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Prev Med. Author manuscript; available in PMC 2018 February 01.

Published in final edited form as:

Prev Med. 2017 February ; 95: 110–118. doi:10.1016/j.ypmed.2016.12.009.

Detecting Prediabetes among Hispanics/Latinos from Diverse Heritage Groups: Does the Test Matter? Findings from the Hispanic Community Health Study/Study of Latinos

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Conflict of Interest
The authors do not have conflicts to declare.

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Previous presentation: Analyses based on the first year of data collection were presented at the 71st American Diabetes Association Scientific Sessions in June 2011.

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Abstract

The objectives of this analysis were to compare the ability of fasting plasma glucose (FPG), post oral load plasma glucose (2hPG), and hemoglobin A_{1c} (HbA_{1c}) to identify U.S. Hispanic/Latino individuals with prediabetes, and to assess its cardiovascular risk factor correlates.

This is a cross-sectional analysis of baseline data from 15,507 adults without self-reported diabetes mellitus from six Hispanic/Latino heritage groups, enrolled in the Hispanic Community Health Study/Study of Latinos, which takes place in four U.S. communities. The prevalence of prediabetes was determined according to individual or combinations of ADA-defined cut points: FPG = 5.6–7.0 mmol/L, 2hPG = 7.8–11.1 mmol/L, and HbA_{1c} = 5.7%-6.4% (39–46 mmol/mol). The sensitivity of these criteria to detect prediabetes was estimated. The prevalence ratios (PRs) for selected cardiovascular risk factors were compared among alternative categories of prediabetes versus normoglycemia [FPG < 5.6 mmol/L and 2hPG < 7.8 mmol/L and HbA_{1c} < 5.7% (39 mmol/mol)].

Approximately 36% of individuals met any of the ADA prediabetes criteria. Using 2hPG as the gold standard, the sensitivity of FPG was 40.1%, HbA_{1c} was 45.6%, and that of HbA_{1c}+FPG was 62.2%. The number of significant PRs for cardiovascular risk factors was higher among individuals with isolated 2hPG = 7.8–11.1 mmol/L, FPG = 5.6–7.0 mmol/L + HbA_{1c} = 5.7%-6.4%, or those who met the three prediabetes criteria.

Assessing FPG, HbA_{1c}, and cardiovascular risk factors in Hispanics/Latinos at risk might enhance the early prevention of diabetes mellitus and cardiovascular complications in this young and growing population, independent of their heritage group.

Keywords

Prediabetic state; Hispanics; Latinos; hypertension; obesity; LDL cholesterol; triglycerides

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Introduction

Prediabetes or increased risk of diabetes mellitus is a term that refers to early states of abnormal glucose homeostasis including impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) [1,2]. IGT reflects inadequate postprandial insulin secretion [1,3], and is considered the earliest abnormality in glucose homeostasis that leads to the development of diabetes mellitus [3]. The oral glucose tolerance test (OGTT) detects IGT and is considered the gold standard test to detect diabetes mellitus [3]. IFG reflects increased hepatic glucose output, which leads to fasting hyperglycemia [2], and is assessed by fasting plasma glucose (FPG). Hemoglobin A_{1c} (HbA_{1c}) correlates directly with the preceding 2–3 month-mean plasma glucose levels, and has been shown to be elevated during states of intermediate glucose homeostasis [2–8].

In 2010, the American Diabetes Association (ADA) recommended cut points for the diagnosis of diabetes mellitus and prediabetes based on FPG, OGTT, and HbA_{1c} [9]. Although the tests and criteria recommended by the ADA are generally accepted, studies continue to report differences in sensitivity, variability, and reproducibility of HbA_{1c} [2–8], FPG [3,10], and OGTT [11–15]. For instance, HbA_{1c} has a direct association with glycemic levels, and has been shown to have a low intra-individual variability in the diabetes state [3]. However, some have reported that HbA_{1c} has high inter-individual variability, and that its expected correlation with mean plasma glucose levels has not been observed among different racial/ethnic groups [3,10,16–18].

These observations are relevant to the clinical care of Hispanics/Latinos. Like the rest of the nation, they have experienced an increased prevalence of diabetes mellitus, and are considered a group at high risk of diabetes mellitus [19]. Given their diverse ethnic/racial and sociocultural backgrounds, it would be clinically useful to examine whether current ADA screening criteria for prediabetes are comparable for Hispanics/Latinos of different heritage groups.

The analyses presented in this manuscript describe the prevalence of prediabetes among adults from six different Hispanic/Latino heritage groups who participated in the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) baseline examination. The prevalence of prediabetes was determined according to ADA diagnostic criteria across age, sex, and Hispanic/Latino heritage categories. The ability of FPG and HbA_{1c} to identify Hispanic/Latino individuals with prediabetes was compared using the 2h-post oral load plasma glucose (2hPG)-obtained during the OGTT- as the gold standard. Previous studies have suggested that prediabetes is associated with an increased burden of cardiovascular risk factors and increased risk of coronary heart disease among Hispanics/Latinos from specific heritage groups [20,21]. Thus, we also assessed the prevalence of selected cardiovascular risk factors according to individual prediabetes criteria and their combinations.

Subjects, Materials, and Methods

The HCHS/SOL study design and sampling design have been published elsewhere [22,23]. Briefly, the HCHS/SOL is a longitudinal, population-based study whose objectives include

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describing the prevalence of selected chronic diseases; identifying their risk and/or protective factors; and quantifying morbidity and mortality prospectively. From March 2008 to June 2011, 16,415 persons, aged 18–74 years at the time of screening, who self-identified with Central American, Cuban, Dominican, Mexican, Puerto Rican, and South American heritage groups were examined. Participants were recruited following a multi-stage probability sampling of the communities in San Diego, California; Chicago, Illinois; Miami, Florida; and the Bronx, New York. The study was approved by each of the Field Center's and the Coordinating Center's Institutional Review Board. All enrolled individuals provided signed informed consent. Approximately 93% of participants completed all baseline interviews and tests.

Interviews (including sociodemographic information, self-identified Hispanic/Latino heritage group, family history of diabetes mellitus, place of birth, and years living in the U.S.), phlebotomy, processing of biospecimens, and anthropometric measurements [including body mass index (BMI)] were performed by trained and certified staff following a standard protocol [22]. Place of birth was defined as born in the U.S. mainland (born in any of the 50 states), or born outside of the U.S. mainland. Further detailed information is available at http://www.cscc.unc.edu/hchs. Participants were asked to consume only water and necessary medications after 10 p.m. the night before the baseline visit, and to refrain from smoking or physical activity before undergoing the fasting examination procedures. The examination of pregnant women was postponed until three months postpartum. Individuals with other chronic diseases or health conditions were not excluded from the study. All participants had FPG and HbA_{1c} measured. After the initial venipuncture, those without self-reported diabetes mellitus and/or not taking antihyperglycemic medications and/or a FPG ≤ 8.4 mmol/L underwent a standard 75 g two-hour OGTT, and 2hPG was measured.

Plasma glucose, serum high-density lipoprotein-cholesterol (HDL-C), and serum triglycerides (TG) were measured using a Roche Modular P Chemistry Analyzer (Roche Diagnostics Corporation); urine albumin was measured using an immunoturbidometric method on the ProSpec nephelometric analyzer (Dade Behring GMBH, Marburg, Germany D-35041); and HbA_{1c} concentration was measured in EDTA whole blood using a Tosoh G7 Automated HPLC Analyzer. Low-density lipoprotein cholesterol (LDL-C) was not measured directly, but estimated using the Friedewald's formula when TG < 4.5 mmol/L.

Definition of prediabetes states

Using ADA criteria [1,9], participants without self-reported diabetes mellitus, who were not taking antihyperglycemic medications, or who did not have laboratory tests within the diabetes range were classified as having prediabetes [IFG if FPG = 5.6–7.0 mmol/L; and/or IGT if 2hPG = 7.8–11.1 mmol/L; and/or impaired HbA_{1c} if HbA_{1c} = 5.7–6.4% (39–46 mmol/mol)]; or as having normal glucose tolerance (NGT) [FPG < 5.6 mmol/L and 2hPG < 7.8 mmol/L and HbA_{1c} < 5.7% (39 mmol/mol)]. The total prevalence of prediabetes was defined as the percent of individuals who met at least one ADA diagnostic criterion.

A total of 16,415 individuals were enrolled and examined at baseline [24]. Individuals with missing diabetes mellitus screening laboratory data (n = 832), whose age was outside of the

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selected range (n = 9), or who were taking antihyperglycemic medications and did not report having diabetes mellitus (n = 67) were not included in the analysis. A total of 15,507 individuals had complete sets of relevant data for this analysis. Among these, 2,148 individuals reported having physician-diagnosed diabetes mellitus and 1,194 had unrecognized diabetes mellitus [25], and were excluded from the analysis.

Definition of Cardiovascular Risk Factors

Selected cardiovascular risk factors were defined based on current national guidelines [26–28]. Hypertension was defined as a systolic blood pressure ≥ 140 mm Hg, diastolic blood pressure ≥ 90 mm Hg, or receiving antihypertensive medications. Low HDL-C was defined as < 1.2 mmol/L in men and < 1.4 mmol/L in women; high LDL-C was defined as ≥ 3.4 mmol/L; high TG were defined as ≥ 1.7 mmol/L; high urine albumin/creatinine ratio (UACR) was defined as > 30 mg/g; and obesity was defined as a BMI ≥ 30 kg/m^2.

Statistical Analyses

All reported values were weighted by sampling weights using survey-specific procedures to account for the multi-stage sampling design, stratification, and clustering [29,30]. The sampling weights were calculated as the product of a “base weight” (reciprocal of the probability of selection) and three adjustments: (1) non-response adjustments made relative to the sampling frame, (2) trimming to handle extreme values (to avoid a few weights with extreme values being overly influential in the analyses), and (3) calibration of weights to the 2010 U.S. Census according to age, sex, and Hispanic/Latino heritage group. The age, sex, and Hispanic/Latino heritage distributions based on the sampling weighted estimates were very similar to the Census 2010 population within the target recruitment areas, with size of the differences below 0.45% in the majority of cases.

Prevalence of total prediabetes and its individual criteria was age-standardized to the 2010 U.S. Census population and reported as percentages with 95% confidence intervals (95% CI). Prevalence estimates were compared according to sex and age groups and Hispanic/Latino heritage group using multilog modeling based Wald Chi square test. P-values were reported for the sex and age group comparisons and the overall comparison across Hispanic/Latino heritage groups. A Venn diagram was constructed to illustrate the concordance and discordance among FPG-, HbA_{1c}-, and 2hPG-based categories.

Marginal logistic regression models were used to estimate the sensitivity and specificity of the diagnostic criteria for prediabetes. The OGTT has long been recognized as the gold standard test for the detection of early abnormalities of glucose homeostasis. However, because clinical evaluation of prediabetes is now most often based on FPG or HbA_{1c}, we were interested in comparing FPG, HbA_{1c}, and the combination of FPG and HbA_{1c} versus the 2hPG measured during the OGTT as the standard comparison. Age, sex, BMI, and Hispanic/Latino heritage group were added separately as covariates in the models to obtain strata-specific estimates of sensitivity and specificity.

We next examined the association between prediabetes and selected cardiovascular risk factors using separate Poisson regression models for each sex. In comparison with the reference group of NGT individuals, adjusted prevalence ratios (PRs) were estimated with

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95% CI. The Taylor series linearization approach was used to compute robust estimates of standard errors for the regression coefficients and confidence intervals for the PRs [31,32]. Individual cardiovascular risk factors were modeled for five prediabetes glycemic categories: isolated IFG (individuals with IFG + normal 2hPG + normal HbA_{1c}); isolated IGT (individuals with IGT + normal FPG + normal HbA_{1c}); isolated Impaired HbA_{1c} (individuals with Impaired HbA_{1c} + normal FPG + normal 2hPG); IFG + Impaired HbA_{1c} (individuals with IFG + Impaired HbA_{1c} + normal 2hPG)], and IFG + IGT + Impaired HbA_{1c}. These glycemic categories represent the spectrum of loss of glucose homeostasis in the prediabetes state. In addition, the first three categories represent different mechanisms of disease, and both FPG and HbA_{1c} tests are commonly assessed in clinical settings. The first three categories did not overlap. All categories were adjusted for age and Hispanic/Latino heritage group. To determine whether Hispanic/Latino heritage group modified the association between individual cardiovascular risk factors and glycemic category, an interaction term was included in each model and assessed using the likelihood ratio test.

Statistical tests were two-sided at a significance level of 0.05. Adjustments for multiple comparisons were not made. All analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC), SUDAAN release 10.0.0 (Research Triangle Institute, Raleigh, NC), and Stata version 14 (StataCorp, LP, College Station, TX).

Results

Forty-five percent (45.0%) of the target population was classified as having NGT, and 36.3% met any of the three prediabetes criteria [Table 1]. The total prevalence of prediabetes and by individual criterion (or combinations) varied by age and sex. Total IFG was consistently higher in men across age groups. The prevalence of total prediabetes and individual criteria were consistently higher among individuals with BMI ≥ 30 kg/m^2 compared to individuals with lower BMI. The prevalence of total prediabetes or individual criteria did not differ within each category of years living in the U.S. After stratifying by age group, the overall prevalence of prediabetes was similar between individuals born in the U.S. mainland born and those born outside of the U.S. mainland- aged 18–64 years- independent of years living in the U.S. [data not shown]. The prevalence of total prediabetes and its different criteria varied by Hispanic/Latino heritage group and between men and women within the same heritage group [Table 2]. Individuals of Dominican heritage had the lowest prevalence of prediabetes, total IFG, and total IGT. The prevalence of total Impaired HbA_{1c} [Impaired HbA_{1c} + (either normal FPG or IFG) + (either normal 2hPG or IGT)] and the combination of IFG + Impaired HbA_{1c}, or the combination of IFG + IGT + Impaired HbA_{1c} were similar among Hispanic/Latino heritage groups.

The concordance and discordance of the most prevalent prediabetes glycemic criteria or its combinations demonstrated that over a third of individuals – had isolated IFG, isolated IGT or isolated impaired HbA_{1c} [Figure 1]. Using 2hPG as the gold standard, FPG and HbA_{1c} showed low sensitivity and high specificity at detecting individuals within the prediabetes range overall and across Hispanic/Latino heritage groups [Table 3]. However, the sensitivity of the two tests combined increased, but the specificity decreased. The sensitivity of

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individual and combined tests increased with age and BMI, and was consistently higher for men.

After adjusting for age and Hispanic/Latino heritage group, individuals who met all prediabetes glycemic criteria had higher prevalence of most cardiovascular risk factors [Table 4]. In addition, differences in the sex-specific prevalence of cardiovascular risk factors were observed. Overall, women had a greater prevalence of obesity and low HDL-C while men had a greater prevalence of high LDL-C and high TG across most glycemic categories.

Adjusted prevalence ratios of the selected cardiovascular risk factor were estimated separately for all men and women [Figures 2 and 3]. Because the overall prevalence of high UACR was low [Table 4], prevalence ratios were not estimated for this risk factor. Both men and women within each prediabetes category had significant prevalence ratios for obesity and high TG (except men with Isolated impaired HbA_{1c}). Within the Isolated IFG, Isolated IGT, Isolated impaired HbA_{1c}, and the IFG+IGT+Impaired HbA_{1c} categories, the number of significant prevalence ratios varied between men and women. Both men and women with IFG+Impaired HbA1c+normal 2hPG or the three glycemic criteria had higher prevalence ratios than those in other categories.

Subgroup analyses showed that Hispanic/Latino heritage group significantly modified the association between isolated IFG and high TGs in women (P= 0.007) and obesity in men (P=0.037); Isolated IGT and hypertension in women (P=0.023) and high LDL-C in men (P=0.001); Isolated impaired HbA_{1c} and low LDL-C in women (P=0.006); IFG + Isolated impaired HbA_{1c} + normal 2hPG and low HDL-C (P=0.002) and obesity (P=0.026) in women; and the IFG + IGT + Impaired HbA_{1c} and hypertension (P= 0.006), high TGs (P<0.001), and obesity (P=0.031) in women [data not shown]. The associations of IFG + isolated Impaired HbA_{1c} + normal 2hPG and IFG + IGT + Impaired HbA_{1c} with these cardiovascular risk factors were stronger among individuals of South American heritage [data not shown].

Discussion

Using the three diagnostic criteria for prediabetes recommended by the ADA, 36.3% of Hispanic/Latinos from six heritage groups met at least one criterion for prediabetes. The prevalence of total prediabetes and its glycemic subcategories varied among heritage groups. The combination of FPG and HbA_{1c} was more sensitive, but less specific, than FPG or HbA_{1c} alone at identifying individuals with prediabetes in every Hispanic/Latino heritage group. In addition, individuals with IFG and impaired HbA_{1c} or who met the three glycemic criteria had a greater prevalence of cardiovascular risk factors than those with other prediabetes criteria.

Few studies have examined the prevalence of prediabetes and its diagnostic criteria among different Hispanic/Latino heritage groups in the U.S. In 1991, a report based on the Hispanic Health and Nutrition Examination Survey (Hispanic HANES) demonstrated differences in the prevalence of IGT among Mexican Americans, Cubans, and Puerto Ricans [33]. Other

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reports have been based on the National Health Examination and Nutrition Survey (NHANES) [34,35] and the Insulin Resistance Atherosclerosis Study [6], in which Hispanics/Latinos are mostly or entirely of Mexican or Mexican-American descent. To the best of our knowledge, the analyses here presented constitute new data pertaining to identification of prediabetes that had not been described and compared before in a large sample of U.S. Hispanic/Latino adults of diverse heritage groups.

The latest estimate of the multivariable-adjusted prevalence of prediabetes in the U.S. overall population was 34.3% [95% CI, 32.7–35.9], and was based on IFG or HbA_{1c} in the 5.7–6.4% (39–46 mmol/mol) range measurements collected in the NHANES [34]. In the same report, the prevalence among Mexican-Americans in NHANES was 37.8% [95% CI, 33.9–41.7]. The prevalence based on IFG or HbA_{1c} in the 5.7–6.4% range in the entire HCHS/SOL sample was 30.7% [95% CI, 29.7–31.8], and 31.7% [95% CI, 29.9–33.5] among individuals of Mexican heritage [data not shown]. Differences between the NHANES and HCHS/SOL findings may be explained by differences in sampling methodology and weights, age standardization, and laboratory methodology, among other factors.

Some of the analyses presented in this manuscript demonstrate similarities to previous reports. The observed higher prevalence of IFG among men, and a tendency towards higher prevalence of IGT in women in HCHS/SOL have been previously reported in Hispanics/Latinos and other populations [6,19,36–39]. Also, the observed low sensitivity of HbA_{1c} as a sole test to detect prediabetes is consistent with previous analyses in Hispanics and non-Hispanics [4,6]. Similarly, the increased sensitivity of HbA_{1c}+FPG with increasing BMI, and the increased sensitivity of HbA_{1c}+FPG compared to HbA_{1c} alone observed in HCHS/SOL have been previously reported [7,8,35,39,40].

Conversely, some of our findings differ from previous reports. Contrary to previous studies [4,6,36], HbA_{1c} in the range of 5.7%-6.4% (39–46 mmol/mol) was the most prevalent of the prediabetes criteria in HCHS/SOL. Approximately 85% of HCHS/SOL individuals with Isolated impaired HbA_{1c} had HbA_{1c} 5.7%-6.0% (39–42 mmol/mol), that is, in the lower level range [data not shown]. The high prevalence of Impaired HbA_{1c} may be due in part to high intra-individual variability of HbA_{1c} in the prediabetes state [3] or observed differences across heritage groups [41]. Also, hematologic factors known to alter HbA_{1c} concentration – such as hemoglobin variants, hemoglobinopathies, erythrocyte glucose uptake, hemoglobin, and serum iron levels– may explain elevated HbA_{1c} levels, but these were either not examined in the HCHS/SOL or not included in these analyses.

Our findings also have some potential clinical applications. In our study, 23% of men and 16% of women aged 18–29 years and 40% of men and 30% of women aged 30–39 years met at least one prediabetes criterion. Although the ADA recommended age cut point for screening for diabetes mellitus is 45 years [1,42] our data suggest that screening for diabetes mellitus in Hispanics/Latinos at a much younger age may identify individuals who would benefit from preventive interventions earlier in life. Using FPG and HbA_{1c} –versus either test alone– would increase the chances of identifying those at higher risk. Since the prevalence of prediabetes was similar between U.S.-born and foreign-born Hispanics/Latinos, independent on the number of years living in the U.S., we may expect that those

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who have recently migrated would also benefit from earlier screening and interventions to prevent or delay diabetes mellitus, and that public health efforts to prevent diabetes mellitus are equally important abroad.

The association between some prediabetes glycemic abnormalities and the risk of developing diabetes mellitus or fatal and non-fatal cardiovascular disease (CVD) has been described in some Hispanic/Latino groups [13, 20, 43–48]. Non-glycemic cardiometabolic abnormalities may precede the onset of overt diabetes mellitus [21,49]. It has also been suggested that the burden of cardiometabolic abnormalities in the prediabetes state may explain the increased risk for CVD documented in women of Mexican descent with diabetes [21]. In our study, the prevalence of prediabetes glycemic categories varied across Hispanic/Latino heritage groups. However, each prediabetes glycemic criteria or combination was associated with a significant prevalence of various cardiovascular risk factors in both men and women. Some of the associations between glycemic category and cardiovascular risk factors were modified by Hispanic/Latino heritage group, which may be partly attributed to variations in the duration of the glycometabolic dysregulation, anthropometric and nutritional characteristics, genetics, medications or comorbidities, among other factors. It is important to underline that future risk for the development of diabetes mellitus or CVD or how baseline risk factors relate to future CVD across Hispanic/Latino heritage groups cannot be fully determined through a cross-sectional analysis. And currently available cardiovascular risk score equations do not account the racial and ethnic heterogeneity of Hispanics/Latinos [50]. Since the HCHS/SOL has started a second examination the cardiovascular risk associated with each prediabetes criteria will be evaluated in the future.

Although the HCHS/SOL is not a nationally representative sample, the selected communities are located within four of the eleven U.S. metropolitan areas with the largest number of Hispanics/Latinos. Four of the five largest Hispanic/Latino heritage groups are represented in the study, with significant representation of other groups, thus reflecting the contemporary U.S. Hispanic/Latino population. The cohort's large sample size and availability of FPG, OGTT, and HbA_{1c} measurements provide adequate power for carrying out diverse cross-sectional analyses. Like in the NHANES [33,34], the prevalence of prediabetes in our cohort was assessed based on one set of laboratory tests. One-time measurements with potentially variable reliability and repeatability may lead to under- or overestimation of intermediate glycemic abnormalities [51]. Those who met only one of the three criteria would have needed confirmatory tests, as recommended by the ADA [1], but these were not performed in the study.

Conclusions

Over a third of adult U.S. Hispanics/Latinos from diverse heritage groups meet at least one ADA criterion of prediabetes, and the percent of those younger than age 45 merits attention. Since FPG, OGTT, and HbA_{1c} represent different aspects of glucose homeostasis, performing more than one of these tests (at least FPG and HbA_{1c}) and assessing other cardiovascular risk factors should be considered in the clinical evaluation of individuals at risk. Raising awareness on the effectiveness of a physically active lifestyle, improved nutrition and pharmacotherapy (when needed) in delaying the onset of diabetes [52],

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working around individual and cultural paradigms influencing the success of these interventions, and exploring research opportunities to prevent diabetes mellitus and its complications in this young, diverse and growing population should continue.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Thanks: The authors thank the more than 250 staff members across Field Centers, whose dedication and ceaseless energy made the recruitment and baseline examination a success; and the over 16,000 participants who believed in making a difference. *Gracias a ustedes, el Estudio SOL continúa.*

Funding

The first phase of the Hispanic Community Health Study/Study of Latinos was carried out as a collaborative study supported by contracts from the National Heart, Lung, and Blood Institute (NHLBI) to the University of North Carolina (N01-HC65233), University of Miami (N01-HC65234), Albert Einstein College of Medicine (N01-HC65235), Northwestern University (N01-HC65236), and San Diego State University (N01-HC65237). The following NIH Institutes/Offices collaborated and co-funded the first phase of the study: the National Institute on Minority Health and Health Disparities; the National Institute on Deafness and Other Communication Disorders; the National Institute of Dental and Craniofacial Research; the National Institute of Diabetes, Digestive and Kidney Diseases; the National Institute of Neurological Disorders and Stroke; and the NIH Office of Dietary Supplements.

Role of Funding Source

The NHLBI proposed the initiative and overall study design, issued the request for proposals and has provided oversight of the study conduct.

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HIGHLIGHTS

- Over a third of U.S. Hispanic adults are at increased risk for diabetes mellitus.
- A significant percent of individuals younger than age 45 met prediabetes criteria.
- FPG plus HbA_{1c} were more sensitive at detecting prediabetes than either test alone.
- Cardiovascular risk factors were highly prevalent across prediabetes categories.
- Cardiovascular risk factors were highly prevalent in both men and women.

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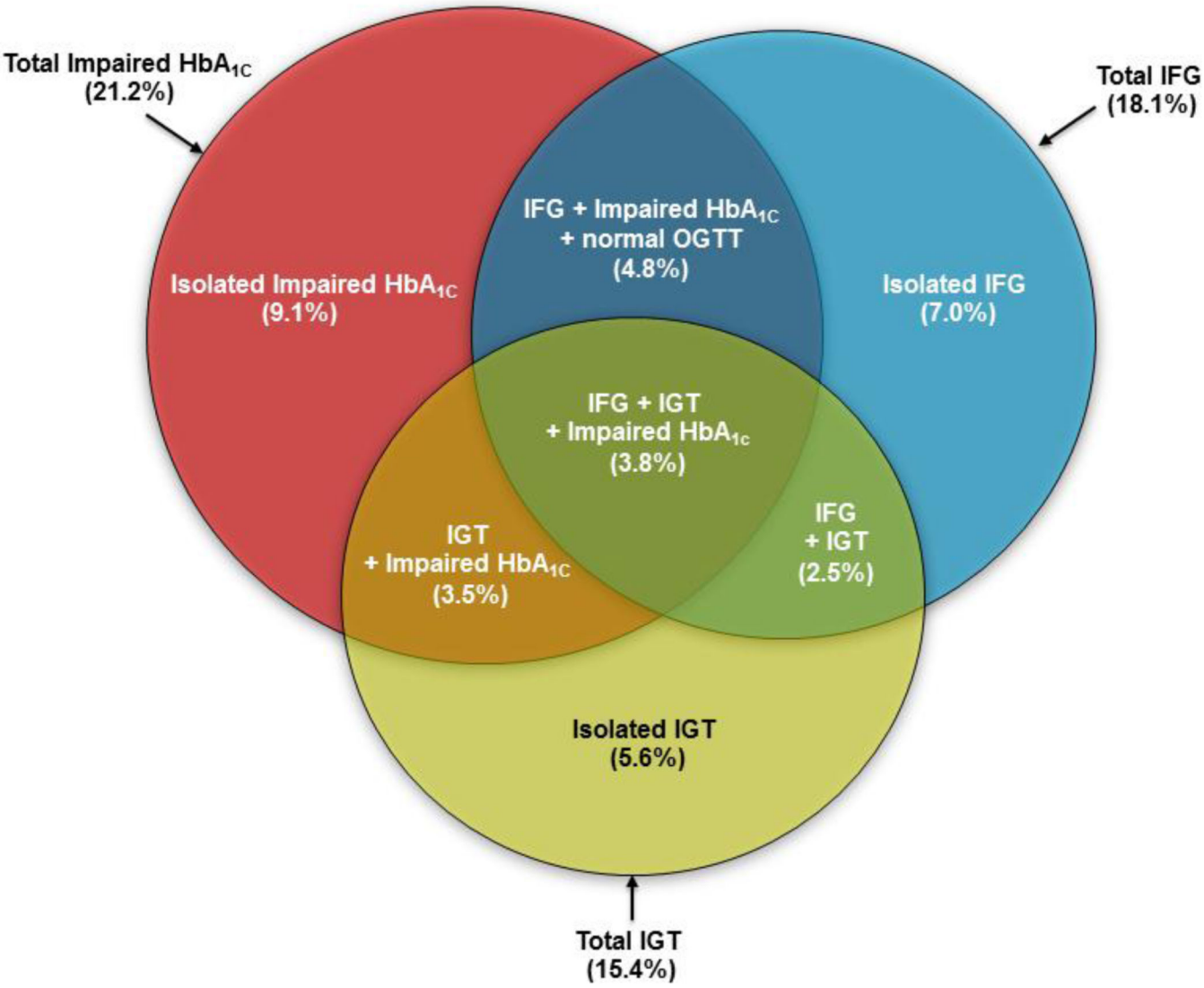

Figure 1. Venn Diagram of the Distribution of Pre-Diabetes Glycemic Criteria

The percentages are based on n = 15,507. (Baseline HCHS/SOL study data, 2008–2011) **Total IFG** = IFG + (either normal 2hPG or IGT) + (either normal or impaired HbA_{1c}); **Total IGT** = IGT + (either normal FPG or IFG) + (either normal or impaired HbA_{1c}); **Total Impaired HbA_{1c}** = Impaired HbA_{1c} + (either normal FPG or IFG) + (either normal 2hPG or IGT); **Isolated IFG** = IFG + normal 2hPG + normal HbA_{1c}; **Isolated IGT** = IGT + normal FPG + normal HbA_{1c}; **Isolated HbA_{1c}** = Impaired HbA_{1c} + normal FPG + normal 2hPG. The three main glycemic categories showed considerable overlap. Over half of individuals with Impaired HbA_{1c} (57%), IFG (61%) and IGT (64%) had them combined with at least another glycemic abnormality. Almost 4% of the target population (or 10% of the population with prediabetes) met all three prediabetes glycemic criteria.

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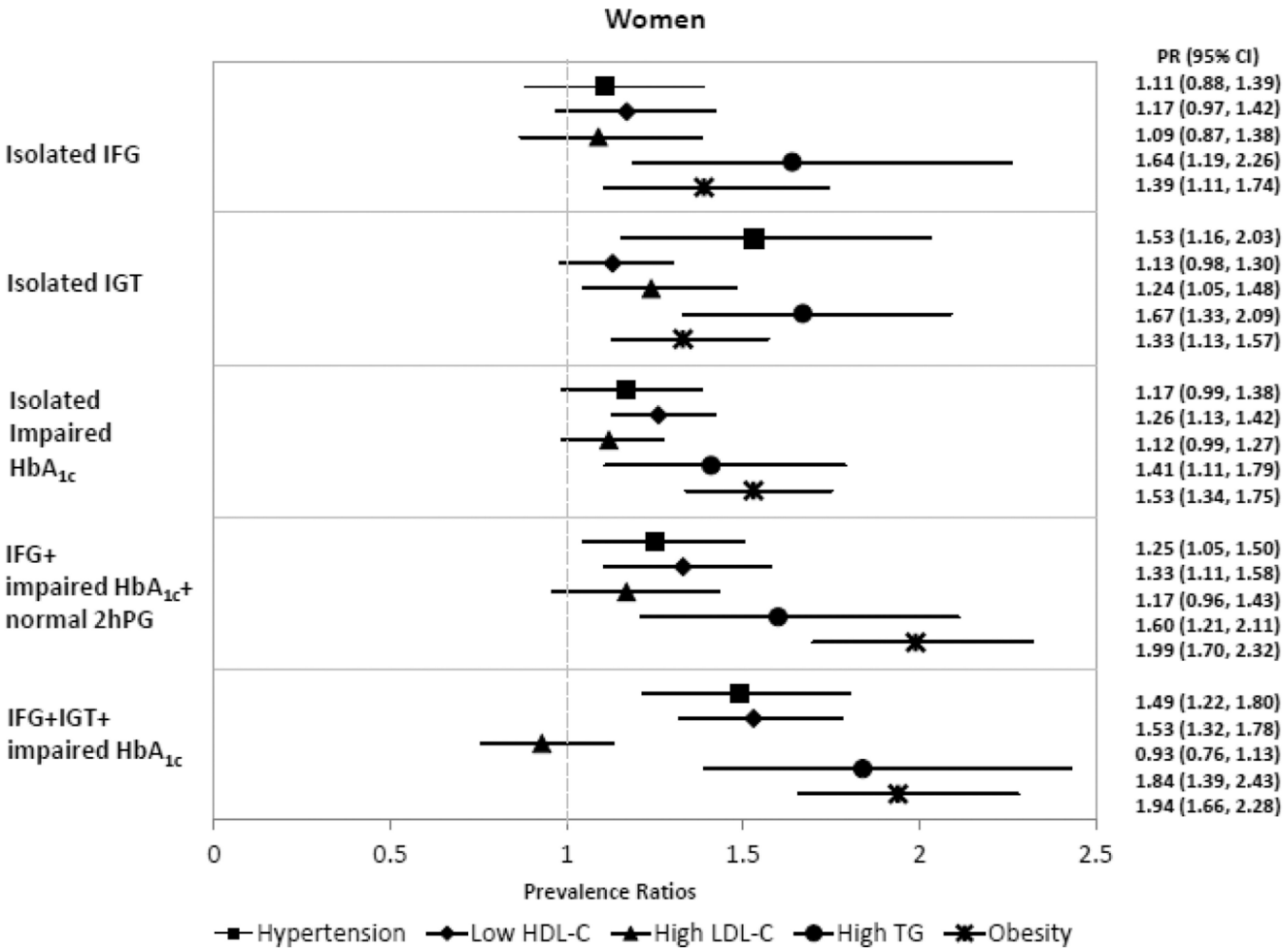

Figure 2. Adjusted Prevalence Ratios of Selected Cardiovascular Risk Factors by Glycemic Category

Prevalence ratios were weighted and adjusted for age and Hispanic/Latino heritage group. (Baseline HCHS/SOL study data, 2008–2011).

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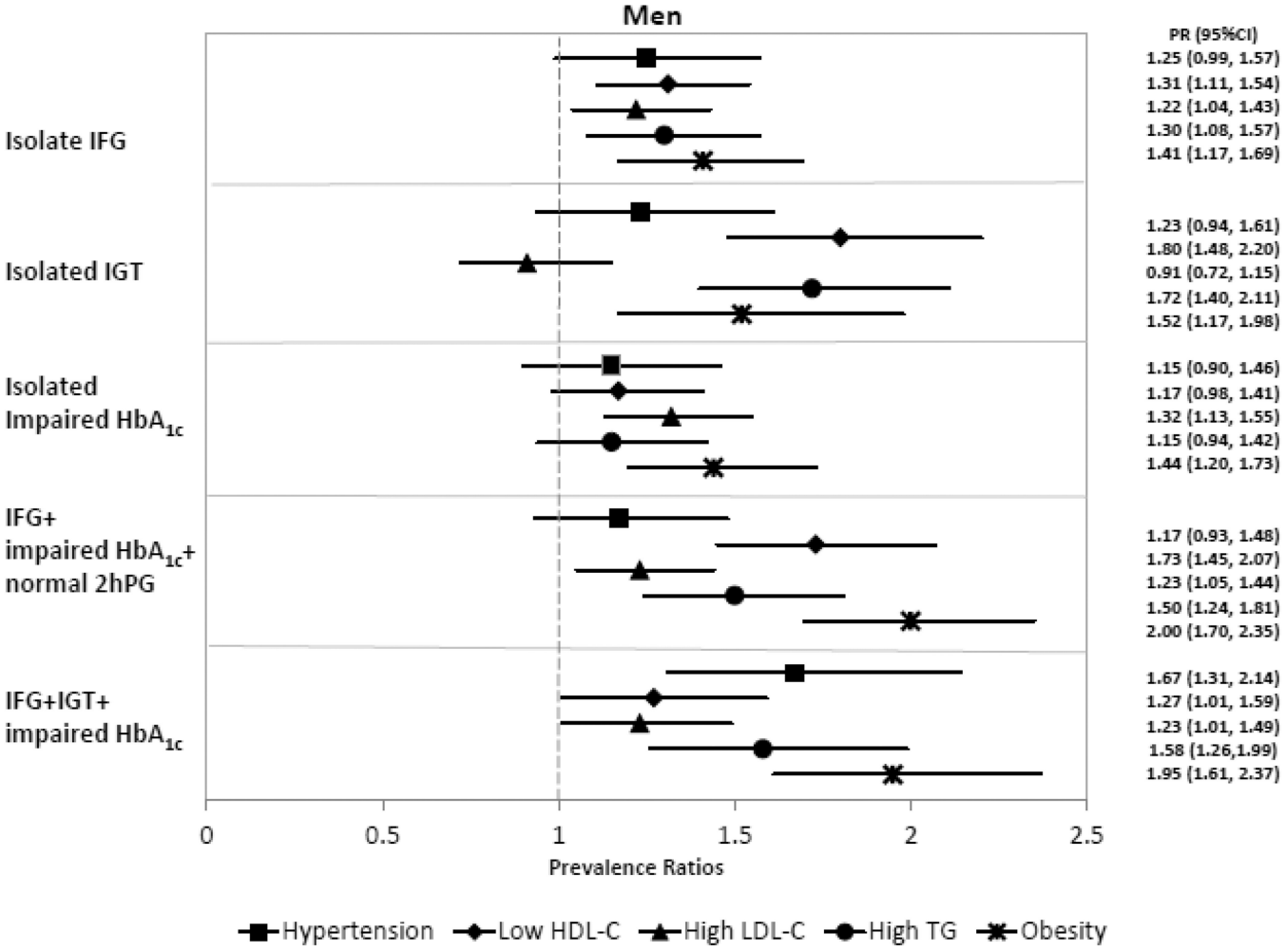

Figure 3. Adjusted Prevalence Ratios of Selected Cardiovascular Risk Factors by Glycemic Category

Prevalence ratios were weighted and adjusted for age and Hispanic/Latino heritage group. (Baseline HCHS/SOL study data, 2008–2011).

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Table 1

Prevalence of prediabetes glycemic categories by age, sex, BMI, and years living in the U.S.

		Total Prevalence of Prediabetes	Total IFG	Total IGT	Total Impaired HbA_{1c}	IFG + Impaired HbA_{1c}	IFG + IGT + Impaired HbA_{1c}
N		5836	2694	2568	3683	1422	662
Percent of the target population (%)		36.3 (35.2–37.4)†	18.1 (17.2–19.1)†	15.4 (14.6–16.3)†	21.2 (20.3–22.1)	8.6 (8.0–9.2)	3.8 (3.4–4.2)
Mean age (years)		43.5 (43.4–43.6)	43.4 (43.3–43.6)	43.7 (43.4–43.9)	43.6 (43.4–43.7)	43.6 (43.3–44.0)	43.7 (43.3–44.0)
Prevalence by sex							
Men	All	39.3 (37.7–40.9)*	24.7 (23.3–26.2)*	14.0 (12.9–15.3)*	21.4 (20.1–22.7)	10.8 (9.8–11.8)*	4.3 (3.6–5.1)
Age group (years)	18–29	22.6 (19.8–25.7)*	15.4 (13.1–18.1)*	5.6 (4.0–7.8)	7.6 (6.1–9.4)	2.9 (1.9–4.3)	1.3 (0.7–2.4)*
	30–39	39.7 (35.6–44.0)*	26.1 (22.5–30.1)*	9.2 (7.1–11.9)*	18.3 (15.1–22.0)	7.9 (5.9–10.4)*	1.5 (0.9–2.6)
	40–49	49.4 (45.9–52.9)*	31.0 (27.7–34.6)*	16.5 (14.0–19.4)	29.4 (26.4–32.6)*	14.5 (12.4–17.0)*	5.3 (3.9–7.1)
	50–59	46.9 (43.7–50.1)	27.7 (24.8–30.9)*	18.5 (16.1–21.1)	28.8 (26.1–31.6)*	14.9 (12.8–17.2)*	5.4 (4.1–7.1)
	60–69	41.8 (37.4–46.3)	25.4 (21.7–29.5)*	21.7 (17.8–26.1)	27.6 (23.7–32.0)*	16.0 (13.0–19.7)	8.7 (6.4–11.6)
	70–74	41.5 (31.5–52.3)	24.6 (17.0–34.2)	26.0 (18.0–35.9)	21.9 (14.8–31.1)	14.2 (8.5–22.8)	9.3 (4.8–17.4)

		Total Prevalence of Prediabetes	Total IFG	Total IGT	Total Impaired HbA_{1c}	IFG + Impaired HbA_{1c}	IFG + IGT + Impaired HbA_{1c}
Women	All	33.4 (31.9–34.8)*	12.0 (11.1–13.1)*	16.8 (15.6–18.0)*	20.8 (19.6–22.1)	6.6 (6.0–7.3)*	3.4 (2.9–3.9)
Age group (years)	18–29	16.1 (13.3–19.3)*	6.4 (4.6–8.9)*	7.8 (6.1–9.9)	5.6 (4.4–7.2)	2.0 (1.1–3.4)	0.3 (0.1–0.7)*
	30–39	29.7 (26.2–33.4)*	8.5 (6.8–10.5)*	15.2 (12.6–18.2)*	14.9 (12.4–17.8)	3.0 (2.2–4.2)*	1.5 (1.0–2.4)
	40–49	37.1 (34.5–39.8)*	13.2 (11.5–15.2)*	18.5 (16.4–20.7)	21.8 (19.7–24.2)*	6.7 (5.5–8.2)*	3.4 (2.5–4.6)
	50–59	45.4 (42.1- 48.9)	16.4 (14.4–18.6)*	20.1 (17.3–23.2)	33.8 (30.6–37.2)*	11.0 (9.3–13.0)*	5.2 (4.1–6.5)
	60–69	45.6 (41.1–50.1)	17.0 (13.9–20.7)*	24.7 (20.6–29.3)	35.0 (30.8–39.5)*	11.8 (9.3–14.9)	7.2 (5.3–9.8)
	70–74	35.3 (26.9–44.7)	17.9 (11.7–26.5)	25.5 (17.9–35.1)	22.7 (16.2–30.8)	11.0 (6.6–18.0)	8.2 (4.5–14.6)
Prevalence by BMI (kg/m^2)	≤25.0	29.25 (27.28, 31.30)	13.00 (11.40, 14.78)	10.31 (9.10, 11.67)	15.91 (14.34, 17.62)	4.87 (3.81, 6.21)	1.67 (1.18, 2.35)
	25–29.9	35.94 (34.35, 37.57)	17.80 (16.60, 19.06)	15.06 (13.81, 16.40)	19.96 (18.48, 21.52)	7.68 (6.84, 8.60)	3.55 (2.98, 4.24)
	≥30.0	41.02 (39.16, 42.90)	21.27 (19.71, 22.91)	18.41 (16.97, 19.94)	25.29 (23.80, 26.84)	11.18 (10.23, 12.20)	5.00 (4.35, 5.74)
Prevalence by place of birth and years living in the U.S.	**Born in U.S mainland**	38.10 (34.96, 41.34)	20.17 (17.39, 23.26)	14.54 (11.63, 18.04)	22.71 (19.90, 25.78)	9.71 (7.50, 12.49)	3.28 (2.24, 4.77)
	Born outside U.S mainland	36.60 (33.85, 39.45)	18.22 (15.94, 20.75)	15.92 (13.68, 18.45)	20.50 (18.40, 22.77)	8.09 (6.53, 9.98)	4.04 (2.92, 5.56)

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		Total Prevalence of Prediabetes	Total IFG	Total IGT	Total Impaired HbA_{1c}	IFG + Impaired HbA_{1c}	IFG + IGT + Impaired HbA_{1c}
	< 5	39.08 (36.39, 41.84)	18.39 (16.09, 20.94)	18.77 (16.56, 21.19)	21.46 (18.86, 24.32)	8.82 (7.18, 10.79)	4.32 (3.07, 6.05)
	6–10	36.24 (33.41, 39.18)	18.00 (15.76, 20.48)	16.91 (14.73, 19.34)	21.95 (19.52, 24.60)	9.37 (7.64, 11.45)	5.05 (3.73, 6.81)
	11–15	37.19 (34.92, 39.52)	18.44 (16.51, 20.55)	15.59 (14.09, 17.21)	22.00 (20.13, 24.00)	8.87 (7.85, 10.01)	3.55 (3.05, 4.12)
	≥16	38.10 (34.96, 41.34)	20.17 (17.39, 23.26)	14.54 (11.63, 18.04)	22.71 (19.90, 25.78)	9.71 (7.50, 12.49)	3.28 (2.24, 4.77)

Total prevalence = percent of individuals who met at least one criterion; **Total IFG** = IFG + (normal 2hPG or IGT) + (normal or impaired HbA_{1C}); **Total IGT** = IGT + (normal FPG or IFG) + (normal or impaired HbA_{1C}); **Total Impaired HbA_{1C}** = Impaired HbA_{1C} + (normal FPG or IFG) + (normal 2hPG or IGT); **IFG + Impaired HbA_{1C}** = IFG + Impaired HbA_{1C} + (normal 2hPG or IGT); **IFG + IGT + Impaired HbA_{1C}** = individuals with all three laboratory tests within the prediabetes range.

Data were weighted and are presented as means or percentage and 95% CI in parentheses. Percentages are based on target population, n = 15,507.

* $p<0.05$ was considered statistically significant when the prevalence of the specific criterion was compared between sexes.

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Table 2

Prevalence of prediabetes glycemic categories by Hispanic/Latino heritage group and sex

		N (Total)	N (Prediabetes)	Total Prevalence of Prediabetes*	Total IFG*	Total IGT*	Total Impaired HbA_{1c}	IFG + Impaired HbA_{1c}	IFG + IGT + Impaired HbA_{1c}
Central American	All	1670	647	35.4 (32.8–38.1)	16.6 (14.6 18.9)	16.2 (14.1 18.6)	21.5 (19.3–24.0)	8.5 (7.0–10.2)	4.1 (3.0–5.6)
	Men	665	265	36.9 (32.7–41.3)	22.01 (18.49, 25.99)	14.05 (11.27, 17.38)	23.10 (19.42, 27.25)	11.26 (8.70, 14.45)	4.74 (2.99, 7.42)
	Women	1005	382	33.5 (30.0–37.3)	11.92 (9.58, 14.73)	18.17 (15.03, 21.81)	19.70 (17.12, 22.56)	6.22 (4.61, 8.36)	3.57 (2.47, 5.14)
Cuban	All	2201	888	35.9 (33.5–38.3)	19.3 (17.4 21.3)	15.3 (13.7 17.1)	19.2 (17.3–21.2)	8.3 (7.2–9.7)	3.7 (3.0–4.6)
	Men	1038	478	40.42 (36.86, 44.07	25.85 (22.86, 29.10)	14.66 (12.43, 17.22)	21.38 (18.73, 24.28)	10.88 (9.17, 12.87)	4.52 (3.40, 5.98)
	Women	1163	410	30.72 (27.85, 33.74)	11.87 (10.03, 14.00)	16.21 (13.96, 18.74)	16.57 (14.39, 19.00)	5.53 (4.28, 7.13)	2.87 (2.03, 4.06)
Dominican	All	1375	489	31.8 (28.9–34.9)	14.4 (12.1 17.0)	12.3 (10.5 14.3)	21.5 (18.7–24.5)	8.4 (6.7–10.6)	2.6 (1.9–3.6)
	Men	482	182	36.71 (31.73, 41.99)	22.02 (17.41, 27.45)	11.04 (8.24, 14.66)	23.88 (19.65, 28.70)	13.19 (9.60, 17.84)	2.72 (1.67, 4.40)
	Women	893	307	28.92 (25.61, 32.47)	9.60 (7.38, 12.41)	13.01 (10.70, 15.73)	20.21 (17.33, 23.44)	5.52 (4.00, 7.57)	2.53 (1.69, 3.78)
Mexican	All	6215	2357	37.8 (35.9–40.0)	18.1 (16.6 19.8)	16.6 (15.3 18.0)	22.3 (20.7–23.9)	8.7 (7.8–9.8)	2.6 (1.9–3.6)
	Men	2379	929	39.26 (36.64, 41.94)	24.31 (21.83, 26.97)	15.21 (12.96, 17.76)	20.37 (18.22, 22.71)	9.98 (8.38, 11.84)	4.53 (3.11, 6.54)

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		N (Total)	N (Prediabetes)	Total Prevalence of Prediabetes*	Total IFG*	Total IGT*	Total Impaired HbA_{1c}	IFG + Impaired HbA_{1c}	IFG + IGT + Impaired HbA_{1c}
	Women	3836	1428	36.36 (33.94, 38.85)	12.54 (10.82, 14.49)	17.97 (16.15, 19.93)	23.71 (21.60, 25.96)	7.57 (6.35, 9.00)	3.83 (2.90, 5.06)
Puerto Rican	All	2516	888	34.6 (31.9–37.4)	17.3 (15.3 19.5)	13.3 (11.1 15.7)	22.2 (19.8–24.8)	8.9 (7.4–10.7)	3.8 (2.8–5.0)
	Men	1064	400	37.99 (34.23, 41.90)	23.18 (19.97, 26.75)	11.06 (9.02, 13.50)	23.23 (19.97, 26.83)	10.94 (8.57, 13.87)	3.76 (2.58, 5.43)
	Women	1452	488	30.00 (26.72, 33.50)	10.84 (8.98, 13.02)	15.15 (12.17, 18.71)	20.42 (17.72, 23.41)	6.76 (5.23, 8.69)	3.75 (2.60, 5.38)
South American	All	1005	391	36.2 (32.9–39.5)	18.1 (15.3 21.2)	17.2 (14.5 20.3)	20.3 (17.6–23.4)	8.3 (6.5–10.7)	4.6 (3.2–6.5)
	Men	411	164	39.43 (34.33, 44.78)	24.98 (20.75, 29.75)	17.15 (13.12, 22.10)	17.12 (13.12, 22.04)	9.54 (6.54, 13.72)	3.93 (2.03, 7.49)
	Women	594	227	33.08 (29.33, 37.05)	11.66 (8.71, 15.45)	17.40 (14.18, 21.17)	21.81 (18.76, 25.20)	7.13 (5.11, 9.86)	4.73 (3.11, 7.14)

Total prevalence = percent of individuals who met at least one criterion; **Total IFG** = IFG + (normal 2hPG or IGT) + (normal or impaired HbA_{1C}); **Total IGT** = IGT + (normal FPG or IFG) + (normal or impaired HbA_{1C}); **Total Impaired HbA_{1c}** = Impaired HbA_{1C} + (normal FPG or IFG) + (normal 2hPG or IGT); **IFG + Impaired HbA_{1c}** = IFG + Impaired HbA_{1C} + (normal 2hPG or IGT); **IFG + IGT + Impaired HbA_{1c}** = individuals with all three laboratory tests within the pre-diabetes range.

Data were weighted and are presented as means or percentage and 95% CI in parentheses. The prevalence of BMI categories and years living in the U.S. within each diabetes category is presented as percentages. Percentages are based on target population, n = 15,507. Note that only 525 individuals from the target population and 176 individuals from the group with prediabetes self-identified with "Other Hispanic/Latino heritage" and were not presented in the analysis.

* $p<0.05$ was considered statistically significant when the prevalence of the specific criterion was compared among Hispanic/Latino groups (men and women combined).

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Table 3

Sensitivity and specificity of FPG, HbA_{1c}, and the combination of FPG and HbA_{1c} in the target population using 2hPG as the gold standard

	HbA1c vs. 2hPG		FPG vs 2hPG		HbA_{1c}+FPG vs 2hPG	
	Sensitivity % (95% CI)	**Specificity % (95%CI)**	**Sensitivity % (95% CI)**	**Specificity % (95% CI)**	**Sensitivity % (95% CI)**	**Specificity % (95% CI)**
All	45.6 (42.5, 48.7)	80.7 (79.5, 81.8)	40.1 (37.3, 43.0)	82.8 (81.6, 84.0)	62.2 (59.2, 65.1)	70.1 (68.7, 71.4)
Age group (years)						
18–44	26.8 (23.7, 30.0)	87.2 (86.1, 88.3)	31.3 (28.3, 34.5)	85.5 (84.2, 86.8)	46.1 (42.5, 49.7)	77.3 (75.9, 78.7)
45–64	58.2 (54.7, 61.6)	64.2 (62.0, 66.3)	45.9 (42.6, 49.1)	76.0 (72.2, 77.7)	72.9 (69.9, 75.7)	51.9 (49.8, 54.1)
65–74	64.4 (57.9, 70.4)	57.9 (51.4, 64.2)	49.3 (42.6, 56.1)	73.4 (67.8, 78.4)	78.6 (73.4, 83.1)	44.2 (37.7, 50.8)
Sex						
Men	46.6 (42.9, 50.3)	80.1 (78.9, 81.3)	54.1 (50.6, 57.7)	75.9 (74.3, 77.4)	69.7 (66.4, 72.8)	64.2 (62.7, 65.7)
Women	44.9 (41.7, 48.1)	81.2 (79.7, 82.6)	29.7 (27.0, 32.6)	89.8 (88.6, 90.9)	56.7 (53.4, 59.9)	75.9 (74.3, 77.5)
BMI (kg/m^2)						
≤ 25	27.2 (23.7, 30.9)	89.2 (87.8, 90.5)	25.1 (21.3, 29.2)	89.6 (87.7, 91.2)	43.1 (38.8, 47.5)	81.8 (79.8, 83.7)
25–29.9	41.8 (38.1, 45.7)	81.1 (79.3, 82.8)	37.7 (34.5, 41.1)	82.6 (81.1, 84.0)	59.4 (55.8, 62.9)	69.9 (68.0, 71.8)
≥ 30	53.4 (49.8, 56.9)	72.9 (70.9, 74.9)	45.6 (42.0, 49.2)	77.4 (75.3, 79.4)	69.2 (66.0, 72.2)	60.3 (58.0, 62.6)
Hispanic/Latino heritage group						
Central American	44.6 (40.1, 49.2)	81.3 (78.8, 83.5)	36.0 (31.8, 40.4)	85.0 (82.9, 87.0)	59.3 (55.0, 63.5)	72.5 (69.6, 75.2)
Cuban	46.5 (42.2, 50.8)	80.1 (77.6, 82.4)	44.4 (40.0, 48.9)	80.0 (77.8, 82.2)	64.9 (60.7, 68.8)	67.5 (64.5, 70.4)
Dominican	46.0 (39.9, 52.1)	80.4 (77.1, 83.3)	33.2 (28.0, 38.9)	86.5 (83.6, 89.0)	57.5 (51.8, 63.0)	73.9 (70.2, 77.3)
Mexican	43.7 (40.2, 47.3)	81.8 (80.1, 83.4)	39.5 (36.2, 42.9)	83.0 (81.0, 84.9)	61.4 (58.2, 64.5)	70.7 (68.5, 72.8)

	HbA1c vs. 2hPG		FPG vs 2hPG		HbA_{1c}+FPG vs 2hPG	
	Sensitivity % (95% CI)	**Specificity % (95%CI)**	**Sensitivity % (95% CI)**	**Specificity % (95% CI)**	**Sensitivity % (95% CI)**	**Specificity % (95% CI)**
Puerto Rican	51.2 (46.2, 56.2)	76.9 (73.9, 79.6)	41.1 (36.3, 46.2)	82.1 (79.4, 84.4)	65.4 (61.0, 69.5)	67.0 (63.8, 70.0)
South American	42.4 (37.1, 48.0)	82.6 (79.6, 85.3)	38.5 (32.9, 44.3)	83.6 (80.2, 8.6)	59.2 (53.8, 64.4)	72.5 (68.7, 76.1)

Data were weighted and are presented as percent and 95% CI in parentheses

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Table 4

Prevalence* of cardiovascular risk factors according to glycemic category and sex

Glycemic category	Sex	Hypertension	Low HDL C	High LDL-C	High TG	High UACR	Obesity
Isolated IFG	Women (n=303)	11.2 (7.2, 16.8)	45.1 (36.8, 53.8)	37.8 (30.6, 45.7)	28.7 (22.0, 36.5)	8.9 (5.7, 13.6)	43.6 (35.0, 52.7)
	Men (n=615)	18.6 (14.4, 23.6)	33.6 (28.1, 39.4)	50.0 (43.5, 56.5)	39.1 (33.1, 45.4)	2.9 (1.8, 4.6)	33.6 (28.2, 39.4)
Isolated IGT	Women (n=639)	27.1 (20.5, 34.8)	41.5 (36.0, 47.2)	46.6 (39.9, 53.4)	28.1 (23.3, 33.4)	6.4 (4.4, 9.4)	42.1 (35.6, 48.8)
	Men (n=242)	22.0 (15.4, 30.5)	47.2 (38.4, 56.2)	38.1 (30.4, 46.5)	51.1 (41.9, 60.3)	7.8 (3.9, 14.8)	38.2 (29.9, 47.3)
Isolated Impaired HbA_{1c}	Women (n=1018)	16.5 (13.1, 20.5)	49.4 (44.7, 54.1)	41.8 (37.2, 46.6)	23.9 (20.5, 27.8)	7.1 (5.2, 9.6)	47.7 (42.7, 52.7)
	Men (n=572)	18.3 (14.1, 23.3)	31.7 (26.9, 37.0)	50.0 (44.1, 55.9)	33.2 (28.0, 38.8)	4.9 (3.1, 7.5)	39.0 (33.5, 44.9)
IFG + Impaired HbA_{1c} + Normal 2hPG	Women (n=326)	12.0 (6.8, 20.2)	54.2 (44.6, 63.4)	48.2 (39.7, 56.7)	27.4 (20.8, 35.1)	5.6 (3.2, 9.7)	68.6 (59.8, 76.3)
	Men (n=434)	18.9 (14.6, 24.0)	46.3 (39.6, 53.2)	48.0 (41.7, 54.5)	42.1 (35.8, 48.6)	7.6 (5.1, 11.4)	52.8 (46.1, 59.4)
IFG + IGT + Impaired HbA_{1c}	Women (n=389)	36.0 (28.4, 44.4)	62.9 (54.4, 70.7)	45.3 (37.2, 53.7)	39.1 (31.7, 47.1)	11.3 (7.6, 16.5)	69.7 (61.5, 76.9)
	Men (n=273)	35.1 (25.4, 46.3)	36.4 (28.8, 44.7)	52.2 (42.4, 61.9)	52.5 (42.4, 62.4)	10.9 (5.5, 20.4)	51.9 (43.4, 60.3)
Normal glucose tolerance	Women (n=3833)	13.2 (11.4, 15.2)	39.7 (37.0, 42.5)	36.4 (33.5, 39.4)	17.5 (15.3, 20.0)	6.4 (5.2, 7.8)	32.6 (30.0, 35.4)
	Men (n=2496)	16.4 (13.9, 19.3)	27.9 (25.2, 30.8)	40.4 (37.2, 43.6)	30.9 (27.7, 34.2)	4.6 (3.5, 6.1)	26.5 (23.6, 29.7)

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* Prevalence was weighted and adjusted for age and Hispanic/Latino heritage group.