Linking socioeconomic inequalities and type 2 diabetes through obesity and lifestyle factors among Mexican adults: a structural equations modeling approach

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Abstract
Objective. To assess the association between type 2 diabetes (DM2) and socioeconomic inequalities, mediated by the contribution of body mass index (BMI), physical activity (PA), and diet (diet-DII). **Materials and methods**. We conducted a cross-sectional analysis using data of adults participating in the Diabetes Mellitus Survey of Mexico City. Socioeconomic and demographic characteristics as well as height and weight, dietary intake, leisure time activity and the presence of DM2 were measured. We fitted a structural equation model (SEM) with DM2 as the main outcome, and BMI, diet-DII and PA served as mediator variables between socioeconomic inequalities index (SII) and DM2. **Results.** The prevalence of DM2 was 13.6%. From the fitted SEM, each standard deviation increases in the SII was associated with increased scores of DM2 (β=0.174, P<0.001). **Conclusion.** The results in the present study show how high scores in the index of SII may influence the presence of DM2.

Keywords: type 2 diabetes; socioeconomic inequalities; survey; Mexico

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Resumen
Objetivo. Evaluar la asociación entre diabetes tipo 2 y las inequidades socioeconómicas (IS), mediada por la contribución del índice de masa corporal (IMC), actividad física (AF) y dieta (dieta-DII). **Material y métodos.** Se realizó un análisis transversal utilizando datos de la Encuesta de Diabetes Mellitus de la Ciudad de México. Se midieron las características sociodemográficas, altura, peso, ingesta dietética, actividad de tiempo libre y presencia de diabetes. Se ajustó un modelo de ecuaciones estructurales (MEE) con diabetes como resultado principal, e IMC, dieta-DII y PA sirvieron como variables mediadoras entre el IS y la diabetes. **Resultados.** La prevalencia de diabetes fue de 13.6%. A partir del MEE ajustado, cada aumento de la desviación estándar en el IS se asoció con un aumento en las puntuaciones de diabetes (β=0.174, P<0.001). **Conclusión.** Los resultados en el presente estudio muestran cómo los puntajes altos en las IS pueden influir en la presencia de diabetes.

Palabras clave: diabetes tipo 2; desigualdades socioeconómicas; encuesta; México

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Worldwide, type 2 diabetes (DM2) prevalence has doubled in past decades,[1] representing one of the largest widespread epidemics faced by the world population. Due to increasing disease burden, DM2 has been recognized as one of the most important non-communicable diseases (NCDs).[2] According to the International Diabetes Federation (IDF), in 2017, there were 451 million people living with DM2 and this number is expected to increase to 693 million by 2045.[3] From an economic perspective, previous report[4] suggest that total DM2-related health expenditure in 2015 was 673 billion US dollars and it is projected that in 2040 it will cost 802 billion US dollars. The IDF shows that Mexico ranks among top five countries in the world for DM2,[2] with approximately 12 million people living with this condition. In addition, in 2016, in agreement with the Global Burden of Disease study, 65% of premature mortality and 88% of disability-adjusted life-years (DALYs) were caused by NCDs[5] in Mexico with DM2 among top five leading causes.[6]

Genetic as well as environmental factors, particularly lifestyle factors (i.e. poor diet, physical inactivity, sedentary lifestyle, smoking, etc.), joined by economic transition, urbanization, industrialization, and globalization have been defined as important components in the growing burden of NCDs.[7] In addition to environmental and genetic factors, primary determinants of disease, essentially social and economic in nature, have been linked with DM2 and also with changes in diet and other lifestyles.[8] In this sense, socioeconomic status (SES)—a construct determined through access to health-care and information, healthy foods and access to exercise venues, income level, education and occupational opportunities as well as individual lifestyle choices[9]—has been defined as a factor of the unequal distribution in the prevalence, incidence, and mortality of DM2.[10] Unequal distribution of risk factors for DM2 (i.e. obesity, unhealthy diet, physical inactivity) between levels of SES have been reported.[11] Unequal distribution of access to resources and opportunities necessary to achieve a healthy lifestyle has been defined as socioeconomic inequalities.[12]

Despite the fact that socioeconomic inequalities and DM2 have been widely studied in different populations, the causal pathway is not yet fully understood. Moreover, as previously reported,[13] there is a lack of comprehensive information about how some factors (i.e. body mass index, diet, physical activity, family history of DM2, etc.) mediate and potentially compound the impact of socioeconomic inequalities on DM2. Thus, the main objectives of this study are to evaluate, using a structural equation modeling approach, the relation between socioeconomic inequalities and DM2 and to examine body mass index, diet, and physical activity as potential mediators in this relationship in a group of adults participating in the Diabetes Mellitus Survey of Mexico City 2015 (DMS-MC 2015).

Materials and methods

Study design

The DMS-MC 2015, a probabilistic population-based survey, collected cross-sectional data from a sample representative of adult residents of Mexico City aged 20-69 years. The DMS-MC 2015 was conducted in 2015 by a research team from the National Institute of Public Health (INSP, by its Spanish acronym) to obtain information and measurements of NCDs, as well as socio-economic conditions, lifestyle risk factors (i.e. diet and physical activity), and other health indicators. The methodology and participant characteristics have been previously detailed.[14]

In total, 1 174 subjects were included in the present analysis. Altogether, 242 participants were excluded for the following reasons: 142 participants had missing information regarding biomarkers and other important covariates. We also excluded subjects with more than 10% missing items on their food frequency questionnaires, those who did not consume between 600 kcal and 5 500 kcal daily, and subjects with more than 12 months past their DM2 diagnosis date.

We executed the current study according to the Declaration of Helsinki guidelines. The Research, Ethics and Biosecurity Committee at INSP reviewed and approved the study protocol and informed consent forms. Written informed consent was obtained from each participant.

Dietary intake

A semi-quantitative food frequency questionnaire (SFFQ) previously validated in Mexican populations[15] was used to assess dietary intake over the past seven days prior to the interview. The SFFQ included information concerning the consumption of 140 foods items. For each food, a commonly used portion size was specified (i.e. one slice of bread or one cup of coffee). Frequency intake options were characterized by set categories ranging from "never" to "six or more times per day". We converted frequency, which was originally measured as times per day, into portion size per day. Then, to estimate the nutrient and total energy (kcal/day) intake, we multiplied the frequency of consumption of each food by the estimated nutrient content with a food content database, compiled by INSP.[16] The administration and collection of the SFFQ was carried out by trained personnel using standardized data collection and entry procedures.

To compute the dietary inflammatory index (DII) scores for participants in the DMS-MC 2015, 27 food items and nutrients were linked to the world database that provided estimates of mean intake and standard deviation for each food parameter.[17] Then, these were expressed using Z-score. Finally, all the food parameter-specific DII scores were summed to create the overall DII score for every participant in the study. The methodology has previously been described.[14]

Biomarkers

Total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c), triglycerides (TG), glucose, and glycated hemoglobin A1c (HbA1c) were measured in a standardized laboratory. A fasting venous blood sample (fasting time was ≥ 8 hours) was collected from an antecubital vein from each participant.

Plasma TG was measured with a colorimetric method following enzymatic hydrolysis performed with the lipase technique. TC, HDL-c, and LDL-c were measured using the colorimetric method following enzymatic assay. Plasma glucose was measured with the enzymatic colorimetric methods by using oxidized glucose. In addition, the proportion of HbA1c was determined using the immunocolorimetric method.[18]

Type 2 diabetes

Previous DM2 diagnosis methods in the DMS-CM 2015 have been previously reported.[14] In short, first subjects were asked whether or not they had a diabetic condition and whether they had ever been diagnosed with DM2 by a physician. Additionally, subjects whose glucose concentration was ≥126 mg/dL and had levels of [HbA1c (%) ≥6.5] were defined as displaying fasting glucose and/or HbA1c values consistent with DM2 diagnostic criteria[19] and were also defined as participants with DM2. The manifest continuous variables glucose levels and HbA1c were included into the SEM model as a latent variable of DM2 for SEM analysis.

Anthropometric and blood pressure

Using standardized procedures, trained personnel measured participants' height and weight. Body weight was assessed with a previously calibrated electronic (SECA 874) scale with a precision of 0.1 kg. Height was evaluated by using a conventional stadiometer (SECA 213) to the nearest 0.1 cm. Body mass index was estimated as weight in kilograms divided by the square of height in meters [BMI= weight (kg)/height (m^2)]. We categorized BMI into three categories: normal <25.0 kg/m^2, overweight ≥25.0 and <30.0 kg/m^2, and obesity ≥30.0 kg/m^2. For the structural equation model (SEM), BMI was included as a continuous variable. With a measuring tape, waist circumference was evaluated to the nearest 0.1 cm at the highest point of the iliac crest to the end of normal expiration, which was placed below any clothing, directly touching the participant's skin. Central obesity was defined as a waist circumference of ≥90 cm in men and ≥80 cm in women.[20] Additionally, participants' blood pressure was measured twice using an automatic medical grade monitor (OMROM HEM-907). The first measurement was taken after five minutes of rest, while participants were sitting with the dominant arm supported at heart level. The second measurement was taken in the same way, five minutes after the first.

Physical activity

A short version of the international physical activity questionnaire (s-IPAQ), previously validated in Mexican populations, was used to evaluate physical activity (PA).[21] The questionnaire includes nine items that assess time spent performing moderate-intense PA for at least 10 minutes of each activity over seven days. The data of the s-IPAQ was examined as follows: first, physical activity interval duration gathered in hours was converted into minutes; second, data which was described as a weekly frequency was transformed into an average daily time; and third, subjects whose responses were "do not know", or "refused", or had "missing data" for time duration or frequency were excluded. In the SEM analysis, PA was analyzed as a continuous variable.

Socioeconomic status

A household wealth index (HWI) was created using principal components analysis with household characteristics and family assets. In general, HWI was constructed by combining eight variables that assessed household characteristics, goods, and available services including: construction materials of the floor, ceiling, and walls; household goods (stove, microwave, washing machine, refrigerator and boiler); and electric goods (television, computer, radio and telephone). The index was divided into tertiles and used as a proxy for low, medium, and high SES, for the multivariate logistic regression models the highest tertile (high SES) was the category of reference.

Education

Education level was based on a question, "What level of education do you have?", and the responders were requested to state their maximum level of education. The response options ranged from "elementary school" to "master and doctoral degree". For SEM analysis, we stratified subjects into five groups according to the highest level of education obtained: "elementary or less", "secondary", "high school", "university", and "master and doctoral degree". For the multivariate logistic regression models, we stratified subjects into three categories according to the highest level of education obtained as follow: "elementary or less and secondary" "high school" and "Bachelor's degree or higher", being Bachelor's degree or higher the category of reference.

Income

Using a self-administered questionnaire (household level), income was determined using two questions, "What is your income for your actual job?", and "Do you have other sources of income?". Response categories ranged from "daily income" to "annual income." With this information, we computed the monthly income of each person. In the SEM analysis, income was analyzed as a continuous variable. For the multivariate logistic regression models, income was divided in tertiles, being the highest tertile of income the category of reference.

Other participant characteristics

In general, two self-administered questionnaires (at the household and individual level) were completed for each participant. With these questionnaires, detailed information concerning their demographic characteristics (i.e. age, sex, marital status), self-perception of body weight, past medical history, family history of DM2, current medication use, lifestyle information (i.e., diet, physical activity, smoking status, etc.), depression symptoms, sleep quantity, and information about reproductive history (for females) were obtained.

Variables for the SEM

Index of socioeconomic inequalities

In order to establish a unidimensional measure of socioeconomic inequality, we incorporated sociodemographic variables (such as income, SES, and education) into a latent variable called the socioeconomic inequalities index (SII). The latent variable SII was included in the SEM analysis as an exogenous variable. The reliability of this latent variable is 0.70.

Type 2 diabetes

We used two manifest variables to assess DM2 as a latent variable, one is the glucose level and the other is the HbA1c. The reliability of this latent variable is 0.96. The rest of the variables in the SEM (PA, diet-DII., BMI, and family history of DM2) were measured as manifest variables, as described previously. Latent variables are indicated in the figures 1 and 2 as ellipses and manifest variables as rectangles.

Statistical analysis

In all analyses, complex sampling design was considered using survey-related commands and specifying PSUs, strata, and weights. All P-values are 2-tailed and $p<0.05$ was considered significant. All analyses were performed using Stata software, version 13.0. For SEM analyses we used MPLUS 7.11.

A descriptive analysis of the main characteristics of interest, frequencies, means, and standard deviations, was conducted. One-way ANOVA was used to test for differences in general characteristics across socioeconomic inequalities tertiles, while, chi-square tests were used to evaluate the distribution of qualitative variables across SII tertiles. To evaluate the magnitude of the association between specific SII tertiles and DM2, we estimated multivariable adjusted odds ratios (OR) and 95% confidence intervals (95%CI) using logistic regression models. In all multivariate models, the first tertile of the SII score was used as the reference. The Mantel-Haenszel extension chi-square test was used to assess the overall trend of OR across increasing tertiles of SII scores. We also computed OR and 95%CI, using multivariate logistic regression models, to assess the association between education, SES, income (independent variables of the SII score), and DM2.

We fit an SEM model (using the DM2 latent variable as continuous outcome) to study direct effects, indirect effects, and gender effects. We included BMI, PA, and diet-DII as mediator variables between SII and DM2 (figure 1). The method of estimation was Maximum Likelihood based on the covariance matrix. Global goodness of SEM fit indices included the chi-square statistic that tested the null hypothesis: that the reproduced covariance matrix has the specified structure, or the model fits the data. In addition, the Comparative Fit Index (CFI) is presented, which ranges between 0 and 1 (model fits). Other goodness of fit statistics were also

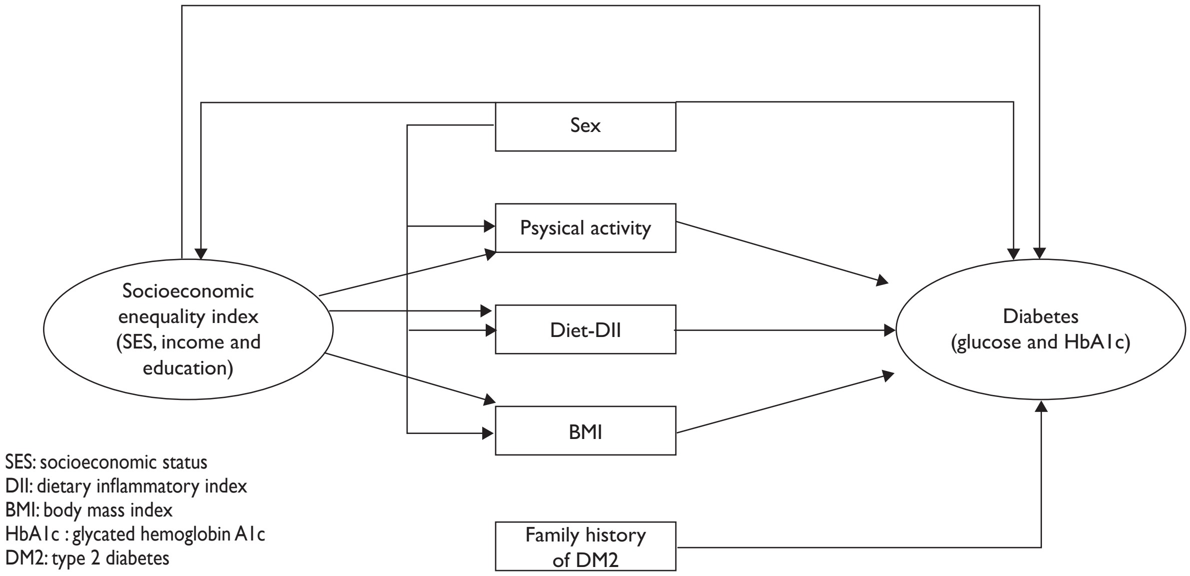


Figure 1. Conceptual framework of the association between diabetes socioeconomic inequality index, body mass index and lifestyle factors

examined, and included the Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR).[22]

Finally, SEM was used to study the relationship between socioeconomic inequalities and DM2 onset, mediated by PA, diet-DII, BMI, controlled by family history of DM2. This model was replicated for men and women to study the possible changes in the estimates by gender.

Results

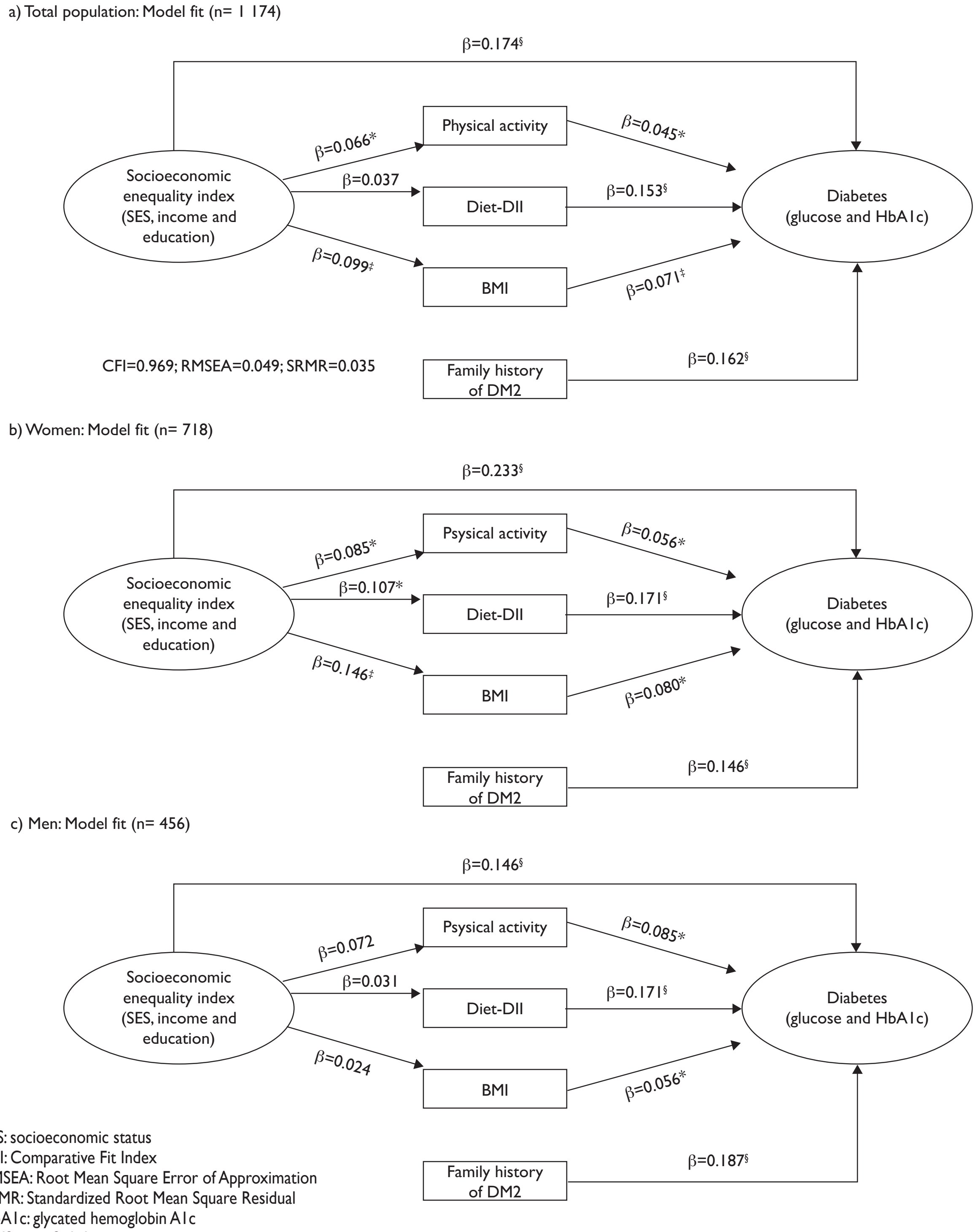
The main characteristics of the participants in the DMS-MC 2015 are presented in table I. While DM2 prevalence was similar between men (14.0%) and women (13.8%), they differed in other characteristics. Particularly, women were more likely to be obese (37.9 vs. 30.6%), less educated (21.9 vs. 16.7%), and had lower SES (25.2 vs. 18.4%). In relation to family history of DM2 and the presence of hypertension, 41.2% of women had a family history of DM2 and approximately 19.0% had hypertension.

According to SII score tertiles, when we compared participants in the highest level vs. participants in the lowest level of SII, individuals in the highest level were significantly older (42.5 vs. 38.5 years), with higher prevalence of obesity (37.6 vs. 31.1%) and a higher prevalence of DM2 (20.6 vs. 9.3%). Concerning DII, participants in the highest level of SII had higher DII scores (0.51, SE:0.16), which means that subjects with the highest level of SII were more likely to have a pro-inflammatory diet (table II).

After adjustment for potential confounders, like: age, sex, tobacco use, family history of DM2, presence of hypertension, alcohol intake, PA, BMI, and diet-DII, DM2 was positively associated with SES, income, and education. For example, participants in the lowest category of SES were more likely to be diabetic (OR=1.99, 95%CI: 1.27-3.12), compared to subjects in the highest level of SES. On the other hand, participants in the lowest category of income had higher odds of DM2 (OR= 1.45; 95%CI: 1.01-2.30) compared with subjects in the highest tertile of income.[23]

Figure 1 evaluates a theoretical model in which SII and DM2 were used to predict each other in a structured manner. Among the total population (figure 2a), pathways linking SII to DM2 included a pathway through diet-DII, BMI, and PA, in addition the major and significant contribution of indirect effects from SII to DM2 onset was via BMI (ß=0.071, $p<0.01$). In general, SII was negatively associated with PA (ß= -0.066, $p<0.05$), which, in turn, was inversely associated with DM2 (ß= -0.045, $p<0.05$). Finally, SII had a direct effect on DM2 (ß= 0.174, $p<0.001$).

Among women (figure 2b), the direct effect of SII on DM2 was the major pathway explaining its total effect (ß=0.233, $p<0.001$). Lastly, a direct effect of SII on DM2 was observed among men (figure 2c) (ß= 0.146, $p<0.001$).



SES: socioeconomic status
CFI: Comparative Fit Index
RMSEA: Root Mean Square Error of Approximation
SRMR: Standardized Root Mean Square Residual
HbA1c: glycated hemoglobin A1c
DM2: type 2 diabetes
* $p<0.05$
‡ $p<0.01$
§ $p<0.001$

Figure 2. Findings of estructural equation models: mechanism explaining socioeconomic inequalities (SII), diabetes through physical activity, dietary inflamatory index (DII), body mass index (BMI), and family history of DM2

Table I

MAIN CHARACTERISTICS OF ADULTS PARTICIPATING IN THE DIABETES MELLITUS SURVEY OF MEXICO

Characteristic	*Men (n = 456)*		*Women (n = 718)*	
	%	SE	%	SE
Age (years)*	39.1	0.67	40.7	0.65
Socioeconomic status, %				
Low	18.4	2.0	25.2	2.0
Medium	37.1	3.0	35.6	3.0
High	44.4	4.0	39.1	3.0
Income (US dollar/month)*	277.5	28.4	126.9	11.6
Education, %				
Elementary and secondary education	16.7	1.9	21.9	1.8
High school	27.8	2.6	26.6	2.3
Bachelor's degree or higher	55.5	2.9	51.5	2.7
Socioeconomic inequality index	-0.22	0.05	-0.11	0.04
Smoking status, %				
Current	60.0	2.6	32.0	2.3
Past	11.5	1.8	11.7	1.4
Never	28.5	2.3	56.3	2.4
Physical activity, %				
Low	28.6	2.5	26.7	2.1
Moderate/intense	71.4	3.1	73.3	2.2
Family history of DM2, (% Yes)	38.0	2.5	41.2	2.2
Hypertension, (% Yes)‡	12.3	1.4	18.9	2.0
Body mass index (kg/m^2)*	28.1	0.33	29.1	0.31
BMI, %				
Normal	26.0	2.9	25.0	2.2
Overweight	43.4	3.0	37.1	1.8
Obesity	30.6	2.8	37.9	2.3
Glucose (mg/dL)*	108.7	2.5	106.9	2.6
Glycated hemoglobin (HbA1c)*	5.9	0.08	5.9	0.09
DM score	5.6	2.6	3.8	2.6
DM2, (% Yes)	14.0	1.8	13.8	1.6
Triglycerides (mg/dL)*	230.8	9.9	181.8	6.4
HDL-C (mg/dL)*	40.0	0.68	44.4	0.47
Dietary variables				
Energy intake (kcal/day)*	2479.3	60.1	2007.4	53.1
Carbohydrates (% energy)*	54.4	0.54	56.3	0.39
Total fats (% energy)*	30.9	0.45	31.2	0.29
Saturated fats (% energy)*	12.7	0.14	13.2	0.14
MUFA (% energy)*	10.9	0.17	10.8	0.17
PUFA (% energy)*	7.0	0.11	7.0	0.11
Fiber (g/day)*	29.4	1.0	26.2	0.83
Magnesium (mg/day)*	441.9	13.2	371.1	10.9
DII score*	-0.35	0.013	-0.85	0.08

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* Mean and SE (standard error)
‡ ≥ 140/90 mmHg
BMI: body mass index [normal (<25.0 kg/m^2), overweight (≥ 25.0 to <30.0 kg/m^2), obesity (≥ 30.0 kg/m^2)]
MUFA: monounsaturated fatty acids
PUFA: polyunsaturated fatty acids
DII: dietary inflammatory index
HDL-c: high density lipoprotein cholesterol
DM: diabetes mellitus

Statistical differences for the models by gender were tested using Wald Test, as indicated in table III.

Discussion

Using representative data collected in Mexico City, we assessed, through a structural equation model approach, the complex association between DM2 and socioeconomic inequalities, mediated by the contribution of body mass index, physical activity, and diet. Our results show that a higher score of socioeconomic inequalities was related to a higher score of DM2. Additionally, we found that this association was partially mediated by BMI, diet-DII, and PA--variables frequently considered as modifiable health behaviors or characteristics. The relation between DM2 and socioeconomic inequalities observed in the present study has been reported in other populations previously.[24-27] For example, in a representative sample of the European population, Espelt and colleagues[24] found that women with a lower socioeconomic position (characterized by low education, low income, and low socioeconomic status) had 2.2 (95%CI: 1.9-2.7) higher prevalence ratio of DM2, while for men it was 1.6 (95%CI: 1.4-1.9).

In this sense, multiple possible mechanisms have been described in the relation between socioeconomic inequalities and health. These mechanisms, among others, include: unhealthy behaviors (poor diet, physical inactivity, alcohol intake, etc.), restricted access to health care and inadequate resources, higher psycho-social stress levels, and inadequacies in material circumstances.[28]

Potential mediator variables (BMI, diet-DII, PA) examined in our study have been previously discussed.[11,24,29,30] We found that obesity was an important

Table II

Characteristics of participants according to tertiles of socioeconomic inequality index: The Diabetes Mellitus Survey of Mexico City

Characteristic	*Socioeconomic inequality index (SII)*					
	Low SII		*Medium SII*		*High SII*	
	%	*SE*	*%*	*SE*	*%*	*SE*
Age (years)*	38.5	0.81	40.1	0.82	42.5	0.76
Sex (women), %	48.2	2.8	50.4	2.5	59.2	2.6
Socioeconomic status, %						
Low	6.4	2.0	16.7	2.3	42.4	2.9
Medium	14.6	3.0	29.2	2.9	35.2	3.0
High	79.0	3.1	54.1	3.0	22.4	3.2
Income (US dollar/month)	364.4	41.3	194.4	12.6	148.5	11.5
Education, %						
Elementary and secondary education	8.4	2.0	19.8	2.5	39.4	2.7
High school	17.8	3.0	34.2	3.0	33.4	2.9
Bachelor's degree or higher	73.8	3.0	46.0	2.8	27.2	2.9
Smoking status, %						
Current	46.7	3.2	45.9	3.0	43.1	3.8
Past	10.4	1.9	12.4	2.0	12.1	2.3
Never	42.9	2.7	41.7	3.2	44.8	3.4
Physical activity, %						
Low	36.3	2.9	20.5	2.2	22.2	2.3
Moderate/intense	63.7	3.5	79.5	2.3	77.8	2.9
Family history of DM2, (% Yes)	41.6	2.9	43.1	3.2	41.1	2.9
Hypertension, (% Yes)‡	14.8	1.9	15.7	2.0	17.8	2.2
Body mass index (kg/m2)*	28.1	0.31	28.9	0.39	29.1	0.35
BMI, %						
Normal	26.0	2.8	25.8	2.5	24.0	3.0
Overweight	42.9	2.9	38.4	3.0	38.4	3.4
Obesity	31.1	2.9	35.8	2.8	37.6	3.3
Glucose (mg/dL)*	100.6	1.9	107.9	2.7	122.7	5.3
Glycated hemoglobin (HbA1c)*	5.6	0.08	5.9	0.10	6.5	0.15
DM2, (% Yes)	9.3	1.6	13.9	2.1	20.6	2.3
DM score	-11.9	0.19	-5.6	0.27	10.7	0.53
Triglycerides (mg/dL)*	198.5	8.9	203.8	9.2	221.9	12.7
HDL-c (mg/dL)*	43.2	0.82	41.3	0.62	42.1	0.85
DII score*	-0.91	0.18	0.13	0.14	0.51	0.16

* Mean and SE (standard error)
‡ ≥ 140/90 mmHg
BMI: body mass index [normal (<25.0 kg/m^2), overweight (≥ 25.0 to <30.0 kg/m^2), obesity (≥ 30.0 kg/m^2)]
DII: dietary inflammatory index
HDL-c: high density lipoprotein cholesterol
DM: diabetes mellitus

Table III
Parameter estimates for SEM and fit index, for the general model and by gender

Coeficiente	Overall Model	Men	Women	Wald Test
β1 SII”Diabetes	0.194***	0.146***	0.233***	0.2724
β2 SII “BMI	0.109**	-0.024NS	0.146**	0.0174
β3 SII “PA	-0.071*	0.072NS	-0.085*	0.0601
β4 SII “Diet-DII	-0.050NS	-0.031NS	-0.107*	0.3138
β5 BMI”Diabetes	0.091**	0.056NS	0.080*	0.8726
β6 PA”Diabetes	-0.056*	-0.085*	-0.056*	0.9361
β7 Diet-DII “Diabetes	0.159***	0.171***	0.171***	0.7794
β8 FHD”Diabetes		0.187***	0.146***	0.4109
Adjustment indexes				
CFI	0.971	0.919		
RMSEA	0.54	0.074		
SRMR	0.34	0.046		
BIC	52 726.69			

SEM: structural equation model
SII: socioeconomic inequalities
DII: dietary inflammatory index
BMI: body mass index
PA: physical activity
FHD: family history of diabetes
SES: socioeconomic status
CFI: Comparative Fit Index
RMSEA: Root Mean Square Error of Approximation
SRMR: Standardized Root Mean Square Residual
BIC: Bayesian information criteria
NS: Not statistically significant

risk factor in the association between socioeconomic inequalities and DM2. Our data suggests that individuals with higher SII had higher BMI values (ß = 0.109, $p<0.01$). This correlation is consistent with a previous review[31] where subjects with lower socioeconomic status, lower educational level, and lower income had a higher prevalence of obesity. The relevance of BMI as a risk factor for DM2 has been amply demonstrated.[32,33] Several biological mechanisms, including at the molecular level, have been proposed to explain the relation between BMI and DM2. For example, high BMI has been associated with higher plasma levels of free fatty acids which promote insulin resistance, abnormal lipid levels, and increased inflammation, all of which are predictors of incident DM2.[32,33]

We also found that subjects with higher SII score had lower levels of physical activity (ß = -0.066, $p<0.05$). In agreement with our findings, Bird and colleagues[27] found that participants with lower income had higher levels of physical inactivity. This finding could relate to fewer and less safe environments, and/or lack of infrastructure (sidewalks and parks) that would decrease the practice of leisure physical activities.[34] Finally, our analysis indicates that individuals with higher SII had higher levels of diet-DII (ß= 0.037). Though in our study the relationship was not statistically significant, previous studies have demonstrated that people with lower socioeconomic status and income (and related time restriction), have less access to healthy foods and consume less diverse diets with important differences in micronutrient intake and status.[12,35,36]

Notwithstanding important findings, some potential limitations need to be considered in the interpretation of our results. The design is cross-sectional in nature; therefore, it is not possible for this study to address causal sequencing. Additionally, we cannot ignore the possibility of reverse causation. Some important elements related to socioeconomic inequalities (such as neighborhood characteristics) were not evaluated in the first cycle of the DMS-MC. However, using a robust statistical methodology, we developed a SII that includes variables such as socioeconomic status, education, and income, that reflect certain conditions of the individual's living environment.[12,35,36] Additionally, the DMS-MC 2015 is a self-reported survey and consequently may be susceptible to measurement error and recall bias. Finally, the findings of the present study, while pertinent to Mexico City, may not be generalizable. Hence, we should use caution if drawing conclusions at the national level.

In spite of these limitations, our study has an important number of strengths:

First, the random stratified cluster design of the DMS-MC 2015 and the representation of the sample of adults in Mexico City, which means that the data collected possess a better picture of the relative characteristics of the general population included in our study.

Second, the use of validated questionnaires; in this case, using questionnaires that have been previously validated in the population of interest decreases the probability of measurement error, and therefore, our conclusions may be less biased.

Third, stratified analysis was carried out to identify gender differences in patterns of association.

And fourth, the use of SEM to analyze the complex relation between SII and DM2. SEM are very relevant in exploratory studies, particularly when variables of interest cannot be measured perfectly, as with those involving behavioral/social issues and having complex interrelationships between variables.

To the best of our knowledge, this is the first study that evaluates, through SEM, the complex relationship between socioeconomic inequalities and DM2 in the Mexican population. In summary, it was found that a higher socioeconomic inequalities score was related to a higher DM2 score and that this association is partially mediated by BMI, diet-DII, and PA.

Conclusion

In Mexico, the increasing prevalence of DM2 as well as the widening of the socioeconomic gap between individuals has become a pressing and important issue. Although multiple studies, mainly in high income countries, have evaluated the relation between socioeconomic inequalities and DM2; the complex mechanisms of this relationship are not completely documented. On the other hand, as reported previously,[30,31] the efforts to identify a primary or single risk factor or mechanism has not resulted in the development of effective strategies to reduce the increasing prevalence of DM2 globally. Thus, schemes for DM2 prevention and management must address social, political, and economic determinants and also individual-level risk factors. In this context, assessing and predicting the multiple risk factors related to the progression of the disease (DM2 and other chronic diseases), in order to control and prevent it, modeling complex relationships is a crucial task of epidemiology and public health. Therefore, the employment of innovative epidemiological methodologies and statistical techniques (i.e., structural equation models, machine learning algorithms, among others) commonly used in marketing or social studies should be widely applied in health sciences.

Lastly, our results emphasis the need for public health programs and policies that specifically target disadvantaged populations. In this sense, the promotion and access to healthy behaviors—like places to exercise and healthy foods, healthy living conditions, and access to and use of health care services—may help in diminishing the link between socioeconomic inequalities and DM2.

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