Hemoglobin A1c, fasting plasma glucose, and 2-hour plasma glucose distributions in US population subgroups: NHANES 2005–2010

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Abstract

Purpose—Although mean concentrations of hemoglobin A1c (A1C), fasting plasma glucose, and 2-hour plasma glucose differ by demographics, it is unclear what other characteristics of the distributions may differ, such as the amount of asymmetry of the distribution (skewness) and shift left or right compared to another distribution (shift).

Methods—Using kernel density estimation, we created smoothed plots of the distributions of fasting plasma glucose (N=7,250), 2-hour plasma glucose (N=5,851), and A1C (N=16,209) by age, race-ethnicity, and sex in the 2005–2010 National Health and Nutrition Examination Survey, a nationally representative sample of US adults including people with and without diabetes. We tested differences in distributions using cumulative logistic regression.

Results—The distributions were generally unimodal and right-skewed. All distributions were shifted higher and more right-skewed for older age groups (p<0.001 for each marker). Compared to non-Hispanic whites, the distribution of fasting plasma glucose was shifted higher for Mexican-Americans (p=0.01) while the distribution of A1C was shifted higher for non-Hispanic blacks (p<0.001). The distribution of fasting plasma glucose was shifted higher for men (p<0.001) and the distribution of 2-hour plasma glucose was shifted higher for women (p=0.01).

Conclusions—We provide a graphic reference for comparing these distributions and diabetes cutpoints by demographic factors.

Keywords

Hemoglobin A1c; fasting plasma glucose; 2-hour plasma glucose; kernel density estimation; NHANES

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Introduction

Mean concentrations of fasting glucose, 2-hour glucose, and hemoglobin A1c (A1C) differ by demographic characteristics. Older people have higher levels of all glucose markers [1–7]. Blacks tend to have higher A1C than whites while fasting glucose and 2-hour glucose concentrations appear similar [5, 7–14]. Although relatively few studies have compared Hispanics with people of other ethnicities, Hispanics may have higher levels of glucose biomarkers than non-Hispanic whites [8, 10, 12, 15, 16]. There are no clear differences in A1C by sex, while some studies have shown fasting glucose may be higher in men and 2-hour glucose higher in women [6, 7, 17–19].

The extent to which the distributions of glucose measures differ by demographic characteristics is unclear. There are several ways in which the distributions could differ, some of which will have little or no effect on the mean levels of a variable. A distribution that is shifted left or right relative to another distribution is reflected in a comparison of means. Differences in the level of asymmetry of the two distributions, or skewness, will be somewhat reflected in a comparison of means but will be indistinguishable from a distribution shift. Differences in kurtosis, or the thickness of the tails, will not be evident when comparing the mean levels among two groups. Previous studies have indicated glucose biomarkers are often skewed and occasionally bimodal, but the shapes of the distributions of fasting glucose, 2-hour glucose, and A1C have not been explored in the US general population, and differences in the distributions by demographic characteristics have not been fully characterized [5, 20–22].

We characterized the distributions of fasting glucose, 2-hour glucose, and A1C by age group, race-ethnicity, and sex using kernel density plots, which display smoothed distributions [23]. To do so, we analyzed data from the 2005–2010 National Health and Nutrition Examination Survey (NHANES), which was designed to be representative of the US general population.

Methods

Study population

The NHANES is a stratified, multistage probability survey designed to be representative of the civilian, non-institutionalized US population including people with and without diabetes [24]. It consists of an in-home interview and a subsequent visit to a mobile examination center. Our aim was to allow comparisons across demographic groups for a given marker. Because fasting glucose, 2-hour glucose, and A1C were measured in different subsamples, we analyzed each biomarker using a different study sample. In 2005–2010, 18,318 adults ≥ 18 years of age were interviewed and 17,689 were subsequently examined (96.6%). We excluded pregnant women (n=479) and individuals with missing data for A1C (n=1001), yielding 16,209 participants who were available for A1C analyses. Approximately half of the examination sample (n=8,332) was randomly assigned to a morning examination session during which a fasting blood sample was drawn and an oral glucose tolerance test (OGTT) was performed. Our analyses of fasting glucose excluded persons who did not fast between 8 and 24 hours (n=883) or had missing data for fasting glucose (n=199), resulting in 7,250 participants. Our analyses of 2-hour plasma glucose from an OGTT further excludes participants who were not administered an OGTT because they were taking insulin (n=214), oral diabetes medication (n=563), or met another exclusion criteria such as having refused the OGTT, had hemophilia, or had recent chemotherapy (n=623), yielding 5,850 participants.

The 2005–2010 NHANES protocol was approved by the National Center for Health Statistics of the Centers for Disease Control and Prevention Institutionalized Review Board. All participants gave written informed consent.

Data Collection

During the in-home interview, a standardized questionnaire was used to collect demographic information including age, race-ethnicity, and sex. During the visit to the mobile examination center, height and weight were measured and body mass index (BMI, weight/height^2) was calculated. A blood specimen was drawn from the participant's antecubital vein by a trained phlebotomist according to a standardized protocol. A1C was measured using a Tosoh A1C 2.2 Plus Glycohemoglobin Analyzer or a Tosoh G7 Automated HPLC Analyzer, which had reportable ranges of 3.4–18.8% (14–182 mmol/mol) and 3.0–19.0% (9–184 mmol/mol), respectively [24]. The inter-assay coefficient of variation ranged from 0.7–1.7% and 0.8–1.5%, respectively. Both analyzers used in A1c measurement were standardized by participating in the National Glycohemoglobin Standardization Program (NGSP). Certain hemoglobinopathies may affect the A1C measurement [25–28], but hemoglobinopathies were not determined in NHANES. Eligible participants were administered a 75-g (or a calibrated dose for participants weighing <94 pounds) glucose load (Trutol) oral-glucose tolerance test and a blood sample was drawn 2 hours later. Fasting and 2-hour glucose were measured in plasma by a hexokinase method using a Roche/Hitachi 911 Analyzer and Roche Modular P Chemistry Analyzer, which had an analytical measurement range of 2–750 mg/dL in 2005–2006 and 0–750 mg/dL in 2007–2010. The inter-assay coefficient of variation ranged from 0.8–2.6%.

Statistical Analysis

Distributions of fasting glucose, 2-hour glucose, and A1C were plotted using weighted kernel density estimation, a non-parametric method of estimating the probability density function [23]. Kernel density plots smooth over small fluctuations in data due to random sampling variation and therefore may better reflect the underlying distribution in the source population than, for example, a histogram of the study data. We do not show the y-axes since these are normalized distributions and the y-axes do not have useful interpretations; the goal is to show the shape of the overall distributions. For all kernel density plots, we used a bandwidth double that given by "Silverman's rule of thumb". Silverman's rule of thumb is $0.9*A*n^{-0.2}$, where A = min(SD; IR range/1.34) and SD = standard deviation and IR = interquartile range [23]. First, kernel density plots for all participants and for participants who were not previously diagnosed with diabetes were superimposed. Since our goal was to characterize the entire US population, subsequent analyses including kernel density plots by age group, race-ethnicity, and sex included all participants. Mean, percentiles, and mode (the estimated most common value in the population indicated as the highest point in the estimated kernel density distribution) were calculated. To test for differences in the kernel density plots, we used cumulative logistic regression [29] on deciles of A1C, fasting glucose, or 2-hour glucose to compare age (18–39, 40–59, and ≥60 years), race-ethnicity (non-Hispanic white, non-Hispanic black, Mexican-American), and sex categories. Other race-ethnicities were included in all analyses except analyses stratified by race-ethnicity. Initial models were unadjusted and subsequent models adjusted for the other demographic variables. An additional model further adjusted for BMI (continuous) and a final model further adjusted for height (continuous) as a proxy for metabolically active tissue which may affect rate of glucose metabolism [18, 30].

Plots were generated using R (version 2.14.0) and additional data analyses were done using SUDAAN (version 10.0.1; Research Triangle Institute, Research Triangle Park, NC) to account for the complex sampling design used by NHANES, including unequal probabilities

of selection, over-sampling, non-response, and the stratified, clustered, sample design [24]. Separate sample weights were applied to each analytic population (i.e., fasting plasma glucose, 2-hour plasma glucose, and A1C) so that all three groups were representative of the noninstitutionalized US general population.

Results

The kernel density plots of the overall population were generally unimodal and right skewed (Figure 1). Kernel density plots among people without previously diagnosed diabetes were similar to those that included everyone in the study population except that the fasting glucose and A1C plots were slightly less right-skewed. In subsequent analyses including all participants, kernel density plots of fasting glucose, 2-hour glucose, and A1C stratified by age showed distributions were shifted higher and more right skewed for older age groups (Figure 2). For participants 18–39 years, 40–59 years, and ≥ 60 years, the median fasting plasma glucose was 94, 99, and 105 mg/dL, respectively; the median 2-hour plasma glucose was 94, 107, and 132 mg/dL, respectively; the median A1C was 5.1, 5.4, and 5.6% (32, 36, and 38 mmol/mol), respectively (Table 1). Modes of the distributions for these respective ages were 95, 98, and 102 mg/dL for fasting plasma glucose; 90, 100, and 119 mg/dL for 2-hour plasma glucose; 5.2, 5.4, and 5.6% (33, 36, and 38 mmol/mol) for A1C. In order to test for differences in the entire distributions, we used cumulative logistic regression on deciles of A1C, fasting glucose, or 2-hour glucose. Compared to younger age groups, participants in older age groups had higher cumulative odds of being in higher deciles of fasting plasma glucose, 2-hour plasma glucose, and A1C (each p<0.001) and results were similar after adjustment for race-ethnicity, sex, BMI, and height (Table 2), illustrating the well-known increase in glucose intolerance with age.

Kernel density plots of fasting glucose, 2-hour glucose, and A1C stratified by race-ethnicity are presented in Figure 2. Compared to non-Hispanic whites, the distribution of fasting glucose for Mexican-Americans was shifted slightly higher while the distribution of A1C for non-Hispanic blacks was shifted higher. Compared to non-Hispanic blacks, the distributions of fasting glucose and 2-hour glucose for Mexican-Americans were shifted higher and the distribution of A1C for Mexican-Americans was shifted lower. For non-Hispanic whites, non-Hispanic blacks, and Mexican-Americans, the median fasting glucose was 98, 97, and 99 mg/dL, respectively; the median 2-hour glucose was 106, 102, and 107 mg/dL, respectively; the median A1C was 5.3, 5.5, and 5.4% (34, 37, and 36 mmol/mol), respectively (Table 1). Modes of the distributions for these respective race-ethnicities were 96, 95, and 98 mg/dL for fasting plasma glucose; 96, 96, and 100 mg/dL for 2-hour plasma glucose; 5.3, 5.5, and 5.3% (34, 37, and 34 mmol/mol) for A1C. Compared to non-Hispanic whites, non-Hispanic blacks had similar cumulative odds of being in higher deciles of fasting and 2-hour plasma glucose; however, non-Hispanic blacks had higher cumulative odds of being in higher deciles of A1C (p<0.001) in unadjusted and age, sex, BMI, and height adjusted models (Table 2). Compared to non-Hispanic whites, Mexican-Americans had higher cumulative odds of being in higher deciles of fasting glucose, 2-hour glucose, and A1C (each p<0.05) in unadjusted and age, sex, BMI, and height adjusted models (except for unadjusted 2-hour glucose [p=0.18]). Compared to non-Hispanic blacks, Mexican-Americans had higher cumulative odds of being in higher deciles of fasting glucose and 2-hour glucose (each p<0.01) and lower cumulative odds of being in higher deciles of A1C (p<0.001) in unadjusted and age, sex, BMI, and height adjusted models.

Kernel density plots stratified by sex showed the fasting glucose distribution was shifted higher for men, the 2-hour glucose distribution was shifted higher for women, and A1C distributions were nearly identical (Figure 2). For men and women, the median fasting glucose was 100 and 96 mg/dL, respectively; the median 2-hour glucose was 104 and 107

mg/dL, respectively; the median A1C was 5.4 and 5.3% (36 and 34 mmol/mol), respectively (Table 1). Modes of the distributions for men and women were 99 and 95 mg/dL, respectively, for fasting plasma glucose; 95 and 97 mg/dL, respectively, for 2-hour plasma glucose; both 5.3% (34 mmol/mol) for A1C. Compared to men, women had lower cumulative odds of being in higher deciles of fasting glucose (p<0.001) and higher cumulative odds of being in higher deciles of 2-hour glucose (p=0.01) in unadjusted models (Table 2). After adjustment for age, race-ethnicity, and BMI, women had lower cumulative odds of being in higher deciles of fasting glucose and A1C (each p<0.01), while differences in 2-hour glucose were no longer significant (p=0.14). After additional adjustment for height, women had lower cumulative odds of being in higher deciles of fasting glucose, 2-hour glucose, and A1C (each p<0.01).

Discussion

We characterized the distributions of fasting plasma glucose, 2-hour plasma glucose, and A1C in the 2005–2010 National Health and Nutrition Examination Survey, a nationally representative sample of the general non-institutionalized U.S. population. These results illustrate the differences in distributions between glucose biomarkers and their variation by age, race-ethnicity, and sex. The distributions of all biomarkers were shifted higher and more right skewed for older age groups. The shift in older ages was fluid affecting people throughout the entire distribution for each higher age group, and not merely reflecting a higher prevalence of diabetes in older age groups. Age was more strongly associated with A1C than fasting glucose or 2-hour glucose. Although previous studies have shown A1C levels increase with age, the effect of age on A1C is similar to the effect of age on average plasma glucose (based on 7 or 8 days of continuous glucose monitoring during a 12 week study) [31].

The distribution of A1C was shifted higher and more right skewed for non-Hispanic blacks, even after adjustment for age, sex, BMI, and height. This difference may due to more than just a difference in prevalence of diabetes since even the low side of the A1C distribution differs between non-Hispanic blacks and other race-ethnicities. The distributions of all three biomarkers were shifted slightly higher for Mexican-Americans compared to other race-ethnic groups (except A1C compared to non-Hispanic blacks), and the differences substantially increased after adjusting for age in regression models. The differences in A1C by race-ethnicity are consistent with previous studies that found mean concentrations differed by race-ethnicity, even at the same blood glucose levels [7–9, 13, 15, 32]. It is not clear why these differences exist, but there are several possibilities including genetics [33, 34], erythrocyte lifespan [35], and rate of hemoglobin glycation [36]. Despite the differences in A1C levels, race-ethnicity did not modify the association between A1C and cardiovascular outcomes and death in a previous study; the hazard ratios of coronary heart disease, ischemic stroke, and death associated with higher levels of A1C were similar for white and black participants [37].

The distribution of fasting glucose was shifted higher for men while a difference by sex for 2-hour glucose and A1C depended on which covariates were adjusted in the model. Several previous studies found men have higher levels of fasting glucose while women have higher levels of 2-hour glucose [18, 30, 38, 39]. Our study is consistent with previous studies [18, 30] that found differences in fasting glucose were not due to confounding by age or adiposity. A physiologic cause is possible, but the mechanism for the difference by sex has not been elucidated. Higher unadjusted 2-hour glucose in women may be due to women receiving the same amount of glucose during oral-glucose tolerance tests despite having, on average, less fat-free mass and consequently less metabolically active tissue [18]. The 2005–2010 NHANES did not measure fat-free mass. When we adjusted for height as a proxy for

fat-free mass in cumulative logistic regression models, men had higher 2-hour glucose levels than women, which is consistent with previous studies [18, 30]. Although we considered height a proxy for fat-free mass, it may affect 2-hour glucose levels through another unknown mechanism. Iron deficiency results in higher A1C levels independent of plasma glucose levels [40] and since it is more common among women [41], it may cause a relatively more right skewed distribution of A1C for women.

We found the distributions of fasting glucose, 2-hour glucose, and A1C to be unimodal, a finding that persisted even after varying the smoothing bandwidth. However, previous studies characterizing these distributions have found they follow bimodal distributions [21, 22] in populations that have a high prevalence of diabetes. In comparison, the NHANES participants in our study were representative of the non-institutionalized US population (except 2-hour plasma glucose analyses excluded people taking insulin or oral diabetes medication) and relatively healthy, which resulted in no noticeable second peak in the distribution.

Rather than test for differences in mean levels by demographics, we used cumulative logistic regression on deciles of glucose biomarkers to test for differences across the entire distribution while taking into account the complex sampling design used in NHANES. While this method may identify differences in the distribution beyond differences in mean, it is likely to not be very sensitive to certain differences, particularly differences in kurtoses in otherwise similar distributions. Another potential limitation is NHANES did not collect information on hemoglobinopathies or thalassemias, which may affect measurement of A1C. Despite these limitations, our study has a number of strengths. We used kernel density estimation to create smooth plots of the distributions of fasting plasma glucose, 2-hour plasma glucose, and A1C. These distributions are derived from NHANES data and these data, including the analytic populations for all three biomarkers we investigated, are designed to be representative of the US noninstitutionalized civilian population. Also, NHANES data were collected using a rigorous study protocol with extensive quality control procedures including technicians trained and certified in data collection procedures.

To look at the potential clinical impact of these observed associations, we provide a visual reference for comparing distributions of glucose biomarkers and cutpoints for prediabetes and diabetes by age, race-ethnicity, and sex. Longitudinal data are needed to determine if these differences have any clinical difference in terms of progression to diabetes. Distribution variation may be particularly important for diagnosing prediabetes since the modes of the distributions are relatively close to the prediabetes cutpoints whereby even relatively small differences may have a substantial impact on the number of people defined as having prediabetes. Variable cutpoints have been used in definitions of other diseases, such as the World Health Organization definition of metabolic syndrome which varies by sex and race-ethnicity [42]. However, many factors need to be considered in an evaluation of cutpoints used to define diabetes and prediabetes. Our data should be used in conjunction with other studies comparing progression of diabetes and long-term complications when evaluating whether cutpoints should differ by age, race-ethnicity, and sex. The differences in glucose biomarker distributions by age, race-ethnicity, and sex may highlight the importance of considering which biomarker is used when comparing diabetes prevalence among groups with different demographic profiles.

Acknowledgments

Abbreviations

A1C	hemoglobin A1c
BMI	body mass index
NHANES	National Health and Nutrition Examination Survey
OGTT	oral glucose tolerance test

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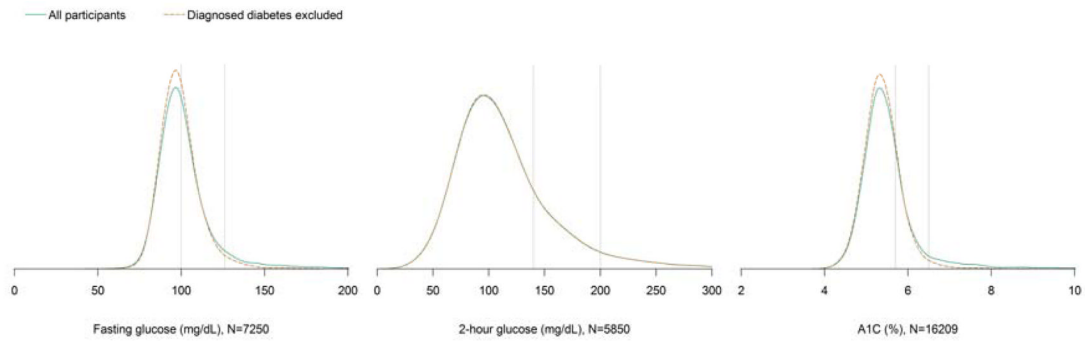
Figure 1.
Kernel density plots of fasting plasma glucose, 2-hour plasma glucose, and A1C among the total population and after excluding participants with previously diagnosed diabetes. The vertical lines denote the American Diabetes Association cutpoints for prediabetes (5.7% [39 mmol/mol], 100 mg/dL, and 140 mg/dL) and diabetes (6.5% [48 mmol/mol], 126 mg/dL, and 200 mg/dL). Among participants without diagnosed diabetes, 38.9% had a fasting plasma glucose 100–125 mg/dL, 3.5% had a fasting plasma glucose 126 mg/dL, 27.4% had a 2-hour plasma glucose 140–199 mg/dL, 5.4% had a 2-hour plasma glucose 200 mg/dL, 20.9% had an A1C 5.7–6.4%, and 2.3% had an A1C 6.5%.

Figure 2.
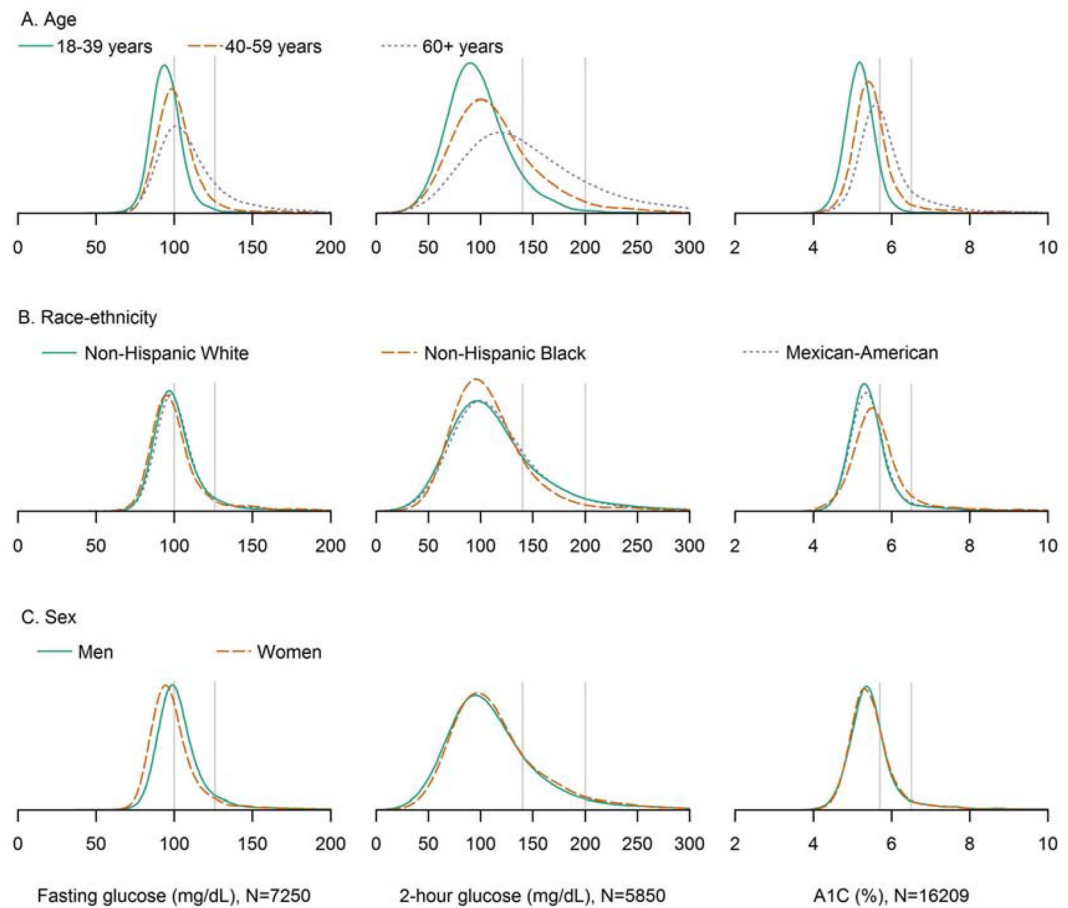Kernel density plots of fasting plasma glucose, 2-hour plasma glucose, and A1C by A) age group, B) race-ethnicity, and C) sex. The vertical lines denote the American Diabetes Association cutpoints for prediabetes (5.7% [39 mmol/mol], 100 mg/dL, and 140 mg/dL) and diabetes (6.5% [48 mmol/mol], 126 mg/dL, and 200 mg/dL). Differences in distributions were tested using cumulative logistic regression as presented in Table 2.

Table 1

Percentiles, mean, and mode of the kernel density distribution of fasting plasma glucose, 2-hour plasma glucose, and A1C by age, race-ethnicity, and sex

	5th	10th	25th	50th	75th	90th	95th	Mean	Mode
Fasting plasma glucose, N=7250									
Overall	83	86	91	98	107	122	144	105	97
Age									
18–39	80	84	88	94	100	107	115	98	95
40–59	84	88	93	99	107	121	145	107*	98
60	86	90	96	105	119	144	169	114*	102
Race-ethnicity									
Non-Hispanic white	83	86	92	98	107	122	139	104	96
Non-Hispanic black	81	84	90	97	105	128	158	106	95
Mexican-American	84	87	93	99	109	131	174	110*	98
Sex									
Men	85	89	94	100	109	125	149	108	99
Women	81	84	89	96	104	120	141	102*	95
2-hour plasma glucose, N=5850									
Overall	62	70	85	105	133	173	206	116	96
Age									
18–39	58	65	78	94	113	136	157	100	90
40–59	63	71	86	107	133	170	197	117*	100
60	74	84	105	132	171	220	256	144*	119
Race-ethnicity									
Non-Hispanic white	61	70	84	106	134	177	210	117	96
Non-Hispanic black	65	72	84	102	124	153	181	110*	96
Mexican-American	63	73	87	107	135	176	214	120	100
Sex									
Men	59	68	84	104	131	170	205	115	95
Women	64	72	85	107	134	176	206	117	97
A1C, N=16209									

	5th	10th	25th	50th	75th	90th	95th	Mean	Mode
Overall	4.7 (28)	4.8 (29)	5.1 (32)	5.4 (36)	5.7 (39)	6.1 (43)	6.8 (51)	5.6 (38)	5.3 (34)
Age									
18–39	4.6 (27)	4.7 (28)	4.9 (30)	5.1 (32)	5.4 (36)	5.6 (38)	5.8 (40)	5.3 (34)	5.2 (33)
40–59	4.8 (29)	4.9 (30)	5.2 (33)	5.4 (36)	5.7 (39)	6.2 (44)	7.0 (53)	5.6 (38) *	5.4 (36)
60	5.0 (31)	5.1 (32)	5.4 (36)	5.6 (38)	6.0 (42)	6.8 (51)	7.5 (58)	5.9 (41) *	5.6 (38)
Race-ethnicity									
Non-Hispanic white	4.7 (28)	4.8 (29)	5.1 (32)	5.3 (34)	5.6 (38)	6.0 (42)	6.6 (49)	5.5 (37)	5.3 (34)
Non-Hispanic black	4.7 (28)	4.9 (30)	5.2 (33)	5.5 (37)	5.9 (41)	6.5 (48)	7.6 (60)	5.8 (40) *	5.5 (37)
Mexican-American	4.7 (28)	4.9 (30)	5.1 (32)	5.4 (36)	5.7 (39)	6.3 (45)	7.6 (60)	5.7 (39) *	5.3 (34)
Sex									
Men	4.7 (28)	4.8 (29)	5.1 (32)	5.4 (36)	5.7 (39)	6.1 (43)	7.0 (53)	5.6 (38)	5.3 (34)
Women	4.7 (28)	4.9 (30)	5.1 (32)	5.3 (34)	5.7 (39)	6.1 (43)	6.7 (50)	5.5 (37) *	5.3 (34)

A1c is presented in % (mmol/mol)

*
p-value<0.05 compared to first category (i.e., 18–39 years, non-Hispanic white, or men)

Table 2

Cumulative odds ratios (95% confidence intervals) of fasting plasma glucose, 2-hour plasma glucose, or A1C decile associated with age, race-ethnicity, and sex

	Unadjusted	Adjusted for age, race-ethnicity, and sex	Adjusted for age, race-ethnicity, sex, and BMI	Adjusted for age, race-ethnicity, sex, BMI, and height
Fasting plasma glucose, N=7250				
Age				
18–39	1.00	1.00	1.00	1.00
40–59	2.59 (2.16–3.10)	2.82 (2.40–3.31)	2.61 (2.20–3.09)	2.61 (2.20–3.09)
60	5.60 (4.80–6.54)	6.56 (5.52–7.80)	6.52 (5.47–7.78)	6.48 (5.41–7.76)
Race-ethnicity				
Non-Hispanic white	1.00	1.00	1.00	1.00
Non-Hispanic black	0.84 (0.66–1.07)	1.06 (0.89–1.27)	0.86 (0.71–1.05)	0.86 (0.71–1.04)
Mexican-American	1.28 (1.02–1.61)	1.80 (1.48–2.18)	1.72 (1.43–2.08)	1.70 (1.40–2.07)
Sex				
Men	1.00	1.00	1.00	1.00
Women	0.52 (0.47–0.58)	0.44 (0.39–0.50)	0.43 (0.37–0.49)	0.41 (0.34–0.51)
2-hour plasma glucose, N=5850				
Age				
18–39	1.00	1.00	1.00	1.00
40–59	2.05 (1.79–2.35)	2.05 (1.76–2.40)	1.91 (1.64–2.23)	1.88 (1.61–2.19)
60	6.06 (4.96–7.40)	6.36 (5.20–7.79)	6.29 (5.17–7.66)	5.66 (4.66–6.88)
Race-ethnicity				
Non-Hispanic white	1.00	1.00	1.00	1.00
Non-Hispanic black	0.86 (0.74–1.01)	1.05 (0.91–1.21)	0.89 (0.76–1.04)	0.87 (0.75–1.02)
Mexican-American	1.13 (0.95–1.34)	1.63 (1.37–1.94)	1.55 (1.30–1.84)	1.28 (1.07–1.54)
Sex				
Men	1.00	1.00	1.00	1.00
Women	1.16 (1.04–1.3)	1.10 (0.96–1.25)	1.10 (0.97–1.25)	0.75 (0.61–0.92)
A1C, N=16209				
Age				
18–39	1.00	1.00	1.00	1.00

	Unadjusted	Adjusted for age, race-ethnicity, and sex	Adjusted for age, race-ethnicity, sex, and BMI	Adjusted for age, race-ethnicity, sex, BMI, and height
40–59	3.50 (3.25–3.78)	3.94 (3.62–4.29)	3.72 (3.43–4.04)	3.70 (3.41–4.02)
60	8.89 (7.93–9.96)	11.02 (9.86–12.31)	10.91 (9.82–12.12)	10.44 (9.35–1.66)
Race-ethnicity				
Non-Hispanic white	1.00	1.00	1.00	1.00
Non-Hispanic black	1.93 (1.69–2.21)	2.82 (2.48–3.20)	2.49 (2.21–2.81)	2.47 (2.19–2.78)
Mexican-American	1.20 (1.02–1.41)	2.01 (1.71–2.35)	1.90 (1.63–2.21)	1.74 (1.48–2.04)
Sex				
Men	1.00	1.00	1.00	1.00
Women	0.98 (0.93–1.04)	0.88 (0.82–0.94)	0.89 (0.83–0.96)	0.76 (0.67–0.85)