

Associated factors to the consumption of non-nutritive sweeteners in the Mexican adult population

Alonso Romo-Romo, MSc, PhD,⁽¹⁾ Lilia Castillo-Martínez, MSc, PhD,⁽²⁾ Carlos A Aguilar-Salinas, MSc, PhD Endocr,^(3,4) Griselda X Brito-Córdova, RD, MSc,⁽¹⁾ Alexandro J Martagón, MD, PhD,⁽⁴⁾ Francisco J Gómez-Pérez, MD Endocr,⁽¹⁾ Paloma Almeda-Valdes, MSc, PhD Endocr.^(1,4)

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Abstract

Objective. To identify the associated factors to the consumption of non-nutritive sweeteners (NNS) in the Mexican adult population since its consumption has increased exponentially worldwide. **Materials and methods.** An online survey was applied to 5 038 Mexican adults to evaluate the frequency of NNS consumption and classify the population in tertiles. The sociodemographic, lifestyle and health status characteristics of the participants were compared by gradient of NNS consumption, and a multiple linear regression analysis was performed to determine the associated factors to the NNS consumption. **Results.** The variables that showed a positive association ($p \leq 0.01$) with the consumption of NNS were economic income, BMI, smoking, physical activity, diet quality, the presence of chronic diseases (diabetes, hypertension, or dyslipidemias), and the consumption of fruit. The age and the consumption of confectionery and sugar-sweetened beverages were negatively associated ($p < 0.01$) with the consumption of NNS. **Conclusion.** The results of this study help to characterize the target population that is a consumer of NNS since it is recommended not encourage the preference for sweet taste and to promote a decrease in the consumption of both caloric and NNS, preferring the natural flavor of food.

Keywords: non-nutritive sweeteners; food industry; diet; sweetening agents; diabetes; nutrition

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Resumen

Objetivo. Identificar los factores asociados con el consumo de edulcorantes no nutritivos (ENN) en la población adulta mexicana debido a que ha incrementado exponencialmente a nivel mundial. **Material y métodos.** Se aplicó una encuesta en línea a 5 038 adultos mexicanos para evaluar la frecuencia del consumo de ENN y clasificar a la población en terciles. Las características sociodemográficas, estilo de vida y estado de salud de los participantes se compararon por gradiente de consumo de ENN y se realizó un análisis de regresión lineal múltiple para determinar los factores asociados con el consumo de ENN. **Resultados.** Las variables que mostraron asociación positiva ($p \leq 0.01$) con el consumo de ENN fueron el ingreso económico, IMC, tabaquismo, actividad física, calidad de la dieta, presencia de enfermedades crónicas (diabetes, hipertensión o dislipidemias) y el consumo de frutas. La edad y el consumo de dulces y bebidas con azúcar se asociaron negativamente ($p < 0.01$) con el consumo de ENN. **Conclusión.** Los resultados de este estudio contribuyen a caracterizar a la población objetivo consumidora de ENN, ya que se recomienda no alentar la preferencia por el sabor dulce y disminuir el consumo de edulcorantes calóricos y ENN, prefiriendo el sabor natural de los alimentos.

Palabras clave: edulcorantes no nutritivos; industria alimentaria; dieta; agentes endulzantes; diabetes; nutrición

- (1) Departamento de Endocrinología y Metabolismo, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Mexico City, Mexico.
- (2) Servicio de Nutriología Clínica, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Mexico City, Mexico.
- (3) División de Nutrición, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Mexico City, Mexico.
- (4) Unidad de Investigación de Enfermedades Metabólicas, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Mexico City, Mexico.

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Corresponding author: Paloma Almeda-Valdes. Departamento de Endocrinología y Metabolismo, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán. Vasco de Quiroga 15, Col. Belisario Domínguez Sección XVI. 14090 Tlalpan, Mexico City, Mexico.
email: paloma.almedav@incmnsz.mx

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The consumption of non-nutritive sweeteners (NNS) has increased globally as a strategy to reduce the consumption of energy-dense foods rich in sugar that contribute to the current pandemic of overweight and obesity.¹ This led the food industry to offer as an alternative a variety of processed products with less calories by using different food additives that replace the use of sucrose.² Nowadays, it is easy to consume any of the NNS, since they are present in many foods and are not only used in the low-calorie versions of products, which makes it difficult to identify all the sources of these substances in the diet.³ It has been reported that 11% of processed food and beverage products in Mexico contain NNS, being this proportion higher than the estimated in other countries like the United States (4%), New Zealand (1%) and Australia (<1%).⁴ The use of NNS have been controversial due to their possible effects to health.^{5,6} New evidence has emerged regarding the metabolic effects that some of the NNS could generate in glucose metabolism, appetite regulation, cardiovascular system, gut microbiota, and adiposity.⁷ Specifically, it has been shown in different clinical trials that the consumption of sucralose reduces insulin sensitivity in lean subjects and with obesity. Additionally, this NNS can modify the gut microbiota increasing the relative abundance of Gram-negative bacteria which leads to higher serum concentrations of lipopolysaccharide and creating a systemic inflammatory process that could affect the insulin signaling pathway.⁸⁻¹³ It is important to understand the trends and patterns concerning the consumption of the NNS, recognizing which are the people that are most exposed to the ingestion of these substances. Therefore, the aim of this study is to describe the main characteristics of the Mexican adult population according their NNS consumption, including sociodemographic variables, lifestyle habits, and health conditions; to identify the associated factors to the consumption of NNS in the Mexican adult population.

Materials and methods

Description of participants

This is a cross-sectional study based on an online survey applied between November 2020 and June 2021 promoted by social media (Facebook, Instagram, and Twitter) and by mailing to universities, health institutions and influencers, using a convenience sampling with the purpose to recruit participants living in different regions of Mexico, and to obtain a diverse sample regarding age, economic income, schooling, lifestyle, health status, etc.

The study was evaluated and approved by the Ethics and Research Committees of the *Instituto Nacional de*

Ciencias Médicas y Nutrición Salvador Zubirán in Mexico City and followed the principles established in the Declaration of Helsinki. The requirements to participate in the survey were to be over 18 years old and to be Mexican with internet literacy. People interested in answering the survey received a full explanation about the voluntary and completely anonymous participation. No identifiable information was collected, and participants consented online to take part in the survey.

Study design

The time required to answer the survey was estimated between 10 and 15 minutes. Some of the answers to the questions were open and others were multiple choice, according to the nature of the variables evaluated. Variables including sex, age, education level, weight, height, and smoking habit were collected. The economic income was evaluated and classified in three categories, being the lowest income less than 10 000 Mexican pesos per month and the highest 20 000 or more Mexican pesos per month. The diagnosis of chronic diseases was asked, including diabetes, hypertension and/or dyslipidemia. In addition, it was questioned whether the participants were health professionals such as dietitians, physicians, psychologists, dentists, nurses, physical therapists, etc.

Physical activity was evaluated with the short last 7 days self-administered version of the International Physical Activity Questionnaire (IPAQ), which has been validated for the Mexican population.^{14,15} This questionnaire evaluates the minutes and days of the previous week in which walking, moderate and vigorous physical activity were performed. Also, the sedentary behavior is evaluated through the spent hours sitting per day. This tool provides a quantitative score in Metabolic Equivalents of Task (METs)-min/week and based on the IPAQ scoring protocol, can be classified in three categories according to the physical activity level: low, moderate, and high.¹⁶

Diet quality was evaluated with the adapted and validated Spanish version of the Healthy Eating Index, based on the frequency (daily, 3 or more times a week but not daily, 1 or 2 times a week, less than 1 time a week, and never or almost never) of consumption of nine different food groups and the variety of the diet. A higher score is given for a frequent consumption of grains, vegetables, fruits, and low-fat dairy; a higher score for a moderate consumption of unprocessed meats and legumes; and a higher score for an infrequent consumption of processed meats, confectionery, and sugar-sweetener beverages.¹⁷ This tool provides a final score from 0 to 100, where the higher the score, the higher the quality of the diet. Besides, diet quality was classified in

three categories according to the cut-off points proposed in the validation study: unhealthy (<50), needs changes (50-80) and healthy (>80). The questions included in the diet quality questionnaire, the way of scoring the answers, and the interpretation of the result are shown in the supplementary information.¹⁸

Other questions included in the survey were if they considered that the NNS are part of a healthy lifestyle (with the following answer options: true, false or I do not know) and if they knew the allowed amount that they could consume of the NNS.

The consumption of NNS was evaluated based on the frequency of consumption of 8 categories of products containing NNS using a questionnaire previously elaborated by our group including products in the Mexican market: sugar substitute sachets, beverages, dairy, gelatins, gums and mints, water flavoring enhancers powders, cereals, and desserts.¹⁹ To obtain a semiquantitative variable that evaluated the degree of exposition to the NNS, the answers to these questions were weighted as follows: 0 points for never or very few times a year, 1 point for at least once a month but not every week, 2 points for at least once a week but not every day, and 3 points for every day. Accordingly, the score of this variable could be from 0 to 24 points, which allowed to classify the population in tertiles to evaluate the characteristics of the participants according to the gradient of NNS consumption. The tertiles were as follows: first tertile ≤ 2 points, second 3-6 points, and third tertile ≥ 7 points. The questions included in the food frequency questionnaire of products with NNS, the way of scoring the answers, and the interpretation of the result are shown in the supplementary information.¹⁸

Statistical analysis

The survey was open until June 2021 ended and the final sample was 5 038 participants. Variables distribution was evaluated with the Kolmogorov-Smirnov normality test and are presented as means \pm standard deviations or as medians (interquartile range) for parametric and nonparametric distribution, respectively. Categorical variables are described as frequencies and percentages. Differences between gradient of NNS consumption (tertiles) were evaluated using Pearson's Chi-square test for trend, one-way analysis of variance (ANOVA) or Kruskal-Wallis test, as appropriate. In addition, a multiple linear regression analysis was performed, including all the variables evaluated in this study to determine which are the main factors that could influence the consumption of NNS. Data were collected and analyzed using the IBM SPSS Statistics version 25.0 software and a p value <0.05 was considered significant.

Results

Of the 5 038 participants included in this study, 81.9% were women with a median of age of 30 years old [IQR: 24,41]; however, the range for this variable was 63 with a minimum age of 18 and a maximum of 81. Diagnosis of one or more of the following chronic diseases was reported in 14.7%: diabetes (4.5%), hypertension (5.6%) and dyslipidemia (7.4%). The average BMI was 25.3 ± 4.6 kg/m², 10.3% of the participants were smokers, 39.3% were health professionals, and 11.3% did not consume NNS at all. The general characteristics of the population are described in table I. Figure 1 shows the proportions of participants by education level, income, diet quality category, and BMI category.

Sociodemographic, health status and lifestyle variables by tertiles of NNS consumption are detailed in table II. The characteristics that were significantly different by NNS gradient of consumption were sex, age, income, the presence of chronic diseases, weight, BMI, smoking habit, being a health professional, physical activity, and diet quality. Only sedentary behavior was not associated with NNS consumption ($p=0.57$). A higher economic income, BMI, physical activity level and diet quality were found in the third tertile of NNS consumption ($p<0.01$). In addition, it was observed that the higher the consumption of NNS, the higher the prevalence of men, chronic diseases, smokers, and health professionals ($p<0.05$).

Table I
DESCRIPTION OF THE CHARACTERISTICS OF THE
STUDY POPULATION.
MEXICO, NOVEMBER 2020-JUNE 2021

	<i>n</i> = 5 038
Female sex, <i>n</i> (%)	4 128 (81.9)
Age, years	30 [24-41]
Chronic diseases, <i>n</i> (%)	743 (14.7)
Diabetes, <i>n</i> (%)	229 (4.5)
Hypertension, <i>n</i> (%)	285 (5.6)
Dyslipidemia, <i>n</i> (%)	374 (7.4)
Weight, kg	67.3 \pm 14.8
Height, m	1.62 \pm 0.08
BMI, kg/m ²	25.3 \pm 4.6
Smoking habit, <i>n</i> (%)	521 (10.3)
Health professionals, <i>n</i> (%)	1 980 (39.3)
Physical activity, METs-min/w	1 116 [360-2 400]
Diet quality	69.4 \pm 11.5

BMI: body mass index; METs: metabolic equivalents of task. Values are means \pm SDs or medians [IQRs] unless otherwise indicated.

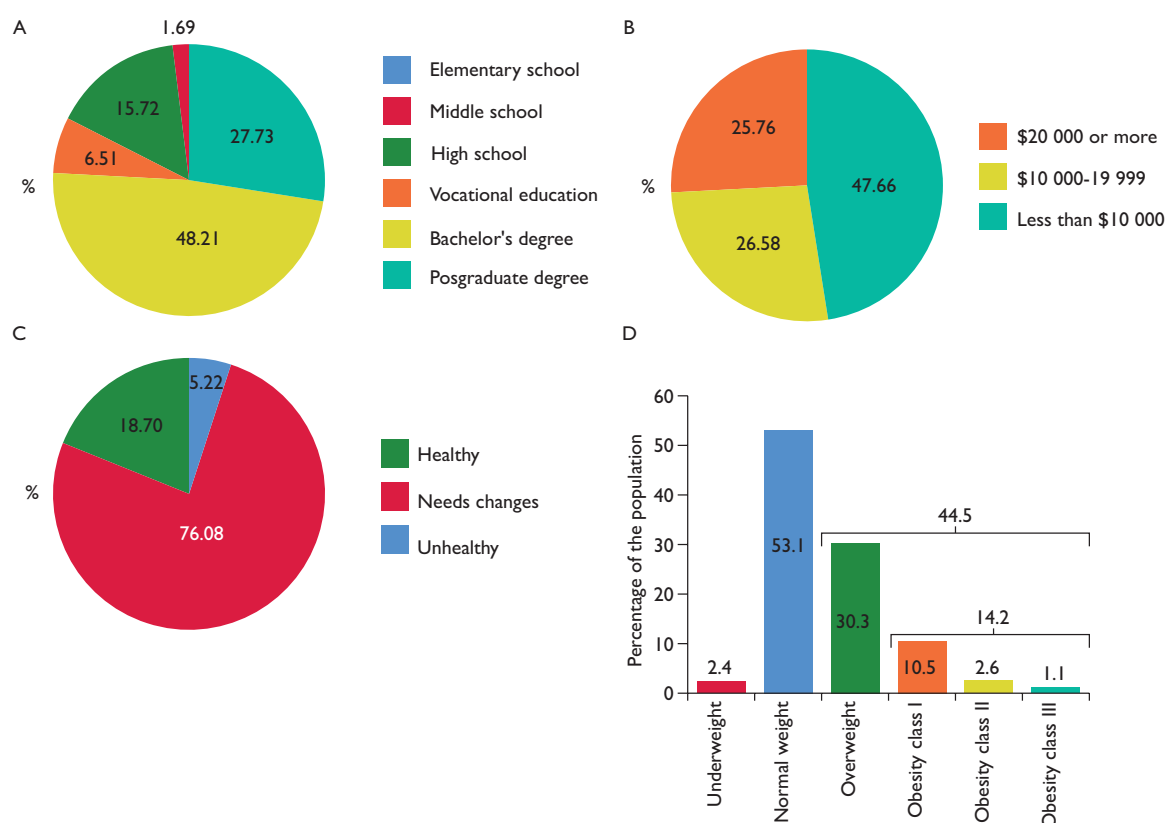


FIGURE 1. PROPORTIONS OF THE POPULATION BY (A) EDUCATION LEVEL, (B) ECONOMIC INCOME IN MEXICAN PESOS PER MONTH, (C) DIET QUALITY CATEGORY, AND (D) BODY MASS INDEX CATEGORY. MEXICO, NOVEMBER 2020-JUNE 2021

A stratified analysis was performed dividing the population into health professionals and general population, to identify differences between the variables of interest by tertile of NNS consumption. The tables of this analysis are shown in the supplementary information.¹⁸ Only gender and income lost statistical significance in health professionals. No differences were found in the general population compared to table II, except that some variables such as sex, smoking, presence of chronic diseases, and body weight showed a greater difference by gradient of NNS consumption.

The β coefficients with their 95% confidence intervals (CI) of the independent variables included in the multivariate linear regression analysis are shown in table III. The overall regression was statistically significant ($R^2 = 0.062$, $F [14, 5\ 023] = 23.66$, $p < 0.001$). The variables that showed a significant positive association with the consumption of NNS were the income, BMI, smoking, physical activity level, diet quality, the presence of chronic diseases, and the consumption of fruit. The

age and the consumption of confectionery and sugar-sweetened beverages were negatively associated with the consumption of NNS. According to this analysis, sex, education level and vegetables consumption were not associated with the consumption of NNS. Being a health professional showed a tendency to be related with the consumption of NNS, however, this was not significant. Finally, in relation to the idea of whether the NNS are part of a healthy lifestyle, 14.5% thought that this was true, 63.8% that it was false, and 21.7% answered they did not know. The opinion to this question differed by gradient of consumption of NNS ($p < 0.01$), observing a higher proportion of participants considering that NNS are part of a healthy lifestyle in the third tertile of consumption in comparison with the first (28.9 vs. 5.3%), and in contrast, the first tertile showed a higher proportion of participants who disagreed with this idea in comparison to the third (75.3 vs. 48.6%). Of the total number of responders, 22% reported knowing the allowed amount of NNS that they can consume, being

Table II
DIFFERENCES IN THE VARIABLES EVALUATED BETWEEN TERTILES OF NNS CONSUMPTION.
MEXICO, NOVEMBER 2020-JUNE 2021

	<i>Tertile 1 (n= 1 726)</i>	<i>Tertile 2 (n= 1 895)</i>	<i>Tertile 3 (n= 1 417)</i>	<i>p*</i>
Female sex, n (%)	1 436 (83.2)	1 559 (82.3)	1 133 (80.0)	0.04
Age, years	31 [24-42]	29 [23-39]	32 [24-43]	<0.01
Economic income, n (%)				<0.01
Category 1 (low)	889 (51.5)	946 (49.9)	566 (39.9)	
Category 2 (medium)	436 (25.3)	509 (26.9)	394 (27.8)	
Category 3 (high)	401 (23.2)	440 (23.2)	457 (32.3)	
Chronic diseases, n (%)	207 (12.0)	275 (14.5)	261 (18.4)	<0.01
Weight, kg	65.2 ± 13.9	67.4 ± 15.0	69.9 ± 15.1	<0.01
BMI, kg/m ²	24.6 ± 4.5	25.3 ± 4.6	26.0 ± 4.7	<0.01
Smoking habit, n (%)	143 (8.3)	196 (10.3)	182 (12.8)	<0.01
Health professional, n (%)	632 (36.6)	753 (39.7)	595 (42.0)	<0.01
Physical activity, METs-min/w	1 000 [330-2,227]	1 078 [346-2,346]	1 299 [426-2,620]	<0.01
Sedentarism, h/d	7 [5-10]	7 [5-10]	7 [5-9]	0.57
Physical activity level, n (%)				<0.01
Low	657 (38.1)	651 (34.4)	450 (31.8)	
Moderate	522 (30.2)	596 (31.5)	399 (28.2)	
High	547 (31.7)	648 (34.2)	568 (40.1)	
Diet quality	68.9 ± 11.2	68.6 ± 11.6	70.8 ± 11.6	<0.01
Diet quality category, n (%)				<0.01
Unhealthy	86 (5.0)	118 (6.2)	59 (4.2)	
Needs changes	1 345 (77.9)	1 446 (76.3)	1 042 (73.5)	
Healthy	295 (17.1)	331 (17.5)	316 (22.3)	

NNS: non-nutritive sweeteners; BMI: body mass index; METs: metabolic equivalents of task. Values are means ± SDs or medians [IQRs] unless otherwise indicated.
 * Differences were evaluated with Pearson's Chi-square test for trend, one-way analysis of variance (ANOVA) or Kruskal-Wallis test, as appropriate.

this proportion higher in the third tertile of consumption compared to the first (32.7 vs. 14.8%; $p < 0.01$).

Discussion

According to the results of this survey, we found that people who consume a higher amount of NNS tend to have a higher economic income, BMI, physical activity level and diet quality. In addition, people who smoke, are health professionals and with chronic diseases such as diabetes, hypertension, and dyslipidemias tend to consume more NNS.

Apparently, it was observed a higher proportion of men in the third tertile of NNS consumption, however, in the multiple linear regression this variable was not significantly associated. Also, in the multivariate analysis, age was negatively associated with the consumption of NNS. In contrast, a study in coffee consumers from fast food establishments, reported that the age groups

that more frequently sweetened their beverages with NNS were 18-29 years and 46-55 years, with a higher proportion of NNS consumption in women.²⁰

An analysis from the Australian National Nutrition and Physical Activity Survey, found similar results to those of our study, reporting that the characteristics associated with the consumption of NNS were a higher BMI, the presence of diabetes, being female, and being on a weight-loss diet.²¹ Other studies have also reported that people with a better socioeconomic status tend to consume more NNS, as well as the female sex and people with obesity.^{22,23}

With this information, it could be inferred that since the sugar-free or diet versions of products, which contain NNS, are usually more expensive, the consumption of these food additives is more frequent in people with higher income. People with chronic diseases, mainly those related to metabolic disorders, frequently use the NNS because it is a dietary strategy that has been used

Table III
MULTIPLE LINEAR REGRESSION TO PREDICT THE IMPACT OF DIFFERENT VARIABLES IN THE CONSUMPTION OF NNS. MEXICO, NOVEMBER 2020-JUNE 2021

Variable	β coefficient	95%CI	P*
Sex (men vs. women)	-0.052	-0.327,0.223	0.71
Age (years)	-0.019	-0.030,-0.008	<0.01
Economic income (categories) [‡]	0.482	0.331,0.632	<0.01
Education level (categories) [‡]	0.055	-0.062,0.173	0.35
Chronic diseases (absence vs. presence)	0.691	0.376,1.007	<0.01
BMI (kg/m ²)	0.088	0.064,0.111	<0.01
Smoking habit (absence vs. presence)	0.783	0.445,1.121	<0.01
Health professional (no vs. yes)	0.211	-0.012,0.435	0.06
Physical activity level (categories) [‡]	0.401	0.274,0.527	<0.01
Diet quality (score)	0.055	0.042,0.068	<0.01
Consumption of vegetables (score)	0.047	-0.121,0.215	0.58
Consumption of fruits (score)	0.164	0.026,0.301	0.01
Consumption of confectionery (score)	-0.282	-0.379,-0.185	<0.01
Consumption of SSB (score)	-0.375	-0.478,-0.273	<0.01

NNS: non-nutritive sweeteners; CI: confidence interval; BMI: body mass index; SSE: sugar-sweetened beverages. Dependent variable: NNS consumption evaluated with the frequency questionnaire by product category.

* All the variables were introduced simultaneously in the model to adjust the association by all these factors.

[‡] Categories in order for the analysis: economic income (low, medium, high), education level (elementary school, middle school, high school, vocational education, bachelor's degree, and postgraduate degree) and physical activity level (low, moderate, high).

for years to reduce the consumption of sugars. Also, younger people could consider products with NNS as part of a regular diet due to the important presence that they have today in processed foods.

The consumption of NNS also was associated with a higher score in diet quality and a higher proportion of participants in the third tertile were in the category of a "healthy dietary pattern". This finding is consistent with that reported in the literature, since multiple studies have associated the consumption of NNS with a better diet quality.^{22,24,25} One study has found that NNS consumers tend to have lower diet quality; nevertheless, the consumption of NNS was evaluated in beverages and this is not the only source of these food additives, besides that commonly the consumption of these beverages is accompanied by fast or junk food.²⁶ Also, the consumption of NNS showed a positive association with the consumption of vegetables and a negative association with the consumption of confectionery and sugar-sweetened beverages. Grech and colleagues also reported that NNS consumers had lower free sugar intake.²¹

As important components of a healthy lifestyle, we found that NNS consumers perform more physical activity, however, a higher proportion of smokers was also observed in this population. In contrast with these

findings, Drewnowski and colleagues reported that NNS consumers were more likely to be physically active and non-smokers.²²

In comparison to the first tertile, the third tertile of NNS consumption showed a higher proportion of participants considering that the NNS are part of a healthy lifestyle (28.9 vs 5.3%) and a higher proportion of participants who mention knowing the amount of NNS that they can consume (32.7 vs 14.8%). In a study conducted in Ireland including 741 individuals, 89.2% reported being unaware of the amount of NNS that they can consume, and it was observed that those who were aware of the amount, were more likely to have a positive perception of NNS.²⁷ Also, in a study in the United Kingdom adult population including 1 589 responders of a survey, 36.7% agreed and 10.1% strongly agreed that they consume NNS because they are healthier than sugars.²⁸

In general, it seems logical that people trying to have a healthier lifestyle, including diet and physical activity, consume more NNS to replace the consumption of sugary foods. This could also be a possible explanation for why these substances are consumed more in health professionals.

Even though the multivariate model explained a low proportion (6.2%) of the NNS consumption, many

of the variables studied were significantly associated with consumption of NNS and could be factors that influence this phenomenon. However, it is complex to explain human behavior, including NNS consumption. With the information obtained from this study, it can be inferred that certain sociodemographic and health status variables can influence the consumption of NNS; although other factors could probably play an important role in this decision, such as the person's own ideology.

The limitations of this study include that the consumption of NNS was evaluated in a semiquantitative way with a food frequency questionnaire, in a self-reported way, and only considering the conscious consumption because nowadays the NNS can be present in regular version of products, and it can be difficult to identify all the sources of these food additives. Also, all the surveys were applied online, which can interfere with the interpretation of some questions since respondents were unable to personally ask the researchers, and that some variables were self-reported and not measured directly. In addition, dietary intake was not evaluated and the instrument to measure diet quality may not fully represent the eating habits of the participants. Finally, we recognize that the results of this study might not be representative of the entire Mexican population due to the convenience sampling strategy used.

It is quite relevant to understand the worldwide trends of the NNS consumption since the production of foods and beverages with NNS is increasing as well as the evidence emerging in relation to their possible negative effects to health. It is recommended not encourage the preference for sweet taste in the population and to promote a decrease in the consumption of both caloric and NNS, preferring the natural flavor of food. The information generated in this and other studies, helps to characterize the main target population that is a consumer of NNS and to understand their consumption behavior, with the purpose of generating policies and strategies that contribute to reduce the production and consumption of NNS, especially in new generations.

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