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Article

Diabetes Awareness, Treatment, and Control among Mexico City Residents

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Abstract: Early diagnosis and control of diabetes can reduce premature mortality and disability. We described the diabetes prevalence, awareness, treatment, and control in Mexico City. Data came from the Mexico City Representative Diabetes Survey, conducted between May to June 2015. Participants (20–69 y, n = 1307) reported their diabetes condition, treatment, and outcomes. Fasting blood samples were collected and HbA1c, blood glucose, and blood lipids were determined. We used multivariate logistic regression to identify inequalities in diabetes prevalence and awareness. The overall prevalence of diabetes was 13.6% (95% CI: 11.7, 15.7). Of those living with diabetes, 70.5% were aware of their condition. Among those aware of their diabetes, around 10% to 65% received diabetes care according to international guidelines, and around 30% to 40% achieved HbA1c, LDL cholesterol, or blood pressure targets. Overall, only 4.1% of those aware of their diabetes achieved all treatment targets and 35.4% had never presented a diabetes complication. Diabetes prevalence was higher among older age groups and lower among the most educated. Having access to health care was associated with lower odds for diabetes and diabetes awareness. The low rates of diabetes awareness, treatment, and control highlight the urgent need of strengthening diabetes care in Mexico City.

Keywords: diabetes; rule of halves; diabetes care

1. Introduction

Mexico is a middle-income country with the highest diabetes mortality rates among megacountries (i.e., countries with at least 100 million inhabitants) [1], and this disease has been considered a public health national emergency [2]. From 2000 to 2012, the prevalence of type 2 diabetes (T2D) in Mexico increased by 31.4%, with 13.7% of Mexican adults living with it in 2016 [2].

The increase in diabetes prevalence is a result of demographic change (increase in the older age group), urbanization, and modifiable risk factors such as increases in alcohol use, dietary patterns, physical inactivity, and obesity [3–6]. Mexico City is one of the most populated cities in the developing world and has experienced rapid urbanization in the past 30 years. Currently, Mexico City residents have some of the highest rates of physical inactivity and sedentary time [7] in the country and have a diet characterized by a high content of calories, simple sugars, and saturated fat, associated with the high availability of ultra-processed foods and sugar-sweetened beverages, among other food products [8–11]. The exposure to these risk factors has made Mexico City the leading state in diagnosed T2D (12.5%) and age-standardized mortality rates related to this disease in the country [12].

Poorly controlled T2D can lead to complications, that result in substantial direct and indirect costs to the national health system [13,14]. Costs attributable to diabetes in Mexico were estimated to be 6116 million US dollars in 2015 [15]. Early diagnosis and control of diabetes can reduce premature mortality and disability [16]. However, the World Health Organization estimates that worldwide at least 20% of people living with diabetes have not been diagnosed [17]. In Mexico, approximately 30% of people living with diabetes are not aware of their disease and only 40.8% of those with a diabetes diagnosis received adequate medical care [18]. The rule of halves proposes that approximately half of most common chronic disorders are not detected, and half of those detected are not treated, and that half of those treated are not controlled [19,20]. This rule was introduced in a diabetes survey in 1947 [21] and has been used in other chronic disorders included hypertension and asthma in different contexts and cities of other countries [22].

Socioeconomic inequalities play a major role in diabetes prevalence [23]. Associations are likely to be contextually dependent. For instance, studies conducted mainly in high-income countries have shown that diabetes prevalence is associated with low socioeconomic status [24–26], however, results from middle- and low-income countries have shown a positive association between diabetes and higher socioeconomic status [27–30]. Similarly, low socioeconomic status has been linked with worse glycemic control compared to higher socioeconomic status, leading to more complications of the disease and a higher mortality rate [24,31–33]. In Mexico, evidence suggests that diabetes prevalence is higher among the lowest educational level groups, in the least deprived municipalities, and in urbanized localities [23].

Mexico City faces complex challenges for the provision of adequate health care to more than 20 million inhabitants, placing the city among the top five cities with the highest diabetes mortality rates in the country [34]. While national estimates of diabetes awareness, treatment, and control are available [2,35], specific analyses to understand the diabetes epidemic in Mexico City are scarce and mainly focused on low-income residents [36,37]. To better target local interventions, a deep understanding of the epidemic in the city is needed. Thus, based on the rule of halves approach, we described the magnitude of the T2D epidemic in Mexico City including awareness, treatment targets, and treatment outcomes. We also aimed to identify subgroups of people with the highest prevalence of diabetes, as well as inequalities in diabetes diagnosis.

2. Materials and Methods

We used data from the Mexico City Representative Diabetes Survey (MCRDS). This survey was conducted from May to June 2015. The MCRDS has a probabilistic multistage stratified cluster sampling design. Participants were selected through a cluster sampling, using Mexican census tracts or basic geostatistical areas (AGEB, by its Spanish acronym) as the primary sampling unit. From each AGEB, systematic sampling was conducted to select six houses within six blocks. In each house, up to two adults aged 20–69 were systematically selected.

Trained personnel interviewed participants in person, to collect information on diabetes care, sociodemographic, and individual characteristics; and collected a fasting blood sample ($\geq$8 h). The response rate for the original study was 71.4%. Information on 1334 adults was collected. All participants signed and provided informed consent prior to participating (No. B04). The Ethics Review Board of the Mexican National Institute of Public Health approved the study protocol (#1658).

For this study, we included 1307 adults with complete information on diabetes status and sociodemographic characteristics. The weighted sample represented 5,440,315 adults living in Mexico City in 2015.

We defined diabetes status by combining self-reported information on diabetes condition and diabetes metabolism indicators (serum glucose and glycated hemoglobin [HbA1c]). Participants were asked Have you ever been diagnosed with diabetes by a physician? Response options included Yes and No.

Trained personnel collected fasting blood samples from the antecubital vein. Blood samples were centrifuged at the site of collection. Aliquots of blood were transported and stored at −70 °C until they were analyzed. HbA1c was processed in Bio-Rad Variant II turbo by means of high-pressure liquid chromatography. Serum glucose was measured using automatized glucose oxidase method with an overall inter-assay coefficient of variation <5% [38].

We classified participants as normoglycemic if they did not report a previous medical diagnosis of T2D, had fasting glucose levels < 100 mg/dL (<5.6 mmol/L), and HbA1C <5.7% (48 mmol/mol); as with "prediabetes" if they did not report a previous diagnosis of T2D but had fasting glucose levels between 100–125 mg/dL (5.6–6.9 mmol/L) or HbA1c levels between 5.7–6.4% (39–47 mmol/mol); as "aware of their diabetes" if they reported a previous medical diagnosis of T2D; and as "unaware of their diabetes" if indicators of the glucose metabolism were as follows: fasting glucose ≥ 126 mg/dL (≥7.0 mmol/L) or HbA1c ≥ 6.5% (≥48 mmol/mol), and if individuals did not report having been previously diagnosed [39].

Participants aware of their diabetes reported their health care provider. For other participants, the health care provider was reported by the head of the family. We categorized health care providers as None (no access to health-care), Public (including all medical services provided by a governmental institution), or Private.

We measured the extent to which participants that reported a previous diagnosis of diabetes received examinations for complications and had clinical markers assessed according to indicators used in previous National Surveys and the American Diabetes Association [39–41]. Participants reported the number of medical consultations in the prior year and the number of measurements to detect cardiovascular risk factors in the last 12 months, such as HbA1C, fasting glucose, proteinuria, total cholesterol, triglycerides, and blood pressure. They also reported other quality of care indicators such as eye examinations in the previous two years and feet examinations in the previous year, medical recommendations of diet and physical activity, as well as a pharmacological treatment for diabetes and dyslipidemias. Except for the number of medical consultations, all variables were dichotomized as meeting or not meeting (yes/no) diabetes care guidelines. The number of medical appointments was dichotomized using four consultations as the reference point.

We measured dyslipidemia, hypertension, and elevated HbA1c levels as those are known risk factors for diabetes complications and considered treatment targets for T2D [42]. Fasting serum triglycerides, total cholesterol, and high-density lipoprotein cholesterol (HDL-c) were assessed by the enzymatic method. Non-HDL cholesterol was calculated by subtracting HDL-c to total cholesterol. Low-density lipoprotein cholesterol (LDL-c) concentration was estimated using the Martin method [43]. VLDL cholesterol was estimated as the 20 percent of the triglycerides level [44]. LDL-c was classified as high when concentrations were ≥100 mg/dL (≥3.4 mmol/L). Hypertriglyceridemia was defined as having levels ≥ 150 mg/dL (≥1.7 mmol/L). Hypercholesterolemia was defined as having levels ≥ 200 mg/dL (≥5.2 mmol/L). HDL-c was defined as having levels < 40 mg/dL (<1.0 mmol/L) [45].

Trained personnel measured blood pressure using an electronic sphygmomanometer (Omron HEM-907 XL®). Participants rested for 5 min before having their blood pressure measured two times. The average of both blood pressure measures was used for the analyses. Participants were classified as having hypertension if their blood pressure was ≥140/90, or if they were previously diagnosed by a physician, or if they were taking antihypertensive medication [46].

We defined that a participant with previous diagnosis of diabetes met treatment targets when HbA1c was <7% (<53 mmol/mol), blood pressure was <130/80 mmHg, and LDL was <100 mg/dL (<3.4 mmol/L) [42].

Participants aware of their diabetes reported micro and macrovascular diabetes complications. Microvascular complications included retinopathy (sight loss, blindness, or damage to the retina), nephropathy (dialysis or kidney disease), and neuropathy (e.g., numbness or pain in extremities). Macrovascular complications included cardiovascular outcomes, including peripheral artery disease (e.g., foot or leg ulcers), amputations, and heart failure or stroke. Additionally, participants reported the occurrence of diabetic coma. Participants reporting not to have presented these complications before were considered as meeting treatment outcomes.

A socioeconomic status (SES) index 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 electrical goods (television, computer, radio, and telephone). The index was divided into tertiles and used as a proxy for low, medium, and high SES. Education level was categorized into three groups according to the highest level of education obtained: elementary school or less, secondary school, and high school or higher [47].

Physical activity was measured using the short version of the International Physical Activity Questionnaire [48]. and participants were classified as with low (<600 MET-minutes/week or without activity reported), moderate (600–1500 MET-minutes/week), and high levels (>1500 MET-minutes/week) of total physical activity [49].

Weight and height were measured to the nearest 0.1 kg and 0.1 cm. BMI status was based on the WHO's adult cutoff points: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obesity (≥30.0 kg/m^2) [50]. For the present study, BMI was divided into two categories: normal weight (<24.9 kg/m^2) and overweight/obesity (≥25.0 kg/m^2). Waist circumference was measured using a fiberglass tape to the nearest 0.1 cm at the midpoint between the iliac crest and the lower rib [51]. Participants were classified as having abdominal obesity if women had ≥80 cm and men ≥90 cm of waist circumference [50].

We explored if the rule of halves applied to diabetes in Mexico City. First, we estimated the proportion of participants living with and without diabetes among the whole population. Among those living without diabetes, we estimated the prevalence of diabetes and prediabetes. Among those already living with diabetes, we estimated the percentage aware and unaware of their diabetes. We used multivariate logistic regression to identify inequalities in prediabetes, diabetes prevalence, and diabetes awareness, based on demographic characteristics.

Second, to assess diabetes care, treatment targets, and treatment outcomes among participants aware of their diabetes, we estimated the proportion of individuals who received examinations for complications and had clinical markers assessed according to international standards [39], as well as the proportion meeting treatment targets and treatment outcomes (i.e., not having any diabetes complications) [39]. We used Bonferroni tests to estimate differences in indicators of diabetes quality of care across categories of glycemic control (HbA1C < 7.0% and HbA1C ≥ 7.0%) among participants with a previous diagnosis of diabetes. We used logistic regression to identify inequalities in meeting treatment targets, based on demographic characteristics. Analyses were performed using

Stata version 14.1 (StataCorp LLC, College Station, TX, USA). Estimates were adjusted by sample weights and the design of the survey.

3. Results

Participants were evenly distributed by sex, more than half were aged 20–39 years or were classified within the high or highest education level, approximately 40% were classified in the highest SES tertile, and more than 60% had a public health care provider (Table 1). In total, 88.4% (95% CI: 86.0, 90.5) reported being very active, around 70% were either overweight or obese or had abdominal obesity, and about one third had high blood cholesterol (≥200 mg/dL). More than half of participants had high levels of LDL- (≥100 mg/dL), VLDL- (≥30 mg/dL), or non-HDL-cholesterol (≥130 mg/dL), as well as triglycerides (≥150 mg/dL). Overall, 15.5% (95% CI: 13.2, 18.1) had hypertension. Table S1 shows the mean concentration of biological indicators.

Table 1. Characteristics of study participants. The Mexico Representative Diabetes Survey, 2015. (*n* = 1307, *n* [thousands] = 5,440,315).

Characteristic	*n*	*n* (Thousands)	% (95% CI) [1]
Gender			
Men	489	2,552,120	46.9 (43.9, 49.9)
Women	818	2,888,195	53.1 (50.1, 56.1)
Age group			
20–39	492	2,892,281	53.2 (49.6, 56.7)
40–59	572	2,030,659	37.3 (33.5, 41.3)
60+	243	517,374	9.5 (7.7, 11.6)
Education			
Elementary or less	370	1,035,269	19.0 (16.3, 22.1)
Secondary	384	1,512,950	27.8 (24.4, 31.5)
High school or higher	553	2,892,096	53.2 (48.8, 57.4)
Parent diagnosed with diabetes	565	2,170,385	42.0 (38.7, 45.4)
Socioeconomic status			
Tertile 1	405	1,196,362	22.0 (18.5, 26.0)
Tertile 2	488	1,978,067	36.4 (32.2, 40.7)
Tertile 3	414	2,265,886	41.6 (36.4, 47.1)
Primary health care provider			
None	89	307,952	5.7 (4.3, 7.4)
Public	844	3,371,338	62.0 (58.0, 65.8)
Private	374	1,761,024	32.4 (28.5, 36.5)
Physical activity			
Inactive	98	469,079	8.6 (6.9, 10.6)
Active	38	162,524	3.0 (2.0, 4.5)
Very Active	1171	4,808,711	88.4 (86.0, 90.5)
BMI category [2]			
Normal	284	1,419,482	26.3 (22.9, 30.0)
Overweight	515	2,092,387	38.7 (35.6, 42.0)
Obesity	499	1,890,403	35.0 (32.2, 37.9)
Abdominal obesity	1000	3,781,384	72.0 (68.8, 75.0)
Dyslipidemias			
Total cholesterol (≥200 mg/dL)	523	1,935,626	35.6 (32.2, 39.2)
LDL cholesterol (≥100 mg/dL)	903	5,435,430	65.2 (62.4, 67.9)
HDL cholesterol (<40 mg/dL)	549	2,410,851	44.3 (40.5, 48.2)
VLDL cholesterol (>30 mg/dL)	754	3,031,427	55.8 (52.4, 59.1)
Non-HDL cholesterol (>130 mg/dL)	875	5,435,430	62.5 (59.3, 65.7)
Triglycerides (>150 mg/dL)c	756	3,034,931	55.8 (52.4, 59.2)
Hypertension	252	686,869	15.5 (13.3, 18.1)

[1] Estimates (% and 95% CI) were adjusted for complex survey design. [2] *n*= 1298 due to missing values.

Table 2 presents the prevalence and odds for prediabetes and diabetes among participants. Overall, 26.4% (95% CI: 23.1, 29.9) had prediabetes and 13.6% (95% CI: 11.7, 15.7) lived with diabetes. In total, 71.5% of prediabetes diagnosis was based on high levels of glycated hemoglobin, while the rest were based on high levels of blood glucose (data not shown). The odds of having prediabetes were 2.3 (95% CI: 1.7, 3.1) and 3.8 (95% CI: 2.3, 6.5) times higher in participants aged 40–59 or 60+ compared to the youngest participants, respectively. Similarly, participants aged 40–59 (OR = 4.9, 95% CI: 3.2, 7.4) and 60+ (OR = 10.2, 95% CI: 6.1, 17.2) had higher odds for diabetes compared to participants aged 20–39 years. Compared to peers, those having a high school or higher education level (OR = 0.5, 95% CI: 0.3, 0.8) or with a public (OR: 0.3, 95% CI: 0.1, 0.6) or a private (OR = 0.2, 95%CI: 0.1, 0.5) health care provider had lower odds for diabetes.

Table 2. Prevalence and odds for prediabetes and diabetes, by demographic and socioeconomic factors.

	Prediabetes [1]		**Diabetes [2]**	
	% (95% CI)	**OR (95% CI)[3]**	**% (95% CI)**	**OR (95% CI) [3]**
Overall	26.4 (23.1, 29.9)	–	13.6 (11.7, 15.7)	–
Gender				
Men	25.3 (19.5, 32.1)	Ref	13.1 (10.1, 17.0)	Ref
Women	27.3 (23.0, 32.0)	1.1 (0.7, 1.7)	13.9 (11.9, 16.2)	1.0 (0.7, 1.5)
Age group				
20–39	20.6 (16.5, 25.5)	Ref	4.3 (3.0, 6.1)	Ref
40–59	32.5 (28.2, 37.1)	**2.3 (1.7, 3.1)**	20.4 (17.3, 23.9)	**4.9 (3.2, 7.4)**
60+	34.2 (27.4, 41.7)	**3.8 (2.3, 6.5)**	38.2 (29.9, 47.3)	**10.2 (6.1, 17.2)**
Education				
Elementary or less	33.3 (27.8, 39.4)	Ref	26.3 (21.3, 31.9)	Ref
Secondary	26.1 (20.4, 32.8)	0.8 (0.5, 1.2)	17.4 (13.0, 22.8)	1.0 (0.6, 1.6)
High school or higher	24.0 (19.6, 29.0)	0.7 (0.5, 1.0)	7.0 (5.2, 9.5)	**0.5 (0.3, 0.8)**
Socioeconomic status				
Low	29.0 (24.4, 34.1)	Ref	20.8 (16.7, 25.6)	Ref
Middle	27.8 (22.8, 33.5)	0.9 (0.6, 1.4)	13.6 (11.1, 16.5)	0.7 (0.5, 1.1)
High	23.7 (18.9, 29.3)	0.7 (0.5, 1.2)	9.7 (7.1, 13.2)	0.6 (0.4, 1.1)
Primary health care provider				
None	18.5 (8.9, 34.7)	Ref	34.1 (22.5, 47.9)	Ref
Public	27.3 (23.1, 31.9)	1.1 (0.5, 2.7)	13.7(11.3, 16.6)	**0.3 (0.1, 0.6)**
Private	25.9 (20.4, 32.3)	1.1 (0.4, 2.9)	9.6 (6.9, 13.2)	**0.2 (0.1, 0.5)**

OR, Odds Ratio; 95% CI, 95% Confidence Interval. [1] Defined as those with no diabetes diagnosis and fasting glucose levels between 100–125 mg/dL (5.6–6.9 mmol/L) or HbA1c levels between 5.7–6.4% (39–47 mmol/mol) [39]. [2] Defined as those with a previous diabetes diagnosis or those with fasting glucose levels between 100–125 mg/dL (5.6–6.9 mmol/L) or HbA1c levels between 5.7–6.4% (39–47 mmol/mol) and without a diabetes diagnosis. [3] Estimates were adjusted for complex survey design. OR and 95% CI estimated using a multivariate logistic regression model adjusted by the variables listed in the table. **Bolds** indicate significant associations ($p < 0.05$).

Among participants living with diabetes, 29.5% (24.3–35.2%) were not aware of their condition (Table 3). The odds for having a diabetes diagnosis was lower among participants with a private health care provider (OR = 0.2, 95% CI: 0.1, 0.6) compared to those with no health care provider.

The proportion of participants aware of their diabetes meeting standards of diabetes care is shown in Table 4. Among those with an awareness of their diabetes, 62.7% received between 4 and 12 medical consultations, 5.5% received at least one HbA1c test, and 56.5% received at least one glucose test in the prior year. Approximately 5% of participants reported receiving at least one measurement of total cholesterol in the prior year; a similar proportion was observed for and triglycerides or blood pressure measurements. The prevalence of meeting standards of diabetes quality of care for the prevention of diabetes complications ranged from 16.5% for ophthalmological evaluations to 53.0% for feet examinations. The prevalence of participants reporting at least one feet examination in the prior year was higher in those with HbA1c $\geq$ 7.0% compared to those with HbA1c < 7.0%. Most participants reported receiving diet (71.3%), physical activity (57.9%) or both (75.2%) recommendations in the prior year; participants with HbA1c $\geq$ 7.0% reported receiving physical activity recommendations more frequently than those with lower HbA1c levels ($p < 0.05$). Almost 90% of those with a previous diabetes diagnosis reported having a diabetes pharmacological treatment, including pills, insulin, or both, whereas around 80% and 70% reported having blood pressure or high cholesterol medication. The prevalence of mixed diabetes treatment (insulin and pills) or high cholesterol medication was significantly higher among those with HbA1c $\geq$ 7.0% ($p < 0.05$). No other differences in indicators of diabetes quality were observed according to HbA1c levels.

Table 3. Prevalence and odds for a diabetes awareness among those living with diabetes (n = 327).

	Unaware	Aware	OR for Diabetes Awareness (95% CI) [1]
	% (95% CI)	**% (95% CI)**	
Overall	29.5 (24.3, 35.2)	70.5 (64.8, 75.7)	
Gender			
Men	33.2 (25.0, 42.6)	66.8 (57.4, 75.0)	Ref
Women	25.1 (18.2, 33.6)	74.9 (66.4, 81.8)	1.4 (0.7, 2.9)
Age group			
20–39	45.8 (26.1, 66.8)	54.2 (33.2, 73.9)	Ref
40–59	29.9 (22.0, 39.2)	70.1 (60.8, 78.0)	2.2 (0.8, 6.4)
60+	18.2 (8.1, 35.8)	81.8 (64.2, 91.8)	3.6 (0.7, 18.1)
Education			
Elementary or less	24.4 (14.7, 37.7)	75.6 (62.2, 85.2)	Ref
Secondary	38.4 (25.4, 53.1)	61.6 (46.9, 74.6)	0.7 (0.2, 2.0)
High school or higher	24.7 (14.1, 40.0)	75.3 (60.4, 85.8)	1.2 (0.4, 3.9)
Socioeconomic status			
Low	30.1 (21.6, 40.1)	69.9 (59.9, 78.4)	Ref
Middle	27.6 (19.1, 38.0)	72.4 (62.0, 80.9)	1.1 (0.5, 2.4)
High	31.1 (20.1, 44.7)	68.9 (55.3, 79.8)	0.9 (0.4, 2.0)
Primary health care provider			
None	14.4 (5.3, 33.9)	85.6 (66.1, 94.7)	Ref
Public	27.0 (18.5, 37.7)	73.0 (62.3, 81.5)	0.3 (0.1, 1.2)
Private	45.5 (32.2, 59.4)	54.5 (40.6, 67.8)	**0.2 (0.1, 0.6)**

[1] OR and 95% CI estimated using a multivariate logistic regression model considering having a diabetes diagnosis among those living with diabetes as an outcome, adjusted by the variables listed in the table. **Bolds** indicate significant associations ($p < 0.05$).

In total, 85.8% (95% CI: 80.2, 89) of participants aware of their diabetes had access to health care. Of these, the proportion meeting LDL cholesterol, blood pressure and HbA1c targets was of 28.3% (95% CI: 22.4, 35.0), 44.9% (95% CI: 37.6, 52.5), and 29.0% (95% CI: 22.2, 37.0), respectively (Table 5). Among those receiving insulin, pills or both, 17.3% (95% CI: 6.1, 40.2), 31.7% (95% CI: 23.6, 40.0) and 6.4% (95% CI: 1.9, 19.8), respectively, met HbA1c target (data not shown). Among those receiving statins, 18.9% met the target for LDL cholesterol (data not shown), while 28.1% (95% CI: 19.4, 38.7) of those receiving medication to control their blood pressure met the blood pressure target (data not shown). In total, less than 5% of participants aware of their diabetes met the three treatment targets (Table 5).

Table 4. The proportion of participants aware of their diabetes meeting standards of diabetes care, across diabetes control categories.

Diabetes Quality of Care Indicators	Total (*n* = 297)	HbA1C < 7.0% (*n* = 81)	HbA1C > 7.0% (*n* = 216)	*p* Value [1]
Quality health care indicators				
Medical consultations (4–12 per year)	62.7 (55.2, 69.6)	52.8 (40.7, 64.6)	66.8 (57.9, 74.6)	0.056
HbA1C measurements (at least 2 per year)	5.5 (3.0, 9.7)	4.9 (1.8, 12.9)	7.6 (3.4, 16.2)	0.476
Glucose measurements (4–12 per year)	56.5 (48.2, 64.5)	58.5 (44.4, 71.3)	56.8 (47.5, 65.7)	0.841
Early detection of cardiovascular risk factors [2]				
Total cholesterol and triglycerides measurements	4.7 (2.3, 9.4)	6.0 (2.0, 17.1)	4.0 (1.7, 9.3)	0.543
Blood pressure measurements	3.6 (2.2, 5.8)	5.4 (1.9, 14.5)	4.1 (1.4, 11.6)	0.783
Screening for complications [2]				
Measurement of protein levels in urine	26.6 (19.5, 35.2)	20.6 (9.4, 39.4)	29.1 (20.5, 39.5)	0.371
Ophthalmological evaluation	16.5 (11.6, 23.1)	20.6 (12.1, 33.0)	14.8 (9.3, 22.7)	0.329
Feet examination	53.0 (44.7, 61.0)	38.1 (26.0, 51.8)	59.1 (49.6, 67.9)	0.010
Lifestyle recommendations by a physician				
Diet	71.3 (63.8, 77.7)	66.4 (52.4, 78.0)	73.3 (64.9, 80.3)	0.333
Physical activity	57.9 (51.9, 63.6)	45.7 (33.4, 58.6)	62.9 (55.5, 69.7)	0.033
Both	75.2 (69.1, 80.5)	69.8 (57.4, 79.8)	77.5 (70.6, 83.1)	0.214
Pharmacological treatment				
Diabetes treatment	86.0 (79.2, 90.9)	78.4 (65.3, 87.5)	89.2 (81.1, 94.1)	0.072
Insulin	9.5 (6.0, 14.9)	5.7 (2.3, 13.0)	11.1 (6.6, 18.2)	0.161
Pills	64.6 (57.0, 71.6)	70.1 (59.3, 79.1)	62.4 (52.8, 71.1)	0.246
Both (insulin and pills)	11.9 (8.0, 17.5)	2.6 (0.9, 7.6)	15.7 (10.3, 23.4)	0.001
High blood pressure treatment	78.9 (64.9, 88.3)	80.8 (49.8, 94.7)	78.2 (64.1, 87.8)	0.825
High cholesterol treatment	67.9 (51.0,81.1)	98.3 (86.9, 99.8)	56.7 (39.1, 72.8)	<0.001

Estimates were adjusted for complex survey design. [1] *p* value of a X2 test. [2] At least one during the previous year (self-reported).

Table 5. The proportion of participants aware of their diabetes and with access to care meeting treatment targets and treatment outcomes (*n* = 270).

	% (95% CI) [1]
Treatment targets	
LDL cholesterol < 100 mg/dLd	28.3 (22.4, 35.0)
Blood pressure < 130/80 mmHg	44.9 (37.6, 52.5)
HbA1c < 7%	29.0 (22.2, 37.0
Meeting three targets	4.1 (1.7, 9.5)
Treatment outcomes [2]	
Diabetic coma	98.6 (96.4, 99.5)
Cardiovascular disease	89.3 (83.5, 93.2)
Nephropathy	90.0 (83.0, 94.3)
Neuropathy	60.6 (52.2, 68.4)
Retinopathy	51.9 (45.0, 58.8)
No complications	35.4 (29.0, 42.0)

[1] Estimates (% and 95% CI) were adjusted for complex survey design. [2] Defined as not presenting the corresponding diabetes complication.

Regarding treatment outcomes (Table 5), most participants did not report having had a diabetic coma (98.6%, 95% CI: 96.4, 99.5), a cardiovascular disease (89.3%, 95% CI: 83.5, 94.3) or nephropathy (90.0%, 95% CI: 83.0, 94.3) caused by diabetes. More than half (60.6%, 95% CI: 52.2, 68.4) reported not having presented a diabetes complication related to neuropathy, and around half (51.9%, 95% CI: 45.0, 58.8) mentioned not having had eye damage (retinopathy).

The odds for meeting treatment targets among those aware of their diabetes across demographic characteristics are shown in Table 6. Participants in a higher age category had decreased odds (OR's ≈ 0.1–0.2) for meeting individual treatment targets (i.e., HbA1c and blood pressure) compared to those aged 20–39 years. Additionally, being a woman was associated with higher (OR = 2.8, 95% CI: 1.3, 6.1) and lower odds (OR = 0.4, 95% CI: 0.2, 0.9) for meeting HbA1c and LDL cholesterol targets, respectively, compared to men. Being from the middle socioeconomic status was associated with lower odds (0.4, 95% CI: 0.2, 0.9) for meeting LDL cholesterol target compared to the low socioeconomic status.

Table 6. Prevalence and odds for meeting treatment targets among participants aware of their diabetes, across demographic characteristics (n = 272).

	HbA1c < 7%		**LDL Cholesterol a < 100 mg/dL**		**Blood Pressure < 130/80 mmHg**	
	% (95% CI)	**OR (95% CI)**	**% (95% CI)**	**OR (95% CI)**	**% (95% CI)**	**OR (95% CI)**
Gender						
Men	20.3 (12.7, 30.8)	Ref	39.0 (29.2, 50.0)	Ref	46.6 (41.1, 63.5)	Ref
Women	35.9 (26.0, 47.1)	**2.8 (1.3, 6.1)**	20.1 (13.3, 29.2)	**0.4 (0.2, 0.9)**	43.3 (34.8, 51.4)	1.0 (0.5, 1.9)
Age group						
20–39	62.3 (39.9, 80.4)	Ref	26.9 (11.0, 52.5)	Ref	77.6 (55.2, 90.7)	Ref
40–59	23.4 (16.2, 32.6)	**0.1 (0.0, 0.3)**	30.4 (22.8, 39.2)	1.2 (0.3, 4.3)	40.7 (32.2, 49.8)	**0.2 (0.1, 0.7)**
60+	25.6 (16.8, 37.0)	**0.1 (0.0, 0.5)**	25.0 (15.4, 38.0)	1.1 (0.3, 4.3)	38.0 (27.2, 50.1)	**0.2 (0.1, 0.6)**
Education						
Elementary or less	26.2 (16.0, 38.5)	Ref	18.8 (12.1, 28.0)	Ref	38.4 (28.2, 49.7)	Ref
Secondary	33.8 (23.4, 46.10)	1.1 (0.4, 2.9)	26.7 (17.7, 38.2)	1.4 (0.6, 3.4)	52.5 (40.6, 64.2)	1.2 (0.6, 2.6)
High school or higher	28.3 (17.0, 43.2)	1.2 (0.5, 3.0)	42.5 (29.0, 57.2)	3.1 (0.9, 9.8)	44.9 (29.9, 60.9)	1.1 (0.4, 2.8)
Socioeconomic status						
Low	24.6 (13.4, 40.8)	Ref	31.3 (22.5, 41.7)	Ref	45.6 (35.6, 56.1)	Ref
Middle	26.3 (16.7, 38.9)	1.2 (0.4, 3.4)	22.4 (13.6, 34.7)	**0.4 (0.2, 0.9)**	45.4 (32.3, 59.2)	1.0 (0.4, 2.4)
High	38.1 (24.6, 54.7)	2.6 (0.9, 7.6)	32.3 (20.4, 47.0)	0.7 (0.2, 2.0)	42.7 (29.3, 57.2)	1.0 (0.4, 2.2)
Primary health care providera						
None	24.8 (13.8, 40.7)	Ref	23.5 (11.9, 41.1)	Ref	57.7 (37.6, 75.5)	Ref
Public	31.8 (23.8, 41.0)	1.8 (0.7, 5.0)	29.2 (20.3, 40.0)	1.9 (0.5, 6.9)	44.3 (33.8, 55.3)	0.7 (0.2, 2.0)
Private	23.9 (12.8, 40.3)	1.0 (0.3, 3.6)	29.5 (7.2, 45.96)	1.7 (0.4, 6.8)	33.7 (20.2, 50.5)	0.4 (0.1, 1.2)

Estimates were adjusted for complex survey design. **Bolds** indicate significant associations ($p < 0.05$).

4. Discussion

The results of our study indicated that 13.6% of participants were living with diabetes. In total, 70.5% of individuals with diabetes were aware of their condition, of which 85.8% reported having access to health care. Around 10% to 65% of those with a diabetes diagnosis and with access to care received complications screening and clinical assessments according to international guidelines, and between 30% to 60% achieved treatment targets for HbA1c, LDL cholesterol, or blood pressure. Overall, less than 5% aware of their diabetes achieved all treatment targets and 35% had never presented a diabetes complication.

These results are in line with national estimates indicating that around 13.7% of Mexican adults are living with diabetes [2]. Our results are also consistent with various reports that have identified an opposite relation between higher education and lower diabetes incidence [25,26,35]. Similarly, age has been previously identified as a positive correlate for diabetes [2,35]. Importantly, in Mexico City living with diabetes was negatively associated with having access to care, either public or private. One in three adults without access to health care lived with diabetes, placing them at higher risk for diabetes complications and highlighting the need to provide better health care access for all.

Recent reports using the rule of halves approach to describe diabetes epidemiology have shown a wide range of results [20,52]. For instance, in Copenhagen, a study reported a prevalence of diabetes of 5%, with only 1.1% undiagnosed cases; around 80–90% of those diagnosed with diabetes received adequate diabetes care, resulting in high rates (40–60%) of patients living with diabetes meeting treatment targets [20]. In India, evidence indicates that the epidemiology of diabetes tends to follow the rule of two-thirds, rather than halves [52]. Our results indicated that in Mexico City, indicators of diabetes awareness presented a better scenario than the one posed by the rule of halves care (i.e., proposing that half of the people living with diabetes are not aware of their condition) [20,22,53]. In line with national reports [2], the proportion of participants unaware of their diabetes in Mexico City was 30%. Importantly, our data suggest that having access to a health care provider does not correlate with improved diabetes awareness. Deficient implementation of the current programs for early diabetes detection and of the standards in medical care for diabetes established in clinical practice guidelines could be a factor that hampers diabetes awareness in Mexico City. These scenarios have been reported nationwide and in other Latin-American countries [54–57]. Despite recent efforts in Mexico to improve awareness and care of diabetes [13], this study indicates that stronger actions should be implemented to reinforce diabetes screening locally. First, targeted efforts to improve diabetes screening among health care providers, especially private health care, should be put in place, as the lowest rates of diabetes awareness were found among those with access to care. The use of diabetes screening tests has been proposed as a potential strategy to improve diabetes awareness among those with access to healthcare [58]. Second, massive detection campaigns could enhance early diabetes detection across the Mexican population, especially among those without health care. Previous experiences for HIV detection in the country could be used to inform local strategies to improve diabetes screening [59,60].

Although there is still room to reinforce diabetes awareness, improving management and quality of diabetes care are major challenges in Mexico City. Adequate diabetes management using standardized protocols can potentially prevent complications and premature mortality. According to national reports, in 2016 15.6% and 20.9% of people diagnosed with diabetes had received an HbA1c test or a feet examination, respectively, in the previous year, whereas only 4.8% had received an annual microalbuminuria test [2,35]. Our results indicate that in Mexico City the proportion of participants receiving screening tests may be lower. This study enriches the literature by investigating the prevalence of quality of care indicators across participants with controlled and uncontrolled diabetes, finding a higher prevalence of some indicators, such as medical consultation, feet examination, and physical activity recommendations, in adults with uncontrolled HbA1c values (<7.0). These unexpected results may be explained by reverse causality. That is, it is possible that instead of using diabetes care examinations as preventative measures for diabetes complications, physicians are using such approaches among those patients with worse diabetes control. This standpoint could be confirmed with the higher prevalence of complex treatment (both pills and insulin usage) and a greater time with a diabetes diagnosis (data not shown) observed in uncontrolled adults. Taken together, results suggest that in Mexico City early diabetes treatment recommendations are not being met. Instead, patients with a worse physiological deterioration derived from a long diabetes duration are treated using intensive pharmacological treatment by health professionals. Concerted efforts are urgently needed to provide educational opportunities for physicians and other health care providers regarding adequate diabetes management, as well as to empower patients with type 2 diabetes to be involved in their own care [61].

Regarding diabetes treatment targets, in line with national estimates [2], our results indicate that 1 in 3 patients aware of their diabetes met HbA1c targets. Additionally, our results also indicate that less than 5% of those aware of their diabetes met all treatment targets. This means that in Mexico City at least two-thirds of adults aware of their diabetes are at high risk of developing complications; this proportion may be higher among low socioeconomic individuals. In fact, our data indicate that around 50% and 40% of people aware of their diabetes had already presented diabetic retinopathy and diabetic neuropathy, respectively. Considering that national and local specific screening programs to address these conditions do not exist in Mexico as of 2021, this scenario represents an important challenge for Mexico City in terms of productivity and economy because of the heavy burden of disability and health costs diabetes complications produce [13,14]. eHealth approaches, such as telemedicine strategies and other available tools are relevant complements that must be taken into consideration by authorities to prevent and control diabetes complications. Evidence has shown how beneficial these instruments can be for the early detection and treatment of these conditions [62,63]. Multi-component integrated diabetes care is also effective in improving and maintaining treatment targets [64], and successful local experiences could inform new initiatives in the city and nationally [65].

In our study, women were more likely to meet HbA1c target compared to men. This could be explained by a greater engagement of women in self-care practices or greater usage of health services than men, as reported in previous evidence in Mexico and other countries [62]. For this reason, it is imperative to improve and create new strategies aimed at engaging men living with diabetes with the use of health services in Mexico City to reach their adequate diabetes control.

The results of this study should be interpreted with consideration of its limitations. First, although we used a representative sampling framework and the demographic characteristics of our sample are similar to those reported for Mexico City residents, our ability to explore outcomes among some groups of interests (i.e., older adults) was limited by the small sample size. Second, most of the information was self-reported. Therefore, some estimations might be biased because of residual confounding. This may be especially true for physical activity measures, given that social desirability bias has been related to over-reporting physical activity [66].

Our study also had strengths. To the author's knowledge, this is the first study to analyze diabetes awareness, treatment, and control in a representative sample of Mexico City residents. Although previous estimates for diabetes outcomes are available for Mexico City, mainly through the National Health and Nutrition Survey [2,35], to date no study had been able to investigate the distribution of diabetes outcomes among potentially vulnerable strata.

5. Conclusions

Despite diabetes awareness in Mexico City is better than what the rule of halves proposes, urgent actions are needed to improve diabetes treatment and control. Given the actual increasing trends in the health burden of diabetes, as well as recent public health situations related to COVID19, it is imperative to improve the health system in Mexico. Similar situations may be found in other highly urbanized and overpopulated cities. These findings may help other efforts to describe and address diabetes situation in similar contexts.

Supplementary Materials: The following are available online at https://www.mdpi.com/2673-4540/2/1/2/s1. Table S1: Mean concentration of biological indicators (*n* = 1307).

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