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Sex and age differences in prevalence and risk factors for prediabetes in Mexican-Americans

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ABSTRACT

Aims: Over 1/3 of Americans have prediabetes, while 9.4% have type 2 diabetes. The aim of our study was to estimate the prevalence of prediabetes in Mexican Americans, with known 28.2% prevalence of type 2 diabetes, by age and sex and to identify critical socio-demographic and clinical factors associated with prediabetes.

Methods: Data were collected between 2004 and 2017 from the Cameron County Hispanic Cohort in Texas. Weighted crude and sex- and age- stratified prevalences were calculated. Survey weighted logistic regression analyses were conducted to identify risk factors for prediabetes.

Results: The prevalence of prediabetes (32%) was slightly higher than the alarmingly high rate of type 2 diabetes (28.2%). Hispanic men had the highest overall (37.8%) and highest age stratified prevalence of prediabetes. Males had higher odds of prediabetes than females 1.56 (1.19, 2.06), controlling for the effect of family history of diabetes, age, BMI, and high-density lipoprotein. Family history of diabetes was a strong independent risk factor for prediabetes in all men, and in men and women in the age group 40–64 years. Elevated triglycerides ($p = 0.003$) was an independent risk factor for men and women in the age group 18–39 years.

Conclusions: Despite the very high prevalence of type 2 diabetes, prediabetes prevalence among Mexican Americans is only marginally less than national prediabetes rates. This suggests that progression to type 2 diabetes is more rapid and occurs earlier than nationally. Earlier screening and interventions for prediabetes, especially for men, are necessary to slow the transition to diabetes.

1. Introduction

Prediabetes can be envisaged as an approaching tsunami of disease [1]. Approximately 34% of the adults aged 18 years or older in the U.S. have prediabetes placing them at high risk of transition to type 2 diabetes [2] with approximately 5–10% converting annually [3,4]. Diabetes is associated with cardiovascular diseases, neuropathy, retinopathy, and other

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complications [5]. For many US ethnic groups, far more people have prediabetes compared to diabetes ranging between 8 and 13%. The prevalence of prediabetes and socio-demographic and clinical determinants of prediabetes have been examined across ethnic groups [6–16]. In U.S. the rates of prediabetes, defined by the American Diabetes Association 2010 definition, are consistently high with over 36% across non-Hispanic whites, African Americans, and over 37% in Mexican Americans/other Hispanics [16]. Age-adjusted national data for 2011–2014 indicated that 31.7% of Hispanics had prediabetes while only 7.5% of Hispanics reported awareness of prediabetes [2]. In addition, more Hispanic men (36.6%) than women (29.3%) had prediabetes [2]. These sex differences were also found elsewhere [10,12,17,18]. In the U.S., Hispanics constitute the largest and the fastest growing ethnic minority, within which those of Mexican origin are largest ethnic subgroup, and those with the highest prevalence of diabetes [19]. While previous analyses of the Cameron County Hispanic Cohort (CCHC) data have provided unique insight into the health issues faced by Mexican American populations including extremely high rates of obesity, type 2 diabetes, metabolic complications and other diseases [20–22], detailed examination of sex and age, and risk factors for prediabetes has not been reported in this population. Given the significant impediment posed by prediabetes to reducing the burden of diabetes, understanding the risk factors associated with prediabetes in this population is particularly important for targeting screening and intervention.

We conducted a cross-sectional study using enrollment data from the CCHC collected from 2004 to 2017 years. The aim of our study was to estimate the prevalence of prediabetes in Mexican Americans by age and sex and to identify critical socio-demographic and clinical factors associated with prediabetes.

2. Methods

2.1. Study population and data collection

The CCHC was initiated in Brownsville, Texas on the U.S./Mexico border in 2004 and now numbers >4800 participants aged 18 years or older [22]. Participants are recruited using two-stage stratified random sampling of U.S. census tracks and blocks, and households in the city of Brownsville, Texas. Consented participants received detailed clinical evaluations and responded to questionnaires in either Spanish or English at our Clinical Research Unit [22]. Participant data were collected by trained staff members at all visits according to standard CCHC protocols and were routinely entered into the database [22].

The institutional review boards at The University of Texas Health Science Center Houston reviewed and approved the protocol.

2.2. Definitions of prediabetes and type 2 diabetes

Prediabetes was defined by the American Diabetes Association (ADA) 2010 definition as any participant who did not have present or previously diagnosed type 2 diabetes, did not take any diabetes medications, and who had a HbA1c level of 5.7% to 6.4% or a fasting blood glucose level of 100 mg/dL to 125 mg/dL [23]. Participants were categorized to have type 2 diabetes based on the response to the question “Have you been told by a doctor or other health professional that you have diabetes?”, or if they were taking hypoglycemic medications, or their laboratory findings met the 2010 ADA definition, which includes HbA1c ≥6.5% and/or a fasting blood glucose >126 mg/dl [23]. We did not perform OGTT due to time and budget constraints.

2.3. Covariates

Sociodemographic and clinical variables considered in this study were sex, age in years, completed high school or higher education, employment, marital status, health insurance, hypertension, family history of diabetes, smoking status, alcohol consumption, physical activity, fruit and vegetable consumption, waist circumference, body mass index (BMI), high-density lipoprotein (HDL), low-density lipoprotein (LDL), total cholesterol, and triglycerides. Age was categorized into three groups: 18–39 years, 40–64 years, and 65 years or more. Alcohol consumption was defined based on the response to the question “Would you describe yourself as a person who never drinks alcoholic beverages or a person who sometimes drinks alcoholic beverages?”. Heavy drinking was defined based on reported >14 drinks per week for men, and more 7 drinks per week for women; and low or moderate drinking was defined based on reported 1–13 drinks per week for men, and 1–6 drinks per week for women [24]. Individuals with self-reported hypertension, currently taking antihypertensive medications, or with mean systolic blood pressure≥140 mm Hg or mean diastolic blood pressure ≥90 mm Hg were considered hypertensive. Readings of blood pressure were taken following standard protocols. Participants sat quietly for 5 min and then readings were taken three times 5 min apart using a Hawksley Random Zero sphygmomanometer. Diastolic blood pressure was determined at the 5th Korotkoff sound. The final pressure was based on the average of the 2nd and 3rd measurements. Waist circumference (WC) was measured at the level of the umbilicus with participants in a standing position and breathing normally, to the nearest 0.2 cm. Men with WC > 102 cm and women with WC > 88 cm were classified as having abnormal WC. BMI was calculated as weight in kilograms divided by height squared in meters (kg/m^2). BMI was categorized into normal weight (BMI < 25 kg/m^2), overweight (25 ≤ BMI < 30 kg/m^2), and obese (BMI ≥ 30 kg/m^2).

2.4. Laboratory methods

Fasting blood specimens were collected, processed and stored as previously described [22]. Specimens were sent to a Clinical Laboratory Improvement Amendments-approved (CLIA) laboratory for measurement of clinical chemistries and other blood estimations.

2.5. Statistical analysis

We conducted survey-weighted analysis of the study data. CCHC data were collected using two-stage stratified cluster sampling design in which the primary sampling units (PSUs) are the census tracts and blocks (clusters) and the secondary sampling units (SSUs) are the study participants within randomly selected PSUs [22]. We used the appropriate SAS SURVEY analysis procedures incorporating the design variables for sampling stratification by socio-economic status (SES) and clustering effects by census tracts and blocks and multiple participation from the same household; and considering the age- and sex- adjusted probability weights. The sampling weights are the product of the inverse probabilities of selection of each cluster within SES stratum and each participant within cluster and sex and age specific groups. Incorporating the sampling weights and design variables provides robustness against a misspecified model [25] and robust variance estimation [26]. The prevalence of prediabetes was calculated using all cohort participants. The analysis of prediabetes was conducted in the type 2 diabetes-free CCHC subpopulation, and by sex and age-defined groups within this subpopulation using the appropriate DOMAIN statement in the SURVEY procedures [26]. Unweighted frequencies and weighted percentages were generated to describe categorical variables and means and standard errors described continuous variables. Student's *t*-test [27] and Rao-Scott F adjusted chi-square test [28] were used to compare continuous and categorical variables, respectively. Independent factors associated with the presence of prediabetes were identified by multivariable weighted logistic regression models that were fitted with variables with p-value ≤ 0.10 from the bivariate analyses and controlling for potential confounders. We conducted rigorous multivariable regression analyses while following the regression modeling steps suggested by Hosmer DW et al. (2013) [29]. Crude and adjusted odds ratios (ORs) and their respective 95% confidence intervals (CIs) for prediabetes compared to individuals with normal glucose were estimated. Multicollinearity between the predictors in the models was assessed using bivariate Pearson and/or Spearman correlation coefficients, variance infraction factors, and examination of changes in the coefficient estimates along with the changes in their standard errors [30]. BMI and WC were highly correlated ($r = 0.89$, $p < 0.001$) and were evaluated in separate regression models. Potential two-way interactions were assessed by testing, one at a time, for non-zero regression coefficients at significance level $\alpha = 0.05$ of the arithmetic products of all pairs of variables included in the models. The best model was selected using Akaike information criterion (AIC) [31] and the area under the Receiver Operating Characteristic (ROC) curve, which provides a measure of the model's ability to discriminate between those subjects who have prediabetes versus those who do not [29]. Model's goodness of fit test was performed using SVYLOGITGOF command in STATA [26]. All statistical tests were two-sided and were performed at significance level of 0.05. All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc).

3. Results

3.1. *Prevalence of prediabetes*

From the total 3089 CCHC participants, available at the time of the analysis, 28.2% (95% CI: 25.7%, 30.8%) were identified as having type 2 diabetes and 32.0% (95% CI: 29.5%, 34.6%) had prediabetes (Fig. 1). Males had higher overall and age stratified

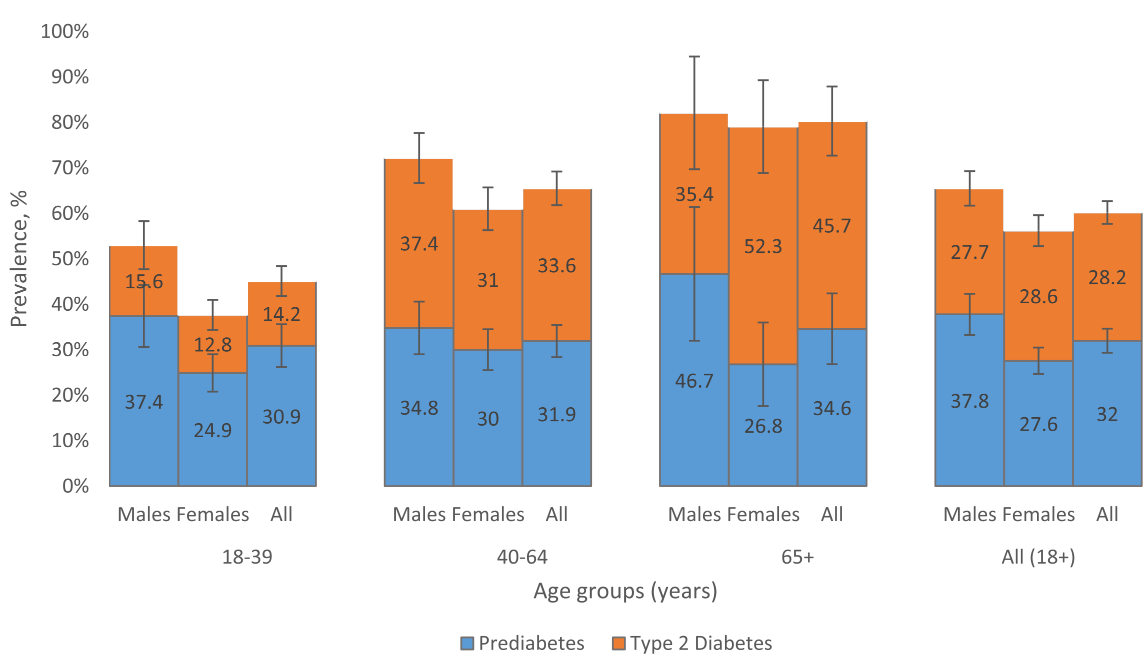

Fig. 1 – Weighted prevalence of prediabetes and type 2 diabetes with 95% confidence intervals according to sex and age groups, Cameron County Hispanic Cohort, 2004–2017. This figure shows that prevalence of prediabetes is above 34% across age groups for males. Overall and in all age groups, except 40–64 years, males have significantly higher prevalence of prediabetes than females. The prevalence of prediabetes is lower than the prevalence of type 2 diabetes in age groups 40–64 and 65 + years. The error bars represent 95% confidence intervals.

prevalence of prediabetes than females ($p < 0.001$) (Fig. 1). Younger men aged 18–39 years had higher prevalence of prediabetes (37.4%, 95% CI: 30.6%, 44.2%), compared to middle age men (34.8%, 95% CI: 29.4%, 40.1%) ($p < 0.001$), but lower prevalence than men aged 65 years or older (46.7%, 95% CI: 32.0%, 61.5%) ($p < 0.001$). In contrast, the highest prevalence of prediabetes (30.0%, 95% CI: 25.5%, 34.5%) ($p < 0.001$) in women was found in the middle age group (Fig. 1).

3.2. *Characteristics of the study population*

Table 1 provides the main socio-demographic, anthropometric and clinical baseline characteristics of the 2220 (71.8%) of type 2 diabetes-free individuals. There were high levels of obesity (44.5%) in the study population and across prediabetes and normal glucose groups (56.2% and 34.8% respectively). The mean age of the study population was 43.3 years but participants with prediabetes were older than participants with normal glucose levels (means 47.2 vs. 40.2). Females (56.4%) exceeded males overall, particularly in the normal glucose (62.4%) subgroup. More (46.9%) of the prediabetes population reported incomplete high school education compares with 40.1% of those with normal glucose levels. More than half of the study participants were employed (52.4%) with higher employment rate reported among subjects with prediabetes (55.8%). Having any form of health insurance was reported in 38.1% in subjects with prediabetes and 31.4% in subjects with normal glucose level.

3.3. *Factors associated with prediabetes in the study population*

Based on univariable weighted logistic regression analyses (Table 1) all variables with p-value $\leq$ 0.10 and potential confounders were further included in the multivariable weighted regression analyses. The two preliminary multivariable regression models included sex, age groups, employment status, type of health insurance, marital status, level of education, family history of type 2 diabetes, BMI groups or waist circumference, HDL, LDL, and triglycerides (Supplementary Table 1, Appendix). Since no interaction effect or confounding was detected with non-significant variables at significance level $\alpha = 0.05$, we excluded employment status, type of health insurance, marital status, level of education and LDL. A final multivariable regression model (Supplementary Table 2, Appendix) revealed that in the overall study population males compared to females remained at significantly higher odds of having prediabetes (OR = 1.70, 95% CI: 1.29, 2.24, $p < 0.001$), controlling for the effect of age, family history of diabetes, BMI, HDL, triglycerides, hypertension, level of education, and the interaction term of hypertension and level of education. In the same model, the odds of prediabetes in those aged 40–64 years (OR = 1.80, 95% CI: 1.36, 2.39. $p < 0.001$) and $\geq$ 65 years (OR = 3.35, 95% CI: 1.82, 6.15, $p < 0.001$), obese vs. normal BMI (OR = 2.44, 95%CI: 1.63, 3.66, $p < 0.001$), and participants with family history of diabetes (OR = 1.49, 95% CI: 1.14, 1.94, $p = 0.004$) remained significantly higher, controlling for the effect of all other covariates. The significant interaction effect between level of education and hypertension, indicated that individuals with hypertension and incomplete high school education had 1.62 (95% CI: 1.06, 2.50, $p = 0.03$) times higher odds of prediabetes compared to those with hypertension and completed high school or higher education. In a second model, evaluating abnormal waist circumference in the place of BMI, subjects with abnormal versus normal waist circumference had 1.86 (95% CI: 1.38, 2.51, $p < 0.001$) times higher odds of prediabetes, controlling for the effect of age, sex, family history of diabetes, HDL, triglycerides, systolic blood pressure, and level of education. In this model, lower HDL (OR = 0.99, 95% CI: 0.98, 0.999, $p < 0.001$) and higher systolic blood pressure (OR = 1.001, 95% CI: 1.00, 1.002, $p = 0.02$) remained significantly associated with the presence of prediabetes.

3.4. *Factors associated with prediabetes by sex*

Table 2 presents the results from the multivariable weighted logistic regression analysis of prediabetes by sex. Univariable weighted logistic regression analysis results are shown in Supplementary Table 3 in the Appendix. In the male population, aged 40–64 years ($p = 0.03$), aged $\geq$ 65 years ($p < 0.001$), obesity ($p = 0.02$), lower HDL ($p = 0.03$), and family history of prediabetes ($p = 0.02$) remained strong independent risk factors for prediabetes, controlling for the effect of systolic blood pressure, and triglycerides (Table 2). In the female population, aged 40–64 years ($p = 0.006$), aged $\geq$ 65 years ($p = 0.03$), obesity (<0.001), and systolic blood pressure ($p = 0.02$) were independent risk factors for prediabetes, controlling for the effect of the rest of the variables included in the model (Table 2). Based on the interaction between alcohol consumption and family history of diabetes, women who reported any alcohol consumption and family history of diabetes had 47% (OR = 0.53, 95% CI: 0.34, 0.83, $p = 0.005$) lower odds of prediabetes compared to those who reported no alcohol consumption and family history of prediabetes, controlling for the effect of the rest of the covariates (Table 2). In a smaller sample ($n = 367$) the drinking pattern (heavy, low or moderate, and no drinking) was not significantly associated with prediabetes in females.

3.5. *Factors associated with prediabetes by age groups*

Table 3 presents the results from the multivariable weighted logistic regression analysis of prediabetes by age groups. Univariable weighted logistic regression analysis results are shown in Supplementary Table 4 in the Appendix. Multivariable weighted logistic regression analysis in the age group 18–39 years showed that, males ($p = 0.005$), obese ($p < 0.001$), and individuals with higher levels of triglycerides ($p = 0.003$) had higher odds of prediabetes, controlling for the effect of family history of diabetes and LDL (Table 3). In the group aged 40–64 years, males ($p = 0.04$), incomplete high school education ($p = 0.008$), family history of diabetes ($p = 0.04$), and obese ($p = 0.004$) remained positively significantly associated with the presence of prediabetes, when adjusted for the effect of HDL and systolic blood pressure (Table 3). In the age group $\geq$ 65 years, in a bivariate analysis, we found that only not meeting the physical activity guidelines of 150 moderate and vigorous minutes per week (OR = 5.06, 95% CI: 1.24, 20.68) is significant risk factors for prediabetes.

Table 1 – Baseline socio-demographic, anthropometrics and clinical characteristics (SI units) of type 2 diabetes free study population (n = 2220) by prediabetes and normal glucose groups, Cameron County Hispanic Cohort, 2004–2017.

Characteristic	All (n = 2220)	Prediabetes (n = 971)	Normal glucose (n = 1249)	Crude Odds Ratio for Prediabetes	P value
Categorical variables	n (%) [a]	n (%) [a]	n (%) [a]	OR (95% CI) [b]	
Age groups (n = 2220)					
18–39 years	1066 (45.9)	340 (37.1)	726 (53)	reference	<0.001
40–64 years	978 (41.1)	528 (44.3)	450 (38.5)	1.70 (1.22, 2.22)	
$\geq$65 years	176 (13)	103 (18.6)	73 (8.5)	3.10 (1.91, 5.10)	
Sex (n = 2220)					
Male	770 (43.6)	378 (51.1)	392 (37.6)	1.73 (1.33, 2.27)	<0.001
Female	1450 (56.4)	593 (48.9)	857 (62.4)	reference	
Employment status [c] (n = 2218)					
Employed	1148 (52.4)	517 (55.8)	631 (49.7)	reference	0.07
Unemployed	1070 (47.6)	452 (44.2)	618 (50.3)	0.78 (0.60, 1.02)	
Country of birth (n = 2185)					
Mexico	1394 (58.2)	648 (60.3)	746 (56.5)	1.17 (0.87, 1.59)	0.31
USA	791 (41.8)	312 (39.7)	479 (43.5)	reference	
Level of education (n = 2218)					
Incomplete high school education	1102 (43.1)	520 (46.9)	582 (40.1)	1.32 (1.02, 1.71)	0.04
High school or higher education	1116 (56.9)	450 (53.1)	666 (59.9)	reference	
Annual household income (n = 1480)					
<$15,000	789 (49.5)	367 (51.8)	422 (47.5)	1.28 (0.86, 1.91)	0.68
$15,000 to 19,999	168 (11.7)	81 (11.6)	87 (11.8)	1.15 (0.66, 2.01)	
$20,000 to 29,999	198 (12.7)	82 (12.7)	116 (12.7)	1.18 (0.71, 1.95)	
>$30,000	325 (26.1)	140 (23.9)	185 (28.1)	reference	
Health insurance [d] (n = 2218)					
Insured	601 (34.4)	299 (38.1)	302 (31.4)	1.35 (0.96, 1.88)	0.08
Uninsured	1617 (65.6)	671 (61.9)	946 (68.6)	reference	
Marital status (n = 2216)					
Married	1349 (59.5)	624 (63.9)	725 (56)	1.39 (1.06, 1.83)	0.02
Single or divorced	867 (40.5)	346 (36.1)	521 (44)	reference	
Smoking[e] (n = 2220)					
Yes	789 (39.8)	336 (39.3)	453 (40.1)	0.97 (0.73, 1.28)	0.82
No	1431 (60.2)	635 (60.7)	796 (59.9)	reference	
Alcohol consumption[f] (n = 2217)					
Yes	1146 (55)	496 (53.6)	650 (56.1)	0.90 (0.70, 1.17)	0.14
No	1071 (45)	474 (46.4)	597 (43.9)	reference	
Drinking pattern (n = 708)[g]					
Heavy drinking	77 (11.8)	40 (9.1)	37 (14.3)	0.62 (0.32, 1.23)	0.32
Low or moderate drinking	253 (36.2)	115 (38.4)	138 (34.2)	1.10 (0.66, 1.84)	
No drinking	378 (52.0)	168 (52.5)	210 (51.5)	reference	
Met vegetable and fruit consumption $\geq$ 5 servings per day (n = 848)					
Yes	113 (14.8)	47 (11.6)	66 (17.5)	0.62 (0.36, 1.07)	0.09
No	735 (85.2)	320 (88.4)	415 (82.5)	reference	
Met physical activity guidelines of 150 moderate and vigorous minutes per week (n = 901)					
Yes	295 (35.7)	119 (29.2)	176 (41.8)	0.58 (0.39, 0.84)	0.004
No	606 (64.3)	309 (70.8)	297 (58.2)	reference	
Family history of type 2 diabetes [h] (n = 2220)					
Yes	1103 (47.3)	536 (54.6)	567 (41.5)	1.70 (1.30, 2.21)	<0.001
No	1117 (52.7)	435 (45.4)	682 (58.5)	reference	
BMI groups					
Normal (BMI < 25 kg/m^2)	428 (19.4)	113 (13.1)	315 (24.6)	reference	<0.001
Overweight (25 $\leq$ BMI < 30 kg/m^2)	765 (36.1)	303 (30.7)	462 (40.6)	1.42 (0.94, 2.13)	
Obese (BMI $\geq$ 30 kg/m^2)	1020 (44.5)	551 (56.2)	469 (34.8)	3.03 (2.02, 4.54)	
Hypertensive [i] (n = 2216)					
Yes	534 (24.8)	309 (32.2)	225 (18.9)	2.03 (1.49, 2.77)	<0.001
No	1682 (75.2)	660 (67.8)	1022 (81.1)	reference	
Abnormal waist circumference[j] (n = 2216)					
Yes	1489 (65.2)	732 (73.2)	757 (58.5)	1.94 (1.47, 2.56)	<0.001
No	727 (34.8)	237 (26.8)	490 (41.5)	reference	

(continued on next page)

Table 1 – (continued)

Characteristic Categorical variables	All (n = 2220) n (%) [a]	Prediabetes (n = 971) n (%) [a]	Normal glucose (n = 1249) n (%) [a]	Crude Odds Ratio for Prediabetes OR (95% CI) [b]	P value
Abnormal LDL[k] (n = 2198)					
Yes	1305 (57.6)	601 (63.4)	704 (52.9)	1.54 (1.18, 2.02)	0.002
No	893 (42.4)	357 (36.6)	536 (47.1)	reference	
Abnormal HDL[l] (n = 2207)					
Yes	1184 (49.5)	547 (52.9)	637 (46.9)	1.27 (0.96, 1.76)	0.09
No	1023 (50.5)	414 (47.1)	609 (53.1)	reference	
Abnormal triglycerides [m] (n = 2202)					
Yes	786 (36.1)	411 (42.3)	375 (31.2)	1.61 (1.16, 2.24)	0.004
No	1416 (63.9)	545 (57.7)	871 (68.8)	reference	
Continuous Variables	mean (SE)[n]	mean (SE)[n]	mean (SE)[n]	OR (95% CI) [b]	P value
Age, years (n = 2220)	43.3 (0.65)	47.24 (1.06)	40.15 (0.71)	1.03 (1.02, 1.04)	<0.001
Waist circumference, cm (n = 2216)	99.9 (0.44)	103.5 (0.62)	96.9 (0.55)	1.04 (1.03, 1.05)	<0.001
Diastolic blood pressure, mmHg (n = 2217)	71.3 (0.33)	72.9 (0.57)	70.1 (0.39)	1.03 (1.01, 1.04)	<0.001
Systolic blood pressure, mmHg (n = 2217)	115.5 (0.58)	119.2 (0.94)	112.4 (0.64)	1.03 (1.02, 1.04)	<0.001
BMI, kg/m^2 (n = 2213)	29.9 (0.19)	31.2 (0.29)	28.8 (0.24)	1.07 (1.05, 1.09)	<0.001
Triglycerides, mmol/L (n = 2202)	1.7 (0.04)	1.8 (0.06)	1.6 (0.05)	1.003 (1.001, 1.01)	<0.001
Total cholesterol, mmol/L (n = 2204)	4.8 (0.03)	4.8 (0.05)	4.7 (0.04)	1.002 (0.999, 1.005)	0.15
Low density lipoprotein (LDL), mmol/L (n = 2198)	2.8 (0.03)	2.9 (0.04)	2.8 (0.04)	1.002 (0.99, 1.01)	0.25
High density lipoprotein (HDL), mmol/L (n = 2207)	1.2 (0.01)	1.2 (0.02)	1.3 (0.01)	0.98 (0.97, 0.99)	<0.001
Fasting blood glucose, mmol/L (n = 2220)	5.3 (0.02)	5.6 (0.03)	5.0 (0.01)	1.19 (1.16, 1.21)	<0.001
Alanine aminotransferase, mmol/L (n = 2213)	0.7 (0.01)	0.7 (0.02)	0.6 (0.02)	1.006 (0.999, 1.01)	0.040
Aspartate aminotransferase, mmol/L (n = 2213)	0.6 (0.01)	0.6 (0.01)	0.6 (0.02	0.998 (0.992, 1.004)	0.56

Abbreviations: SE, standard error; OR, odds ratio; CI, confidence interval; BMI, Body Mass Index; LDL, low density lipoprotein; HDL, high density lipoprotein.

[a] Categorical variable are reported with unweighted frequencies and weighted percentages. Weighted percentages may not reflect the expected value due to designed based sampling weights.

[b] Unadjusted for other covariates weighted odds ratios for individuals with prediabetes versus individuals with normal glucose level and their respective 95% confidence intervals.

[c] Employed includes both full- and part-time employed.

[d] Health insurance includes both public and private coverage of any type.

[e] Defined as an affirmative response to: "Do you now smoke cigarettes, every day, some days, or not at all?".

[f] Defined as an affirmative response to: "Would you describe yourself as a person who never drinks alcoholic beverages or a person who sometimes drinks alcoholic beverages?".

[g] Heavy drinking: >14 drinks per week for men, and more 7 drinks per week for women; Low or moderate drinking: 1–13 drinks per week for men, and 1–6 drinks per week for women.

[h] Defined as an affirmative response to: "Did your father have diabetes or was high blood sugar diagnosed?", or "Did your mother have diabetes or high blood sugar diagnosed?", or "How many siblings had diabetes or high blood sugar diagnosed by a physician?".

[i] Defined as mean systolic blood pressure ≥ 140 mm Hg, or mean diastolic blood pressure ≥ 90 mm Hg, or currently taking antihypertensive medications.

[j] Defined as waist circumference > 102 cm for men cm and waist circumference > 88 cm for women.

[k] Defined as low density lipoprotein > 100 mg/dL.

[l] Defined as high density lipoprotein < 40 mg/dL for men, and < 50 mg/dL for women.

[m] Defined as triglycerides ≥ 150 mg/dL.

[n] Continuous variable are reported with weighted means and standard errors.

4. Discussion

Two findings are worth noting from this study including the difference in the prevalence of prediabetes and diabetes among Mexican Americans versus nationally, and the significant risk of prediabetes among Mexican American men. We found an overall prevalence of prediabetes of 32.0% in Mexican-American adults aged 18 years or older in this sample. This finding set alongside the previously reported diabetes prevalence in this sample of 28.2% [21] portrays a unique burden of disease compared to national rates. Nationally, it is common to find high rates of prediabetes but significantly lower type 2 diabetes rates [2]. For example, past research on nationwide-population representative data reported overall prevalence of prediabetes varying from 13.8% to 37.5%, while diabetes rates reported were varying from 14.3% to 34.4% [8–10,17]. Differences in the criteria of prediabetes, population grouping by age, and population ethnicity, and measured compared to self-reported make reported prevalences not fully comparable across different studies [32]. Our findings show a similar burden of prediabetes and type 2 diabetes and the reported increasing trend in the overall prevalence of prediabetes from younger to older age are similar to what has been previously reported for the

Table 2 – Weighted model based adjusted OR (95% CI) for prediabetes by sex groups in type 2 diabetes free study population (n = 2220), Cameron County Hispanic Cohort, 2004–2017.

Characteristic	Males (n = 770)		Females (n = 1450)	
	Model based Adjusted Odds Ratio (95% CI) for Prediabetes [a]	P value	Model based Adjusted Odds Ratio (95% CI) for Prediabetes [a]	P value
Age groups				
18–39 years	reference		reference	
40–64 years	1.67 (1.06, 2.62)	0.03	1.62 (1.15, 2.28)	0.006
≥65 years	4.22 (1.15, 9.90)	<0.001	2.19 (1.10, 4.39)	0.03
Level of education				
Incomplete high school education			1.05 (0.75, 1.47)	0.78
High school or higher education			reference	
Family History of type 2 diabetes [b]				
Yes	1.67 (1.12, 2.51)	0.02		
No	reference			
BMI groups				
Normal (BMI < 25 kg/m^2)	reference		reference	
Overweight (25 ≤ BMI < 30 kg/m^2)	0.98 (0.51, 1.87)	0.94	1.27 (0.80, 2.02)	0.31
Obese (BMI ≥ 30 kg/m^2)	2.52 (1.23, 5.17)	0.02	2.41 (1.55, 3.76)	<0.001
Abnormal triglycerides [c]				
Yes	1.21 (0.78, 1.88)	0.40		
No	reference		reference	
Systolic blood pressure, mmHg	1.21 (0.99, 1.02)	0.61	1.012 (1.002, 1.023)	0.02
Abnormal LDL [d]				
Yes			1.16 (0.82, 1.63)	0.40
No			reference	
HDL, mmol/L	0.977 (0.956, 0.997)	0.03		
Drinking [e] and with family history of diabetes [f]			0.53 (0.34, 0.83) [g]	0.005
Drinking [e] and with no family history of diabetes [f]			1.10 (0.71, 1.73) [g]	0.67

Abbreviations: CI, confidence interval; BMI, Body Mass Index; LDL, low density lipoprotein; HDL, high density lipoprotein.

[a] Empty cells indicate variables not included in the multivariable weighted logistic regression model.

[b] Defined as an affirmative response to: "Did your father have diabetes or was high blood sugar diagnosed?", or "Did your mother have diabetes or high blood sugar diagnosed?", or "How many siblings had diabetes or high blood sugar diagnosed by a physician?".

[c] Defined as triglycerides >=150 mg/dL.

[d] Defined as low density lipoprotein > 100 mg/dL.

[e] Defined as an affirmative response to: "Would you describe yourself as a person who never drinks alcoholic beverages or a person who sometimes drinks alcoholic beverages?".

[f] Reporting odds ratio for drinking status by the levels of the effect modifier family history of diabetes, based on the significant interaction effect found in the multivariable weighted logistic regression model for prediabetes in female subpopulation.

[g] Odds ratio estimated using CONTRAST statement in SAS PROC SURVEYLOGISTIC.

overall U.S. population [7,8,15]. The data from this population show the onset of obesity, metabolic syndrome and diabetes at an early age (<40 years), particularly in men. This observation would appear to be the process that allows for early onset of pre-diabetes but the same conditions that result in early onset of pre-diabetes also results in the early transition from pre-diabetes to type 2 diabetes. Consequently, we see higher levels of pre-diabetes than diabetes in those under 40 years of age but by the age over 40 years the preponderance of pre-diabetes has occurred with rapid progression to type 2 diabetes, and therefore the prevalence of pre-diabetes is lower in those over 40 years than type 2 diabetes prevalence. Metabolic health has not only a greater effect on the increased risk for type 2 diabetes [4] but our findings indicate that the entire process of the metabolic shift might be occurring faster in this population.

We found significant differences in rates of prediabetes by sex. Men had significantly higher overall prevalence of prediabetes of 37.8% compared with women, as high as the highest nationwide reported prevalence of prediabetes in Mexican Americans [2]; and the highest prevalence of prediabetes in men across all age groups. A similar phenomenon in men was observed in other studies conducted in US and abroad [10,12,17,18]. In both men and women the prevalence of prediabetes varied by age groups and these variations were reported by other national and international studies as well [11–13].

In the overall study population and men, in the age groups 18–39 and 40–64 years, were more likely to have prediabetes. Diaz-Redondo et al (2015) found differences in measured prediabetes between Spanish men and women [33]. However, in U.S.-Mexico border population based study, Díaz-Apodaca

Table 3 – Weighted model based adjusted OR (95% CI) for prediabetes by age groups[a] in the type 2 diabetes free study population (n = 2220), Cameron County Hispanic Cohort, 2004–2017.

Characteristic	Age 18–39 years (n = 1066)		Age 40–64 years (n = 978)	
	Model based Adjusted Odds Ratio (95% CI) for Prediabetes [b]	P value	Model based Adjusted Odds Ratio (95% CI) for Prediabetes [b]	P value
Sex				
Male	1.77 (1.19, 2.63)	0.005	1.47 (1.02, 2.11)	0.04
Female	Reference		reference	
Level of education				
Incomplete high school education			1.64 (1.14, 2.37)	0.008
High school or higher education			reference	
Family history of type 2 diabetes [c]				
Yes	1.31 (0.88, 1.94)	0.17	1.48 (1.02, 2.13)	0.04
No	reference		reference	
BMI groups				
Normal (BMI < 25 kg/m^2)	reference		reference	
Overweight (25 ≤ BMI < 30 kg/m^2)	0.91 (0.52, 1.58)	0.73	1.20 (0.68, 2.13)	0.53
Obese (BMI ≥ 30 kg/m^2)	3.31 (1.97, 5.55)	<0.001	2.29 (1.30, 4.05)	0.004
LDL, mmol/L	0.999 (0.993, 1.005)	0.78		
HDL, mmol/L			0.99 (0.97, 1.002)	0.11
Triglycerides, mmol/L	1.003 (1.001, 1.005)	0.003		
Systolic blood pressure, mmHg			1.01 (0.999, 1.002)	0.07

Abbreviations: CI, confidence interval; BMI, Body Mass Index; LDL, low density lipoprotein; HDL, high density lipoprotein.
[a] Multivariable weighted logistic regression model with significant variables was not found in age ≥ 65 years subgroup.
[b] Empty cells indicate variables not included in the multivariable weighted logistic regression model.
[c] Defined as an affirmative response to: "Did your father have diabetes or was high blood sugar diagnosed?", or "Did your mother have diabetes or high blood sugar diagnosed?", or "How many siblings had diabetes or high blood sugar diagnosed by a physician?".

et al. (2010) reported no difference in the presence of measured impaired fasting blood glucose between men and women [9], and in a study conducted in Florida, age and sex were not significantly associated with self-reported prediabetes [14]. Our study emphasized again the burden of poor health outcomes in the young Mexican-American male population, previously described as having high rates of elevated liver enzymes, dyslipidemia, obesity, abnormal cholesterol, smoking and drinking behavior [34]. Younger and middle age Mexican-American males, who were obese, with low HDL, and with family history of diabetes were shown to have higher prevalence of prediabetes. The independent association of high triglycerides levels with prediabetes is particularly strong in individuals aged 18–39 years and male population. We cannot say with our cross-sectional study if the triglyceride association is causal or a consequence of prediabetes. Another finding was that family history of diabetes was strong independent risk factor for prediabetes in the overall population and remained a significant independent risk factor in men only and among those aged 40–64 years. The results are consistent with previously reported familial clustering risk, which may be due to genetic and/or family shared socioecological factors, and/or their interaction [35].

Multivariable regression analysis identified a different set of independent risk factors for prediabetes in Mexican American women. Along with general and central obesity and le vel of education, systolic blood pressure was independently significantly associated with prediabetes. In the analysis conducted in women, we found a negative multiplicative interaction between alcohol consumption and family history of diabetes. Alcohol consumption was a significant protective factor for prediabetes in women based on the univariable analysis as well. This finding is controversial with numerous articles in the literature demonstrating a decreased risk of type 2 diabetes associated with light and moderate alcohol consumption [36,37] and heavy alcohol consumption having little or no effect on subsequent type 2 diabetes risk [37]. Others showed reductions in risk among moderate alcohol drinkers in women and non-Asian populations [36,38]. Although based on a minority of studies, there is a possibility that reductions in risk may have been overestimated by studies using a referent group contaminated by less healthy former drinkers [38]. Excessive alcohol consumption was associated with the appearance of abnormal glucose in men [33,36].

This study has some limitations. The cross-sectional nature of the study limits the causality interpretation. The study was conducted on a large sample size in the overall study population and in the sex- and age- defined groups 18–39 years and 40–64 years providing an adequate power to detect significant factors associated with prediabetes. However, the study may have lacked enough power to identify important covariates independently associated with prediabetes in the age group ≥ 65 years. Due to the lower response on the number of alcohol beverages servings question we were not able to evaluate the association of the number of alcoholic drinks with prediabetes in the entire study population.

5. Conclusions

Equally high rates of prediabetes and type 2 diabetes among a US Mexico border population already burdened with high rates of poverty and lower educational achievement raises the importance of public health and medical efforts to screen and intervene in a coordinated and comprehensive manner to slow the transition of prediabetes to type 2 diabetes. Our findings provide insight into who most specifically should be the focus of those efforts. Our results indicate that younger and middle-aged Mexican American individuals, in particular males, and those with high triglycerides, who are obese, with low HDL levels, hypertension, limited education, or family history of diabetes should be prioritized for screening and intervention. The evidence-based Diabetes Prevention Program is a gold standard program that has been shown to delay onset of diabetes [39] and could be part of the intervention approach. However, any efforts must ensure that they take into account the recruitment and retention and effectiveness for men. Research indicates that sex specific strategies are important in producing behavior change as the gender-neutral strategies [40]. While identifying criteria for individuals who should be prioritized is necessary for population strategies, it is also clear that critical risk factors associated with prediabetes overlap with risk factors associated with other obesity-related conditions and diseases in this population, such as metabolic syndrome and cardiovascular diseases. Therefore, promotion of lifestyle changes and treatment of related comorbid conditions such as hypertension, obesity and abnormal levels of HDL and triglycerides will also benefit the general population.

Findings from this study raise questions concerning socioecological, clinical, age and sex differences in Mexican American population. Longitudinal data should further explore population subgroups differences in conversion from normal status to prediabetes and from prediabetes to type 2 diabetes.

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Author contribution

Research idea and study design: KPV, BMR, MHR; CCHC data acquisition: JBM; statistical analysis KPV; interpretation: KPV, BMR, MHR, SFH; wrote the manuscript: KPV; reviewed/edited manuscript: BMR, MHR, SFH. Each author: provided intellectual content; contributed significantly to the preparation and/or revision of the manuscript; and approved the final version of the manuscript. KPV takes responsibility for the integrity of the data and the accuracy of the data analysis.

Declaration of Competing Interest

The authors declared that there is no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.107950.

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