MATERNAL RISK FACTORS AND ADOLESCENT OVERWEIGHT AND OBESITY IN CHIAPAS, MÉXICO, A CASE-CONTROL ANALYSIS

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Abstract

In the 21st century, Mexico has seen an increasing prevalence of overweight and obesity (ow/ob), posing a significant burden to social resource usage and public health. Rural areas in Mexico are experiencing a nutritional transition with increased consumption of commercialized diets with high caloric and low nutritional value. Maternal anthropometric and sociodemographic characteristics correlate with children's health, identifying a need to analyze the influence of these factors on children's nutritional status in areas with increasing ow/ob prevalence. This study used El Colegio de la Frontera Sur (ECOSUR) data collected in 2003 and 2017 on mother and child pairs in Chiapas, Mexico. The analysis was formatted as a case-control study with the outcome of interest being adolescent ow/ob and exposures of interest being the mother's education, language, waist circumference, and ow/ob status. Cases were likelier to have mothers above median schooling levels and ow/ob mothers. No statistically significant conclusions about the probability of indigenous language, adolescent mothers, or high maternal waist circumference for adolescents with ow/ob were possible.

Resumen

Durante el siglo XXI, México ha visto un aumento en prevalencia de sobrepeso y obesidad (ow/ob), contribuyendo a una carga significativa en el uso de recursos sociales y la salud pública. Las áreas rurales están experimentando una transición nutricional con un mayor consumo de una alimentación comercializada con un alto nivel calórico y un nivel bajo nutricional. La salud materna y los factores sociodemográficos se han demostrado que se correlacionan con la salud pediátrica y esto identifica una necesidad analizar la influencia de factores maternos sociodemográficos y antropométricos en el estatus nutricional de los niños. Esta investigación usó los datos de El Colegio de la Frontera Sur (ECOSUR) de 2003 y 2017 sobre la salud de parejas de madres y niños en Chiapas, México. El análisis se formateó como un estudio de casos y controles con el resultado de interés como si el adolescente tiene sobrepeso u obesidad. Las exposiciones del interés fueron la escolaridad, el idioma, la circunferencia de la cintura y el estatus IMC de la madre. Los casos tuvieron más probabilidad tener madres con años de escolaridad más de la mediana y madres con sobrepeso/obesidad. No se encontró una asociación estadísticamente significativa para las exposiciones del idioma, madres que fueron adolescentes ni la circunferencia alta de cintura.

Background

Malnutrition includes undernutrition, inadequate vitamins/minerals, overweight, obesity, and diet-related non-communicable disease. Undernutrition is measured on three facets stunting (low weight-for-age), wasting (low weight-for-height), and underweight (low weight-for-age). Overweight and obesity (ow/ob) is measured through body mass index calculated through weight-for-height. In 2020, 149 million children under five were stunted, and 45 million were wasted, with 45% of deaths among children under five linked to undernutrition. In contrast, 38.9 million children under 5, with increased prevalence in low- and middle-income countries, and 1.9 billion adults measuring as ow/ob. Those in poverty are particularly vulnerable to the risks of malnutrition as associated health care costs, reduced productivity, and economic impacts leave these populations particularly susceptible to ill health and the cycle of poverty (*Malnutrition*, 2021).

For adults, body mass index (BMI), calculated through weight in kilograms divided by meters squared, estimates body fat and related health status. Underweight is considered <18.5, normal is between 18.5-24.9, overweight is between 25.0-29.9, and obese >30. Waist circumference is also used to screen for health risks related to overweight/obesity. Fat around the waist measuring greater than 35 inches for females and 40 inches for males is associated with coronary artery disease, type II diabetes, and high blood pressure (*Assessing Your Weight*, 2022). For children aged 5 to 19 years, BMI for age is calculated using z-scores. Interpretation of cutoffs are as follows: overweight (>+1SD, equivalent to BMI 25 at 19 years), obese (>+2SD, equal to BMI 30 at 19 years), thinness (<-2SD), and severe thinness (<-3SD) (*BMI-for-Age (5-19 Years)*, 2022).

In the 21st century, Mexico has seen a rise in the prevalence of obesity, with only 32% of men and 25% of women being of normal weight in 2010. Concerningly, an association exists between obesity rates and dia. The linkage between weight and burden on the health system and economy is seen through evidence that NCDs as the most prevalent cause of death and disability-adjusted life years (DALYs) in Mexico and contributed to approximately $1931 million (USD) in economic loss in 2008 through decreased productivity (Rtveladze et al., 2014).

Rural areas of Mexico are experiencing the double burden of malnutrition as infant undernutrition continues while obesity in adults creates a new challenge. The double burden of malnutrition refers to rising rates of ow/ob in parallel with the burden of undernutrition. Ruiz García and colleagues (2018) attribute the current nutritional patterns to Popkin's nutritional transition theory, suggesting commercial success in rural areas leads to degenerative diseases through increased fat, cholesterol, sugar, and refined carbohydrate intake. The new commercialized diets are high in calories and nutritionally insufficient compared to traditional diets. Mothers' diets during pregnancy lack micronutrients and diversity, contributing to the risk of degenerative disease and obesity later in life (Popkin, 1994; Ruiz García et al., 2018).

As outlined above, child bearers'[°] nutrition during pregnancy is significant in children's health and influences the intergenerational burden of malnutrition. García Parra (2015) explains, "when women are the result of a vicious nutritional cycle and do not reach a height greater than 150cm, one can speak of the intergenerational cycle of lack of growth,[*]" emphasizing how malnutrition in child bearers influence the growth of children and leads to the continued burden

[°] The author attempts to broaden the language used regarding those with the capacity to birth in aiming to support people who identify in ways different to traditional vocabulary used about health of childbearing people. Throughout the text, sex and gendered vocabulary are used in concordance with the manner used in source material, and when Spanish text was translated *mujer* was translated to woman.

[*] "*cuando las mujeres son el resultado del ciclo vicioso de la nutrición y no alcanzaron una estructura superior a 150 cm, se puede hablar del ciclo intergeneracional de la falta de crecimiento*" (García Parra, 2015)

of hindered growth. The burden of malnutrition has an economic disadvantage as health and development connect to human capital. As a result of the failure to develop healthily, human capital is stunted, and the cycle of poverty is passed between generations (García Parra, 2015).

Pregnancy, while a child bearer is ow/ob, is associated with adverse outcomes, including congenital disabilities and macrosomia, in addition to health and reproductive risks for the birthing person like infertility, pregnancy-induced hypertension, prolonged labor, gestational diabetes, and postpartum anemia (Siega-Riz & Laraia, 2006). High rates of ow/ob in the Mexican population, particularly among people with the capacity for childbirth of childbearing age, also hold dangerous implications for pregnancy, delivery, and prenatal wellbeing. Additionally, Mexican child bears who were ow/ob were more likely to have a cesarean delivery than those with normal BMI. These results are concerning given the high prevalence of ow/ob in the Mexican population and the high proportion of deliveries using the cesarean method (45%), above the recommended 10-15% considered appropriate by the World Health Organization (Brenes-Monge et al., 2019).

Regarding the impacts of maternal BMI on child ow/ob, a meta-analysis of 79 international studies found maternal pre-pregnancy body mass index increased the odds of child obesity by 264% (Heslehurst et al., 2019).In addition, a study with a similar goal of connecting maternal pre-pregnancy BMI to children's nutritional health identified maternal pre-pregnancy ow/ob as a significant risk factor for adolescent ow/ob at age 12-13 in the United States (Salsberry & Reagan, 2007). These studies show the importance of familial ow/ob on future generations' nutritional status and support this paper's aims to contribute to the literature on maternal risk factors for adolescent ow/ob.

Other factors relating to the birthing person, including age, can impact a child's nutritional health. Between 1970 and 2019, all but three OECD countries, one of which being Mexico, observed a 2–5-year increase in the age of the child bearer at the time of childbirth. Additionally, Mexico is one of three countries with an average age at childbirth under 28 years. Since 2000 international trends have shown a postponement of individuals having their first child and falling adolescent fertility global context on the delay of the first birth, but in Mexico, rates remain high compared to other OECD countries with over 70 births per 1000 women aged 15-19, second only to Colombia (SF2.3: Age of Mothers at Childbirth and Age-Specific Fertility, 2021).

In 2017, Chiapas had Mexico's third highest number of adolescent pregnancies. The heightened prevalence of teenage pregnancy is a product of sociocultural and demographic factors, including the social construction of gender and the value placed on motherhood. It is related to the contexts of poverty and vulnerability (Núñez-Medina & María Jiménez-Acevedo, 2018). Adolescent fertility, particularly high levels observed in Chiapas, is vital to understanding the nutritional status of the population as "early pregnancies in women who are still growing, generate low-weight births, which leads to a cyclical process of stunting and creating an intergenerational cycle of poverty and low returns on human capital"[*] (Meneses Álvarez et al., 2018).

In the spatial analysis done by Núñez-Medina and María Jiménez-Acevedou (2018), areas with the highest levels of marginalization, female illiteracy, and proportion of the indigenous population in addition to low levels of schooling coincided with the highest rates of adolescent fertility in Chiapas. In indigenous populations, the adolescent fertility rate was 96.7 (per 1000

[*] "embarazos a temprana edad en mujeres aún se encuentran en etapa de crecimiento, generando a su vez, nacimientos con bajo peso, lo que conlleva a un proceso cíclico del retraso en el crecimiento y crear un ciclo intergeneracional de pobreza y bajo rendimiento del capital humano" (Meneses Álvarez et al., 2019)

women) in 2014, compared to 68 (per 1000 women) for non-indigenous populations, and in 2015 total fertility rate (TFR) was 3.1 children per woman, compared to 2.3[1] overall in Mexico at the time (Núñez-Medina & María Jiménez-Acevedo, 2018). When applied to Chiapas, socioeconomic factors are integral in the distribution of adolescent fertility, therefore requiring more research into the intergenerational impacts on nutrition and poverty in communities with high levels of marginalization.

Malnutrition in concordance with social marginalization is prevalent in the south-southeastern states, Oaxaca, Guerrero, Chiapas, Tabasco, and Campeche, of which the latter three form the southern border of Mexico with Guatemala. The region houses the highest proportion of indigenous residents and the highest rates of malnutrition (27.5%), measuring double the country's overall prevalence. Additionally, Chiapas ranks first in low weight (8.4%) and short stature (31.4%) for children under five and is observed mainly in rural areas, showing the nutrition challenges facing the population (Meneses Álvarez et al., 2018). The high social marginalization, childhood malnutrition, and increasing prevalence of adult overweight and obesity outline the need for further investigation into the intergenerational cycle of poverty and the relationship between adult and child nutrition.

As rates of overweight and obesity continue to rise in low- and middle-income countries and pose challenges to Mexican public health, the intergenerational ow/ob in marginalized areas of Mexico requires further investigation. Additionally, the relationship between socioeconomic factors and social marginalization is integral to understanding the nutritional patterns in southeastern Mexico. Thus, this study aims to assess the association between maternal socioeconomic, demographic, and physical characteristics and adolescent ow/ob in Chiapas.

[1] In 2020, the TFR in Mexico was 2.1 (Fertility rate, total (births per woman) - Mexico , 2020).

Research Question

What is the influence of maternal risk factors on adolescents' overweight/obese status?

Objectives

The overarching aim of this study is to analyze the relationship between maternal risk factors and adolescent overweight/obesity in Chiapas through a case-control design. To best explore the goals of this study, the following objectives were articulated:

1. To analyze how maternal physical characteristics (waist circumference, overweight/obesity) may impact the probability that an adolescent is overweight/obese
2. To analyze how maternal socioeconomic/demographic characteristics (age, language, schooling) may impact the probability that an adolescent is overweight/obese
3. To contextualize the relationship between maternal health and adolescent health concerning intergenerational nutrition and poverty

Methods

Study Area

Chiapas

Chiapas is located on the southern front of Mexico with Guatemala and borders the Mexican states of Oaxaca (west), Veracruz (northwest), and Tabasco (north), as well as the Pacific Ocean. The state contains 123 municipalities and has a total population of 5,543,828 (Male: 2,705, 947; Female: 2,837,881). The median age is 24 and 25 for males and females, respectively, demonstrating an increase from 19 for both males and females in 2000 (INEGI, 2020). *El Consejo Nacional de Población* categorizes the state as having very high (*Muy alto*) levels of marginalization, second only to Guerrero (*Población Total, Indicadores Socioeconómicos, Índice y Grado de Marginación Por Entidad Federativa, 2020*, 2021). Of the population aged three years and older, 28.7% speak an indigenous language. Of monolingual residents five years and older, 25.3% (1,387,295) speak an indigenous language, predominantly Tzeltal (10.7%), Tzotzil (11.2%), Chol (2.5%), Tojolabal (0.6%) and Zoque (0.2%) (INEGI, 2020).

In both 2006 and 2012, Chiapas had a prevalence of 28.9% of ow/ob in adolescents (12-19 years), which is lower than the national average in 2012 of 35%. Adult female residents and adolescents had higher rates of ow/ob, 32.1% and 33%, respectively. In 2012, 70.9% of adult female Chiapas residents presented with 0/0, showing an increase of 3.3% since 2006 attributed to a rise in overweight prevalence (Encuesta Nacional de Salud y Nutrición. Resultados Por Entidad Federativa. Chiapas, 2013)

Región V Altos Tsotsil-Tseltal

The original study recruited participants from two regions of Chiapas as geographically assigned by the *Programa Regional de Desarrollo* led by the *Gobierno de Chiapas Secretaría de Hacienda*. The *Región V Altos Tzotzil-Tzeltal* houses San Felipe and Women's Hospital used for

recruitment of newborn participants in 2003. Most of the region (75.08%) consists of high mountain ranges with hanging slopes (*Sierra alta de laderas tendidas*) and consists of predominantly temperate subhumid climates with rain in the summer (*Templado subhúmedo con lluvias de verano*, 35.41%) and humid semi-warm climates with abundant summer rain (*Semicálido húmedo con lluvias abundantes de verano*, 31.57%). Land use consists mainly of agriculture cultivation (35.25%) and forest (49.14%) (*Programa Regional de Desarollo Región V Altos Tsotsil-Tseltal*, 2012).

The region's total population is 601,190 (male: 290,416, female: 310,774), and in 2010 it was the third most populous region in Chiapas. The population residing within indigenous households is 479,753, and 408,958 residents above the age of 3 speak an indigenous language. Of the 17 municipalities, San Cristóbal de Las Casas and Teopisca are the sole areas that do not rank with very high (*Muy alto*) levels of marginalization, with 88% of the population affected by poverty overall (*Programa Regional de Desarollo Región V Altos Tsotsil-Tseltal*, 2012).

Región XII Selva Lacandona

The third hospital, Ocosingo hospital, is located within the Ocosingo municipality of *Región XII Selva Lncandona*, made up of Ocosingo and Altamirano. Most of the region consists of low hills with plains (*Lomerío con llanuras*, 52.76%) and folded mountain ranges with gullies (*Sierra alta plegada con cañadas*, 32.88%) in warm humid climate with abundant summer rain (*Semicálido húmedo con lluvias abundantes de verano*, 63.04%) and semi warm humid climate with abundant summer rain. The principal land uses are pasture cultivation (12.36%) and forests (21.17%) (Programa Regional de Desarollo Región XII Selva Lacandona, 2012).

The region's total population is 228,742 (male: 114,132, female: 14,610), with 182,942 residents living in indigenous households and 150,055 residents over the age of 3 speaking an

indigenous language. Both municipalities in the region present very high (*Muy alto*) levels of marginalization, with 91% of the population affected by poverty (Programa Regional de Desarollo Región XII Selva Lacandona, 2012).

Study Population

This study identified 284 adolescents born in 2003 at three hospitals within the San Cristóbal de Las Casas and Ocosingo municipalities. The two hospitals in San Cristóbal included San Ecatepec and Women's Hospital. In Ocosingo the hospital used was Hospital of the Mexican Institute of Social Security- *Oportunidades.* Participants of the sample hailed from the *Tzotzil-Tzeltal* and *Selva* Regions of Chiapas. In *Tzotzil-Tzeltal* region, areas of residence included: Pantelhó, Chenalhó, Chamula, Zincantán, Larráinzar, Tenejapa, San Juan Canuc, Teopisca, Amatenango, Comitán, and San Cristóbal de Las Casas. In *Selva* region, areas included Sitalá, Chilón, and 78 localities of Ocosingo. (Flores-Guillén et al., 2019).

Data sources of the 2003 cohort of newborns

The data used in this study is original data collected by El Colegio de la Frontera Sur (ECOSUR), located in San Cristóbal de las Casas, Chiapas, Mexico, for the study titled "Randomised equivalency trial comparing 2.5% povidone-iodine eye drops and ophthalmic chloramphenicol for preventing neonatal conjunctivitis in a trachoma endemic area in southern Mexico" (Ramirez-Ortiz et al., 2007). The study, led by Dr. Héctor Ochoa Díaz-López, collected information on a cohort of neonates from March to October 2003. Newborns and their mothers were recruited at three hospitals in the Tzotzil-Tzeltal and Selva regions of Chiapas (Ramirez-Ortiz et al., 2007).

The original study collected anthropometric measures (weight, length, and head circumference) of 2184 newborns and sociodemographic data from the mothers. The study was designed following the Declaration of Helsinki, and ethics approval for the study was obtained

through the Hospital Infantil de Mexico Committee on Human Research and the ethics committees of the corresponding hospitals (Ramirez-Ortiz et al., 2007, Flores-Guillén et al., 2019).

Data sources 2017 cohort of adolescents

In 2017, 303 adolescents from the 2003 cohort were identified using a two-stage sampling design for a subsequent investigation on the effects of low birth weight and intrauterine growth restriction titled "Intrauterine growth restriction and overweight, obesity, and stunting in adolescents of indigenous communities of Chiapas, Mexico." Localities were grouped into clusters according to urban/rural criteria and population size. Participants were then selected based on a systematic sampling method with a randomized start. From these methods, thirteen clusters were selected for participants concerning the proportion of urban/rural homes in the 2003 cohort (Flores-Guillén et al., 2019).

The program Survey to Go® 2015, along with written information, voice clips, and photos of anthropometric and clinical measurements, was used to record data. Using mobile devices, anthropometric and sociodemographic data were obtained through a structured and pre-codified questionnaire. Informed consent was signed before the interview (Flores-Guillén et al., 2019).

Anthropometric measurements utilized a standardized protocol, and nutritionists took measurements under the supervision of a fieldwork coordinator and the principal investigator. Weight and the fat mass percentage of participants were measured in kilograms using a Tanita UM081, Tanita Corporation (precision +/- 100 g, Tokyo, Japan) scale. Height was measured in centimeters using SECO E123 (precision +/- 1 mm, Berlin, Germany) stadiometers, and waist circumference was measured through SECA anthropometric tapes (accuracy +/- 1mmm). Body mass index was calculated using weight (kg) divided by height squared (m^2). BMI for

adolescents was then calculated into z-scores using World Health Organization (WHO) references using WHO Anthro plus V 1.0.4. Categorizations of z-scores were calculated as follows: overweight/obese (>1 standard deviation), normal (-1.9 to 1 SD), and thinness (≤ -2 SD). Low birth weight was defined as ≤ 2500g, and intrauterine growth restriction (IUGR) used a low ponderal index with a cutoff of 2.32 [weight (g) x 100]/[length (cm)]^3 (Rohrer, 1921; Flores-Guillén et al., 2019).

Informed consent was obtained through the signatures of the adolescents and their mothers before the interviews. The original study was conducted following the Declaration of Helsinki and approved by the Research Ethics Committee of El Colegio de la Frontera Sur (CEI-O-076/16) (Flores-Guillén et al., 2019).

Table 1. Anthropometric measurement results of study population based upon WHO references. (n=284)

	Adolescents
***Not* overweight/obese**	71% (201)
Overweight/obese	29% (83)

Study Design

This study aimed to evaluate the influence of maternal risk factors on adolescent nutritional status. The investigation was designed as an unmatched case-control study (n=284) of adolescents born in 2003 at three public hospitals in San Cristóbal de Las Casas and Ocosingo. Participants were selected based on participation in the original birth cohort sample (n=2,184) and inclusion in the follow-up study during adolescence (Ramirez-Ortiz et al., 2007; Flores-Guillén et al., 2019).

Participants were excluded from the analysis when maternal information was not present for maternal BMI recorded in 2017 (n=17). Additionally, two additional participants were excluded

due to BMI recorded outside the possible range of human capability, attributed to an error in data records (n=2, BMI=0, 600.2). One participant lacked data on intrauterine growth, and another lacked information on the mother's schooling in 2017. For both, the median for the corresponding variable was substituted for the missing data. One participant lacked data for the mother's language; therefore, a new category classified as missing was created. Analysis followed the missing at random (MAR) assumption that the true value of missing data information for confounding variables in the analysis does not influence its observability (Vach & Blettner, 2005).

Using data collected in 2017 on the nutritional health of the adolescents born in 2003, participants in the study (n=284) were defined as cases (n=83) or controls (n=201) based on BMI z-score. Cases were classified as adolescents exhibiting overweight or obesity, defined through a BMI z-score equal to or above +1 standard deviation from the median for sex and age (*BMI-for-Age (5-19 Years)*, 2022). Controls were classified as those not exhibiting overweight or obesity, defined through BMI z-scores lower than +1 standard deviation from the mean (*BMI-for-Age (5-19 Years)*, 2022).

Data analysis

Tests for statistical interaction were performed for each identified variable to test whether the association of participant characteristics differed between cases and controls. For continuous variables, normality was tested through Shapiro-Wilk analysis, followed by a histogram. If data was shown to be distributed normally ($p>=0.05$), a two-way t-test assuming equal variance was used to assess if there were statistical differences between cases and controls. If data lacked a normal distribution ($p<0.05$), the Mann-Whitney U test was used to test for differences across

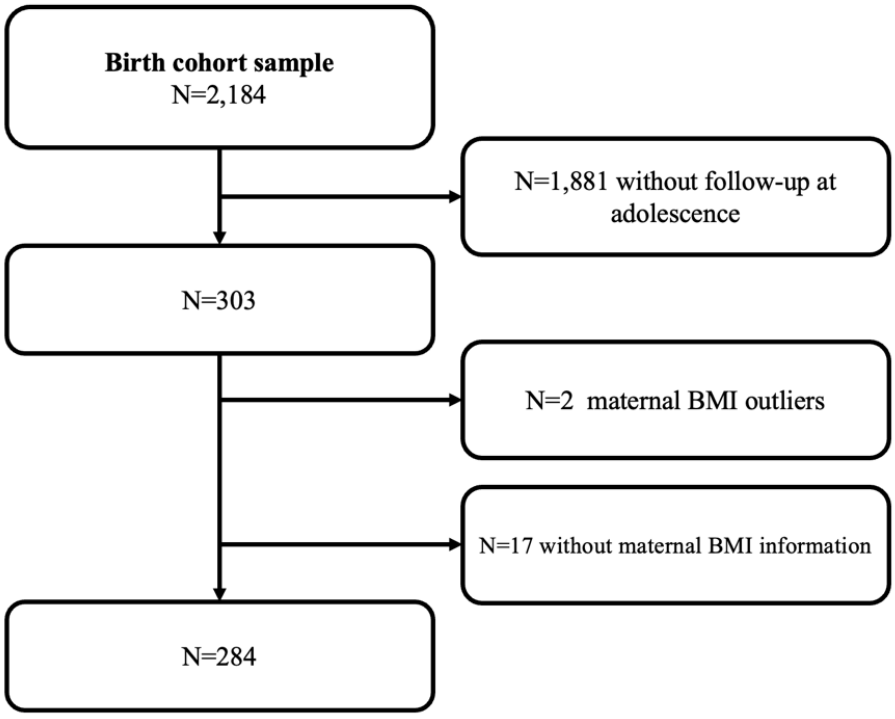
cases and controls. Categorical variables utilized Chi-square analysis or Fisher's exact test (when five or fewer observations) to measure for differences across cases and controls.

Crude odds ratios (OR) were calculated as an initial evaluation to measure the relationship between maternal factors used as exposures and adolescent ow/ob. The author identified potential covariates with assistance from ECOSUR staff, and models were then adjusted for covariates through likelihood-ratio analysis using variables shown to differ statistically across cases and controls. Correlation analysis using chi-square analysis and Spearman correlation were used to identify multicollinearity relationships within the model. In cases where correlation between variables existed, the most significant variable was used in the adjusted multivariate logistic regression model. Sensitivity analysis was then used to account for the impact of confounding variables. The following variables were tested for statistical significance and fit within the model before adjusting for significance and multicollinearity: intrauterine growth, adolescent birth weight, mother's schooling 2003, mother's schooling 2017, mother's BMI, mother's weight, mother's height, mother's waist circumference, adolescent sex, and stratum (urban/rural). Final adjusted odds ratios were calculated using the adapted multivariate logistic regression model for each exposure variable.

Statistical significance was defined as a p-value below 0.05. All statistical analysis was done using STATA® Stata/BE 17.0 (StataCorp LP, College Station, Texas, USA).

Results

Figure 1. Flow chart showing participant selection. (n=284)



Note. Adapted from (Castro-Quezada et al., 2019).

General characteristics of the study population

For this study, 284 adolescent and mother pairs were identified after excluding participants without follow-up in adolescence (n=1,881), mothers with BMI outside the possible range (n=2), and mothers without information on BMI (n=17). Following the exclusion criteria, intrauterine growth, mother's years of schooling in 2017, and mother's language all missed one respective data point from three separate participants. For continuous variables, the missing value was replaced with the median for data analysis. An additional category labeled "missing" was created for the absent mother's language data. Of the adolescent participants, 83 were identified as cases through BMI z-score defining cases as overweight or obese (≥ +1 SD), and 201 were identified as controls with BMI z-score below the overweight cutoff (< +1 SD).

Table 2. Descriptive statistics of case-control population. (n=284)

	Cases	Controls	Total	p-Value*
	n=83	n=201	n=284	
Age•	14.1, 0.2, [13.6-14.7]	14.1, 0.2, [13.7-14.8]	14.1, 0.2, [13.6-14.7]	0.117
Sex (%)				0.028
Male	36 (43.4)	116 (57.7)	152 (53.5)	
Female	47 (56.6)	85 (42.3)	132 (46.5)	
Region of residence (%)				0.274
Altos	62 (74.7)	137 (68.2)	199 (70.1)	
Selva	21 (25.3)	64 (31.8)	85 (29.9)	
Stratum (%)				0.020
Urban	70 (84.3)	143 (71.1)	213 (75.0)	
Rural	13 (15.7)	58 (28.9)	71 (25.0)	
IUGR (%)†				0.006
Restriction	14 (17.1)	67 (33.3)	81 (28.6)	
Normal	68 (82.9)	134 (66.7)	202 (71.4)	
LBW (%)				0.098
Low	5 (6.02)	26 (12.94)	31 (10.9)	
Normal	78 (94.0)	175 (87.1)	253 (89)	
Household items - Yes (%)				
Electric lights	83 (100)	200 (99.5)	283 (99.7)	0.520
Gas stove	83 (100)	135 (67.2)	195 (66.7)	0.061
Cell phone (head of household)	83 (100)	152 (75.6)	219 (77.1)	0.352
Piped water	81 (97.6)	190 (94.5)	271 (95.4)	0.261
Refrigerator	56 (67.5)	122 (60.70)	178 (62.7)	0.283
Distribution of maternal characteristics				
Adolescent mother				0.490
19 and under	20 (24.1)	41 (20.4)	61 (21.5)	
>19	63 (75.9)	160 (79.6)	223 (78.5)	
Mother's language (%)†				0.794
Indigenous	37 (44.6)	92 (45.8)	129 (45.4)	
Spanish	46 (55.4)	108 (53.7)	154 (54.2)	
Years of schooling 2003•	6, 4.2, [0-16]	6, 3.9, [0-16]	6, 4.0, [0-16]	0.028
Median schooling 2003 (%)				0.027
Median schooling & below	42 (49.4)	130 (64.7)	172 (60.6)	
Above median schooling	41 (50.6)	71 (35.3)	112 (39.4)	
Years of schooling 2017†•	9, 4.8, [0-17]	6, 4.4, [0-17]	6, 4.5, [0-17]	0.038
Median schooling 2017 (%) †				0.024
Median schooling & below	40 (48.2)	126 (62.7)	166 (58.5)	
Above median schooling	43 (51.8)	75 (37.3)	118 (41.6)	
Maternal BMI	30.7, 4.0, [21.5-39.5]	29.3, 4.5, [17.8-44.7]	29.7, 4.4, [17.8-44.7]	0.015
Maternal ow/ob (%)				0.024
Ow/ob	78 (94.0)	169 (84.1)	247 (87.0)	
Maternal waist circumference (%)				0.026
Above 88.9 cm	63 (75.9)	125 (62.2)	188 (66.2)	
Below 88.9 cm	20 (24.1)	76 (37.8)	96 (33.8)	

Mean (normal distributions) *or* median (non-normal distribution), SD, [Range]

*Differences across categories were analyzed using a two-tail t-test for normally distributed continuous variables, Mann-Whitney U test for continuous variables not normally distributed, and Chi-square analysis or Fisher's exact test (when five or fewer observations)

•Non-normal distribution

†Missing data point, median used for continuous variables

As displayed in Table 2, the average age of adolescent participants was 14.1 years showing no statistical difference across cases and controls. The sample was 53.5% male and 46.5% female, with a statistically higher proportion of males in the control group than in the case group ($p=0.028$). Most mother-adolescent pairings lived in the Altos region (70.1%) and urban areas (75.0%). Cases were more likely to reside within urban areas than controls ($p=0.02$). The language spoken within the households was mostly Spanish, with 54.2% indicating Spanish as the mother's language. The overall percentage of intrauterine growth restriction was 28.6%, with controls being more likely to have recorded IUGR ($p=0.006$). There was no statistical difference between cases and controls for low birth weight ($p>0.05$), with an overall prevalence of 10.9%. Most households contained all five items identified as representations of socioeconomic status, and none showed a difference in prevalence between cases and controls ($p>0.05$). Most mothers in the sample had a BMI that was ow/ob (87.0%) and an average BMI of 29.7.

The minority (21.5%) had given birth in 2003 as an adolescent. Mothers had a median of 6 years of schooling in 2003 and 2017. To examine if there was a change in mothers' schooling between 2003 and 2017, a Shapiro Wilk Test for Normality determined both years to lack a normal distribution ($p<0.05$), and visual representations through a histogram showed a curve that was not normal. Therefore, a Wilcoxon Signed Rank Test was used to indicate no statistical difference between years of schooling achieved in each respective year ($p=0.1978$). When the maternal level of education was grouped into two categories: 1) median schooling and below (exposed), 2) above median schooling (not exposed), chi-square analysis showed a statistical difference between data for 2003 and 2017 ($p<0.001$), therefore data from both years was used in the case-control study design.

Socioeconomic Factors

Schooling 2003 & 2017

Table 3. Crude OR table for mother median schooling in 2003 and below and adolescent ow/ob in study cohort (n=284).

	Median schooling & below	Above median schooling	Total	Proportion exposed
Cases	42	41	83	0.5060
Controls	130	71	201	0.6468
Total	172	112	284	0.6056

Crude OR	0.56
p-Value	0.027
95% CI	0.32-0.97

Table 4. Crude OR table for mother median schooling in 2017 and below and adolescent ow/ob in study cohort (n=284).

	Median schooling & below	Above median schooling	Total	Proportion exposed
Cases	40	43	83	0.5060
Controls	126	75	201	0.6468
Total	166	118	284	0.6056

Crude OR	0.55
p-Value	0.024
95% CI	0.32-0.96

The crude odds ratio presented in Table 3 shows mothers with years of education being the median or above were more likely to have children who were overweight or obese. The crude odds ratio for 2003, reported in (Table 3) was 0.56 (95% CI 0.32-0.97, p=0.027). The crude odds ratio for 2017 data (Table 4)on schooling was 0.55 (95% CI 032-0.960, p=0.024).

When adjusting for confounding variables using multivariate logistic regression, the odds (Table 9) of having a mother with median schooling or below in 2003 was 0.49 (95% CI 0.28-0.85, p=0.011) times lower among adolescents displaying ow/ob. Similarly, in 2017, the odds of having a mother with median schooling or below are 0.51 (95% CI 0.29-0.88, p=0.015) lower in

adolescents displaying ow/ob. Adolescent sex, intrauterine growth, and mother's BMI were used as confounding factors in the logistic regression models for both years.

Language

Table 5. Crude OR table for mother's language and adolescent ow/ob in study cohort (n=284).

	Indigenous language	Spanish	Total	Proportion exposed
Cases	37	46	83	0.5060
Controls	93	108	201	0.6468
Total	130	154	284	0.6056

Crude OR	0.93
p-Value	0.795
95% CI	0.54-1.61

Most of the mothers in the sample indicated their language as Spanish (54.2%), with the remainder speaking an indigenous language and data missing for one subject. Chi-square analysis showed no difference between cases and controls (p=0.794). Maternal language showed a crude odds ratio (Table 5) that was not statistically significant at 0.94 (p=0.827), signifying no identifiable relationship between maternal indigenous language and adolescent ow/ob. When adjusting for confounding variables using multivariate logistic regression, the odds of the mother's language (Table 9) being indigenous among cases is 1.59 (95% CI 0.85-3.00, p=0.148) times higher than controls, but the results are not statistically significant. Adolescent sex, intrauterine growth, mother's BMI, mother's schooling in 2003, and stratum (urban/rural) were used as confounding variables in the logistic regression model.

Physical characteristics

Age at childbirth

Table 6. Crude OR table for maternal adolescence at time of childbirth and adolescent ow/ob in study cohort (n=284).

	Adolescent mother	Adult mother	Total	Proportion exposed
Cases	20	63	83	0.2410
Controls	41	160	201	0.2040
Total	61	223	284	0.2148

Crude OR	1.24
p-Value	0.490
95% CI	0.64-2.36

The average maternal age at the time of adolescent's birth was 24.8 years, and the Mann-Whitney U Test indicated no difference in maternal age (2003) between cases and controls (Table 2, p=0.1172). Adolescent mothers made up 21.5% of the sample, and Chi-square analysis indicated no statistical difference between maternal adolescence between cases and controls (p=0.49). The crude odds ratio (Table 6) of 1.24 (95% CI 0.64-2.36, p=0.491) calculated for mother's adolescents as an exposure variable was not statistically significant. When adjusting for confounding variables using multivariate logistic regression, the odds (Table 9) of being born to an adolescent mother is 1.51 (95% CI 0.78-2.90, p=0.220) times higher among cases than controls, but the results are not statistically significant. Adolescent sex, intrauterine growth, mother's BMI, and mother's schooling in 2003 were used as confounding factors in the logistic regression.

Overweight/obesity

Table 7. Crude OR table for maternal ow/ob and adolescent ow/ob in study cohort (n=284).

	Mother ow/ob	Mother *not* ow/ob	Total	Proportion exposed
Cases	78	5	83	0.5060
Controls	169	32	201	0.6468
Total	247	37	284	0.6056

Crude OR	2.95
p-Value	0.024
95% CI	1.08-20.05

Mothers of adolescents in the sample had an average BMI score of 29.7 in 2017, and mothers of cases had a statistically significant higher score than mothers of controls Table 2, (p=0.0148). Additionally, 87% of the mothers in the study were ow/ob, and mothers of cases were more likely to be categorized as ow/ob (p=0.024). The crude odds ratio (Table 7) using maternal ow/ob as an exposure variable was 2.95 (95% CI 1.21-7.870, p=0.0240). When adjusting for confounding variables using multivariate logistic regression, the odds of maternal ow/ob was 2.70 (95% CI 0.1.001-7.31, p=0.05) times higher among cases than in controls, and the results are only the borderline of statistical significance (Table 9). Adolescent sex and intrauterine growth were used as confounding factors in the logistic regression.

Waist circumference

Table 8. Crude OR table for high maternal waist circumference and adolescent ow/ob in study cohort (n=284).

	High waist circumference	Normal waist circumference	Total	Proportion exposed
Cases	63	20	83	0.5060
Controls	125	76	201	0.6468
Total	188	96	284	0.6056

Crude OR	1.92
p-Value	0.026
95% CI	1.04-3.61

Mothers of adolescents in the sample had an average waist circumference of 93.0 cm, with mothers of cases having statistically higher measurements (p=0.045). Using the barrier of

88.9 cm as specified by the Center for Disease Control and Prevention (*Assessing Your Weight*, 2022), 66.2% of the mothers in the sample measured above the specified cutoff in 2017, with mothers of cases more likely to be above 88.9 cm (p=0.026). The crude odds ratio (Table 8) using high maternal waist circumference as an exposure factor was 1.92 (95% CI 1.07-3.41, p=0.028). When adjusting for confounding variables using multivariate logistic regression, maternal high waist circumference odds are 1.77 (95% CI 0.98-3.19, p=0.059) times higher among cases than controls. Still, the results are not statistically significant (Table 9). Adolescent sex and intrauterine growth were used as confounding factors in the logistic regression.

Table 9. Using the logistic regression model, the odds ratios of maternal risk factors compared to adolescent overweight/obesity. (n=284).

Factor variables	Crude OR	p-Value	95% CI	Adjusted OR	p-Value	95% CI
Adolescent mother	1.24	0.491	0.67-2.28	1.51	0.220	0.78-2.90
Indigenous language (mother)	0.94	0.827	0.56-1.58	1.59	0.148	0.85-3.00
Median maternal schooling 2003	0.60	0.028	0.33-0.94	0.49	0.011	0.28-0.85
Median maternal schooling 2017	0.55	0.025	0.33-0.93	0.51	0.015	0.29-0.88
Maternal ow/ob	2.95	0.030	1.10-7.87	2.70	0.050	1.001-7.31
High maternal waist circumference	1.92	0.028	1.07-3.41	1.77	0.059	0.98-3.19

Discussion

Based upon data utilized in this study, maternal schooling above median years and maternal ow/ob were identified as statistically significant exposures for adolescents ow/ob compared to controls. In the present study, no conclusion was reached about the probability of indigenous language, adolescent mothers, or high maternal waist circumference for adolescents with ow/ob. While these findings do not prove causation, they contribute to the concept of intergenerational nutrition influences and the impact of maternal factors on a child's nutrition as an adolescent. These also contribute to knowledge on the influence of maternal socioeconomic factors on children's nutrition.

The results of this study are consistent with findings by Brambila-Paz and Hernández-Ángeles (2022), in which the overweight or obesity of a parent was the most significant factor in the prediction of a transition to overweight or obesity in young adults. In research done by Brambila-Paz and Hernández-Ángeles (2022), the impact of the transition of other family members to ow/ob and the context of the family environment changing weight/height was used to analyze adolescent transition to ow/ob. Using a similar approach, contextualizing the family environment would be a practical next step in further understanding household influence and socioeconomic factors on adolescent ow/ob in the region. While the focus of this study was on the pairwise relationship between mother and adolescent, it presents an opportunity to expand research on the cohort to include other family members' ow/ob status, which may be an important factor in domestic influence on nutritional status.

This investigation focuses on nutritional status during early adolescence and provides an opportunity to understand further the transition to overweight and obesity in young adults. As mentioned previously, parental obesity during adolescence is the most influential familial factor

influencing the transition from normal weight in adolescence to obesity in young adulthood (Brambila-Paz & Hernández-Ángeles, 2022). Therefore, adolescents with a normal BMI z-score in 2017 who have mothers with ow/ob may still be at increased risk for ow/ob outcomes as they enter young adulthood.

Similarly, a systematic review of obesity prevention interventions in Mexico for children and adolescents found twelve (41.3%) of identified methods included parents or siblings as active participants. The justification for including family members was defended by behavioral theory, in which the children/adolescents were influenced by observing and imitating others' dietary behaviors. The authors defended the inclusion of family members through arguing family involvement may help understand the environment in which obesity develops and the effectiveness of obesity prevention (Aceves-Martins et al., 2022). Studies such as this case-control analysis, support arguments made by Aceves-Martins and colleagues by showing the influence of familial ow/ob (in the case of this study, maternal ow/ob) as an exposure for adolescent ow/ob.

The results of this study found that maternal schooling of the median and above was a statistically significant exposure factor related to the analysis of ENSANUT data finding that adults with secondary or technical education residing in highly marginalized areas had an increased odds of obesity compared to adults with primary educations within average marginalization regions. The authors state that "this association implies that higher levels of marginalization at the municipality level were more harmful for adults with more education than for those adults with less education" (Sparks & Sparks, 2012). These conclusions on education level and obesity using national data support this study's finding of the increased odds of exposure to high maternal education from ow/ob adolescents in Chiapas and contextualize the

findings of this study within national data trends. Additionally, Sparks & Sparks (2012) propose education as an indication of increased economic resources leading to purchases of foods higher in fat, protein, and carbohydrates and drinks high in sugar or alcohol, therefore, contributing to the risk of obesity. The use of education is an important indicator of socioeconomic status as Chiapas has the second highest statewide marginalization in Mexico, implying that the population, in general, may have less purchasing power for the highly commercialized and calorie-dense foods identified by Sparks & Sparks (*Población Total, Indicadores Socioeconómicos, Índice y Grado de Marginación Por Entidad Federativa, 2020*, 2021).

This research focused on adolescents born in 2003 and their mothers, limiting the study to a sole generation of Chiapas residents, creating a potential bias of focusing on a single generation. This analysis does not account for modernization's changing economic and social factors. Therefore, continued research examining similar relationships in different birth cohorts would be required to make further generalizations.

Both points in time in which maternal information was collected (2003 & 2017) were after childbirth. For this reason, no information is known on maternal nutritional status prior to or during pregnancy. Additionally, the data provided lacks an understanding of the development of ow/ob in the years between 2003 and 2017. In future research, more frequent data collection would allow for a greater understanding of the transition from childhood to adolescence relating ow/ob in the study area. Building upon the established relationships between exposure to maternal risk factors and adolescent ow/ob, this study presents opportunities to conduct further in-depth analysis on intergenerational nutrition within the study population. Due to constraints in time, maternal height was not used as an independent variable. Given the prevalence of stunting within the study area, maternal and adolescent height as it relates to nutrition requires further

investigation. This cohort of adolescents and their mothers presents the necessary anthropometric data for continued analysis.

Adolescents of normal weight were more likely to have mothers with median years of schooling or below. This finding contributes to understanding how maternal socioeconomic factors may relate to familial nutrition because education is a commonly used indicator influencing socioeconomic status. A possible explanation for the relationship between adolescent ow/ob and higher maternal education observed in this study is the commercialization of diets followed in rural areas of México and, therefore, the transition to increased fat, cholesterol, sugar, and refined carbohydrate intake as outlined by Popkin's nutrition transition theory (Popkin, 1994; Ruiz García et al., 2018). While families with higher socioeconomic status may be able to purchase more commercialized foods, lower socioeconomic status families, indicated by lower levels of schooling, may purchase traditional, avoiding the increased calorie intake. More research is required to understand this relationship and evaluate the influence of education on ow/ob.

This cohort also presents an opportunity to continue research on intergenerational nutrition and poverty. Currently, the data set includes two generations, with the 2003 cohort of adolescents having already reached the age at which some of the mothers in the study had them. As the 2003 cohort exits adolescence in 2023, further investigation could collect data on the next generation, contributing to the body of research on intergenerational health and the effect of health on intergenerational poverty.

No relationship between mothers having children in adolescence and adolescent ow/ob was found through the data in this study. On a global scale, México continues to have a low average at childbirth for mothers and over 70 births per 1000 women aged 15-19, with Chiapas having

the third highest number of adolescent pregnancies in México (SF2.3: Age of Mothers at Childbirth and Age-Specific Fertility, 2021). Within Chiapas, adolescent childbirth was associated with marginalization, female illiteracy, high proportions of indigenous residents, and low levels of schooling (Núñez-Medina & María Jiménez-Acevedo, 2018). While this study could not reach a conclusion on the impact of births to females of a young age, adolescent pregnancy can pose health risks to both child bearer and child. Meneses Álvarez and colleagues (2018) state that pregnancies in women who are still growing have an increased risk for low birth weight, which can contribute to stunting, showing the impact on health.

The importance of sociocultural context and the analysis of gender roles, specifically the cultural values placed upon motherhood, is critical when looking at the maternal-child relationship, including in this context of nutrition (Núñez-Medina & María Jiménez-Acevedo, 2018). When analyzing communities with high levels of marginalization, it is integral to account for the sociocultural context in which phenomena occur. For this reason, these results are specific to the region of interest and are not easily generalizable to other populations. Additionally, social constructions of gender and cultural values change over time. The original data was collected 19 years ago, and follow-up data is five years old, making this information difficult to generalize to other generations

Future research should aim to understand better the cultural, social, and economic factors that shape maternal risk factors for ow/ob and how these factors may influence intergenerational nutrition. While the societal burden of ow/ob on social resource usage and human capital development is clear, more research should be focused on how ow/ob between generations influences local and national nutrition trends as ow/ob increases in México and around the world.

Conclusion

This study gave insight into the relationship between (1) maternal ow/ob and adolescent ow/ob and (2) maternal schooling and adolescent ow/ob. This study was unable to conclude adolescents with displaying ow/ob were more likely to have a mother with median schooling or below and ow/ob. No statistically significant conclusions were reached on the likelihood of indigenous language, adolescent mothers at childbirth, or high waist circumference in adolescents with ow/ob compared to adolescents of normal BMI z-score. This study's findings have implications for future generations' health as ow/ob becomes more prevalent in Mexico, coinciding with a nutritional transition to highly commercialized diets. The study dealt with temporal limitations, given that information on maternal nutrition was only observed in 2017, and no BMI information was available before childbirth. Additionally, the study included a relatively small sample population. Therefore, more research on this cohort and their children may provide more accurate conclusions about the impact of maternal health on intergenerational nutritional status and its influence on cyclical poverty in Chiapas.

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