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Global Epidemiology

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Abstract

Analyzing the association of the built and social environment with the prevalence of Type 2 Diabetes (T2D) in Mexico City, Mexico

By Alana M. Zelaya

Background: Type 2 Diabetes (T2D) is now the leading cause of death in Mexico, with 76,000 lives lost in 2016 and the prevalence of T2D is expected to continue to increase in the upcoming decade. The rise of megacities and urbanization in Latin America has shaped the urban built environment in a way that unfortunately concentrated risks that impact individuals' risk of developing T2D. The risk of T2D is affected by the built and social environment as it influences behavior, like physical activity and diet. The purpose of this study was to characterize the built and social environment exposures that relate to diabetes using Geographical Information Systems (GIS): proximity and density of parks, street connectivity, security from crime, population density and neighborhood poverty, and analyze the relationship between these variables and prevalence of diabetes/prediabetes. **Methods:** A cross-sectional probabilistic population-based survey representative of adults aged 20–69 years (n=1304) living in Mexico City was conducted in 2015 which collected information on diabetes (by self-report and through fasting blood glucose or hemoglobin A1c). Geographical Information Systems (GIS) was used to derive the objectively measured built and social environment characteristics. Logistic regression models were used to explore the association between diabetes/prediabetes and environmental characteristics. **Results:** The adjusted models for individual (age, sex, educational attainment, marital status, and individual socioeconomic status) and environmental variables, showed that participants living in a 500 meter buffer area with medium number of crimes (between 166 to < 240 crimes) were 2.2 (95% CI :1.24 - 3.78) times more likely to have prediabetes or diabetes compared to those living in an area with a low number of crimes (less than 6 crimes). **Discussion:** Our results indicate that medium crime density was a positive correlate for prediabetes and diabetes. In Mexico, injuries and interpersonal violence are leading causes of healthy life lost among Mexican men. We recommend development of public policies to curb crime and increase safety in order to promote healthy behaviors and less stress to prevent the development of T2D.

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CHAPTER I. BACKGROUND

Type 2 Diabetes (T2D) incidence worldwide has quadrupled since 1980, and in 2014 over 422 million adults had diabetes, the majority of whom lived in urban areas of low- and middle- income countries (1). Given the worldwide increase in the prevalence of diabetes, timely prevention of this disease at the population level is essential given the lack of cure available (2). A significant proportion people living with T2D live in Latin America and over 11.5 million of them are in Mexico (3). In Mexico, diabetes is one of top three leading causes of death and affects almost 14% of adults (4). In 2000, T2D became the foremost cause of general mortality in Mexico, being responsible for 10.7% of the deaths registered that year. Diabetes-related mortality is higher in central and northern Mexico. Mexico City for example is nearly 30 points above the national average on diabetes-related mortality (3). The estimated cost of diabetes complications and management in Mexico in 2005-2006 was 1.118 billion US Dollars (5). Diabetes presents a heavy economic burden, so this disease must be tackled with urgency. The consequences of unmanaged and uncontrolled diabetes include blindness, kidney failure, and lower limb amputation (1)

Type 2 diabetes (T2D) occurs as a result of both environmental and genetic factors. However, recent studies indicate that genetics account for at most 10% of heritability of the disease. Therefore, it’s imperative to focus research and policy efforts on the causes of diabetes beyond the scope of genetics (2). Lifestyle, such as diet and physical activity, plays a decisive role in determining whether genetic predisposition will lead to disease (3). T2D can be prevented or delayed by early diagnosis because it allows for treating providers opportunities to mitigate associated risk factors with treatment such as lifestyle interventions (physical activity, diet, and weight loss) and glucose-lowering medication (1, 6). Currently, Mexico has the highest rates of diet-related T2D deaths and DALYs (35 [28–44] deaths per 100 000 population and 1605 [1231–2034] DALYs per 100 000 population) among 195 countries (7). Other risk factors for the development of T2D include family history of T2D, obesity, as well as presence of other chronic diseases such as hypertension, hypercholesterolemia, kidney disease, and microalbuminuria (3)

In the last century, society has migrated and concentrated in urban centers that have promoted sedentary lifestyle as well as increased consumption of diets high in saturated fat, added sugars, and refined carbohydrates. The above referenced factors have certainly contributed to the rise of T2D (8). Notably, Mexico City has such a high diabetes-related mortality and morbidity that can be correlated with the high concentration of the Mexican population urban centers. Almost 20% of Mexico's total population live in Mexico City (9). A study using the 2006 National Health Survey found that nearly 36% of adults had an excessive carbohydrate intake and 13% of adults had an excessive fat intake (10). The result of these changes is reflects a rapid rise in the prevalence of obesity and other cardiometabolic risk factors as well as diabetes.

A randomized trial found that through moderate weight loss, increased physically activity and a healthy diet, the risk of diabetes could be reduced by almost 60 percent (11). Unfortunately, most applied T2D prevention programs aimed at changing individual's lifestyles have been ineffective and unsuccessful in the long term (12). This effect on individual level interventions is hypothesized to be because of an absence of an environment that supports these interventions, individual-level determinants such as motivation and ability are not sufficient to prevent the development of T2D (6). Motivating a person to change in an environment that poses many barriers is not expected to be very effective (8). It is necessary to focus research on more upstream determinants such as accessibility and availability of the environment which allow changing and sustaining healthy lifestyles and behaviors.

Ecological models specify multiple levels of influence on behavior from individual and social factors to institutional, community, built environment, and policy factors. A key principle in this context is that interventions are most effective when they change the individual's built environment and policies. (8). The conceptual framework presented by Dendup et al. (2018) highlights potential pathways by which different characteristics of the environment may determine T2D (6). This framework is also based on socio-ecological theories that highlight how human behavior and choice is influenced by their ability and motivation when their sociodemographic, psychosocial, economic, organizational and physical environment are supportive. Therefore, it is critical to understand the environmental determinants of T2D beyond the individual determinants.

Both the built and social environment are theorized to increase exposure to risk factors of T2D by enchaining or constraining behavioral, psychosocial, and physical stressors and by influencing choice (6, 12, 13). The built environment are the components that are human-made such as building, sidewalks, parks, layout of neighborhoods, and transportation infrastructure (8). The social environment are the social factors of the neighborhood or setting that the individual belongs to and include social support networks, social norms and attitudes, safety and even access to healthcare (13). The distinction between social and the built environment is not clear-cut because both environments influence each other and characteristics could belong to both (14).The mechanism by which the built and social environment influence the development of diabetes is through diet and physical activity which led to obesity. As such, obesity is known to lead to higher risk of diabetes. Diabetes is a disease caused by a caloric intake/expenditure imbalance that leads to obesity and insulin resistance, which then leads to the development of diabetes and depending on this management can led to complications (14).

Built environment attributes ,such as availability as well as proximity to recreational resources or greenspaces that promote walkability, encourage physical activity because these attributes are associated with higher physical activity consistently (6, 12, 15).Walkability is an index that incorporates population density, retail area-to-land ratio, connectivity (number of three or more way intersections) and land-use mix (16). Higher walkability relates to the built environment since attributes such as sidewalks, intersections, dead ends, cul-de-sacs, and number of street lights facilitate or deter the easy access and use of streets. Notably, a meta-analysis found that higher neighborhood walkability was associated with lower T2D risk/prevalence (n = 8, OR = 0.79; 95% CI, 0.7-0.9; I2 = 92%) Likewise, more green space tended to be associated with lower T2D risk/prevalence (n = 6, OR = 0.90; 95% CI, 0.8-1.0; I2 = 95%) (12) .

Population density refers to the number of individuals or households living in a defined area and is consistently associated with higher use of cycling, walking, or public transit for transportation (12). However, more dense neighborhoods also increase stress and promote unhealthy behaviors (6). Stress, through the release of hormones such as cortisol and cytokines, can damage the immune and body systems accelerating chorionic diseases such as T2D (6). Additionally, stress can also motivate unhealthy eating which can negatively impact metabolic changes and body weight. It is well known that an increased body weight is likely to increase risk to T2D (6) . Stress has various pathways that can lead to the development of T2D including social exposures such as social isolation.

Characteristics of the social environments and unsafe neighborhoods may incite social isolation/ fear as well as inhibit physical activity (14). In general, low socioeconomic individuals are more vulnerable to hazardous built and social conditions. A systematic review found 24 studies since 2010 that link neighborhood SES to diabetes prevalence, incidence and control (13, 14) . Further investigation is needed to understand how these socioeconomic disparities led to inequalities in T2D prevalence in low socioeconomic groups.

Urbanization is the migration towards more densely populated areas and as mentioned above, is an ongoing process in Mexico as the population becomes exceedingly concentrated in the capital and other urban centers (12). Urban environments are highly dense, allow for a large number of social interactions, and have significant built environment characteristics (Diez-Roux). The systematic review and meta-analysis, Den Braver et. al (2018) found living in an urban residence was associated with higher T2D risk/prevalence (n = 19, odds ratio (OR) = 1.40; 95% CI, 1.2-1.6; I2 = 83%) compared to living in a rural residence (12). However, authors mention that previous reviews investigating the impact of urbanization or the difference urban vs. rural areas on T2D prevalence/incidence has produced conflicting results (7).While urbanization has consistently been associated with less physical activity and unhealthy dietary habits, urbanization has also been associated with higher total walking, cycling, and use of public transit for transportation (12, 15). Urban areas are interesting settings to conduct research on T2D since each setting is unique and understanding local context and its unique qualities are important to comprehend contradicting interactions of the social and built environment.

The previously cited systematic reviews and meta-analysis have been limited to exclusively or predominantly to studies in high-income countries. Moreover, research in the above reference studies were cross sectional and inferences regarding causality cannot be made even for those environmental characteristics suggestive of being predictors of T2D (6).

Overall, there is a lack of evidence regarding the relationship between the built and social environment with T2D in Latin America. Latin American's environment is fundamentally different from counties such as US, UK, Canada, and Australia. While high-income populations experience demographic and urban transitions, Latin American countries have recently began experiencing high population growth coupled with rising urbanization. In the last half century, megacities like Mexico City and São Paulo have emerged. Today, Mexico City is the largest metropolitan area in the western hemisphere and is the fourth largest city in the world with a population of over 20 million people. Critically, Mexico City has a high population density at 9,700 people per km^2 (9) . This rapid transition is creating significant environmental and public health challenges such as stress, crime, and traffic. As a result, the urban environment in Mexico City is often referred to as causative of disease.

Cultural and social factors unique to Latin America such as gender roles, socioeconomic status, perception, and trust of health care system all impact the prevalence of T2D. Latin America society encourages traditional gender roles which cause women to struggle manage their individual health and neglect the dietary and physical requirements for the reason of not wanting to be perceived as selfish, burdensome or vulnerable. Further, women’s perception of themselves as vulnerable to the violence of others impacts their willingness to leave the safety of their homes and thus represents a major barrier to health-seeking behaviors (9) .

In general, Mexicans distrust the healthcare system. This coupled with high poverty people find themselves having to make a choice between food and medication or paying the bills or paying for transport to their medical appointments. Access to health centers is also problematic and people have to travel long distances to reach healthcare facilities. In the presence of wide-spread distrust in the quality of services offered at hospitals, people tend to seek out alternative forms of care, including homoeopathic treatments, or inquire local pharmacists for formal health advice. These unique social and cultural factors set the foundation to study this relationship in Latin American in light of the concerning rapid rise of diabetes and obesity.

Previous studies studying the association of physical activity and built environment in Mexico indicate a how relationships are context specific. Studies investigating the relationship between characteristics of the built environment and physical activity found that associations reported in high-income countries do not necessarily translate to the context of Mexico. A study conducted in Cuernavaca, Mexico found that there was an inverse association between the walkability index and physical activity. These results are similar to studies conducted in Bogota, Colombia and other low-income countries like Bangladesh (17). Another study that compared perceived and objective measures of built environment for physical activity found that the perception of park safety moderated the association between physical activity and having a park within a street-network buffer area of 500 meters (18). Moreover, the study found the perceived measure of residential density and proximity to parks are associated with objective environmental measure related to physical activity. These results are consistent with high-income countries in that associations between perceived and objective measures are modified by individual socio demographic factors (18).

It is necessary to better understand the relationship among countries with low and medium income and these social and built environment exposures in order to develop evidence-based urban interventions to reduce the prevalence of diabetes. The purpose of this study is to first, characterize the built and social environment exposures that relate to physical activity using GIS: Proximity to and density of public parks, walkability (good street connectivity versus anti-connectivity), population density, and security from crime. Thereafter, this study will analyze the association of these built and social environment exposures with the prevalence of Type 2 Diabetes (T2D) in Mexico City, Mexico using data from the Cities Changing Diabetes study.

CHAPTER II. METHODS

STUDY DESIGN

This study was a cross-sectional probabilistic population-based survey representative of adults aged 20–69 years living in Mexico City conducted in 2015 with the purpose of estimating the prevalence of diabetes and obtaining information regarding risk factors and other health indicators including biomarkers. A total of 2,500 participants between the ages of 20 and 69 were recruited, and fasting blood samples were collected in a sub-sample. This analysis will be focused on the sub-sample of participants with an available blood sample.

RECRUITMENT METHODS

The survey design was complex and included stratification and clustering control by city district and “Area Geostadistica Basica” (AGEB), the “geostatistical area” (the equivalent of census tracts), defined by the Mexican National Institute of Statistics and Geography (INEGI). In the first stage a total of 16 geostatistical area, units were selected systematically and then from each geostatistical area, 6 city blocks where selected. For each of the city blocks, six households where selected and within each household up to two adults between the ages of 20 and 69 where selected. A fasting blood sample was collected in 1,329 participants randomly selected using the methodology of the Mexican National Health and Nutrition Survey 2012 (19, 20).

TYPE 2 DIABETES OR PREDIABETES DEFINITION

The main outcome was T2D and prediabetes. Participants were asked: “Has a physician ever diagnosed you with type 2 diabetes?” with possible answers being either yes or no. Additionally, a fasting venous blood sample (fasting time was ≥8 h) was collected from an antecubital vein from each participant. Serum aliquots were stored in cryovials and transported to a laboratory, where the aliquots were stored at −70 °C until they were used for analysis. Plasma glucose was measured with the enzymatic colorimetric methods by using glucose oxidize and the proportion of hemoglobin A1c (HbA1c) was determined using the immunocolorimetric method. Participants reporting a previous medical diagnosis of T2D were classified as diabetic, independent of their fasting blood glucose or glycated haemoglobin. Additionally, participants having HbA1C ≥ 6.5% or fasting glucose blood level ≥ 126 mg/dl from their blood sample were also classified as with T2D. Further, participants having HbA1C between 5.7% – 6.4% or fasting blood glucose levels between 100-125 mg/dl were classified as prediabetic (n=274). The outcome was dichotomous, as diabetes and prediabetes were grouped for a total of 604 diabetic and prediabetic participants.

OBJECTIVE BUILT ENVIRONMENT AND SAFETY CHARACTERISTICS

We assessed the built environment using Geographical Information System-derived attributes between 2013-2016. Participants' home addresses were geocodified and geographic home coordinates were collected by trained field-workers using Google Maps as a confirmatory strategy. A street-network buffer area of 500 meters was generated around each participant's household and was used to create and measure the built environment characteristics using ArcGIS 10.4. This buffer area was defined as including all possible destinations reached by a 10-min brisk walk.

Using street layer from the Mexican National Institute of Statistics and Geography (21), street connectivity was assessed as the number of three or four-way intersections in each buffer area and street anti-connectivity was assessed as the density of dead-end streets in the buffer area. Crime density was measured as the number of crimes in each buffer area using publicly-available geospatial data on incidence of crimes derived from the Mexico City attorney general's office (22, 23). Density of parks was measured as the number of parks in each buffer area using a previous GIS layer prepared by our research team including park geocodifications for a total of 944 parks. This layer was prepared by consolidating park information from different sources, including the National Commission of Protected Natural Areas, the federal Ministry of the Environment and Natural Resources, the local Ministries of Environment and Urban Development and Housing, as well as city maps from "Guia Roji" (a company producing maps and guides in Mexico) and Google Maps. The geocoding of all parks was confirmed by ground visits by field-workers. Distance to the closest park was calculated using Network Analyst Package and the aforementioned street layer. Neighborhood poverty and census tract population density were assessed using National Demographic Census performed in 2010 (24).

COVARIATES

Information regarding sex, age, education level, and marital status were taken from the survey for each of the participants. Individual-level SES was calculated using variables from the questionnaire using same procedure used by ENSANUT (19, 20).

DATA ANALYSIS METHODS

Analyses accounted for multistage clustered design and were weighted for probability of selection, using SAS 9.4 SURVEYLOGISTIC procedure. Descriptive statistics (means, proportions and 95% confidence intervals) were computed for all variables. Since the majority of the environmental variables were right skewed, the variables were categorized into tertiles (park density) or quartiles (all other characteristics). The category with the lowest value was used as reference (Table 3).

To explore the association between environmental characteristics and prediabetes or diabetes we first used unadjusted logistic regression models for diabetes/prediabetes using each of the GIS variables as independent variables. Then, we adjusted the models for individual variables (sex, age, marital status, individual socioeconomic status, and educational attainment), and each of the environmental variables. To avoid collinearity, when two variables of the same environmental construct were available (i.e. park density and proximity to parks, or intersection density and density of dead-end streets), we decided to include only one of them, based on their theoretical relevance (i.e. intersection density) and/or the significance of the association in unadjusted and adjusted models (i.e. proximity to parks). Statistical significance for all regression analyses was defined by $p < 0.05$.

CHAPTER III. RESULTS

The final analytic sample was 1304 participants, after 25 participants were eliminated because of missing household geolocation. In total, 330 (13.6%) participants out of 1,304 were identified as being diabetic and 274 participants were classified as prediabetic (21.3%). For a total of 604 (34.9%) diabetic and prediabetic participants.

The mean age of the sample was 39.86 years; 53 % were female; 53% had education beyond high school; 54.6% were married or living with someone and only 26 % had a normal Body Mass Index (BMI) (Table 1). Among the diabetic and prediabetic population compared to non-diabetic population, mean age was higher (46.6 vs 36.2 years old), individual socioeconomic status was lower (lowest SES: 15.9% vs 9.4%), education levels were lower (education beyond high school: 38.9% vs 60.6%), BMI was higher (Obese: 55.2% vs 23.3%), and there was a higher prevalence of other cardiometabolic risk factors (Hypertension or High Blood Pressure: 27.5% vs 9.6%; High Cholesterol: 20% vs 13.5%; Triglycerides: 20.4% vs 12%; Heart Attack: 22.4% vs 7.5%; Stroke or Cerebral Embolism: 3.2% vs 0.8%). (Table 1)

Most participants lived in neighborhoods categorized as having High (48.5 %) or Very High Poverty (24.1 %) (Table 2). Also, most participants (63.3%) did not have any parks within a street-network buffer area of 500 meters (Table 2).

Table 3 shows unadjusted and adjusted associations between diabetes/prediabetes and environmental variables. Unadjusted models showed that living in an area with a medium number of crimes (between 166 to < 240 crimes) or with more than two parks was associated with higher odds for diabetes/prediabetes compared to living in an area with low level of crimes or with less than this amount of parks within the street-network buffer area of 500 meters; conversely, a higher density of dead-end streets (anti-connectivity measure) or living farther away from parks were associated with lower odds for the disease.

When adjusting the models for individual (age, sex, educational attainment, marital status, and individual socioeconomic status) and environmental variables, only the associations between crime density and prediabetes or diabetes remained significant. Participants living in a street-network buffer area of 500 meters with medium number of crimes were 2.2 times more likely to have prediabetes or diabetes compared to those living in an area with a low number of crimes (less than 6 crimes). Meanwhile, marginally significant (p=0.0548) associations were found for between diabetes or prediabetes and our measures of park proximity. Participants living close (426-<881 m) to a park were 42% less likely to be diabetic or prediabetic compared to those living very close (<426 m) to a park.

CHAPTER IV. DISCUSSION: SUMMARY, PUBLIC HEALTH IMPLICATIONS, AND POSSIBLE FUTURE DIRECTIONS

This study aimed to explore the associations between built and social environment and prediabetes and diabetes among a representative sample of adults living in Mexico City, one of the biggest mega-cities in the world. Our results indicate that medium crime density was a positive correlate for prediabetes and diabetes. Most of the observed associations were non-linear. Our results had an inverted U-shape where the highest odds of diabetes/prediabetes are in the middle levels of crime. This relationship is different from our hypothesis that there would be a positive linear relationship between the odds of diabetes/prediabetes and the level of crime. Further research is need to understand the drivers of this distinctive relationship shape.

It has been hypothesized that crime and unsafe neighborhoods can create social isolation and fear and inhibit physical activity and other healthy behaviors which increases risk of T2D (6). Another mechanism by which crime can be associated with T2D is through chronic stress. Chronic stress is background stress due to constant stressors entrenched in living or working environments and to acute-incident stressors that have effects that last well beyond the initiating event (25). Chronic stress can lead to biological changes in the immune and endocrine system that impact health outcomes. Our results are different with previous studies that found no association between safety from crime and T2D risk/prevalence (12, 26, 27). However, previous reviews of literature found that childhood abuse associated with adult's obesity, (OR: 1.34, 95% confidence interval [CI]: 1.24-1.45, P<0.001) (28). Similarly, a systematic review found positive association between violence experienced during childhood and cardiovascular outcomes in adulthood (i.e., hypertension, coronary heart disease, and myocardial infarction) (29).

Mexico experienced an important increase in crime rates in the past decade. In fact, injuries and interpersonal violence are leading causes of healthy life lost among Mexican men (30). The implications of this association are important for developing public policies that address both the root causes and “symptoms” of crime insecurity. For example, increasing light around parks can help reduce violence and creating community programs so individuals don’t have to work or walk alone (31, 32). Research has also shown that perinatal home visitation programs and early childhood development programs are effective at reducing violence (33). By improving security and reducing violence, diabetes could be prevented by fostering an environment where it is safe to engaging in healthy behaviors, like regular physical activity and healthy eating.

Previous studies have consistently indicated that parks are related with more physical activity and more favorable health conditions, including diabetes. In contrast, our unadjusted models also showed that having a park within farther distance from home and having less parks around was marginally and more favorably associated with prediabetes and diabetes.

Explaining this counterintuitive result is challenging, especially since evidence in Mexico and Latin America indicates that parks are one of the most relevant environmental factors for physical activity (17, 18, 34-37). However, it is possible that this negative relation is due to the food environment surrounding parks. In Mexico it is common to find high availability and accessibility of food stalls surrounding parks as well as marketing of unhealthy foods. In fact, Mexico City is known for its street food (9). These food stalls sell mostly unhealthy processed foods (e.g. sugar sweetened beverages, salty snacks, pastries) or food preparations (like fruit juices, fruit water with high concentrations of sugar, sandwiches, or high-energy typical Mexican preparations). It is possible that people living close to parks are also highly exposed to this unhealthy food environment. The high accessibility and availability of such foods may in turn increase the intake of critical ingredients for prediabetes and diabetes (e.g. sugar, simple carbohydrates). To confirm our results, studies should examine the food environment surrounding healthy spaces, like parks and gymnasiums, and how they influence lifestyle behaviors. If this hypothesis were to be true, the implications to public policy would be complex since controlling this unique food environment requires different strategies from those targeted towards processed foods or the food industry. Previous strategies implemented in Mexico include taxation of sugar-sweetened beverages, improvement of norms for healthy food in schools, regulation of food and beverage marketing to children and implementation of a national front-of-pack labeling system (38) however they do not address informal food stalls or unhealthy foods preparations. A potential solution is to adapt the norms already in place for healthy foods in schools to parks and public spaces. These strategies might help promote a better diet and reduce the risk of T2D, however it faces challenges from tensions between industry interests and public health objectives and effective accountability and monitoring mechanisms to assess implementation across government sectors (39).

STRENGTHS & LIMITATIONS

To our knowledge this is the first city-wide study exploring the association between environmental attributes and diabetes in a Latin American setting. The main strength of this study is its population representativeness and standardization in data collection that are consistent with previous nation-wide studies in the country, such as the National Demographic Census and the Mexican National Health and Nutrition Survey. We also explored the association between objective measures of the built and social environment and health indicators of the glucose metabolism, limiting the possibility of misclassification bias. Finally, another strength is the use of comparable measures of environmental attributes in line with previous studies.

A limitation of this study was the cross-sectional design which does not allow determination of causality. We measured the built and social environment around the participants' household, however it is also possible that the environment around an individual's work place could also affect on their risk of T2D. We also do not have information of the quality of the parks and the quality of the park has the potential to affect its attractiveness to use (12). Secondly, neighborhood self-selection is a potential bias. Self-selection occurs when residents choose a neighborhood based on socioeconomic or other circumstance such that health behaviors predict neighborhood choice. This bias could affect our interpretation of the association where there really is a reverse causality effect. Another potential weakness in our model was that crimes in Mexico City are widely underreported. The information for density of crime could be an inaccurate or skewed sample. If this is a non-differential underreporting, then we would expect our observed associations to be underestimated. The fact that we were able to see the association would mean that it is impact of crime on prediabetes/diabetes is probably larger. If it is skewed or under- reported by some neighborhoods with characteristics related to T2D, then we would have biased estimations. Other papers have reported that perception of crime might be a better indicator since crimes are highly underreported in Mexico (17, 22). Finally, given the lack of information on the food environment from the parks we were not able to explore the association between the food environment and T2D which may also be relevant correlate for this disease.

In summary, the importance of this study is that diabetes and other cardio-metabolic diseases are an epidemic in Mexico City and understanding the role the environment plays in the development of the disease is important for implementation of prevention strategies and policy change. Understanding the role that the food environment in park plays is also important to understand. Further studies must investigate the role of the food environment in parks in Mexico City and their contribution to obesity, diabetes, and other chronic diseases.

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TABLES

TABLE 1. Characteristics of Study Participants, Mexico City, Mexico, 2015

Characteristic	***Overall Study Population n (% [95% CI]), (N= 1304)***	***Not Diabetic n (% [95% CI]), (n = 700)***	***Diabetic / Prediabetic n (% [95% CI]), (n=604)***
Female	817 (53.0 [50.1-55.8])	425 (51.6 [47.2-56.0])	392 (55.5 [50.1-61.0])
*Age, years**	39.86 (38.98-40.73)	36.22 (35.22-37.23)	46.62 (45.39-47.85)
Age (Categorized as reported by ENSANUT)			
20-39	491 (53.1 [49.5-56.6])	385 (64.7 [60.4-69.1])	106 (31.32 [26.7-35.9])
40-59	569 (37.5[33.6-41.3])	255 (30.4 [26.0-34.9])	314 (50.5 [44.7-56.2])
60 +	244 (9.4 [7.6-11.4]	60 (4.8 [3.1-6.6])	184 (18.2 [14.6-21.7])
Individual-level Socioeconomic Status			
Very Low	222(11.7 [9.3-14.1])	93 (9.4 [6.6-12.2])	129 (15.9 [12.5-19.3])
Low	303 (17.9 [14.1-20.9])	149 (16.8 [13.1-20.5])	154 (19.9 [16.4-23.4])
Medium	276 (21.6 [18.2-24.9])	147 (20.7 [16.4-24.9])	129 (23.3 [19.2-27.3])
High	253 (21.7[18.4-25.1])	151 (23.2 [19.4-24.9])	102 (19.1 [14.3-23.9])
Very High	250 (27.1[22.6-31.7])	160 (30.0 [23.9-36.0])	90 (21.9 [16.9-26.9])
Education Level			
Elementary School or Less	374 (19.4[16.6-22.3])	129 (13.6 [10.8-16.4])	245 (30.3 [25.8-34.9])
6th - 10th grade	378 (27.6 [24.0-31.1])	198 (25.8 [21.5-30.2])	180 (30.7 [25.0-36.5])
10th grade or above	552 (53.0 [48.8-57.2])	373 (60.6 [55.5-65.6])	179 (38.9 [33.0-44.8])
Marital Status			
Single	298 (32.4 [29.2-35.7])	206 (37.8 [33.6-42.1])	92 (22.4 [17.1-27.6])
Married or Living with someone	776 (54.6 [50.6-58.6])	386 (50.1 [44.9-55.2])	390 (63.0 [57.1-68.8])
Divorced or separated or widow	230 (13.0 [11.0-15.0])	108 (12.1 [9.4-14.8])	122 (14.7 [12.4-17.0])
Body Mass Index			
Underweight	8 (0.7 [0.0-1.4])	7 (1.0 [0.0-2.1])	1 (0.03 [0.0-0.1])
Normal	279 (26.0 [22.6-29.4])	205 (32.9 [28.3-37.5])	74 (13.1 [6.9-19.3])
Overweight	516 (38.9 [35.8-42.1]	300 (42.8 [38.5-47.1])	216 (31.7 [26.9-36.5])
Obese	488 (34.4 [31.6-37.2])	183 (23.3 [19.6-27.0])	306 (55.2 [49.8-60.5])
*HbA1C **	5.75 (5.66-5.84)	5.16 (5.13-5.19)	6.85 (6.62-7.08)
Prevalence of Other Cardio metabolic Risk Factors			
Hypertension or High Blood Pressure	276 (15.8 [13.6-18.1])	80 (9.6 [7.1-12.1])	196 (27.5 [23.8-31.1])
High Cholesterol	245 (15.8 [13.4-18.1])	101 (13.5 [10.7-16.3])	144 (20.0 [15.7-24.3])
Triglycerides	234 (14.9 [12.8-17.1])	91 (12.0 [9.2-14.7])	143 (20.4 [16.8-24.1])
Heart Attack	17 (13.4 [6.0-20.8])	3 (7.5 [0.0-16.0])	14 (22.4 [9.6-35.3])
Stroke or Cerebral Embolism	25 (1.6 [0.9-2.4])	6 (0.8 [0.0-1.6])	19 (3.2 [1.6-4.9])

** Variables presented as: Mean (95% CI for Mean)*

TABLE 2. Characteristics of Built and Social Environment among Adults, Mexico City, Mexico, 2018

Variable	***n* (N=1304)**	***% (95 % CI)***
Distance to Closest Park (meters)		
Very Close (< 426)	328	22.7 (15.2-30.2)
Medium (426 to < 881)	331	25.8 (18.5-33.0)
Far (881 to <1463)	318	27.6 (18.9-36.2)
Very far (≥ 1463)	327	24.0 (16.0-31.9)
Number of Parks		
0	779	63.3 (53.0-73.6)
1	252	16.6 (10.2-23.1)
≥ 2	273	20.1 (10.7-29.4)
Intersection Density		
Low (< 87)	325	28.0 (18.6-37.3)
Medium (87 to <113)	327	23.5 (16.2-30.7)
Medium - High (113 to < 163)	333	26.3 (17.0-35.5)
High (≥ 163)	319	22.3 (12.8-31.8)
Number of Dead End Streets		
Low (< 6)	316	23.1 (14.0-32.3)
Medium (6 to < 21)	318	25.6 (17.0-34.2)
Medium - High (21 to < 47)	339	27.9 (19.6-36.2)
High (≥ 47)	331	23.4 (15.1-31.6)
Number of Crimes (2013-2016)		
Low (< 87)	335	24.9 (18.3-31.4)
Medium (87 to <166)	317	23.3 (15.7-30.8)
Medium - High (166 to < 240)	333	28.1 (18.9-37.4)
High (≥ 240)	319	23.8 (14.4-33.1)
Population Density		
Low (< 127)	336	27.3 (20.0-34.5)
Medium (127 to < 209)	310	25.7 (19.4-32.1)
Medium - High (209 to < 350)	317	21.7 (16.4-27.1)
High (≥ 350)	332	25.3 (18.4-32.2)
Neighborhood Poverty		
Low/Very Low	147	10.5 (6.0-15.0)
Medium	175	16.9 (9.5-24.3)
High	634	48.5 (38.5-58.6)
Very High	294	24.1 (14.7-33.4)

TABLE 3. Association of Diabetes/Prediabetes with Built and Social Environment Variables among Mexican Adults, Mexico City, Mexico

	Crude OR (95% CI)	***Adjusted OR (95% CI)***[a]
Distance to Closest Park (meters)		
Very Close (< 426)	Reference	Reference
Close (426 to < 881)	**0.524 (0.316-0.869)**	0.583 (0.336-1.011)
Far (881 to <1463)	0.685 (0.354-1.327)	1.083 (0.519 - 2.258)
Very far (≥ 1463)	**0.529 (0.336-0.833)**	1.063 (0.562 - 2.011)
Number of Parks[b]		
0	Reference	Reference
1	1.150 (0.788-1.678)	0.877 (0.568-1.354)
≥ 2	**2.012 (1.196-3.384)**	1.391 (0.651 - 2.970)
Number of Crimes (2013-2016)		
Low (< 87)	Reference	Reference
Medium (87 to <166)	0.744 (0.531-1.043)	0.831 (0.524-1.317)
Medium - High (166 to < 240)	**1.856 (1.180 - 2.919)**	**2.166 (1.242 - 3.780)**
High (≥ 240)	1.047 (0.677-1.620)	1.570 (0.766 - 3.177)
Intersection Density		
Low (< 87)	Reference	Reference
Medium (87 to <113)	1.173 (0.674-2.041)	1.068 (0.605-1.887)
Medium - High (113 to < 163)	0.826 (0.441-1.548)	0.792 (0.454 - 1.382)
High (≥ 163)	0.663 (0.371-1.185)	0.570 (0.283-1.151)
Number of Dead-End Streets[c]		
Low (< 6)	Reference	Reference
Medium (6 to < 21)	0.988 (0.624-1.564)	1.039 (0.667 - 1.619)
Medium - High (21 to < 47)	0.839 (0.479-1.468)	0.880 (0.413-1.875)
High (≥ 47)	**0.523 (0.306-0.894)**	0.461 (0.201 - 1.060)
Population Density		
Low (< 127)	Reference	Reference
Medium (127 to < 209)	0.760 (0.483-1.197)	0.748 (0.435-1.286)
Medium - High (209 to < 350)	0.863 (0.550-1.353)	0.782 (0.464-1.318)
High (≥ 350)	0.953 (0.617 - 1.471)	0.805 (0.473-1.372)
Neighborhood Poverty		
Low/Very Low	Reference	Reference
Medium	1.351 (0.736-2.480)	1.326 (0.731-2.405)
High	0.970 (0.591 - 1.593)	1.107 (0.711-1.724)
Very High	0.973 (0.548 - 1.729)	1.087 (0.633-1.868)

[a] *Estimations were adjusted for sex, age, education, individual socioeconomic status, marital status, and the remaining environmental variables (distance to nearest park, number of crimes, intersection density, population density, and neighborhood poverty).*

[b] *Distance to Nearest Park variable was not included in order to avoid collinearity*

[c] *Intersection Density variable was not included in order to avoid collinearity*