Food insecurity and obesity in Mexican adults

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body Mass Index
CLOCK	Circadian Locomotor Output Cycles Kaput
CONEVAL	National Evaluation Council
ELCSA	Latin-American and Caribbean Food Security Scale
EMSA	Mexican Food Security Scale
ENIGH	National Household Income and Expenditure Survey
ENSANUT	National Health and Nutrition Survey
ENSANUT MC 2016	Halfway National Health and Nutrition Survey 2016
FAO	Food and Agriculture Organization of the United Nations
FIES	Food Insecurity Experience Scale
HDL	High-Density Lipoprotein
HFIAS	Household Food Insecurity Access Scale
HFSSM	Household Food Security Survey Module
IL-6	Interleukin 6
IMC	Indice de Masse Corporelle
INEGI	National Institute of Statistic and Geography
INSP	National Institute of Public Health
IPAQ	International Physical Activity Questionnaire
LDL	Low-Density Lipoprotein
n-3 PUFA	n-3 Polyunsaturated fatty acids

NHANES	National Health and Nutrition Examination Survey
OR	Odds Ratio
P	P-value
SD	Standard Deviation
SDG	Sustainable Development Goals
SFFQ	Semiquantitative Food Frequency Questionnaire
SPSS	Statistical Package for the Social Sciences
TNF-α	Tumor necrosis factor α
TT	Tour de Taille
U.S.	United States
VLDL	Very Low Density Lipoprotein
WHO	World Health Organization

ABSTRACT

Background: For decades, food insecurity and obesity have been two major public health problems in Mexico. It has been reported that social inequalities are the main determinants for both conditions, given their adverse impact on access to food, health, education, income, and people's well-being in general. Therefore, these situations affect people's dietary intake, lifestyle and living conditions. Moreover, their simultaneity is of higher menace, implying a double burden of malnutrition for those affected. This means that people are "paradoxically" dealing with overweight, obesity, and related comorbidities while experiencing situations such as food scarcity, nutritional deficiencies and hunger. However, it has been observed that both states share common determinants such as poverty and low education level, as well as unhealthy dietary patterns. Given this backdrop, a better understanding of the association between food insecurity and obesity, and monitoring its evolution are necessary to provide a scientific foundation for the design of future policies and interventions. **Objective:** To assess the relationship between food insecurity and body mass index (BMI), waist circumference (WC), overweight, obesity, abdominal obesity among Mexican adults. **Methods:** A cross-sectional study was performed using data from the Halfway National Health and Nutrition Survey 2016 (ENSANUT MC 2016). The sample consisted of 5,456 adults (20 to 59 years old), who represent 45,804,210 individuals at the national level. Descriptive analyses were conducted, followed by multivariate linear and logistic regression models for evaluating the associations between food insecurity and BMI, WC, overweight, obesity, and abdominal obesity. The analysis was conducted using the complex samples option of IBM SPSS Statistics for Windows, v. 25.0. Results were reported as significant with a P <0.05. **Results:** 70.8% of the sample was food insecure. Indigenous people, rural areas, the Southern region, and the lowest socioeconomic levels showed the highest prevalence (P <0.05) of this condition. Obesity and abdominal obesity showed higher proportions in females than in males (P <0.001), with the highest prevalence occurring among those experiencing severe food insecurity. In females, BMI and WC increased as food insecurity worsened (P <0.001). Likewise, multivariate regression models showed significant results only for females. Accordingly, severe food insecurity was positively associated with obesity (OR= 2.36; P= 0.001), BMI (β= 2.24; P <0.001), and WC (β= 4.22; P= 0.002). **Conclusions:** Despite the multiple programs and interventions aimed at addressing food insecurity and obesity in Mexico during recent years, no significant improvements seem to have happened. According to the most recent surveys, the prevalence of both conditions keeps increasing. Furthermore, an association between them shows consistent trends, and thus, future policies should consider their coexistence. Given the serious consequences of both

phenomena, interventions directed to improve food security and nutritional status in Mexico are urgently needed, with a special focus on the most vulnerable population groups. Besides, these should be planned and executed in a comprehensive and coherent way, attending the different dimensions of food insecurity. It is imperative to ensure the availability of healthy foods and access to them over energy-dense, nutrient-poor, highly processed products. Therefore, higher and more effective investments in nutrition and health, and consensually achieved regulations for the food industry are primordial. Additionally, actions directed to overcome the systemic causes of food insecurity and obesity, such as low education and income, need to be contemplated for getting sustainable results.

RÉSUMÉ

Contexte: Pendant des décennies, l'insécurité alimentaire et l'obésité ont été deux majeurs problèmes de santé publique au Mexique. Les inégalités sociales ont été reportées comme étant les principaux facteurs déterminants de ces deux conditions, étant donné leur impact négatif sur l'accès à la nourriture, à la santé, à l'éducation, au revenu et au bien-être des personnes en général. Par conséquent, ces situations affectent l'apport alimentaire, le style de vie et les conditions de vie des gens. En outre, leur simultanéité est d'autant plus menaçante, puisqu'elle implique un double fardeau de malnutrition pour les personnes touchées. Cela signifie que les gens sont "paradoxalement" confrontés au surpoids, à l'obésité et aux comorbidités associées, tout en connaissant des situations telles que la pénurie alimentaire, les carences nutritionnelles et la faim. Cependant, il a été observé que les deux situations partagent des déterminants communs tels que la pauvreté et le faible niveau d'éducation, ainsi que des régimes alimentaires malsains. Dans ce contexte, une meilleure compréhension de l'association entre l'insécurité alimentaire et l'obésité et le suivi de son évolution sont nécessaires pour fournir une base scientifique à la conception des politiques et interventions futures. **Objectif:** évaluer la relation entre l'insécurité alimentaire et l'indice de masse corporelle (IMC), le tour de taille (TT), le surpoids, l'obésité, l'obésité abdominale chez les adultes mexicains. **Méthodes:** Une étude transversale a été réalisée à l'aide des données de l'Enquête nationale sur la santé et la nutrition à mi-chemin 2016 (ENSANUT MC 2016). L'échantillon était composé de 5,456 adultes (20 à 59 ans), ce qui représente 45,804,210 individus au niveau national. Des analyses descriptives ont été menées, suivies de modèles de régression linéaire et logistique multivariés pour évaluer les associations entre l'insécurité alimentaire et l'IMC, le TT, le surpoids, l'obésité et l'obésité abdominale. L'analyse a été réalisée à l'aide de l'option d'échantillons complexes d'IBM SPSS Statistics pour Windows, v. 25.0. Les résultats ont été rapportés comme étant statistiquement significatifs lorsque la valeur-*P* était inférieure à 0.05. **Résultats:** 70.8% de l'échantillon était en situation d'insécurité alimentaire. Ce phénomène était majeur au sein des populations autochtones, des zones rurales, de la région du Sud et des niveaux socioéconomiques les plus bas ($P < 0.05$). L'obésité et l'obésité abdominale étaient plus élevées chez les femmes que chez les hommes ($P < 0.001$), notamment chez celles souffrant d'insécurité alimentaire grave. Chez les femmes, plus leur insécurité alimentaire empirait, plus leur IMC et TT augmentait ($P < 0.001$). De même, les modèles de régression multivariée ont montré des résultats significatifs uniquement pour les femmes. En conséquence, une insécurité alimentaire sévère était associée positivement à l'obésité (OR= 2.36; $P= 0.001$), à l'IMC ($\beta = 2.24$; $P < 0.001$) et aux TT ($\beta= 4.22$; $P= 0.001$). **Conclusions:** Malgré les multiples programmes et interventions mis en place au Mexique au

cours des dernières années afin de lutter contre l'insécurité alimentaire et l'obésité, aucune amélioration significative ne semble s'être produite. En effet, les enquêtes les plus récentes révèlent une augmentation continue de ces conditions. En outre, la présence d'une association entre eux indique que ces tendances prédites sont cohérentes. Par conséquent, les politiques futures devront tenir compte de la coexistence de ces conditions. Compte tenu des graves conséquences de ces deux phénomènes, des interventions visant à améliorer la sécurité alimentaire et l'état nutritionnel au Mexique sont nécessaires de toute urgence, en accordant une attention particulière aux groupes de population les plus vulnérables. En outre, celles-ci doivent être planifiées et exécutées de manière globale et cohérente, en tenant compte des différentes dimensions de l'insécurité alimentaire. Il est impératif de garantir la disponibilité d'aliments sains au lieu de produits hautement énergétiques, faibles en nutriments et hautement transformés. Par conséquent, des investissements plus élevés et plus efficaces dans la nutrition et la santé, ainsi que des réglementations consensuellement réalisées pour l'industrie alimentaire sont primordiaux. En outre, des actions visant à surmonter les causes systémiques de l'insécurité alimentaire et de l'obésité, telles que le faible niveau d'éducation et de revenu, doivent être envisagées pour obtenir des résultats durables.

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CONTRIBUTIONS OF THE AUTHORS

As the candidate for the Master's degree and principal investigator of the study, I developed the research questions, hypothesis, and objectives. I conducted the literature review, designed the methodology, performed the statistical analysis, interpreted the results, and wrote the manuscript that will be submitted for publication to the Public Health Nutrition Journal.

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CHAPTER 1: OUTLINE

1.1 Introduction

Mexico is currently immersed in an economic and epidemiological transition that implies constant changes in its population health and nutritional status[1, 2]. During the last decades, the main nutritional problems have evolved from undernutrition to overweight and obesity, with a growing and alarming prevalence for the last ones[3]. This situation has been associated with the increasing trends in other chronic diseases, which are the leading causes of death in the country[3, 4]. Consequently, health institutions declared in 2016 a state of emergency in relation to the obesity epidemic[5]. Nonetheless, the actions carried out by the government, health sector, food industry, and society have remained short in overcoming the problem[5]. According to the latest national surveys, the prevalence of obesity and associated comorbidities keep increasing[4, 6, 7].

At the same time, socioeconomic inequalities persist in the country; among these, food poverty is a critical issue to be attended[8, 9]. Nutritional deficiencies and hunger still affect the population despite the previously mentioned changes in the national health profile[1, 3, 10]. In fact, the increases in obesity and chronic diseases have also been associated with a lacking access to food[1, 11-14]. Given that this situation derives primarily from a lack of economic access, impoverished and marginalized social sectors are the most affected by food deficiencies[15, 16].

The initiatives conducted to attend the feeding situation have included constitutional reforms and interinstitutional agreements of cooperation to execute cash and in-kind transfers, school feeding programs, and food production programs[15, 17]. However, it has been indicated that to solve the food insecurity condition more effectively, structural changes such as improvements in education, well-paid jobs, and social security need to be achieved[11, 18].

At first sight, the coexistence of obesity and lack of access to food might seem contradictory[19, 20]. Nevertheless, the relationship between both conditions has been found in various countries, receiving explanations from different angles, including economic, dietetic, metabolic, epigenetic, and psycho-social mechanisms[20-22]. In Mexico, other authors have described this phenomenon among children[14], adolescents[1, 12], female adults[1, 11], and elderlies[13]. However, the study and update of the food insecurity-obesity association are crucial to progress in the resolution of both conditions, to design

assertive policies, to implement social programs that are coherent with the ongoing circumstances, and to improve people's health and life conditions.

Given this background, the present thesis recapitulates some of the facts that have driven to the current state of food insecurity and obesity in Mexico, its evolution, and the consequences that have arisen, or that might eventually occur if no immediate action is taken. A comprehensive literature review section precedes a manuscript that seeks to add to the current state of knowledge on the association between food insecurity and overweight, obesity, and abdominal obesity in a nationally representative sample of Mexican adults. This study had a cross-sectional design and was conducted using data from the Halfway National Health and Nutrition Survey 2016 (ENSANUT MC 2016 by its acronym in Spanish Encuesta Nacional de Salud y Nutrición Medio Camino 2016)[23].

1.2 Study Rationale

The international agenda for 2030 establishes 17 sustainable development goals (SDG) intended to end with a series of issues that impede individual, community, and environmental progress[24]. Among this global agreement, the second and third goals refer to eradicate hunger and to ensure health and well-being[24].

Within this policy framework, Mexico is committed to working towards the achievement of the SDG[25]. Hence, assistance to poverty, food insecurity, and the health crisis, described in the introduction, is part of the international agreements[25]. Additionally, the right to food and health is a constitutional mandate, and the state is responsible for facilitating the fulfillment of these basic needs[26]. Accordingly, the Mexican General Health Law establishes in article 115 the promotion of chemistry, biology, social, and economic researches directed to study the nutritional conditions of the population for the maintenance of good health[27].

Supported in these legal foundations and the current food insecurity and health context previously exposed, this research is relevant for governmental institutions, for decision-makers, and for the Mexican society as a whole. It also contributes to the current body of knowledge in the public health and social development fields. The findings presented here are valuable not only in Mexico but in similar contexts, such as the ones prevalent in other countries of Latin-America.

1.3 Study objectives

1.3.1 General objective

The aim of this study was to assess the relationship between food insecurity and overweight, obesity, and abdominal obesity in the Mexican adult population. The ultimate purpose was to contribute to the monitoring of the coexistence between those phenomena, thus providing a reference for the design of adequate future food and health policies in the country.

1.3.2 Specific objectives

1. To provide a comprehensive review of the state of food insecurity and obesity in the Mexican context.
2. To describe the distribution of food insecurity according to the population's sociodemographic characteristics.
3. To assess the changes in BMI and WC in the Mexican adult population according to food insecurity level.
4. To evaluate differences in the prevalence of overweight, obesity, and abdominal obesity by food insecurity level.
5. To analyze the associations between food insecurity and BMI, waist circumference, and the categories derived from these indicators such as overweight, obesity, and abdominal obesity.

CHAPTER 2: LITERATURE REVIEW

2.1 Food insecurity

2.1.1 Concepts and classification

To understand the concept of food insecurity, we should first comprehend what food security refers to, as well as each of its components. The United Nations' Food and Agriculture Organization (FAO) most recent definition establishes that "food security is a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"[28]. This definition has evolved since its origins in 1974 due to a deeper understanding of its complexity, the results obtained from the interventions derived from previous definitions, the changes in population's needs, and its technical and policy implications around the globe[29].

Briefly, the concept initially focused on the availability and sufficiency of food in terms of quantity[29]. Subsequently, the aspect of access was incorporated, mainly because of its relevance to the most vulnerable and poor populations[29]. Finally, points related to food quality and safety complemented this definition[29]. In recap, the ultimate goal of food security is contributing to guarantee an adequate nutritional status of individuals[29]. Thus the risk of not achieving this translates into an increasing vulnerability[29].

Derived from the above, food insecurity has been defined as "a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and to have an active, healthy life"[28]. Other authors mention that "food insecurity happens whenever the availability of nutritionally adequate and safe foods or the ability to acquire them in socially acceptable ways is limited or uncertain"[30]. In summary, food insecurity can result from the unavailability of food, insufficient purchasing power, or the inadequate distribution or use of food at the household level[29].

Depending on the time individuals have suffered from food insecurity, this situation could be chronic, seasonal, or transitory[29]. Additionally, according to the severity of the people's experiences with food insecurity, individuals or households are classified as food secure, mildly food insecure, moderately food insecure, or severely food insecure[31]. Mildly food insecure people suffer from concern and anxiety about their ability to obtain sufficient food supplies and start to adjust their budget allocated

to food[32]. These adjustments can affect the quality and variety of their diets[32], given the affordability of food rich in fat and sugar, but with low content of micronutrients[33]. If additionally, the gravity of the situation leads to reductions in the quantity of food consumed, people are considered moderately food insecure[31, 32]. Finally, in the most severe stage, individuals experience hunger[31].

2.1.2 Measurement

The presence of food insecurity and the level at which this situation is experienced by an individual or a household can be determined by applying appropriate measurement techniques. The relevance of adequately measuring food security resides in its critical role in the design and implementation of accurate policies conceived to effectively identify and attend the most vulnerable population sectors[31]. Feasible and practical measurement techniques allow as well for a better evaluation of the actions undertaken to overcome food insecurity[31].

Some traditional instruments indirectly evaluate the food security/insecurity situation by analyzing their determinants or consequences[34]. Among these methods, the following are the most commonly used: i) food balance sheets from the FAO, which examine the caloric availability per capita in a country; ii) household income and expenditure surveys; iii) individual's dietary intake tools; and iv) anthropometric nutrition indicators[34]. However, the phenomenon of food insecurity, which is directly determined by the food access[34], which in turn is a pillar to achieving food security[35], is not assessable with such instruments[31, 34]. Besides, the high costs or the lack of technical capacity for the application of those instruments make them an infeasible or costly and complicated option to apply for some countries[31]. Alternatives that provide a direct evaluation of the food security/insecurity situation are the methods based on the perception and experiences of the affected subjects[31, 34]. The latter have shown to capture information not only about food access, but as well other underlying dimensions of food insecurity (i.e., psychological, food quality and quantity, and the presence of hunger)[31].

The development of scientifically reliable instruments based on food insecurity related experiences has a long history in their generation, testing, improvement, and application around the globe[36]. As a result of this work, in 2017 the FAO included for the first time in their annual report, "The State of Food Security and Nutrition in the World," the results on 150 countries from the application of a tool called Food Insecurity Experience Scale (FIES), which is currently the worldwide reference for measuring food insecurity[37].

The development of the FIES was largely based on previous similar instruments[36]. These methods include the U.S. national Household Food Security Survey Module (HFSSM), the USAID Household Food Insecurity Access Scale (HFIAS), the Brazilian Food Insecurity Scale, and the Latin American and Caribbean Food Security Scale (ELCSA by its acronym in Spanish, *Escala Latinoamericana y Caribeña de Seguridad Alimentaria*)[36]. The latter emerged from the necessity of a regional tool for the diagnostic and monitoring of food insecurity and sought to give uniformity to the information obtained in countries of Latin America and the Caribbean[31]. For developing this instrument, it was necessary a formal consultation process that included two regional conferences about food security measurement at the household level[31]. These events were followed by the application of an adjusted version of the ELCSA in different countries from Latin America[31]. Finally, workshops about the harmonization and statistical analysis of the instrument were conducted[31, 38].

In Mexico, ELCSA was initially tested as part of public opinion polls carried out in 2007 in the state of Guanajuato and at the national level[38]. The media rapidly spread the results derived from the surveys setting up the discussion of the food insecurity situation in the country[31]. The findings on food insecurity showed associations with poverty indicators, as expected[31]. The scale demonstrated a high psychometric internal validity and a feasible integration to the rapid information systems of the country[31, 39].

Subsequently, this instrument became the official method for measuring food access by the National Council for the Evaluation of Social Development Policy (CONEVAL by its acronym in Spanish, *Consejo Nacional de Evaluación de la Política del Desarrollo Social*)[39]. In 2008, CONEVAL applied the ELCSA in 70,000 Mexican households[31]. Since then, food insecurity measurement has been part of the official assessment of the multidimensional poverty in the country[39]. Later on, the National Public Health Institute (INSP by its acronym in Spanish, *Instituto Nacional de Salud Pública*) incorporated the ELCSA to the National Health and Nutrition Surveys (ENSANUT from its acronym in Spanish, *Encuesta Nacional de Salud y Nutrición*) of 2012, 2016 and 2018[23].

As the present research was based on information collected through the ENSANUT, and therefore food insecurity was evaluated with the ELCSA, a brief explanation of this method follows.

The ELCSA comprehends fifteen questions that inquire about self-reported experienced situations[31]. The first eight questions refer to the food insecurity experiences of the households and the adult members in those households[31]. The following ones are directed to know the conditions affecting

members under 18 years old[31]. The items included in the questionnaire are shown in Appendix 2.1. Each of these questions is to be answered with "Yes" or "No".

After the questionnaire is completed, an index is generated based on the sum of positive answers. The number of affirmative answers, and the presence or absence of members under 18 years of age, allow classifying the household in one of four severity levels. A household is considered food secure when there are no positive answers to the questions. There exists mild food insecurity when the score goes from 1 to 3, and there are no minors at home or when it ranges from 1 to 5, and there are minors. There is moderate food insecurity with a score of 4 to 6 in households integrated exclusively by adults, or from 4 to 10 when there are minors. Finally, severe food insecurity occurs when we find a score from 7 to 8 points, or from 11 to 15 in households without minors and with minors, respectively[11].

In the ENSANUT surveys, the ELCSA has been applied to the mother or woman in charge of preparing food at home[23]. An additional item has been added between questions eight and nine inquiring about the presence of minors at home, in order to facilitate the application of the questionnaire in practice[23]. Such question is obviously not considered for the generation of the score[23].

2.1.3 Food insecurity in Mexico

The history of food insecurity in Mexico dates back to the global food crisis in the 1970s and the rise in the price of basic grains. These events were followed by annual inflation, which was strikingly high in the 1980s, reaching 159.2% in 1987[40]. Additionally, the economic crunch that hit the country in 1994 could have contributed to increasing food poverty, which passed from affecting nineteen million to thirty-five million people[40]. Food poverty would refer to the inability to acquire a basic food basket, even if all the disposable income in the household was used to buy only the goods in the said basket[41]. Then in 2008, the world problems across financial, energy, and food sectors affected Mexico by leading to instability, price volatility, and increasing the cost of basic grains again[15]. These events could have contributed to another increment in food poverty, which went from 13.8% in 2006 to 18.2% in 2010[15].

Later in 2018, it was estimated that 25.5% of the population in the country had a lack of access to food[41]. Under this background, one of the main determinants for not achieving food security has been the low economic capacity of large shares of the population, identified in the last decades[16], given that the caloric sufficiency per capita was achieved since 1980[16]. Likewise, according to the FAO, the caloric

availability in 2012 corresponded to 3,145 kcal per capita, one of the highest in the world and superior to the energy requirements calculated in 2,362 kcal[15].

In the search for the determinants of food insecurity in Mexico, an econometric analysis conducted in 2019 with national data found a positive and significant association between inflation in food prices, unemployment rate, and employment rate in the informal sector, and severe food insecurity[42]. Additionally, a negative and significant association with education and the gross domestic product in the primary sector was reported [42]. This study was based on the capabilities approach proposed by Amartya Sen in 1980[42]. According to this perspective, food insecurity is linked to the level of entitlement people have[42]. In this context, entitlement refers to the individual's capacity to demonstrate ownership or control over goods and services, and their capacity for either producing or buying food[42]. Thereby, the lack of entitlement and low economic growth are two main elements that directly intervene in food insecurity[42].

The results obtained from the econometric models led to the following resolutions on the relationships found with each variable. First, people with higher education degrees have higher probabilities of moving off from the severe food insecurity level, either by getting better jobs or because they have the capabilities to generate higher incomes[42]. Second, the food price is decisive for food acquisition; therefore, when it increases affects the most vulnerable population by reducing the possibility of fulfilling its basic needs[42]. Third, growth in the primary sector is basic for food availability and is a condition to promote food security[42]. Finally, the lack of formal employment is an obstacle to improving the living conditions, especially in moments of economic instability and in the absence of labor protection[42].

As it was mentioned in the preceding section, considering different dimensions of food security provides a completer and more informative scheme of its situation. Therefore, it is necessary to complement the data of caloric availability with knowledge on the access to food, as well as anthropometric indicators[15]. According to the information presented so far, food availability is currently not a problem as serious as food acquisition in the Mexican context. In this regard, the information that has been obtained from experience-based methods provides an approach to food insecurity from the access dimension.

The first time an experience-based method was applied in Mexico was in 2002 in the Sierra de Manantlán Biosphere Reserve, a highly marginalized rural area in the South of Jalisco[38]. The need for measuring the impact of social development programs implemented in the region led to the application

of a Spanish version of the HFSSM[43]. The adaptation of the instrument to the local context was made through work with focus groups[43]. The participants reported having experienced hunger periods but having had at least tortillas to eat[43]. They expressed that the leading causes of food insecurity and hunger in their communities were the lack of well-paid jobs, lack of adequate public transport, high birth rates, and a wrong understanding of the environmental rules of the reserve[43].

The results of this study showed that 44% of the households were mildly food insecure, 33% moderately food insecure, and 19.7% severely food insecure[43]. It was observed that the severity of food insecurity was inversely associated with dietary diversity and the number of food items in the household[43]. The questionnaire used in this study showed to be of low cost and simple application and to provide immediate results[43]. Therefore, it was suggested the integration of similar instruments to the supervision and evaluation systems of food and assistance programs in the country[43].

A year later, and after observing the successful use of a modified and adapted version of the HFSSM in the Brazilian context, researchers from Mexico incorporated a Spanish version of it in a public opinion poll that was applied to 800 households in the capital city of the country[44]. According to the results, 42% of the houses in the sample were food secure, 28% mildly food insecure, 23% moderately food insecure, and 7% severely food insecure[44]. Households with children showed higher proportions of food insecurity than their counterparts[44]. Furthermore, the severity of food insecurity was associated with lower probabilities of consuming a diverse and healthy diet[44]. Besides, it was reported a negative correlation between food insecurity and interpersonal trust and health status[44]. The instrument was useful as well to verify the correct distribution of social programs[44]. It was observed that the assignation of food programs was coherent with the level of food insecurity; nonetheless, it was suggested an even better allocation of the resources to reach the most vulnerable people with priority[44].

In 2006, food insecurity was studied in a sample of elderlies (≥70 years old) in Mexico City using an adaptation of the Radimer-Cornell scale[13]. The authors found an association between food insecurity and poverty, where 40% of the interviewed adults in the most impoverished strata reported to have experienced food insecurity in the previous week[13]. In contrast, this situation occurred only among 14% of the wealthiest individuals[13]. Furthermore, a higher proportion of overweight and obesity was observed among individuals that had experienced food insecurity in the previous year[13].

A year later, a study on food insecurity and its association with overweight in school children was conducted in Mexico City[14]. The authors reported that four out of ten children were food insecure and that the prevalence of this condition was higher in the low social stratum than in the upper socioeconomic

level (30.9% vs. 16.4%)[14]. It was also found that children in a food-insecure situation had higher consumption of foods with high-caloric and low-nutrition content[14]. In adjusted models, the association between severe and moderate food insecurity and overweight was significant only among boys (OR= 2.59, *P*=0.002; OR= 1.87, *P*=0.048, respectively)[14].

As mentioned above, it was until 2008 that food insecurity was evaluated at the national level using the Food Security Mexican Scale (EMSA for its acronym in Spanish, *Escala Mexicana de Seguridad Alimentaria*)[39]. This scale, based on the ELCSA, incorporates twelve from the original fifteen questions and has been validated to provide results that can be interpreted in a similar way to those obtained with its predecessor[39].

The EMSA was included in the National Household Income and Expenditure Survey (ENIGH for its acronym in Spanish, *Encuesta Nacional de Ingreso y Gasto en Hogares*) conducted by the National Institute of Statistics and Geography (INEGI for its acronym in Spanish, *Instituto Nacional de Estadística y Geografía*). According to the results from 2008, mild food insecurity was present in 24.2% of the population, moderate food insecurity in 12.8%, and severe food insecurity in 8.8%[8]. The ENIGH, which takes place every two years, applied the ELCSA instead of the EMSA in the subsequent occasions[45].

Likewise, the ELCSA was incorporated into the ENSANUT since 2012, providing information that can be analyzed in conjunction with other sociodemographic, health, and nutrition indicators. With the data collected at that time, it was possible to identify that food insecurity is more prevalent among indigenous people, those living in rural areas and the Southern region, and households belonging to the lowest socioeconomic levels[46]. In 2012, 41.6% of Mexican households were mildly food insecure, 17.7% moderately food insecure, and 10.5% severely food insecure[46].

Around that time, two events marked a new course for the food security policy framework in the country[15]. First, the constitutional reform to articles 4 and 27 in 2011, recognizing the fundamental right to food for the Mexican society[15]. Second, the launching of the National Crusade against Hunger (in Spanish, *Cruzada Nacional contra el Hambre*)[15] in 2013, which was directed to attend people in extreme poverty and lack of access to food[17].

The objectives of this strategy included the eradication of hunger, the reduction of child malnutrition, increasing the production and income of small farmers, reducing food losses (from postharvest to commercialization), promoting the economic development of the poorest regions, and promoting community participation to eradicate hunger[17]. For the eradication of hunger, the proposed

actions comprised increasing the coverage of cash transfer programs in households in extreme poverty, motivating the purchase of healthy foods in households benefiting by these cash transfers, and implementing community and school canteens[47].

A panel survey (a longitudinal-type study) undertaken in 2015 by the CONEVAL evaluated 207,578 households from the 400 municipalities included in the first stage of the Crusade[48]. According to it, the lack of access to food (a concept that comprehends people with moderate and severe food insecurity) passed from affecting 100% in 2013 to 42.5%[48]. However, national data from the ENIGH 2014 showed non-significant changes in this indicator, in fact, the population with lack of access to food increased from 27.4 to 28 million people from 2012 to 2014[48].

Likewise, a comparison between the 2012 and 2016 ENSANUT data showed non-significant changes in the prevalence of food insecurity or the distribution of moderate and severe food insecurity according to sociodemographic characteristics[49]. Nonetheless, in rural areas, there was an increase of 4.2% in the prevalence of food security, and decreases of 2.3% and 2.0% in moderate and severe food insecurity, respectively[49].

These positive changes were attributed to the impact of the food assistance programs, given that urban areas and households that did not benefit from these interventions showed an increasing trend in the magnitude of moderate and severe food insecurity[49]. Thereby, it was suggested to implement similar strategies in urban areas[49].

According to an evaluation of the coverage and focalization of food assistance programs, 44.2% of the Mexican households benefit from at least one of them[47]. In comparison with 2012, there was a significant increase in the School Breakfast program coverage, passing from 12.2% to 16.9%[47]. Nonetheless, due to the high rates of overweight and obesity in children and adolescents, it has been suggested that the focalization of this program should include a nutritional criterion[47]. Furthermore, the assistance program for older adults increased its coverage from 12.6% to 22.4%, which is positive due to the social and nutritional vulnerability in the elderly population[47]. The National Inclusion Program (Prospera) has one of the broadest coverages in the country by attending 20.7% of the national population[47]. However, its coverage in households belonging to the low and very low socioeconomic levels decreased from 78% to 57.6%. Nonetheless, this decline has been attributed to an improvement in the welfare conditions of the beneficiaries[47].

Moreover, it has been observed that the direction of these interventions corresponds with the conditions of vulnerability among the population[47]. Correspondingly, 54.5% of the households in the southern region of the country beneficiates from such programs. Comparing the coverage of food assistance programs according to the attention of the most affected population from 2012 to 2016, we observe the following changes. These programs moved from attending 65.4% to 68.4% of the households in rural areas, from 64.9% to 70% of those in the lowest socioeconomic level, from 66.9% to 70.6% of the indigenous, and from assisting less than the half (48.7%) of the households in severe or moderate food insecurity to attend 54.3% and 48.7% of the households in these levels, respectively[46, 47].

2.2 Overweight, obesity, and abdominal obesity

2.2.1 Definitions and health consequences

Overweight and obesity are non-communicable chronic diseases[50] that have been defined according to specific cutoff points of the body mass index (BMI)[51]. The latter refers to the ratio between weight (in kg)/height (in m^2)[51]. According to the WHO, an adult with a BMI of 25.0 or more is considered overweight or pre-obese, and over 30.0 obese class I, over 35.0 obese class II, and over 40.0 obese class III[51]. This classification is based on the relative health risks associated with body adiposity. For instance, it has been observed that conditions like premature death, cardiovascular diseases, hypertension, osteoarthritis, certain types of cancer, and diabetes are associated with overweight and obesity[51].

BMI has been widely used in epidemiological and clinical settings due to the ease with which it can be calculated, and for giving a good approximation to adiposity and related health problems[51, 52]. However, this indicator does not account for differences according to sex, age, or physical activity, and might be complemented by other anthropometric measurements such as waist circumference[51], or by body composition techniques[52].

Abdominal obesity, also known as central obesity, is defined as having a high amount of fat in the trunk region[50]. This condition can be assessed by calculating the waist-to-hip ratio or by measuring the waist circumference at the level of the superior iliac crest[50]. Different cutoff points have been proposed for determining abdominal obesity, depending on race and ethnicity[50]. According to the International Diabetes Federation, which is the guideline used in Mexico by the ENSANUT[53], males

and females with a waist circumference ≥90 cm and ≥80 cm, respectively, have abdominal obesity[54]. Abdominal obesity has been considered as a better predictor of cardiometabolic disease and mortality than BMI[55], and therefore this indicator was included in the present research.

As mentioned before, overweight and obesity are risk factors for several health issues. Briefly, these conditions, especially obesity, have been related to affect the cardiovascular, neurologic, pulmonary, genitourinary, gastrointestinal, metabolic, and musculoskeletal systems[56]. They have also been associated with dermatological conditions, cancer (breast, colon, and uterine), and psychological disorders[56], social stigmatization, and consequently to low self-esteem, depression, and discrimination[50]. Likewise, a high deposition of abdominal fat (a hormonally active tissue) is related to metabolic syndrome, cardiovascular disease, and cancer (breast, prostate, and colorectal)[57]. However, discussing each of these relationships is beyond the scope of this research. Therefore, only the associations between obesity and cardiovascular disease, diabetes, and metabolic syndrome, are explained in the following paragraphs, given their high prevalence and mortality rates in Mexico[58].

Overweight and obesity have several adverse effects on cardiovascular health[59]. This is expected given that obesity aggravates risk factors associated with this condition, such as plasma lipid profile, blood pressure, glucose metabolism, and inflammation[59]. Moreover, it overcharges heart capacity by affecting hemodynamics and ventricular structure and operation[59]. Obesity increases cardiovascular work by increments in filling pressure and volume, which leads to left ventricle dilatation changes and hypertrophy[59]. Therefore, obesity is associated with hypertension, coronary heart disease, heart failure, and atrial fibrillation[59].

In relation to atherosclerosis, the main complications of this condition include coronary artery disease and stroke[60]. In this case, abdominal obesity has been considered a better independent risk factor than general obesity[60]. Visceral adiposity is associated with carotid intima-media thickness, plaque area, and total area (carotid intima-media area and plaque area combined)[60]. Additionally, visceral fat can also contribute to a prothrombotic and proinflammatory state (explained in the following paragraphs)[60].

Regarding dyslipidemia, which is another critical cardiovascular risk factor, obesity has been associated with abnormal lipid profiles characterized by elevated triglyceride levels, low HDL, and increased small, dense LDL and VLDL molecules[60]. Among subjects with abdominal obesity, it has been observed an increased number of small LDL molecules[60]. These particles enter easily into the arterial wall where they bind to arterial proteoglycans and become susceptible to oxidation and macrophage uptake, thereby contributing to atherogenesis, and risk of myocardial infarction[60].

In the relationship between obesity and diabetes, the main physio-pathological pathways are the defective insulin release and insulin resistance[61]. At the early onset of obesity, insulin resistance appears in part due to the permanent and elevated circulation of free fatty acids, which inhibit glucose transport activity[61]. Predominate use of lipids by the muscle at expenses of glucose derives in less glucose utilization and then in insulin resistance[61]. Additionally, the reduced glycogen mobilization might also inhibit glucose reception and be another factor for it[61]. Whereas for the reduced insulin secretion, it has been proposed that prolonged hyperglycemia could desensitize insulin secretion[61]. Another explanation has been the affectation of the pancreatic islets by lipotoxicity associated with the excessive free fatty acids in circulation[61].

Accordingly, diet therapy (with reduction mainly in fat intake) and weight loss have shown partial reversibility of diabetes evolution[61]. That is correspondent with the fact that environmental factors for obesity also lead to an increase in diabetes, and have a greater influence than the genetic component in the development of both diseases[61].

Another crucial aspect of diabetes development and metabolic syndrome is the inflammatory response associated with obesity. Metabolic syndrome is defined as the coexistence of at least three of the following risk factors for cardiovascular disease and diabetes: central obesity, elevated triglycerides, reduced HDL cholesterol, hypertension, and raised fasting plasma glucose[62]. Chronic inflammation has been identified as a major factor for the onset of metabolic syndrome[63]. Inflammatory processes in obesity have been associated with "modern" lifestyles that include stress, a positive balance of energy consumption, ingestion of poor-quality food, and altered chronobiology[63]. These factors contribute to disturbances in regulatory body systems, and chronic and cyclic allostasis[63].

Regarding adipose tissue, hypertrophic adipocytes growth derives in cell rupture and fat deposition in organs (i.e., liver), with local and systemic affectations[63]. Additionally, adipocytes' exposure to stressors (oxidative stress, inflammatory cytokines, high concentration of fatty acids) can induce impairment of insulin action, and expression of proinflammatory genes[63]. Moreover, obese adipose tissue also contains lymphocytes, which promote inflammatory reactions and insulin resistance[63].

The disposition of body fat also has different metabolic effects[63]. Visceral fat is associated with proinflammatory molecules production and is an independent predictor of insulin sensitivity, impaired glucose tolerance, high blood pressure, and dyslipidemia[63]. This tissue, in comparison with subcutaneous adiposity, is more prone to lipolysis[63]. In part because it is supported by less dense

connective tissue and is more vulnerable to mechanical pressure variations[63]. And also, because it increases mainly by hypertrophy than by hyperplasia[63].

Furthermore, unhealthy dietary patterns associated with obesity and metabolic syndrome are also associated with inflammation[63]. Inflammation markers increase after a high-fat meal, whereas a low-fat, high carbohydrate diet has shown to decrease them[63]. Additionally, the type of fat leads to different outcomes, while saturated fatty acids trigger the expression of proinflammatory molecules (i.e., IL-6, TNF-α), unsaturated ones inhibit these processes[63]. For instance, supplementation with n-3 PUFA has shown improvements in lipid metabolism and components of the inflammatory response[63]. Additionally, these responses seem to be influenced as well by the composition of gut microbiota[63], which controls metabolic endotoxemia and inflammation associated with high-fat consumption[63]. And in turn, gut microbiota composition is largely regulated by dietary factors like fiber and micronutrient consumption[63].

2.2.2 Obesity in Mexico

Since 1988 overweight, obesity, and related comorbidities trends in Mexico have been regularly monitored by the public health system[2]. Since then, the increasing prevalence of these conditions has been documented and analyzed in conjunction with changes in dietary habits, and the increase in associated comorbidities as part of the nutritional transition[2].

An analysis of data from 1988 to 1999 showed increments in overweight and obesity national prevalence among adult females (from 18 to 49 years) from 24.0% to 35.2%, and from 9.4% to 24.4%, respectively[2]. The North region showed the highest combined prevalence at both moments (38.1% and 65.3%, respectively). Nonetheless, the larger increments occurred in the South (81.3%) and Center (101.4%) areas[2].

These changes were found to be accompanied by a decreased consumption of proteins and increased ingestion of fats, and refined carbohydrates, especially soda[2]. Furthermore, it was reported that mortality rates of diabetes, acute myocardial infarction, and hypertension increased by 62%, 53%, and 55%, respectively, from 1980 to 1999[2]. In this context, the larger increments were observed in the South and Center regions (from 70% to 140%, depending on the disease) in comparison with the North and Mexico City (ranging from 10% to 50%)[2].

These findings led the authors to conclude that obesity was playing a critical role in the etiology of diabetes, acute myocardial infarction, and hypertension[2]. Also, that shared risk factors between these conditions (i.e., inadequate diets, and physical inactivity) were contributing to their observations[2]. Given that type 2 diabetes, coronary artery disease, and cerebrovascular disease due to atherosclerosis are the leading causes of death in the country[58], these observations are of remarkable importance for the national public health.

In 2000, the prevalence of overweight and obesity were 40.9% and 18.6% for males, and 36.1%, and 28.1% for females, respectively[64]. Subsequently, in 2006, 34.5% of the females, and 24.2% of the males >20 years of age were obese[6]. The combined prevalence of overweight and obesity for both genders was 68.7%[6], and in 2012 it increased to 71.3% (38.8% and 32.4%, respectively)[4]. In that year, obesity proportion was higher in females (37.5%) than in males (26.9%), and overweight was higher in males (42.6%) than in females (35.5%)[4]. Furthermore, the prevalence of abdominal obesity was 74.0% (82.8% among females, and 64.5% in males)[4].

Additionally, it was evident that socioeconomic disparities across the country were leading to different outcomes in each region[2]. For instance, the North showed a comparable epidemiological profile to that of developed countries, while the South and Center were in a pre-transitional stage[2]. However, these patterns were present mainly in the '80s. By the last period of study, the South and Center regions had shown more drastic increases in overweight and obesity[2]. Obesity and abdominal obesity prevalence were higher among the upper socioeconomic levels, urban areas, and the North region[4]. Concerning scholarship, females with higher educational level showed lower BMI and waist circumference means[4]. However, the opposite occurred in males; those with the lowest academic preparation had a lower BMI and waist circumference[4].

An evaluation of the obesity prevalence from 2000 to 2012 found that from 2000 to 2006, the mean BMI increased in one unit, while from 2006 to 2012, it increased by 0.3 units[4]. For the slowdown observed in the second period, the authors considered three possible explanations[4]. First, the actions on nutritional education implemented through different social interventions might be starting to give results[4]. Second, it was also possible a saturation-driven stabilization[4]. That means that people susceptible to develop overweight would acquire this condition when being exposed to an obesogenic environment, while a small part of the population would be resistant to it due to cultural, lifestyle, personal preferences, or genetic reasons[4]. Third, it would be possible that counter-transition processes might be taking place (i.e., increases in height)[4].

For the next ENSANUT surveys in 2016 and 2018, the trends in overweight and obesity showed the same direction. In 2016 the overweight/obesity prevalence in adults (>20 years) was 72.5%[53]. This percentage meant an increase of 1.3 pp in comparison with 2012 (71.3%). Nonetheless, the change was not statistically significant[53]. Likewise, as reported in the previous survey, the combined prevalence of overweight/obesity and the prevalence of obesity were higher among females[53].

Summing up, from 1988 to 2016, overweight and obesity increased each by 42.4% and 290.5% in females[53]. And anew, obesity proportion was higher in urban areas (16.8% higher than in rural ones) and the North region, whereas overweight was 11.6% more frequent in rural settings[53]. For abdominal obesity, the prevalence in 2016 was 76.6%. Among males, it was 65.4%, and in females, 87.7%[53].

According to the most recent information, from ENSANUT 2018, the mixed prevalence of overweight/obesity has continued to grow and reached 75.2% that year[7]. The prevalence of overweight was 36.6% in females, and 42.5% in males and obesity was estimated at 40.2% and 30.5% in females and males, respectively[7].

Additionally, among children and adolescents, from 2012 to 2016 overweigh/obesity combined prevalence decreased among girls and boys (<5 years) from 31.8% to 23.5%, and from 35.2% to 21.2%, respectively, and in school-age boys (5 to 11 years) from 36.9% to 33.7%[65]. However, similar to adults, both conditions have increased among school-age girls from 32.0% to 32.8%, and in female and male adolescents from 35.8% to 39.2%, and from 34.1% to 33.5%, respectively[65]. In 2018, overweight/obesity percentage among children (5 to 11 years) was 35.6%, and among adolescents, it was 41.1% in females, and 35.8% in males[7].

Obesity increases among girls and adolescents by 2016 occurred mainly in rural areas[65]. A possible explanation could be a retarded occurrence of the nutritional transition in these settings[65]. The large prevalence of such conditions among Mexican children and adolescents is worrisome, given its impact on health, educational indicators, and future productivity and income[65]. Furthermore, in less than ten years they will become adults, who are considered the most economically productive population sector[65].

In Mexico, the nutritional transition has been proposed as the primary determinant of chronic diseases, including overweight and obesity[6]. This phenomenon has been characterized by increased affordability of low-cost industrialized foods with a high content of fat, sugar, and salt[6]. It also has incremented the consumption of fast food and food prepared away from home, which could be related to

a reduction in the time available to prepare it[6]. Besides, the rise in advertising of industrialized and convenience products, and the higher purchasing power of some sectors of the population makes these products a comfortable and easy option for emerging lifestyles[6]. Finally, these new lifestyles also include reductions in physical activity[6].

Overweight and obesity are a cause of impoverishment; they decrease labor productivity and provoke catastrophic expenses in health associated with chronic diseases[6]. In Mexico, it has been estimated that the national cost for the treatment of comorbidities of obesity is 3,500 million dollars per year[6]. The indirect expenses related to the loss of productivity for premature death associated with overweight and obesity increased from 9,146 million pesos in the year 2000 to 25,099 million in 2008, which is equivalent to an annual increase of 13.51%[6]. For 2017 it was estimated that the total cost associated with obesity was 150,860 million pesos[6].

Some of the actions proposed to overcome the national obesity epidemic underline that the attention to this problem should be contextualized under the situation of the double burden of malnutrition currently experienced in the country (explained in the following sections)[4]. Thereby, actions like the promotion of breastfeeding and appropriate complementary feeding would be primordial[4]. Additionally, there should be education for the acquisition of healthy diets based on the reinstatement of traditional food preparations, and guidance to make healthy food choices[4]. About the elevated consumption of sweet beverages, marketing regulations have been proposed in conjunction with the importance of improving the availability of drinking water[4]. Furthermore, these actions must also be complemented with the reduction of sedentary habits by encouraging the population to increase their moderate and vigorous physical activity, to use active transportation means, and practicing sports[4].

Despite the alarming increases in obesity and associated comorbidities during the last years and the fact that in 2016 the country declared an epidemiological alert given this situation, there have not been enough interventions to counteract these issues effectively[5]. In 2010 the government launched a national plan directed to reduce obesity, and in 2014 a tax over sweetened beverages was imposed[5]. However, the food industry has hindered the exertion of further nutrition policies[5]. Additionally, the diagnosis and treatment of obesity in the public health clinics is technically deficient[5]; for instance, in 2012, from the total of people who received overweight or obesity diagnosis from a health institution, only 5.9% reported to have received treatment[4]. In order to overcome obesity in the country, there are missing higher financial investments and prompt actions from the government, health professionals, and

society[5]. The direction undertaken on these aspects will determine the well-being and quality of life of the Mexican community in the coming years[5].

2.3 Food insecurity, health problems, and nutritional status

2.3.1 The double burden of malnutrition

The effect of food insecurity over health and nutritional status is highly related to the affectations this condition can pose over people's dietary habits. It has been observed that due to the affordability and satiety effect of high-calorie products (rich in fat, sugar, or starch), these foods are chosen over nutrient-dense ones in food insecurity situations[66].

For instance, in Mexico, it has been described that food-insecure households have greater availability of corn, wheat, egg, and sugars, but a lower one of fresh fruits and vegetables, lean meats, chicken, fish, seafood, and dairy[66]. Likewise, other authors have observed similar food patterns and possible substitution of certain animal-origin proteins (red meat, chicken, fish, and milk) by less expensive ones such as egg and legumes[67]. As a result, there could be a deficient consumption of fiber, micronutrients, and high biological value proteins and excessive ingestion of refined carbohydrates and saturated fats[66, 67].

In addition to a deficient dietary diversity and quality[67], certain behaviors observed in food insecurity situations could also contribute to metabolic alterations that would lead to the development of obesity or other chronic diseases. For instance, food-insecure people might experience cyclical patterns in their income or in the reception of social aid, which would be reflected in feast-famine food rounds[21]. The continual experience of food scarcity could lead to overeating episodes in periods of food abundance as a psychological response to future shortages[68]. In fact, certain studies have found unintended effects from assistance programs, which are likely to have a periodic structure, and which have been associated with obesity[69-71]. However, this association has been inconsistent across different food and social assistance programs in Mexico[70, 72].

This nutritional disbalance might be a significant contributor to the so-called double burden of malnutrition. Such term is understood as the co-occurrence of undernutrition with overweight or obesity[1]. This phenomenon can exist and be analyzed at the country level when there is simultaneously

a high prevalence of both conditions[3]. It can also occur at the household level when there coexist stunted children and obese mothers[73, 74], and finally, at the individual level when obesity and nutritional deficiencies coincide in a person[74]. The double burden of malnutrition affects the adequate physical and mental development of individuals, increases the risk of chronic diseases, and is a source of expenses for families and society[15].

In Mexico, the double burden of malnutrition has gone hand in hand with the epidemiological transition observed across the last 25 years[3, 10]. Accordingly, different forms of undernutrition (stunting, wasting, and underweight) and excessive weight conditions have been documented to coexist in the country[3]. Nonetheless, the prevalence of the first ones has shown significant decreases in contrast with the constant and critical rises in overweight and obesity[3].

From 1988 to 2012, there was a decrease of 49.4% and 26.3% in the prevalence of stunting and anemia, respectively, in children <5 years, whereas overweight/obesity mixed prevalence increased in 47.5%[10]. Similarly, among females (from 20 to 49 years), the overweight/obesity prevalence grew by 104%, and obesity alone incremented by 270% during the same period, while anemia prevalence decreased 46% from 2006 to 2012[10].

In 2012 the national prevalence of anemia in children from 0 to 59 months was 23.3%; in those from 5 to 11 years, it was 10.1%, and in females from 12 to 49 years, it was 11.6%[10]. In the same year, stunting prevalence among children from 0 to 59 months was 13.6% and 6.9% in those from 5 to 11 years[10]. In contrast, overweight and obesity mixed prevalence for children from 0 to 59 months was 9.0%, for the ones from 5 to 11 years it was 34.4%, and for females (from 12 to 49 years), 70.5%[10]. Additionally, as has been mentioned in previous sections, the trends in overweight and obesity have continued to increase for most age groups[7].

The double burden of malnutrition at the household level in Mexico (defined as the coexistence of a stunted child (<5 years) and overweight or obese mother) has been reported at 8.6%[10]. At the individual level, it has been studied as: i) the concurrence of overweight or obesity with anemia in females (from 20 to 49 years), with a prevalence of 7.6%; ii) stunting and overweight or obesity coexisting in children (from 5 to 11 years), with a prevalence of 1%; and iii) as the simultaneity of anemia and overweight or obesity in children (from 5 to 11 years), with a prevalence of 2.9%, all according to information from ENSANUT 2012[10]. However, these results seem to appear from the large prevalence of each condition and not because one of them is related to the occurrence of the others[10].

Some of the aforementioned health conditions have been studied in the context of food insecurity, finding an association between mild food insecurity and obesity among women (from 20 to 59 years)[11]. Likewise, it has been reported that mild food insecurity increases the odds of overweight or obesity (OR= 1.02, P <0.05), and mild and moderate levels are associated with i) anemia (OR= 1.3, P <0.05; OR= 1.5, P <0.01, respectively), ii) concurrent anemia with overweight or obesity (OR= 1.5, P <0.01; OR= 1.5, P <0.05, respectively), and iii) concurrent anemia with abdominal obesity (OR= 1.4, P <0.01; OR= 1.6, P <0.01) among adult females of reproductive age (from 20 to 49 years)[1]. In both studies, it has been mentioned that the consumption of energy-dense but nutrient-deficient diets might be significantly contributing to the relationships observed[1, 11].

Although the prevalence of undernutrition has been decreasing in the last decades, it is still alarmingly high, especially in the Southern region and among indigenous people[3]. Besides, the fact that these situations coexist with overweight or obesity at the national, household, or individual levels, although in a lesser extent in the last ones, should still calling the attention to the public health sector for the generation of policies directed to attend both problems[1, 3, 15].

2.3.2 Food insecurity and other chronic diseases

In addition to overweight and obesity, other health conditions associated with food insecurity have been diabetes and hypertension[75, 18]. Some authors have observed these relationships mainly at the severe level of food insecurity among the U.S. population, proposing the following explanations to their findings[75]. The relationship found with diabetes could be linked to a physiological response for preserving muscle mass in food restriction periods, a situation that would be mediated by peripheral insulin resistance, thereby promoting this disease[75]. Additionally, a rising in cortisol levels triggered by psychological and emotional stress associated with food insecurity might increase visceral adiposity, another risk factor for diabetes[75]. Finally, a challenging disease management capacity given the financial restraints observed in food insecurity would be associated with limited resources for both medical expenditures and an adequate diet[75]. For the latter, food insecurity might lead to substitute the consumption of fruits and vegetables by less expensive options like refined starches, which would increase the glycemic load affecting subjects with a proclivity to develop diabetes[75]. Whereas the high sodium and low potassium content in highly industrialized foods, which are frequent products in food-insecure people's diets, could be contributing to hypertension[75].

In Mexico, mild, moderate, and severe food insecurity have shown to increase the odds of diabetes among adult females in 31%, 67%, and 48%, respectively, in comparison with food security[18]. Moreover, severe food insecurity has been related to greater odds of hypertension (OR= 1.28, *P* = 0.037) among females; and mild, moderate, and severe levels have shown a marginally significant association with this disease (OR= 1.25, 1.41, and 1.35, respectively, *P* =0.072) in males[18]. Similar to the studies mentioned above, it has been proposed that poor dietary quality associated with food insecurity would be one of the main contributors to this relationship[18]. Giving that inappropriate diets could add to elevated consumption of sugar and sodium, and be a risk factor for excessive weight gain (a precursor condition for diabetes and hypertension)[18]. Besides, the stress linked to experiencing food insecurity could trigger hypertension, and be partly responsible for increasing visceral adiposity (precursor for type 2 diabetes)[18].

However, as the majority of studies on these associations have had a cross-sectional design, there exists the possibility of a bidirectional relationship; in this sense, conditions such as diabetes could be leading to food insecurity in two possible ways[75]. One, the high medical costs proper of the disease could represent a substantial expense to the subjects, pushing them to food insecurity[75, 76]. Or the health and nutrition guidance received by diabetic patients could make them more aware of food and diet issues, and therefore, keener on their perceptions about food insecurity[75].

According to the information presented, addressing food insecurity might also contribute to progress in the treatment of chronic diseases in Mexico, which have shown increases during the last years. From 2012 to 2018, diabetes prevalence passed from 9.2% to 10.3% in adults (> 20 years), which is equivalent to 6.4 to 8.6 million people[7]. In females, the proportion went from 9.7% to 11.4%, and in males from 8.6% to 9.1%[7]. Likewise, hypertension increased during the same period, from 16.6% to 18.4%, which is equal to 9.3 to 15.2 million people[7]. In females, the prevalence went from 18.5% to 20.9%, and in males from 14.1% to 15.3%[7].

Food insecurity has also been related to dyslipidemia among female participants (18 to 50 years) of the NHANES (National Health and Examination Nutrition Survey from the U.S.)[77]. Among them, marginal food security was associated with abnormal (high) concentrations of LDL (OR= 1.85, *P*= 0.045), and triglycerides/HDL ratio (OR= 1.98, *P*= 0.046)[77]. While food insecurity without hunger was related to higher odds of abnormal concentrations of triglycerides (OR= 1.91, *P*= 0.041)[77]. These results were explained by the association of food insecurity with overweight and obesity, a poor dietary intake, including low ingestion of antioxidants (which are protective against peroxidation of plasma lipids), and

other factors such as the influence of socioeconomic deprivation, psychosocial stress, and restricted physical activity[77].

On the other hand, others have failed to find associations between food insecurity and total cholesterol[78]. However, they have reported a higher risk of low serum concentrations of HDL among women[78]. And some studies have shown inconsistencies when considering self-reported vs. clinically-evaluated hyperlipidemia, finding significant associations between food insecurity and the first one (OR= 1.30, 95% CI= 1.09, 1.55), but not when clinical measurements are considered[75]. These contrasting results might suggest the importance of counting with context-specific research on this topic.

In Mexico, a study conducted among college students reported that those in severe food insecurity had the highest proportions of hypertriglyceridemia (33.3%) and hypercholesterolemia (16.7%)[79]. However, there are missing studies between these two variables at the national level. Having more information about this potential relationship in the Mexican setting is necessary for improving the population's health and might be useful for the public health sector due to the increases observed in dyslipidemias between 2012 and 2018. During this period, the levels of high serum triglycerides and cholesterol have increased in both sexes from 13.0% to 19.5%[7]. In females, these have risen from 14.1% to 21.0%, and in males from 11.7% to 17.7%[7].

Given that food insecurity has been associated with the aforementioned chronic diseases, some studies have also studied its relationship with metabolic syndrome[80-83]. However, inconsistent results have been reported. For instance, U.S. adults living in marginal and very low food security have shown higher odds for metabolic syndrome (OR= 1.80, 95% CI= 1.30,2.49; OR= 1.65, 95% CI= 1.12, 2.42, respectively)[80]. Similarly, in northwest Iran, a higher prevalence of metabolic syndrome has been found among food insecure people in contrast with food-secure ones (45.5% vs. 30.0%)[81]. Still, another study conducted among diabetic subjects from a southeast province in Iran obtained inconclusive results[82]. The authors found higher BMI and significant increases in blood pressure among food-insecure females, and increases in glycosylated hemoglobin among males as food insecurity increased[82]. Nonetheless, fasting blood sugar was higher in food-secure females[82]. These results led to the deduction that food insecurity may deteriorate only some cardiometabolic markers[82].

Other authors have reported steady negative associations between food insecurity and metabolic syndrome markers. A study conducted in low-income communities in Malaysia reported that women in food-insecure households were less likely to present metabolic syndrome, abdominal obesity, elevated glucose, total cholesterol, and LDL cholesterol[83]. Additionally, hypertension, high triglycerides, low

HDL, and overweight/obesity percentages in food security and insecurity situations did not show significant differences[83].

In the Mexican context, a regional study conducted in the state of Queretaro reported that food insecurity in females (from 21 to 45 years) was associated with higher BMI, and some markers of metabolic syndrome such as central obesity, low HDL cholesterol, and higher triglycerides and glucose concentrations[84]. Likewise, the studies mentioned above agree with these findings individually[1, 11, 18, 79].

However, there are no national-level studies analyzing the relationship between food insecurity or social determinants of health with metabolic syndrome. Investigations on this topic would be significant, given its alarming prevalence nationwide[85, 86]. Depending on the criteria used for defining metabolic syndrome, the prevalence in Mexican adults could be between 31% (according to WHO criteria) and up to 54% (when International Diabetes Federation guidelines are used)[85]. A pooled prevalence has been estimated in 41%, which is higher than the one calculated for the U.S. (34.2%[87]) and Latin America (24.9%[88])[85]. Additionally, it is relevant to mention that a large proportion of metabolic syndrome in Mexico occurs in subjects <40 years old[86]. Therefore, researchers have called for the promotion of prevention-related policies that include young adults[86].

Another condition associated with food insecurity has been cancer[89]. Some of the mechanisms proposed for explaining this relationship are related to socioeconomic aspects commonly found in food insecurity scenarios[89]. These include a high incidence of unhealthy behaviors like excessive tobacco and alcohol use, physical inactivity, high exposure to environmental carcinogens, and the lack of adequate access to medical care, screening, and prevention[89]. Accordingly, it has been reported that in comparison to food-secure individuals, food-insecure people are more likely to postpone medical care, sometimes they cannot afford the cost of treatments, or have to decide between getting food or paying for them[90].

Additionally, a less healthy dietary intake could also be an important mediator between both situations[89]. Epidemiological studies have reported that dietary patterns with low consumption of nutrient-dense foods and high intake of inexpensive processed products can contribute to developing cancer[89]. However, this association might also occur in the opposite direction as follows.

Presenting cancer or other chronic diseases might also lead to food insecurity in different ways[89]. As mentioned before, the high cost of medical treatments can reduce the budget allocated to food and

sacrifice the patient's dietary adequacy, especially in conditions of financial vulnerability[89]. Besides, non-medical expenses associated with the disease can undermine people's economic situation, and depending on the severity of the health issue, they might have a reduction in productivity, income, or job loss[89]. These situations could be notably tougher in cases of more expensive dietary requirements[89], as is the case in many chronic diseases. Furthermore, due to the intensity of treatments and the disease process itself, cancer patients suffering from food insecurity can be significantly affected as the dietary restriction in their condition affects not only their life quality but their survival[90].

These observations have led to point out the importance of studying the financial burden associated with the diagnosis and treatment of chronic diseases and how these situations can contribute to food insecurity[90]. Moreover, examining food insecurity in the clinical setting might be a good strategy for improving individual health and societal costs[89]. According to the associations mentioned so far between food insecurity and disease, we might assume that this condition can also hinder an appropriate treatment of such health problems, given that dietary care is crucial in the attention of chronic diseases[90].

Another disease that has been associated with food insecurity is asthma in both children[91] and adults[92]. In children, this situation has been attributed to conditions such as the consumption of a nutrient-poor diet, obesity, and stress[91]. Among adults, a study from Korea found a higher prevalence of asthma as food insecurity worsened, and higher odds for this disease (OR= 2.44, 95% CI= 1.33, 4.46) in households experiencing food insecurity with hunger[92]. In this case, the proposed mediators were the consumption of unhealthy diets and the presence of chronic stress, which could contribute to asthma by promoting systemic inflammation processes[92]. Also, unhealthy behaviors like smoking, physical inactivity, and poor disease management, which are commonly present in food insecurity, may drive to this condition[92].

Nevertheless, few studies worldwide have analyzed the relationship between food insecurity and asthma[92]. There is no information about this association in Mexico, but asthma affects 7% of the population in the country[93]. Given its association with obesity[94] and the established association between obesity and food insecurity[11], it might be assumed that food insecurity could also be worsening comorbidities related to obesity such as asthma.

Finally, food insecurity has also shown to be linked to diseases, which in turn are related to deficient dietary habits and to some of the chronic diseases that have been mentioned. It has been observed that food insecurity can increase the odds for kidney oxalate stones (OR= 2.44, P= 0.022)[95] and chronic kidney disease in people with diabetes (OR= 1.67, 95% CI= 1.14, 2.45) and hypertension

(OR= 1.37, 95% CI= 1.03, 1.82)[96]. Additionally, it has also been associated with osteoporosis in postmenopausal women[97], and with reduced mineral bone content among male children (from 8 to 11 years)[98].

2.3.3 Food insecurity and mental health problems

Food insecurity has also been related to mental disorders, a relationship that might occur through both biological and behavioral means[99]. Biologically, it has been documented that physiological pathways between nutrition and mental processes are highly interconnected, psychological problems are influenced by the action of nutrition-related hormones, gut microbiota, dietary habits, and the consumption or not of specific nutrients[100]. For instance, a diet rich in products such as sweetened beverages, fried foods, processed meat, refined grains, biscuits, snacks, and pastries, has been associated with mood disorders and depression[100]. In turn, these dietary patterns have been widely reported in food insecurity circumstances[67, 101].

Additionally, non-dietary factors derived from food insecurity have also been associated with mental issues[102] like depression and stress[99]. The severity of food insecurity has been associated with an increase in experiencing adverse psychosocial conditions (e.g., sadness, worry, stress, anger) and negatively related to favorable ones (e.g., enjoyment, feeling well-rested, being treated with respect) in a dose-response fashion[102]. These findings might be explained by the lack of affordable, culturally appropriate food, and people's inability to feed themselves and their families, or the acquisition of food in socially unacceptable ways, which can promote feelings of deprivation, alienation, powerlessness, shame, and guilt[99, 102]. In Mexico, research related to food insecurity and health issues has been mainly focused so far on physical health problems, leaving the area of mental wellness barely investigated. However, an analysis of data from ENSANUT 2012 found an association between household food insecurity and depression, and a depressive symptoms score food insecurity worsened[103]. Respectively the OR for depressive symptoms with mild, moderate, and severe food insecurity were 1.47, 2.14, and 3.01 (all P <0.001)[103]. Likewise, a study on maternal depression reported that food-insecure females in the country had a 56% more risk of depressive symptomatology[104].

Food insecurity has also been linked to eating disorders[105]. Low and very-low food security have been associated with binge eating disorder even when the instigator is externally (economic constraint) and not internally (premeditated dietary restriction for weight loss) imposed[68]. Overeating under these

circumstances complies with the criteria of subjective loss of control, frequency, and psychopathology that are considered for binge-eating diagnostic by the American Psychiatric Association[68]. It has been proposed that this conduct could be triggered by hunger-related restrictions, or as an emotional coping strategy as anticipation of future food scarcity or both[68]. Other authors have also reported compensatory actions to reduce displeasure following bingeing episodes (vomiting) among food-insecure people[105]. Additionally, it has been pointed out that weight-self stigma is also present among food-insecure obese subjects, and that this could be related to the anti-obesity campaigns targeted to low-income, marginalized populations[105].

CHAPTER 3: MANUSCRIPT

Severe food insecurity is associated with increasing waist circumference and obesity in Mexican women

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3.1 Abstract

Objective: To examine the association between food insecurity and BMI, overweight, obesity, waist circumference (WC), and abdominal obesity in Mexican adults. **Design:** Cross-sectional study. **Setting:** We analyzed data from the Mexican Halfway National Health and Nutrition Survey 2016, a nationally representative survey that accounted for rural and urban areas in four regions of Mexico: North, Center, Mexico City, and South. **Subjects:** Adults from 20 to 59 years old (*n* 5,456, which represents 45,804,210 individuals at the national level). **Results:** 70.8% of the Mexican adults had some degree of food insecurity. This situation showed larger proportions (P <0.05) among indigenous people, those living in a rural area, in the Southern region, or the lowest socioeconomic quintiles. The prevalence of obesity and abdominal obesity was higher in female adults (P <0.001), with the highest proportions occurring among those experiencing severe food insecurity. Among women, mean BMI and WC increased as food insecurity worsened (P <0.001). According to multivariate regression models, severe food insecurity showed to be positively associated with obesity (OR= 2.36; P= 0.001), BMI (β= 2.24; P <0.001), and WC (β= 4.22; P= 0.002) in Mexican adult females. **Conclusions:** Our findings confirm the association between food insecurity and obesity among Mexican women. Given the sociodemographic characteristics of the food-insecure population, it is alarming that prevailing socioeconomic inequalities in the country might also be contributing to the likelihood of obesity. Therefore, it is crucial to maintain and bolster surveillance systems to track both problems and implement adequate policies and interventions.

Keywords: Food insecurity, obesity, abdominal obesity, BMI, waist circumference, ENSANUT.

3.2 Introduction

"Food insecurity exists whenever the availability of nutritionally adequate and safe foods or the ability to acquire them in socially acceptable ways is limited or uncertain"[30]. This condition derives in a deficient nutritional status and affects social and mental well-being, physical health, and overall quality of life[106]. Food insecurity has been classified in three categories as follows: i) mild food insecurity, which has been defined as worrying about not being able to obtain enough food and/or decreasing dietary quality; ii) moderate food insecurity, which refers to compromising not only the quality but the quantity of the food consumed as well; 3) lastly, severe food insecurity, that exists when people experience hunger episodes[31].

The presence of obesity in situations of economic and food scarcity was identified since 1965 when Goldblatt et al. observed a markedly larger obesity prevalence among people from low socioeconomic status in Manhattan[107]. These findings were attributed mainly to cultural reasons and social values, including aesthetic preferences, ethnicity, culinary traditions, and religious customs[107]. Thirty years later, Dietz described the case of a 7-year old African-American obese girl who participated in a weight control program[19]. The mother reported to be economically incapable of providing her daughter the foods recommended in such program and could only get cheaper high-caloric products[19]. Dietz concluded that either their food choices or physiological adaptations responding to food scarcity episodes could be responsible for this apparently paradoxical association[19]. Since then, the evidence supporting the existence of this association has increased, especially in the U.S.[21, 75, 108, 109] and Latin America[1, 11, 110-112]. Supporting the hypothesis presented by Dietz, a study that evaluated Mexican households with children from 0 to 5 years old, reported an inverse relationship between food insecurity and income[67]. Additionally, in comparison with food-secure households, food-insecure families showed significantly lower expenditure on fruits, vegetables, meats, and dairy, while their spending on eggs, legumes, sugar, fats, and oils, was higher[67].

Initially, the coexistence of food insecurity and overweight or obesity seemed ironic, given that while food insecurity was related to inadequate economic resources to purchase food, overweight and obesity were considered a consequence of caloric overconsumption[19]. Nonetheless, in recent years, analyses of events associated with both conditions have revealed some interesting connections between them, showing that their simultaneity might, in fact, not be a paradox[20]. For instance, both food insecurity and obesity have shown to be associated with poverty, which in turn is also associated with

deficient diets. Nutrient-poor, energy-dense foods are more affordable[113], and their consumption is associated with obesity and other chronic diseases. Furthermore, stress and other psychological and social consequences of poverty can have a negative impact on body weight, hormonal balance, and metabolic functions[22]. Moreover, it has been observed that adults living in food-insecure environments are as well at higher risk of cardiovascular disease, diabetes, and poor physical health[75].

According to recent global reports, context plays a decisive role in people's food choices and health. Current agricultural and economic systems seem to profoundly influence both the food and nutritional security status of the population through the kinds of food available, food prices, shifts in norms and attitudes toward food, as well as consumer's characteristics related to the type of employment, income, and food preferences, which are partially driven by taste, price, and convenience[114, 115]. These factors, in turn, derive in excessive consumption of empty calories, which in developing countries, such as Mexico, affects primarily the poor, and consequently, those who are more vulnerable to food insecurity[114, 115].

During the last decades, Mexico has undergone an economical and nutritional transition characterized by an increased intake of ultra-processed, high energy foods[1]. This situation, accompanied by more sedentary lifestyles, has contributed to a rapid increment in the rates of obesity and chronic illnesses[1]. Since 1980, adult obesity prevalence has tripled[6], and today, the country ranks second highest at the global level[116]. Complications such as type II diabetes mellitus and cardiovascular problems are the leading causes of death among Mexican people[58]. Moreover, the economic impact of the disease, which was calculated in 240 million pesos (more than 12.5 million USD) in 2017[117], makes obesity one of the most relevant public health issues[6]. According to the Mexican Halfway National Health and Nutrition Survey 2016 (ENSANUT MC 2016 by its acronym in Spanish, *Encuesta Nacional de Salud y Nutrición Medio Camino 2016*), a nationwide survey conducted by the National Institute of Public Health of Mexico (INSP by its acronym in Spanish, *Instituto Nacional de Salud Pública*), adult overweight and obesity mixed prevalence was 72.5%, and the prevalence of abdominal obesity was 76.6%[53].

Simultaneously, food insecurity has also affected the Mexican population in the last years. In 2008, this phenomenon was measured for the first time nationwide by the National Council for the Evaluation of Social Development Policy (CONEVAL for its acronym in Spanish, *Consejo Nacional de Evaluación de la Politica de Desarrollo Social*). In that year, it was estimated that 21.7% of the population lacked access to food, a condition that encompasses both moderate and severe food

insecurity[9]. This prevalence decreased to 20.4% in 2018; nonetheless, the number of affected people increased from 24.3 to 25.5 million during that period[9]. Moreover, considering mild food insecurity, a total of 49.7 million people experienced some degree of food insecurity in 2018[9]. For its part, the ENSANUT has reported even higher figures in 2012 and 2016. Without significant changes from one period to the other, food insecurity was reported at 70.0% (41.6% mild, 17.7% moderate, and 10.5% severe) in 2012 and 69.5% (40.1% mild, 18.4% moderate, and 11.1% severe) in 2016[49].

According to 2012 national data, mild food insecurity is associated with obesity[11] and diabetes in women, and with hypertension in men and women[18]. The authors of these studies have suggested that food insecurity might be leading Mexican people to consume high amounts of sugar, fat, sodium, and refine carbohydrates and to acquire unhealthy eating habits as coping mechanisms[11, 18]. Additionally, that living in a scarcity situation could cause women to suffer from stress, affecting not only their mental health but probably increasing visceral fat deposition, thus contributing to the development of other chronic diseases[18]. Based on their observations, the researchers concluded that attending household food insecurity was crucial to solving the ongoing nutritional epidemic[11, 18]. They urged the government to act accordingly by improving the performance of assistance programs while addressing the roots of food insecurity. Recommendations included generating jobs that would allow adequate incomes for families, improving access to education, and developing gender-oriented policies since women were the most affected ones[11, 18].

Since 2013, the Mexican government has increased efforts to confront poverty and hunger[15]. As part of its actions, the National Strategy for Inclusion (*Estrategia Nacional de Inclusión* in Spanish) was implemented to eradicate hunger and provide adequate food and nutrition among the poorest[47]. This strategy proposed to increase the coverage of cash transfer programs, encourage the consumption of nutritious foods, and install school and community canteens[47]. As a result, half of the households in moderate or severe food insecurity were included in a food aid program. In consequence, the need for counting with updated and continuous evidence of the impact of such interventions has been noted[47]. Hence the relevance of performing and analyzing the results from national health and nutrition surveys periodically. In this study, we examined information from ENSANUT MC 2016 with the objective of further shading light on the relationship between food insecurity and body mass index (BMI) and waist circumference (WC). Additionally, we analyzed its association with overweight, obesity, and abdominal obesity in Mexican adults.

3.3 Methods

3.3.1 Data and study design

This cross-sectional study analyzed open access data from ENSANUT MC 2016[23], a probabilistic survey with both regional and national representation, which included urban and rural areas from the four regions of Mexico: North, Central, Mexico City, and South. A detailed description of its design has been published elsewhere[118]. Briefly, the survey gathered information from 9,479 households. In all of them, the head of the family was interviewed face to face by trained personnel following structured questionnaires regarding household characteristics, health, and nutritional situation of its members[118]. The health and nutrition questionnaires considered for this study were applied to subsamples. The number of subjects whose information was available for each of our variables is presented in the following sections.

Our population of interest was adults (20 to 59 years old). According to ENSANUT, an adult is an individual of 20 years or more[53], and according to the National Institute of Statistic and Geography (INEGI for its acronym in Spanish, *Instituto Nacional de Estadística y Geografía*), in Mexico, a subject of 60 years or more is considered an older adult[119]. Only subjects with complete data on the following questionnaires were included in the present study: i) demographic, socioeconomic, goods, and household characteristics; ii) anthropometry; iii) semiquantitative food frequency questionnaire; iv) food security; and v) physical activity, sedentariness and sleeping time. Lactating and pregnant women, as well as subjects whose information on BMI, energy consumption, or physical activity was out of the valid cut-off points (specified later in the variables description section), were excluded from the study.

3.3.2 Exposure variable

The food insecurity level was the independent variable used in the present study. This variable was measured employing the Latin American and Caribbean Food Security Scale (ELCSA for its acronym in Spanish, *Escala Latinoamericana y Caribeña de Seguridad Alimentaria*), a validated method for evaluating food insecurity in the Mexican population[39, 120]. ELCSA inquires about food insecurity-related experiences during the three months previous to the survey[31]. It contains fifteen questions designed to be answered in a dichotomous way (yes or no)[31]. Answers are coded "1" for yes and "0" for

no, generating a score that is subsequently used to classify households into one of four categories: food secure, mildly food insecure, moderately food insecure, and severely food insecure[31]. Information on this variable was available for 9,019 households.

3.3.3 Outcome variables

BMI (weight in kg/ height in m^2) and WC (in cm) were initially analyzed as continuous variables. Subsequently, they were broken into categorical variables as follows. According to the World Health Organization, a BMI of ≥25 kg/m^2 in adults indicated overweight, and ≥30 kg/m^2 indicated obesity[121]. The range for valid BMI measurements was considered from 10 to 58 kg/m^2, as it has been presented in previous studies for the same population of interest[11, 53]. Abdominal obesity was defined according to the International Diabetes Federation with a WC ≥80 cm for women and ≥90 cm for men[53]. For our population of interest, there was information available on BMI of 6,412 subjects and on WC of 6,160 individuals. Anthropometric measurements taken to calculate these variables were performed applying Lohman's techniques[122] and the Habicht procedure for standardizing fieldwork[123], ensuring the quality of the data collected. Height, weight, and WC were measured twice, and the average was reported and used for the analyses. Regarding the equipment used, the scales were SECA brand, model 874, with 100g precision; stadiometers were SECA brand, model 206, with 1mm of precision; and fiberglass anthropometric tapes used were Gulik brand, model M-22C, with a scale from 0 to 150 cm.

3.3.4 Covariates

Sociodemographic characteristics: age (in years); indigenous ethnicity (yes or no, depending on whether they recognized themselves as indigenous and whether they reported using an indigenous language[11]); educational level (preschool or none, primary or secondary education, or high school or higher); marital status (single/divorced/widow, or married/cohabitating); the number of people residing in the household (1 to 2, 3 to 4, 5 or more); area of residence (urban or rural); region of the country (North, Central, Mexico City, or South[118]); and socioeconomic level (quintiles). For the latter, we took the existent classification presented by the INSP in the databases of ENSANUT MC 2016. The construction of this variable was based on a wellness condition index created using the principal components analysis method and the information collected from the sociodemographic questionnaire

included in the survey[11]. The household aspects considered for developing this index were the construction materials of floor, walls, and ceiling, number of rooms used for sleeping, access to water, vehicle possession, number of domestic goods, and number of electronic devices[11]. Finally, the index was divided by quintiles; the first quintile (Q1) represents the lowest socioeconomic level, and the last one (Q5), the highest[11]. Information on these variables was available for all the subjects from the 9 479 households.

Energy consumption: calculated from the semiquantitative food frequency questionnaire (SFFQ) included in the survey. This SFFQ has been designed and validated to estimate energy, macronutrients, and micronutrients consumption in Mexican adults[124]. It includes a list of 140 food and beverage items and inquires about their consumption in terms of days per week, times a day, portions per time, and portion size[124]. Individuals in which the ratio of energy intake/estimated energy requirement was over 3 SD, or in which the ratio of energy intake/basal metabolic rate was under 0.5, were excluded[125]. The extended methodology for estimating dietary data from this SFFQ has been published elsewhere[125]. There was information on this variable of 6,511 subjects from our population of interest.

Physical activity: ENSANUT MC 2016 incorporated the short version of the International Physical Activity Questionnaire (IPAQ). This instrument asks about the execution and duration of different physical activities performed in bouts of at least ten continuous minutes during the last seven days[53]. Data cleaning and classification of physical activity levels were done in agreement with the IPAQ guidelines. In accordance, subjects may have a low, moderate, or high level of physical activity. This classification depends on the MET-minutes per week, and the days per week, the physical activities were performed[126]. For our population of interest, there was information available on this variable for 6,435 subjects.

Sleeping time: For sleeping time sufficiency classification, we applied the criteria of the U.S. National Sleep Foundation. Accordingly, sleeping time was considered sufficient, with at least seven hours per day[127]. For our population of interest, there was information available on this variable for 6,416 subjects.

3.3.5 Statistical analysis

Continuous variables are presented as means and categorical variables as proportions. Bivariate contingency tables were generated for observing the distribution of food insecurity by sociodemographic characteristics, and chi-square tests were performed to detect associations between these variables. Subsequently, all analyses were performed independently for men and women. Prevalence of overweight, obesity, and abdominal obesity was calculated by gender and food insecurity levels. Differences in mean BMI and WC by food insecurity level were evaluated through ANOVA in conjunction with Bonferroni post-hoc testing, following confirmation of homogeneity of the variances by using the Levene's test. Associations between food insecurity and BMI and WC were analyzed through multivariate linear models.

Afterwards, the odds ratios (OR) for overweight, obesity, and abdominal obesity were obtained through bivariate and multivariate logistic regression models adjusting for multiple contrasts. For the regression analyses, the backward elimination method was employed until all covariates in the linear models had a $P < 0.10$[128], and $P < 0.15$ in the logistic ones[129]. Although energy consumption, physical activity level, socioeconomic level, and educational level were not significantly associated with the outcome variables in some models, these variables were incorporated into the analyses due to their physiological or theoretical relationship with body weight. The analyses were conducted using the complex samples option of IBM SPSS Statistics for Windows, v. 25.0. Results were reported as significant with a $P < 0.05$.

Based on available data for the variables included in the multivariate models and after applying the exclusion criteria, the final sample was composed of 5,456 subjects representing 45,804,210 adult individuals at the national level.

3.4 Results

From the final sample, 46.7% of the subjects were males and 53.3% females. Regarding food insecurity level, 29.2% (95% CI= 26.9%, 31.7%) were food secure, 40.7% (95% CI= 38.3%, 43.2%) mildly food insecure, 18.8% (95% CI= 17.1%, 20.7%) moderately food insecure, and 11.2% (95% CI= 9.9%, 12.7%) severely food insecure. Total food insecurity had larger proportions among indigenous people, those living in rural areas, in the Southern region of the country, the ones in the lowest socioeconomic quintiles (Q_1 and Q_2), the larger families (5 members or more), and people with low

education level. The chi-square test showed significant associations between these variables and food insecurity (Table 3.1).

The prevalence of overweight was 39.5% (95% CI= 37.2%, 41.8%), from which men showed a higher prevalence than women (42.8% vs. 36.6%; *P* <0.001). Obesity was present in 34.0% (95% CI= 31.7%, 36.3%), with higher proportion in females (38.7% vs. 28.6%; *P* <0.001). Abdominal obesity was found in 76.4% of the sample (95% CI= 74.2%, 78.5%), with also a higher prevalence among females (87.2% vs. 64.1%; *P* <0.001). No significant associations were found between food insecurity and overweight, obesity, or abdominal obesity among males. However, in females, the chi-square test showed a significant association in the case of obesity (*P*= 0.023) (Table 3.2).

Mean BMI and WC increased along with food insecurity severity among females (*P* <0.001), as shown in Figures 3.1a and 3.1b, respectively. Likewise, the multivariate linear regression models indicated that severe food insecurity is significantly associated with BMI (*P* <0.001) and WC (*P*= 0.002) (Tables 3.3 and 3.4).

The bivariate logistic regression analyses showed a significant relationship between food insecurity and overweight, obesity, and abdominal obesity among females (Table 3.5). Specifically, moderate food insecurity was associated with obesity, whereas severe food insecurity was associated with overweight, obesity, and abdominal obesity. Additionally, we observed associations between insufficient sleeping time, having primary or secondary education or less, and being married or living with a partner, with higher probabilities of obesity or abdominal obesity. Also, a significant relationship between having only preschool education or less and overweight was found. Belonging to the third quintile of the socioeconomic scale was associated with obesity.

The association between severe food insecurity and obesity remained significant in multivariate logistic regression models. Obesity was correlated as well with age, having primary or secondary education, being married or living with a partner, and having insufficient sleeping time (Table 3.6). The relationships between severe food insecurity and overweight and abdominal obesity were not statistically significant after controlling for covariates.

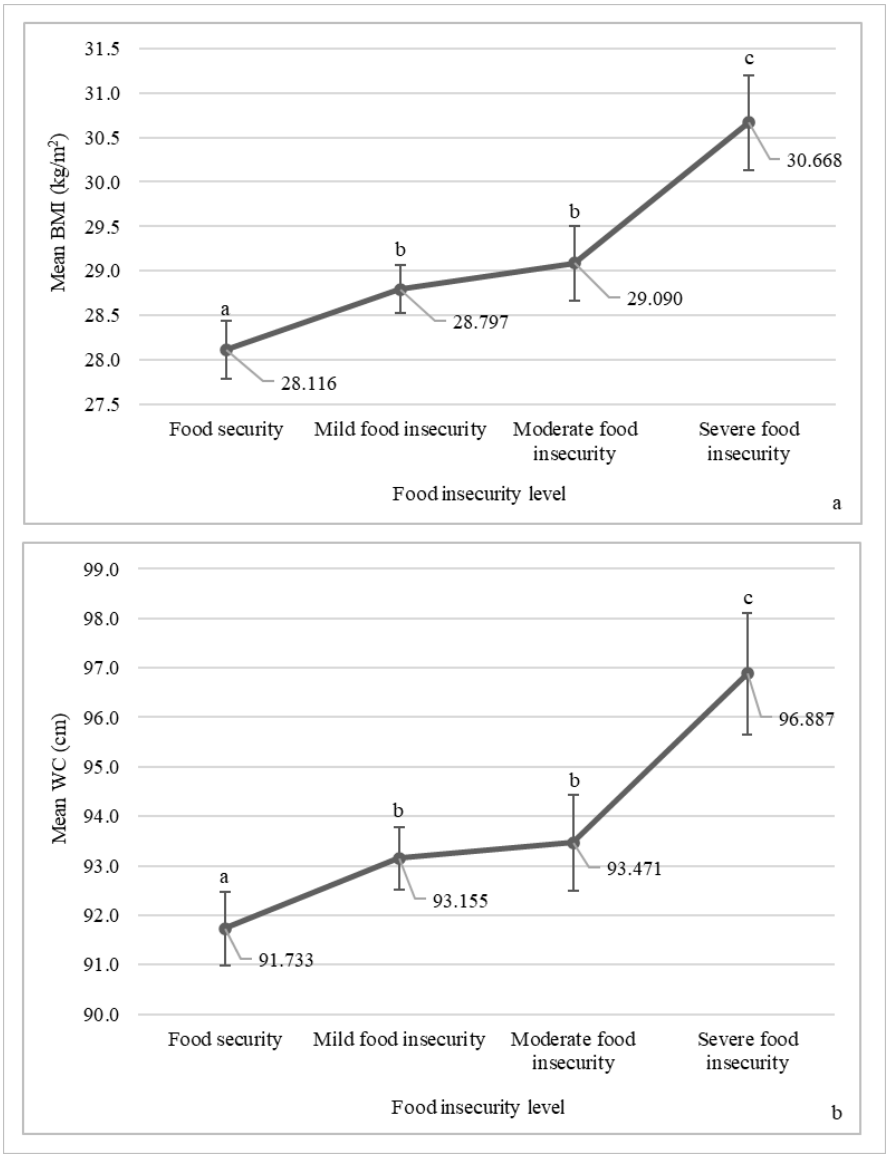

Figure 3.1 Mean BMI (a) and WC (b) by food insecurity level in Mexican women (*n* 3,649 $n_{weighted}$ 24,435,352).

BMI, body mass index. WC, waist circumference.

Error bars represent the 95% CI of the mean based on the standard error.

Significant differences (P <0.05) between food security levels are indicated with dissimilar letters.

Table 3.1 Food insecurity distribution according to sociodemographic characteristics of the population. Mexican adults (20 to 59 years old). ENSANUT MC 2016.

	n (n weighted)	Food secure		Mildly food insecure		Moderately food insecure		Severely food insecure		*P*-value
		%	95% CI	%	95% CI	%	95% CI	%	95% CI	
Gender										0.613
Women	1807 (24435352)	29.8	26.7, 33.3	41.4	38.4, 44.5	17.7	15.6, 20.0	11.0	9.5,12.8	
Men	3649 (21368858)	28.5	25.1, 32.2	39.9	36.3, 43.6	20.1	17.3, 23.3	11.4	9.2, 14.2	
Age group (years)										0.637
20-29	1242 (14494768)	31.7	27.5, 36.3	38.7	34.7, 42.9	17.7	14.4, 21.7	11.8	8.9, 15.5	
30-39	1589 (12339250)	28.8	24.7, 33.3	43.2	38.3, 48.1	18.3	15.1, 22.0	9.7	7.6, 12.3	
40-49	1457 (10927121)	29.0	24.7, 33.7	39.5	35.8, 43.2	20.1	16.7, 23.9	11.5	8.9, 14.7	
50-59	1168 (8043071)	25.7	21.4, 30.5	42.4	38.1, 46.8	19.9	16.4, 24.0	12.0	9.2, 15.6	
Indigenous ethnicity										<0.001

No	4862 (42959191)	30.4	27.9, 33.0	40.5	37.9, 43.1	18.4	16.7, 20.3	10.7	9.3, 12.3	
Yes	594 (2845019)	12.3	7.9, 18.8	44.0	36.4, 51.8	25.0	18.3, 33.2	18.6	12.1, 27.6	
Education level										<0.001
High school or higher	1439 (18132617)	40.2	35.5, 45.2	37.9	33.9, 42.0	14.2	11.6, 17.3	7.7	5.8, 10.1	
Elementary or secondary	3683 (25925694)	22.3	20.0, 24.7	43.1	40.1, 46.1	21.6	19.2, 24.2	13.0	11.2, 15.0	
Preschool or none	334 (1745899)	18.7	11.4, 28.9	35.2	26.1, 45.5	24.7	17.8, 33.1	21.5	13.7. 32.0	
Marital status										0.485
Single/ Divorced/ Widow	1645 (15923111)	28.9	25.1, 32.9	40.1	35.7, 44.6	18.2	15.2, 21.6	12.8	10.5, 15.6	
Married/ Cohabitating	3811 (29881099)	29.4	26.6, 32.4	41.0	38.4, 43.8	19.1	17.2, 21.3	10.4	8.7, 12.3	
Number of people residing in the household										0.014

1 to 2	1786 (10190179)	31.9	28.4, 35.8	38.8	35.4, 42.2	20.3	17.4, 23.6	8.9	7.4, 10.8	
3 to 4	2376 (20893134)	30.4	26.6, 34.4	41.9	38.4, 45.4	18.0	15.5, 20.9	9.7	7.9, 11.9	
5 or more	1294 (14720897)	25.8	21.8, 30.2	40.4	35.5, 45.6	18.9	15.6, 22.6	14.9	12.1, 18.3	
Residence area										<0.001
Rural	2774 (11223115)	21.7	18.8, 25.0	47.8	44.6, 51.0	19.8	17.2, 22.8	10.6	8.7, 12.9	
Urban	2682 (34581095)	31.7	28.7, 34.8	38.4	35.5, 41.5	18.5	16.4, 20.8	11.4	9.7, 13.3	
Region of the country										0.010
Center	1424 (13015506)	28.3	23.8, 33.4	44.2	39.3, 49.2	16.9	14.2, 19.9	10.5	8.1, 13.7	
Mexico City	599 (7601883)	32.2	26.3, 38.9	35.4	30.4, 40.9	21.4	16.9, 26.7	10.9	7.9, 14.9	
North	1714 (12965395)	34.3	29.6, 39.2	37.6	33.1, 42.4	16.4	13.3, 20.0	11.8	9.5, 14.5	
South	1719 (12221426)	23.0	19.6, 26.8	43.6	39.5, 47.7	21.8	18.2, 26.0	11.6	8.9, 14.9	
Socioeconomic level										<0.001

Q_5	1051 (15065559)	43.1	38.3, 48.0	40.1	35.6, 44.9	12.6	9.4, 16.6	4.2	2.9, 6.2
Q_4	1073 (10356599)	28.7	24.6, 33.2	42.0	37.6, 46.5	17.4	14.2, 21.1	11.9	8.7, 16.0
Q_3	1112 (8097522)	26.3	21.4, 31.9	37.0	32.0, 42.2	23.4	19.5, 27.8	13.3	10.0, 17.5
Q_2	1126 (7130301)	17.1	14.0, 20.6	42.1	37.3, 47.1	23.2	19.5, 27.3	17.7	13.5, 22.7
Q_1	1094 (5154228)	11.2	8.5, 14.8	43.7	38.7, 48.9	26.8	21.7, 32.6	18.3	13.8, 23.8

OR, odds ratio. Q_i, quintile and quintile number (Q_5 represents the highest socioeconomic level).

P-values correspond to the chi-square test of independence for each variable and food insecurity level.

Table 3.2 Overweight, obesity, and abdominal obesity prevalence by food insecurity level in Mexican women. ENSANUT MC 2016.

	Food security		Mild food insecurity		Moderate food insecurity		Severe food insecurity	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Overweight	34.46	29.78, 39.46	39.38	35.42, 43.48	34.96	29.79, 41.69	34.74	26.76, 43.68
Obesity*	35.31	30.47, 40.47	36.85	32.59, 41.32	42.26	35.66, 49.14	49.13	40.55, 57.77

Abdominal obesity	86.8%	82.89, 89.90	85.94	82.38, 88.88	86.92	82.13, 90.57	93.24	88.24, 96.21

Mexican women sample size (*n* 3,649, $n_{weighted}$ 24,435,352).

*P =0.023 from the chi-squared test of independence.

Table 3.3 Multivariate linear regression model for the association between food insecurity and BMI in Mexican women. ENSANUT MC 2016.

Variable	Coefficient	95% CI	*P*-value
Food insecurity level			
Food security	Ref		
Mild food insecurity	0.535	-0.367, 1.437	0.244
Moderate food insecurity	0.749	-0.284, 1.781	0.155
Severe food insecurity	2.239	1.055, 3.423	<0.001
Age (years)	0.067	0.040, 0.094	<0.001
Indigenous ethnicity			
No	Ref		
Yes	-0.654	-1.616, 0.307	0.181
Education level			

High school or higher	Ref		
Primary or secondary	0.635	-0.004, 1.274	0.051
Preschool or none	-0.067	-1.469, 1.334	0.925
Marital status			
Single/ Divorced/ Widow	Ref		
Married/ Cohabitating	0.785	0.145, 1.425	0.016
Socioeconomic level			
Q_5 (highest)	Ref		
Q_4	-0.037	-0.941, 0.867	0.936
Q_3	0.900	-0.150, 1.951	0.093
Q_2	-0.069	-1.045, 0.908	0.890
Q_1 (lowest)	-0.326	-1.508, 0.857	0.588
Energy consumption	0.000012	0.000, 0.000	0.955
Physical activity level			
High	Ref		
Moderate	-0.092	-0.722, 0.537	0.773
Low	1.106	0.224, 1.989	0.014

Sleeping time			
Sufficient	Ref		
Insufficient	1.258	0.534, 1.982	0.001

Ref, reference category. Qi, quintile and quintile number (Q_5 represents the highest socioeconomic level).

Mexican women sample size (*n* 3,649, $n_{weighted}$ 24,435,352).

Table 3.4 Multivariate linear regression model for the association between food insecurity and WC in Mexican women. ENSANUT MC 2016.

Variable	Coefficient	95% CI	*P*-value
Food insecurity level			
Food security	Ref		
Mild food insecurity	1.011	-0.750, 2.773	0.260
Moderate food insecurity	1.078	-1.279, 3.434	0.369
Severe food insecurity	4.222	1.530, 6.914	0.002
Age (years)	0.232	0.170, 0.294	<0.001
Indigenous ethnicity			

No	Ref		
Yes	-2.724	-4.746, -0.702	0.008
Education level			
High school or higher	Ref		
Primary or secondary	2.491	0.894, 4.089	0.002
Preeschool or none	0.792	-2.797, 4.382	0.664
Socioeconomic level			
Q_5			
Q_4	-0.920	-3.056, 1.216	0.397
Q_3	0.405	-1.942, 2.752	0.735
Q_2	-0.811	-3.135, 1.513	0.493
Q_1	-0.723	-3.628, 2.182	0.625
Energy consumption	0.00029	-0.001, 0.001	0.555
Physical activity level			
High	Ref		

Moderate	0.812	-0.671, 2.295	0.282
Low	2.479	0.397, 4.561	0.020
Sleeping time			
Sufficient	Ref		
Insufficient	3.137	1.460, 4.814	<0.001

Ref, reference category. Q_i, quintile and quintile number (Q_5 represents the highest socioeconomic level).

Women sample size (*n* 3,649, $n_{weighted}$ 24,435,352).

Table 3.5 Bivariate logistic regression models for the associations between food insecurity and overweight, obesity, and abdominal obesity in Mexican women. ENSANUT MC 2016.

	Overweight			Obesity			Abdominal obesity		
Variable	OR	95% CI	*P*-value	OR	95% CI	*P*-value	OR	95% CI	*P*-value
Food insecurity level									
Food security	1.00			1.00			1.00		
Mild food insecurity	1.48	0.97, 2.25	0.068	1.35	0.87, 2.09	0.181	0.93	0.60, 1.45	0.753
Moderatefood insecurity	1.47	0.86, 2.50	0.158	1.73	1.02, 2.95	0.044	1.01	0.61, 1.68	0.963
Severe food insecurity	1.85	1.08, 3.16	0.025	2.55	1.54, 4.23	<0.001	2.10	1.08, 4.10	0.029
Indigenous ethnicity									

No	1.00			1.00			1.00		
Yes	1.16	0.63, 2.13	0.642	0.71	0.41, 1.24	0.227	0.78	0.38, 1.62	0.507
Education level									
High school or higher	1.00			1.00			1.000		
Elementary or secondary	1.31	0.93, 1.85	0.124	1.84	1.31, 2.60	0.001	2.12	1.52, 2.94	<0.001
Preschool or none	2.49	1.20, 5.16	0.015	2.57	1.33, 4.96	0.005	3.71	1.61, 8.54	0.002
Marital Status									
Single/Divorced/Widow	1.00			1.00			1.00		
Married/ Cohabitating	1.32	0.99, 1.77	0.056	1.624	1.21, 2.17	0.001	1.57	1.13, 2.18	0.008
Number of people residing in the household									
1 to 2	1.00			1.00			1.00		
3 to 4	0.81	0.60, 1.09	0.154	0.74	0.52, 1.05	0.089	0.98	0.69, 1.39	0.905
5 or more	1.12	0.77, 1.64	0.554	0.79	0.52, 1.19	0.260	1.17	0.76, 1.79	0.486
Residence area									
Rural	1.00			1.00			1.00		
Urban	0.88	0.68, 1.15	0.339	1.04	0.80, 1.35	0.760	0.94	0.69, 1.29	0.708
Region of the country									
Center	1.00			1.00			1.00		

Mexico City	1.45	0.94, 2.25	0.096	1.33	0.86, 2.05	0.20	1.05	0.63, 1.76	0.849
North	1.21	0.84, 1.74	0.306	1.33	0.89, 1.99	0.16	1.04	0.70, 1.56	0.840
South	1.23	0.90, 1.69	0.190	1.45	0.98, 2.16	0.06	0.89	0.62, 1.27	0.504
Socioeconomic level									
Q_5	1.00			1.00			1.00		
Q_4	1.02	0.68, 1.53	0.932	1.00	0.68, 1.48	0.994	0.97	0.64, 1.46	0.864
Q_3	1.31	0.84, 2.05	0.234	1.70	1.11, 2.60	0.015	1.12	0.71, 1.76	0.634
Q_2	1.05	0.68, 1.63	0.814	1.11	0.71, 1.72	0.653	0.83	0.51, 1.35	0.447
Q_1	1.06	0.68, 1.66	0.787	0.99	0.63, 1.57	0.990	0.85	0.53, 1.34	0.474
Physical activity level									
High	1.00			1.00			1.00		
Moderate	1.00	0.71, 1.41	0.998	0.73	0.52, 1.01	0.057	0.84	0.58, 1.20	0.332
Low	1.10	0.74, 1.64	0.636	1.10	0.74, 1.63	0.648	0.90	0.58, 1.38	0.614
Sleeping time									
Sufficient	1.00			1.00			1.00		
Insufficient	1.39	0.96, 2.01	0.081	1.86	1.33, 2.59	<0.001	1.98	1.38, 2.85	<0.001

OR, odds ratio. Q_i, quintile, and quintile number (Q_5 represents the highest socioeconomic level).

Women sample size (*n* 3,649, $n_{weighted}$ 24,435,352).

Table 3.6 Multivariate logistic regression model for the association between food insecurity and obesity in Mexican women. ENSANUT MC 2016.

	Obesity		
	OR	95% CI	P-value
Food insecurity level			
Food security	1.00		
Mild food insecurity	1.28	0.81, 2.02	0.299
Moderate food insecurity	1.53	0.88, 2.66	0.133
Severe food insecurity	2.36	1.40, 3.98	0.001
Age (years)	1.04	1.02, 1.05	<0.001
Education level			
High school or higher	1.00		
Primary or secondary	1.43	1.01, 2.03	0.042
Preschool or none	1.44	0.68, 3.04	0.341
Marital Status			
Single/ Divorced/ Widow	1.00		
Married/ Cohabitating	1.53	1.14, 2.06	0.005
Socioeconomic level			
Q_5	1.00		
Q_4	0.92	0.61, 1.39	0.684
Q_3	2.42	1.54, 1.98	0.063
Q_2	0.83	0.58, 1.19	0.303
Q_1	1.12	0.75, 1.67	0.586
Energy consumption (kcal)	1.00	1.00, 1.00	0.607

Physical activity level			
High	1.00		
Moderate	0.83	0.58, 1.19	0.303
Low	1.12	0.75, 1.67	0.586
Sleeping time			
Sufficient	1.00		
Insufficient	1.86	1.28, 2.68	0.001

OR, odds ratio. Q_i, quintile and quintile number (Q_5 represents the highest socioeconomic level).

3.5 Discussion

Through this cross-sectional study, a positive relationship between severe food insecurity and obesity among Mexican women was confirmed. After adjusting for age, educational level, marital status, socioeconomic level, energy consumption, physical activity, and sleeping time, obesity was more than twice as likely to occur in severely food-insecure women than in food-secure ones. Moreover, severe food insecurity was significantly associated with BMI and WC in multivariate models. The latter is consistent with the increases observed in mean BMI and WC as the level of food insecurity aggravates.

Data from 2012 showed an association between mild food insecurity and obesity among Mexican female adults was reported[11], and mild and moderate food insecurity was related to higher odds of overweight and obesity[1]. As discussed by the authors of both studies, these findings were related to the consumption of foods rich in fat, sugar, and refined flours, responding to the lack of economic access of food-insecure people to healthy and more diverse diets[1, 11]. Although our analyses did not show a significant relationship with mild and moderate food insecurity, a similar trend was observed.

Resembling our findings, severe food insecurity was associated with a greater likelihood of obesity in low-income Latino women living in California[21]. This relationship was explained by the possible occurrence of cyclical patterns of involuntary food restriction followed by overeating periods, a situation that could trigger a metabolic response for increasing the body's efficiency for storing energy

in the form of fat[21]. This condition would be promoted by an irregular income in the household throughout time, as it was later confirmed in 2009[109].

Similarly, in Brazil, a relationship between severe food insecurity and excessive weight was observed in female adolescents from a nationally representative sample[110]. In that case, as well, it was suggested that this condition might result from energy overconsumption, which in turn might be incentivized by the affordability of energy-dense foods, as can occur at certain stages of the nutritional transition in a country[110]. In this context, it was suggested that the participation in cash-transfer programs might be a risk factor for excessive weight given the insufficiency of this monetary support for lasting the whole month, leading families to stretch their budgets and relying on low-cost, high-calorie foods[110].

From the analyses of continuous variables, we observed increases in mean BMI as the food insecurity worsened, and an association between severe food insecurity and BMI. Our findings are similar to what has been reported in Monteverde, Costa Rica, where BMI was positively correlated with any level of food insecurity[111]. That study described some of the negative impacts of the low tourism seasons as contributors to their observations[111]. These factors included elevated food prices, seasonal unemployment, and abandonment of agricultural activities, which affected people's diet by leading to increases in the consumption of staples, processed meats and cheeses, and fried snacks while reducing the purchase of more expensive products such as fruits and vegetables[111].

Regarding our evaluation of WC and abdominal obesity, we included these indicators of visceral fat for being better predictors of cardiometabolic risk and mortality than BMI[55]. We found a significant increase in mean WC as food insecurity worsened, an independent association between severe food insecurity and WC, and a higher proportion of abdominal obesity among severely food-insecure women. Although we observed a significant bivariate association between severe food insecurity and abdominal obesity, this finding lost its significance in multivariate models.

The fact that we have found a significant association between food insecurity and WC, but not abdominal obesity, might be explained by the strikingly high and generalized prevalence of the latter among the population, or probably, because of the higher sensitivity of the analyses conducted with continuous variables. Other studies have reported findings similar to ours. For instance, in Malaysia, abdominal obesity prevalence was higher among food-insecure women. That country, like Mexico, is immersed in an economic transition, experiences changes in the dietary and physical activity behaviors of its population, and presents increasing rates of overweight and obesity, mainly among women[130].

Accordingly, in that context, the association was attributed to the consumption of low-diverse diets and physical inactivity[130]. Similarly, in other geographical contexts, such as Iran[131] and Brazil[112], it has been observed that abdominal obesity is more likely to occur in severe food insecurity situations, but a causal association has not been established. Due to the limited inclusion of WC and abdominal obesity in this type of studies, we consider that further evaluation of the association of food insecurity and those indicators is needed.

From a biological perspective, the food insecurity-obesity paradox has been explained through the resource scarcity hypothesis, an approach that deepens in the mechanisms proposed by the aforementioned studies. This theory says that food insecurity, in an environment where high-calorie foods are more accessible than healthier food options, may cause a positive energy balance, especially among individuals of lower social status[22]. Aside from their limited purchasing power, which might restraint their food choices and dietary quality, in this segment of the population, individuals (not only humans, but even animals in the bottom of their organizational structures) are energetically more efficient, having lower fat oxidation and metabolic rates[22, 132]. It has been described that they have higher concentrations of serum cortisol[133], which, when chronically elevated, may influence both food intake and fat metabolism. Furthermore, elevated serum cortisol has been associated with leptin and insulin resistance, thereby promoting fat accumulation[22, 134]. Additionally, poverty and the fact of living in an adverse environment can lead to an increased desire for food and to opting for consuming high amounts of energy-dense products (binging), probably due to the perception that food supply is inadequate or that access to it might be compromised in the future[135].

Interestingly, the majority of studies that have analyzed the association between food insecurity and obesity report positive results more frequently among females than males. The above has been explained by a number of theories indicating that women might have: i) periods of increased food intake due to greater anxiety and social stress[22, 136]; ii) a lower economic capacity to achieve food security[137]; iii) a lower physical activity level[137]; iv) a physiological response for ensuring adequate body fat levels for reproduction[22, 138], or v) due to probable unequal food distribution at the household level, mainly in famine seasons[21, 67], and which can occur in response to protecting children from the adverse effects of food insecurity[110]. This last hypothesis has been suggested for rural and indigenous Mexican populations, where males, as the primary workforce, have priority in feeding, leaving children and women at a disadvantage and, therefore, promoting the corporal adjustments aforementioned[67]. However, more studies on this maternal buffering response are required. As well, it is necessary to clarify that the ELCSA measures food security at the household level. Therefore, individual experiences from

each member might not be wholly reflected in the results. Nonetheless, whenever possible, this questionnaire was applied to the mother, who is usually responsible for feeding the family.

Other observations from this study include the associations found between insufficient sleeping time and BMI, WC, and obesity in the multivariate models. These findings concur with clinical and experimental investigations that evidence the relevance of sleeping as a regulator of endocrine and metabolic processes and how sleeping restriction can contribute to triggering overweight and obesity[139]. The implicated mechanisms in this association are related to modifications in the circadian rhythm, which affect the CLOCK genes and the transcription of metabolism genes, consequently modifying the normal functioning of endocrine organs and glands[139]. Accordingly, altered sleep patterns are related to increased secretions of ghrelin, insulin, cortisol, and orexin, and decreased secretions of leptin and melatonin[139]. Correspondingly, some of the symptoms of reduced sleeping time in the short and medium-term include higher sensations of hunger, cravings for carbohydrate-rich food, greater ingestion of food during the night time, and digestive problems[139].

On the other hand, there is evidence that the direction of the association between insufficient sleep and obesity could also be in the opposite direction. An analysis from ENSANUT MC 2016 found that BMI was a predictive factor for obstructive sleep apnea and daytime sleepiness or not restful sleep[140]. Additionally, it was estimated that 27.3% of the Mexican adult population has a high risk of obstructive sleep apnea and that there is a significant prevalence of other indicators of bad quality sleep such as insomnia (18.8%), snoring (48.5%), and daytime fatigue (32.4%)[140]. Therefore, it has been pointed out the relevance of counting with longitudinal studies that allow a better understanding of the sleep problems in Mexico and their association with obesity[139], as well, the consideration of sleeping habits in the interventions aimed to attend the obesity epidemic in the country, and the promotion of specialized health services for diagnostic and treatment of these conditions[140].

We also observed an association between low physical activity and BMI and WC. However, this was not the case when analyzing the categorical forms of these variables, a fact that we attribute to the higher testing sensitivity that exists when analyzing continuous data. According to our results, physical activity should get more attention in the fight against obesity in Mexico. The National Program for Physical Culture and Sport for 2014 to 2018 reported a lack of governmental promotion and programs for the practice of physical activity and a lack of physical activity habits by the population[141]. According to the ENSANUT MC 2016, 14.4% of Mexican adults did not meet the WHO recommendations for minimal physical activity, being the main barriers for not practicing it lack of time, lack of adequate and

safe spaces, and lack of motivation[53]. In other studies, it has been suggested that the lack of healthy food or the uncertainty of access to food-related to food insecurity could lead people to be physiologically or psychologically less energetic to practice physical activity[142]. This could be another way in which food insecurity might be affecting the health, and weight status of people, however further studies on this hypothesis would be needed in the Mexican setting.

Concerning education, having only primary or secondary schooling has been associated with our outcome variables. Nonetheless, we did not observe a significant result in the case of counting with preschool or none. Other authors have reported an inverse association between education level and obesity among Mexican women from urban areas but not from the rural setting, where obesity prevalence has been higher in females with secondary education than in those with primary or less, but also than those with high school or higher education[143]. In that publication, it was proposed that probably less-educated rural women had a lower economic purchasing power that might protect them for acquiring processed, high-calorie foods; nonetheless, that the increasing availability of these products at low-cost in their communities might eventually revert their situation[143].

Comparability between that study and ours might be limited because of the different periods of time evaluated, the separated analysis of urban and rural areas considered in the first one, and the different categories contemplated for education level. However, our results might have a similar explanation. Another possibility is that people in the lowest education level could be limited to predominantly physical occupations that prevent them from obesity (e.g., agriculture), as it has been suggested previously[144]. The relevance of education in this context lies in its influence over other social determinants of health, such as occupation and income, and consequently on the economic access to food[144]. Furthermore, the level and quality of education are linked to greater health literacy and health behaviors; accordingly, it has also been observed that nutritional education is more effective in higher educated people[144].

The strengths of this study include the exhaustive analysis that we conducted considering different indicators of obesity, as well as the incorporation of both continuous and categorical forms of the dependent variables, which exhibited consistent and reiterative results. Additionally, the research was based on a sample obtained through a multistage, stratified, and conglomerate design. Thus, the results are generalizable nationwide, and to some extent, even to similar contexts to Mexico.

Limitations of our study refer to the inability to infer a cause-effect relationship due to its cross-sectional design. Moreover, the instruments used to assess diet and food insecurity capture information related to defined periods. Thereby, the season in which the survey was carried out could have influenced

the responses on these variables, mainly in families that depend on their food production, as is the case in many rural areas. Another possible limitation could be that the ELCSA approaches food insecurity from the access dimension, and therefore, our study did not consider aspects related to food availability. However, it has been posed that Mexico counts with one of the highest figures of caloric availability per capita in the world (3,145 kcal/day), and that food insecurity derives principally from the lack of purchasing power, in other words, the lack of access to food[15]. Finally, concerning the measurement method of physical activity in ENSANUT MC 2016, it has been suggested that using accelerometers might produce more reliable results since IPAQ has shown a poor validity for estimating moderate and vigorous physical activity accurately[145].

The interpretation of our results could be further complemented by knowing how long people have been experiencing food insecurity. For instance, some authors have found that suffering from food insecurity in the past is related to obesity in the future[146]. Furthermore, it has been reported that experiencing famine and nutritional deficiencies in prenatal and perinatal stages, and early infancy can undermine the physiological performance of the organism even until adulthood, influencing the development of obesity[147]. Likewise, our understanding of the phenomenon of study in this investigation would be clearer by knowing the individual and household coping strategies (i.e., fall-back mechanisms to face short-term insufficiency of food) and adaptative mechanisms (i.e., long-term or permanent changes in the way households and individuals acquire sufficient food or income to deal with food insufficiency) that emerge to face this situation[148]. Perhaps, longitudinal or qualitative studies might be convenient in the last case.

Furthermore, a more detailed analysis of the SFFQ getting information on dietary diversity and quality, in addition to energy intake, could be especially useful in two aspects. First, this information is essential to provide assertive food policy recommendations. Second, it might be helpful in understanding the differences observed between our findings and the reports derived from ENSANUT 2012. At that time, mild food insecurity was associated with obesity[11]. Accordingly, the authors attributed this result to an affectation of the dietary quality, driven by the low purchasing power of the food-insecure families[11]. Since then, these individuals may have improved their diets or the strategies to deal with food insecurity. This hypothesis would be supported by a recent evaluation of the food assistance programs of the last years[47].

On the other hand, a previous study conducted in rural communities from the southern region of Mexico found that both cash-transfers and food baskets contributed to increasing obesity in females[70].

The above let us point out as well the need for future evaluations on the health outcomes derived from food programs, in addition to the assessments on coverage and focalization that have been conducted[47]. These proposed studies should also contemplate the role of food programs in potential abundance-shortage cycles in the household.

As we have confirmed in this study, food insecurity is part of the pile of elements that contribute to obesity in Mexico. Like a chain reaction, it might be affecting people's diet by economic restraints that lead to the consumption of inexpensive calorie-dense products[67]. Moreover, psychologically could be involved in the development of behaviors like eating disorders (binging)[135], stress, and associated hormonal imbalances[22]. The latter, in conjunction with the inconsistent access to food, poor dietary quality, and the lack of healthy habits (physical activity and sleeping), could be triggering metabolic alterations that are reflected in fat and weight gain[21, 109, 139].

In comparison with previous similar studies, our findings show that there has not been a substantial improvement in the food and nutritional problems in the last years, notwithstanding the constitutional reforms and programmatic interventions on these aspects[15]. Given the magnitude of the circumstances, the government and society should consider these problems more seriously and confront them urgently. Our findings are a reflection of the economic inequalities that have existed and persist in Mexico and highlight the need for attending current food insecurity and obesity challenges from the root. Therefore, the health, educational, and economic sectors of the country should respond collectively with even stronger efforts to overcome the current health crisis.

As it has been previously said, the approach to food insecurity and obesity should contemplate a structural perspective[11] with improvements in education, employment and income, and health access. Meanwhile, social assistance and food programs should maintain and increase their progress in coverage and inclusion[47]. The consistency and permanence of government programs directed to alleviate hunger and to improve people's nutritional status should be guaranteed, prioritizing the most vulnerable population sectors (females, indigenous groups, rural areas, the southern region of the country, people of low educational and socioeconomic level). And at the same time, these interventions should look for sustainable and long-term impacts on the availability of healthier foods, assuring permanent economic access to these, and increasing awareness in the population about the adoption of healthy diets and lifestyles, through nutritional education.

CONCLUSIONS

This study confirmed the relationship between two of the major public health issues in the world and the country[2, 37, 46, 149], food insecurity and obesity, among Mexican female adults. In addition, the analyses showed a correlation between food insecurity and waist circumference, which is relevant given the current body of evidence concerning the role of central adiposity in metabolic disorders[55, 57, 63], and the scarce inclusion of this variable in studies of this scope.

Other findings refer to associations between insufficient sleeping and low physical activity with BMI, which might be related to the current economic and epidemiological transition that is characterized by more sedentary and stressing lifestyles[149]. Additionally, the association observed between low education level (primary or secondary) and the outcome variables highlights the impact of this variable over health[143]. As stated in the discussion, the study of these variables should be considered in future research and in the design of public policies.

Similar to previous studies[11], it was observed that some sectors of the population are more vulnerable to food insecurity and concomitant obesity, according to our results, this relationship was significant only among females. This suggests that future interventions should have a gender-oriented approach, and contemplate that females in Mexico have a crucial role as responsible of the family feeding[67]. Additionally, indigenous groups, people living in rural areas, the Southern region of the country, and those with low educational and socioeconomic level are the most affected by food insecurity, reflecting the enduring inequalities among the population.

Food insecurity and obesity impair people's physical and mental health and life quality. Both conditions are known to have existed in Mexico for decades[4, 15, 49]. However, interventions aimed at addressing these issues have not been effective in overcoming the problem[5, 8, 17]. Furthermore, there is no evidence that public programs are considering their coexistence or the possible influence of food insecurity on health problems beyond undernutrition[70]. Besides, from the perspective of the clinical environment, food insecurity is not a relevant factor for the management of chronic diseases[75, 90].

Both situations, food insecurity, and obesity in Mexico share an essential economic determinant[42, 137]. Therefore, despite the importance of assistance programs' interventions, which undoubtedly have a positive impact on people's lives and are necessary for the most impoverished sectors of the country[47], profound changes must be made in the economic, educational, and health systems[11, 18]. The availability and access to healthy foods must be guaranteed to cover the basic needs of the

population and contribute to the development of a healthy and active life. Otherwise, the individual and collective health and economy of Mexico could be even further deteriorated, hindering the future wellbeing and development of the country.

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Appendix 2.1 Latin-American and Caribbean Food Security Scale harmonized for Mexico.

1. In the last three months, due to lack of money or other resources, did you ever worry that your household ran out of food?

2. In the last three months, due to lack of money or other resources, did your household run out of food?

3. In the last three months, due to lack of money or other resources, did your household stop having a healthy, nutritious, or balanced diet in your household?

4. In the last three months, due to lack of money or other resources, did you or any adult in your household have a diet based on a small variety of foods?

5. In the last three months, due to lack of money or other resources, did you or any adult in your household skip breakfast, lunch, or dinner?

6. In the last three months, due to lack of money or other resources, did you or any adult in your household eat less than you should?

7. In the last three months, due to lack of money or other resources, were you or any adult in your household hungry but did not eat?

8. In the last three months, due to lack of money or other resources, did you or any adult in your household have only one meal or stop eating for a whole day?

8.1 Are there any boys or girls under the age of 18 living in your household?

9. In the last three months, due to lack of money or other resources, did anyone under 18 years old in your household stop having a healthy, nutritious, or balanced diet?

10. In the last three months, due to lack of money or other resources, was there a time anyone under 18 years old in your home has a diet based on a small variety of foods?

11. In the last three months, due to lack of money or other resources, did anyone under 18 years old in your home stop having breakfast, lunch, or dinner?

12. In the last three months, due to lack of money or other resources, did anyone under 18 years of age in your household eat less than they should?

13. In the last three months, due to lack of money or other resources, did you have to reduce the amount of food served at meals to anyone under 18 years old in your household?

14. In the last three months, due to lack of money or other resources, did anyone under 18 years of age in your household feel hungry but did not eat?

15. In the last three months, due to lack of money or other resources, did anyone under 18 years of age in your household have only one meal or stop eating for a whole day?

Adapted from: Food Security Questionnaire (ENSANUT MC 2016).