groups, have high Na and low K intakes, as well as an inadequate Na:K ratio. These findings are consistent with studies carried out worldwide showing that Na consumption is high in accordance with international recommendations, while K consumption is low.

In Mexico, it would be important to promote a diet with foods rich in K such as fruits, vegetables, legumes as well as milk from an early age. Although these foods are the main sources of K intake in this population, their current consumption seems insufficient to provide enough K in the diet. There is a relationship between higher sodium consumption and cholesterol, HDL and LDL levels, compared to people who consumed less sodium. In addition, the results of this article highlight the importance of implementing reformulation strategies in processed and ultra-processed foods and beverages because they contribute most of the sodium consumed. If this trend continues, the probability of having an unhealthy Na:K ratio will increase, along with cardiovascular risk.

Supplementary Materials: Table S1: Description of the food groups used in the analysis of the food and beverage groups contributing to sodium and potassium intake- Table S2: Sodium and potassium consumption and contribution by meal times and places of consumption in Mexican population: ENSANUT 2016. Table S3: Supplementary Table 3 Mean and contribution of sodium and potassium intake by Nova classification in Mexican population: ENSANUT 2016.

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