HHS Public Access

Author manuscript

Genet Med. Author manuscript; available in PMC 2019 April 01.

Published in final edited form as:

Genet Med. 2018 October ; 20(10): 1159–1166. doi:10.1038/gim.2017.238.

The Contribution of Family History to the Burden of Diagnosed Diabetes, Undiagnosed Diabetes and Prediabetes in the United States: Analysis of National Health and Nutrition Examination Survey, 2009-2014

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Abstract

Purpose—Given the importance of family history in the early detection and prevention of type 2 diabetes, we quantified the public health impact of reported family health history on diagnosed diabetes (DD), undiagnosed diabetes (UD), and prediabetes (PD) in the United States.

Methods—We used population data from the National Health Examination and Nutrition Survey 2009 to 2014 to measure the association of reported family history of diabetes with DD, UD, and PD.

Results—Using polytomous logistic regression and multivariable adjustment, family history prevalence ratios were 4.27 (CI: 3.57, 5.12) for DD, 2.03 (CI: 1.56, 2.63) for UD, and 1.26 (CI: 1.09, 1.44) for PD. In the United States, we estimate that 10.1 million DD cases, 1.4 million UD cases, and 3.9 million PD cases can be attributed to having a family history of diabetes.

Conclusions—These findings confirm that family history of diabetes has a major public health impact on diabetes in the United States. In spite of the recent interest and focus on genomics and precision medicine, family health history continues to be an integral component of public health

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Disclosure: The authors declare no conflict of interest.

campaigns to identify persons at high risk for developing type 2 diabetes and early detection of diabetes to prevent or delay complications.

Keywords

diabetes; family history; prediabetes; undiagnosed diabetes; public health

Introduction

Type 2 diabetes is a major public health problem in the United States and globally. In 2011-2012, among adults aged 20 years or older in the United States, the prevalence of diagnosed diabetes (DD), undiagnosed diabetes (UD), and prediabetes (PD) based on hemoglobin A_{1C} or fasting plasma glucose were 9.2%, 3.1%, and 36.5% respectively.[1] The prevalence of diabetes including UD in the United States has been projected to increase to between one in five and one in three adults by 2050[2]. Along with overweight, physical inactivity, increasing age, high blood pressure, and minority race/ ethnicity groups, family history of diabetes has long been known to be an important risk factor for the occurrence of type 2 diabetes.[3] While there are a few genetic disorders associated with the risk of type 2 diabetes[4], the cause of most type 2 diabetes is multifactorial involving the interaction of many genes (polygenic inheritance) and environmental/ behavioral risk factors[5].

In addition to being a risk factor for type 2 diabetes itself, family history of diabetes also seems to be positively associated with risk awareness and behaviors that reduce risk of type 2 diabetes.[6] There is also evidence that including family history of diabetes in screening algorithms also improves the detection of previously UD.[7,8] This association may also exist for PD. A study based on a population of European origin conducted in Germany found that having at least one first degree relative with diabetes was significantly associated with PD (odds ratio (OR)=1.4; 95% CI 1.27-1.54) and remained significant after adjusting for sex, age and body mass index (BMI) (adjusted OR (aOR)=1.3; 95% CI 1.14-1.40).[9] In spite of the recent explosion in the discovery of numerous genetic variants associated with type 2 diabetes, most associations have small effect sizes and do not account for the effect of family history as an independent risk factor for type 2 diabetes. Family history of diabetes reflects not only the contribution of genetic factors but also environmental, social, behavioral, nutritional and other potentially modifiable risk factors that are shared among relatives.[3,10,11]

CDC and partners have made a concerted effort to educate the general public about the importance of collecting family health history for diabetes and other common chronic diseases using systematic free online tools.[12,13] After a decade of such efforts, a recent national survey found that most people do not actively collect family health history, even though the vast majority believe it is important for their own health.[14] It is also important to note that information available about the accuracy of such data is sparse. As far as we are aware, only one small study of 10 people with and 10 people without diabetes, conducted in the mid-1980s, has examined accuracy of family history of diabetes. According to this study, family history of diabetes agreed completely with that given by respective relatives in a follow-up interview.[15] Among Hispanics, having a family history of diabetes was associated

with increased reported screening, but a similar association was not seen among non-Hispanic whites.[15]

Given the importance of family history in the early detection and prevention of diabetes, we sought, using a nationally representative sample of the US Population (National Health and Nutrition Examination Survey (NHANES) 2009-2014) to quantify the national prevalence of reported family health history of diabetes and its contribution not only to DD but as importantly to PD and UD. We were interested in identifying the independent contributions of family history to the burden of DD, UD, and PD in the United States. In addition, we were interested in identifying variations in reported diabetes across subsets of the population (e.g. age, race/ethnicity, sex) and impact of family history on the identification of people at risk for developing type 2 diabetes.

Materials and Methods

NHANES is a series of surveys using stratified, multistage probability samples designed to provide assessments on the health and nutrition status of the civilian, noninstitutionalized US population. NHANES is conducted by the CDC's National Center for Health Statistics (NCHS) and has continuously collected data based on personal interviews and physical examination of survey participants in two year cycles since 1999. The present study included samples of adults aged ≥20 years in the cycles 2009-2010, 2011-2012, and 2013-2014. Some population subgroups were oversampled to increase the reliability and precision of estimates of health outcomes for these groups. Sample weights were adjusted to take in to account nonresponse, oversampling, and post-stratification. Detailed description of the NHANES sample design is available elsewhere (https://wwwn.cdc.gov/nchs/data/series/sr02_162.pdf). Participants complete an in-home interview for basic demographic and health information along with a scheduled visit to a mobile examination center for physical examination and laboratory testing. Written informed consent was obtained from each participant for both parts of the survey and all protocols were approved by the research ethics review boards of the NCHS. The response rates for the surveys ranged from 68.5% to 77.3%.[16] . Pregnant women were excluded due to the effect of pregnancy on glucose measurement.

Definition of DD, UD, PD, and reported family history of diabetes

If a participant reported that they had ever been diagnosed with diabetes by a doctor or other health professional other than during pregnancy, we defined that person as having DD. Participants with a hemoglobin A_{1C} level of ≥ 6.5% or a fasting plasma glucose (FPG) level of ≥ 126 mg/dL who reported no previous diagnosis of diabetes were defined as having UD. [1] Participants with a hemoglobin A_{1C} level of between 5.7% and 6.4% or a FPG level of between 100 mg/dL and 125 mg/dl who reported no previous diagnosis of diabetes were defined as having PD.[1] To ensure that glucose values we used were consistent with earlier NHANES data, we corrected the measured FPG values using the equation recommended by NCHS, 0.9835*(FPG-1.139).[17,18] Participants were asked whether any of their close biological (blood) relatives, including father, mother, sisters or brothers, were ever told by a health professional that they had diabetes. We defined participants as having a reported family history of diabetes if they responded “yes” to this question. Further information on

family history of diabetes is not available in NHANES 2009-2014 to do a more comprehensive analysis.

Statistical analysis

We partitioned the US population into PD, UD, DD, and none of these conditions. We used a polytomous logistic regression model to measure the association between the conditions and reported family history of diabetes by treating those with none of the conditions as the referent group. We included other risk factors in the model: age group (20-39, 40-59, ≥ 60 years), sex, race/ ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, others), BMI (< 25, 25-30, ≥ 30 kg/m^2), hypertension (≥ 140/90 / < 140/90 mm Hg), and leisure time physical activity (yes/ no). We defined participants as physically active if they had met the Healthy People 2010 objective of moderate- or vigorous-intensity physical activity.[19] The risk factors selected were based on the recommendation of the American Diabetes Association.[20] We also included income to poverty ratio (< 1/ ≥ 1) and education (< high school/ ≥ high school) in the model as indicators of socio-economic status. There were no significant interactions between family history and other risk factors and these terms were excluded from the final model. The interactions were tested by including all the interaction terms in the model and also including one interaction term at a time in the model.

Next, we estimated the weighted prevalence of DD and evaluated the association between DD and family history of diabetes for the US population and for the subgroups of the populations with the risk factors given above using logistic regression models. For example, for the population aged 20-39 years, we estimated the prevalence of DD, 95% confidence interval, and the OR for family history of diabetes adjusted for all the risk factors except for age. We extended this analysis for UD for the populations without DD and for PD for the populations without DD or UD. We only report significant ($p < 0.05$) ORs.

In case-control and cohort studies, measures of associations are usually reported as ORs and risk ratios. In cross-sectional studies, when prevalent cases are included, the OR may also be mentioned as the prevalence OR; instead of the risk ratio, the prevalence ratio is calculated. For associations between family history of diabetes and DD, UD, or PD having a significant OR, we estimated the population attributable fraction (PAF) for family history of diabetes using the formula, $\text{PAF} = \frac{G(R-1)}{G(R-1)+1}$, where G is the prevalence of family history of diabetes in the population and R is the prevalence ratio. For DD and UD, we used OR as an approximate estimate for prevalence ratio. Since the prevalence of PD is relatively large (> 10%), the approximate estimate of prevalence ratio was obtained from ORs, using the formula, $\text{prevalence ratio} = \frac{OR}{(1-p_0)+OR*p_0}$, where p_0 is the prevalence of PD in the population that do not have a family history of diabetes.[21] Next, we calculated the number of cases impacted by family history of diabetes in the DD, UD, and PD populations by multiplying PAF and the number of cases with each condition. To calculate the total number of cases with each condition by age group, sex, and race/ ethnicity categories, we used the distribution of the civilian noninstitutionalized US population obtained from the Census Bureau's Current Population Survey (CPS) as recommended by NCHS.[16] We multiplied the average population size for the three survey cycles by the prevalence of each condition. For

populations defined by other risk factors, we calculated the product of the average US population size, the prevalence of the risk factor, and the prevalence of each condition. Bonferroni correction was used to determine the significance levels for pair-wise comparison tests of prevalence of family history of diabetes between groups.

The survey data were analyzed using SURVEYFREQ and SURVEYLOGISTIC procedures in SAS V 9.3 (SAS Institute, Cary, North Carolina) that takes into account the complex survey design of the NHANES, and the sample weights were adjusted for pooling three cycles of NHANES data.

Results

The study sample consisted of 8,796 non-pregnant adult respondents that included 2,149 DD cases, 612 UD cases, and 2,719 PD cases. Table 1 gives the crude prevalence of reported family history of diabetes for the US population, by age group, sex, race /ethnicity, and populations with other risk factors for type 2 diabetes. The prevalence of reported family history of diabetes in the US population age 20 years or over was 36.70% (95% CI: 35.05, 38.26). The prevalence of reported family history of diabetes was significantly higher among females (estimate- 38.72%, (CI: 36.71, 40.73)) compared to males (estimate- 34.47%, (CI: 32.57, 36.36)). By race/ ethnicity groups, the non-Hispanic black population had the highest prevalence of family history of diabetes, an estimate of 48.92% (CI: 45.92, 51.91). The relative disparities in the prevalence of family history of diabetes for non-Hispanic black and Hispanic populations (estimate- 41.11% (CI: 37.68, 44.54)) compared to non-Hispanic white population (estimate- 33.61%, (CI: 31.82, 35.40)) were 45.50% and 22.31% respectively. The prevalence of family history of diabetes increased with BMI (estimate- 44.30%, (CI: 41.68, 46.92), in the highest group). Populations with less than high school education (estimate- 42.10%, (CI: 39.0, 45.21)), with hypertension (estimate- 41.76%, (CI: 38.99, 44.54)), and income to poverty ratio < 1 (estimate- 40.68% (CI: 37.53, 43.83)) had significantly higher prevalence of family history of diabetes than those with more education, without hypertension, and income to poverty ratio ≥ 1 respectively.

The results from the polytomous logistic regression model to measure the association between the conditions, PD, UD, and DD, and reported family history of diabetes by treating those with none of these conditions as the referent group are given in Table 2. Among the entire U.S. population age ≥ 20 years, after controlling for all the other variables in the model, the prevalence ratios of DD, UD, and PD were 4.27 (CI: 3.57, 5.12), 2.03 (CI: 1.56, 2.63), and 1.26 (CI: 1.09, 1.44) for those with a family history of diabetes compared to those without relative to those with none of these conditions. As expected, out of all the risk factors considered in the model, age group ≥ 60 years compared to age group 20-39 years had by far the highest adjusted prevalence ratios (DD-26.87, (CI: 19.39, 37.23), UD-16.33, (CI: 10.38, 25.68), and PD-5.11, (CI: 4.16, 6.28)). Those with BMI ≥ 30 kg/m^2 and BMI 25-30 kg/m^2 had significantly higher prevalence ratios for all three conditions compared to those with BMI < 25 kg/m^2 ((DD- 6.60, (CI: 5.31, 8.21), UD-8.19, (CI: 4.65, 14.41), and PD- 2.52, (CI: 1.99, 3.21)) and (DD- 1.93, (CI:1.55,2.41), UD- 2.02 (CI: 1.21, 3.37), and PD- 1.40, (CI: 1.13, 1.73)) respectively). Hispanic (DD- 1.89, (CI: 1.55, 2.30), UD- 2.22, (CI: 1.57, 3.15), and PD-1.23, (CI: 1.03, 1.47)), non-Hispanic black (DD-1.75, (CI: 1.42,

2.16), UD-1.98, (CI: 1.36, 2.87), and PD-1.42, (CI: 1.17, 1.74)), and other race/ ethnicity groups (DD- 3.34, (CI: 2.56, 4.34), UD- 4.24, (CI: 2.44, 7.38), PD- 1.47, (CI: 1.18, 1.85)) had significant prevalence ratios for all three conditions compared to the non-Hispanic white population. The adjusted prevalence ratio for DD was also significant for those with hypertension, with income to poverty ratio < 1, less than high school education, who were not physically active, and for males. Similarly, the prevalence ratio for UD was significant for those with hypertension, less than high school education, not physically active, and for males, and the prevalence ratio for PD was significant for those with hypertension, less than high school education, and for males.

Table 3 gives the prevalence of DD, UD, and PD, aORs and PAFs of reported family history of diabetes in the US population and population subgroups with risk factors considered in this study. Prevalence, aORs, and PAFs of UD are based on the population that does not have DD, and prevalence, aORs, and PAFs of PD are based on the population that does not have DD or UD.

The PAF for reported family history of diabetes for DD, UD, and PD in the US population were 48.66%, 20.59%, and 4.87% respectively. Among the population subgroups studied, the PAFs for family history of diabetes that were calculated with significant odds ratios ranged from 42.53% (age 20-39 years) to 60.17% (Hispanics) for DD, from 13.95% (age ≥ 60 years) to 46.35% (other race/ethnicity) for UD, and from 3.93% (not physically active) to 7.91% (females) for PD. The aORs between family history of diabetes and PD were not statistically significant for most population subgroups.

During 2009-2014, the average US population ≥ 20 years of age was 224.1 million. Using the prevalence estimates of DD (9.26%), UD (3.45%), and PD (40.55%), we found 20.7 million, 7.0 million, and 79.6 million people had DD, UD, and PD, respectively in the US population. Of these, approximately 10.1 million cases (48.7%) with DD, 1.4 million cases (20.6%) with UD, and 3.9 million cases (4.9%) with PD were attributed to having a family history of diabetes (Table 3). Among the non-Hispanic white, non-Hispanic black, and Hispanic cases with DD, 5.6 million, 1.9 million, and 1.8 million, respectively were attributable to having a family history of diabetes: (Table 3). Similar results are given for population subgroups defined by other risk factor status, and for UD and PD.

Discussion

Our findings confirm the public health importance of family history as a risk factor associated with DD, UD, and PD. Given the high prevalence of reported family history and the high prevalence of diabetes and PD, our findings suggest that millions of people who have DD, UD, and PD in the United States can be identified using family history in first degree relatives. Among people 20 years and older in the US, 9.3% had DD, almost half of whom have their diabetes attributable to family history (burden of more than 10 million people). Around 3.4% of adults who were not diagnosed with diabetes had UD with more than 20% population attributable fraction for family history of diabetes (burden of more than 1.4 million people). Finally, 40% of the population without diabetes had PD with 5% attributable to family history (burden of nearly 3.9 million people).

These results show the burden of disease for DD, UD, and PD attributable to having a family history of diabetes. More than one third of the US population aged ≥ 20 years have family history of diabetes. In our analyses we found that approximately 13% of the US population in 2009-2014 had both family history of diabetes and PD (data not shown). Even though not everyone with PD will develop diabetes, it is possible, although still not established, that the risk of developing diabetes is higher for those with PD who also have family history of diabetes.

Based on the formula, the PAF declines sharply with the decline in adjusted prevalence ratio. The decline in PAF for DD, UD, and PD (48.7%, 20.6%, and 4.9% respectively) is due to the decline in adjusted odds ratios (3.6, 1.8, and 1.3 respectively). The magnitudes of the association of family history of diabetes with UD and PD are smaller than that for DD. A possible explanation for this is that people with diagnosed diabetes are more interested in knowing their family history of diabetes than those who are unaware of their disease status.[7] Similarly, the magnitudes of the significant associations of family history of diabetes with UD and PD were smaller than that for DD for population subgroups for the same reason. The PAFs for DD for most of the population subgroups remain close to the PAF for the overall population. Population subgroups, aged 20-39 and non-Hispanic white have somewhat smaller PAFs (42.5% and 44.5% respectively) whereas the minority populations have relatively larger PAFs (> 56%). Lack of significant associations between family history of diabetes and UD in a few population groups could be due to small sample sizes since the prevalence of UD was relatively low**.** However, there were several population subgroups without significant associations between family history of diabetes and PD even in groups with higher prevalence of PD. These findings are consistent with our statement above about the relationship between family history and awareness of disease. Awareness of PD is quite low in the U.S. population (<10% among persons with no family history of diabetes; 10%-11% among those with family history of diabetes).[22] Furthermore, it has been shown that with lower cut-off points for FPG and A1C levels for PD compared to previously used cut-off points, less than half the population diagnosed with PD are likely to develop diabetes in the next 10 years.[23] There is also some concern that the same cut-off points should not be applied to different race/ ethnicity groups.[23,24] Also, not everyone with PD develop diabetes[23] and a more appropriate comparison group may be people with a family history of prediabetes. However, this information is not available in current surveys conducted in the United States.

Based on a genome-wide association study, several common genetic variants associated with type 2 diabetes were determined from different ancestral populations[25]. However, only 10% of the risk can be explained by these genetic variants.[11] A recent study based on large scale sequencing also did not provide evidence that rare and low frequency variants increase the risk of type 2 diabetes.[26] When considering prevention strategies for type 2 diabetes, it is important to stratify the population into groups by risk of developing type 2 diabetes. Genetic variants so far discovered do not seem to provide much further information in classifying those at increased risk of developing type 2 diabetes compared to traditional clinical risk factors. Even for genetic variants with higher relative risks in some ethnic

groups, it is recommended to consider traditional risk factors in combination with these genetic variants.[27]

Direct-to-consumer genetic testing companies make genetic tests available to predict risk of type 2 diabetes. Even without considering clinical validity and utility of these tests, these companies provide personalized genetic profiles, claiming that the genetic information received would persuade people at risk to implement healthier behaviors.[28] However, based on a parallel group, open, randomized control trial to study the outcome of conveying an estimate of genetic or phenotypic risk of type 2 diabetes, researchers found that knowing a genetic or phenotypic risk estimate did not change behaviors when compared with standard lifestyle advice.[28] On the other hand, a study based on a cluster-randomized clinical trial concluded that messages designed to target an individual's familial risk to six common diseases including diabetes moderately increased self-reported physical activity and intake of fruits and vegetables compared with a standard preventive message.[29] Another recent study of non-diabetic patients randomized to counselling that included both family health history and genetic tests for type 2 diabetes found that family history was more highly associated with a perception of risk for type 2 diabetes than was genetic risk testing.[30] These few studies suggest that knowledge of family history may be more likely to influence life style behaviors than knowledge based on genetic tests.

Study limitations

There are several limitations in our study. NHANES is a cross-sectional survey, and cannot be used to show causal effect of the risk factors on diabetes and PD we used in this study. However, these risk factors are well known in the literature, and thus in calculating impact numbers we assumed the causality of family history of diabetes on diabetes and PD. Also, DD was self- reported in the surveys and there could be differences in reporting bias between population groups. The data that NHANES collects do not allow us to differentiate between type 1 and type 2 diabetes, so our results are for diabetes overall, while interventions are based on evidence of risk reduction of type 2 diabetes. However, type 2 diabetes accounts for about 95% of DD in U.S. adults.[29] We also did not estimate the sampling errors of the impact numbers since the estimate of impact numbers includes the product of multiple estimates. The total of the impact numbers in demographic groups may not add up to the total for the US population. Moreover, the collection of family health history information is limited in NHANES. Participants were asked whether any of their first degree relatives were told by a health professional that they had diabetes. Since there is a high prevalence of UD in the population, it is likely that the prevalence of family history is under ascertained in the population and its relationship to the burden of diabetes in the population underestimated. There have been no population-based surveys that examined the accuracy of self-reported family histories of diabetes. However, based on data from 2004 HealthStyles survey, the respondents' reported awareness of type 2 diabetes status of their first degree relatives was high, ranging from 87.8% to 94.5% depending on type of relationship.[32] However, the differences in prevalence of reported family history between men and women suggest that there may be a recall or knowledge bias.[7] Further information on family history of diabetes beyond first degree relatives is not available in NHANES 2009-2014 to do a more comprehensive analysis of family history of diabetes.

In spite of the recent interest and focus on genomics and precision medicine, family health history continues to be an integral component of public health campaigns to identify people at high risk for developing diabetes. Additional national efforts are needed, especially among high risk groups such as Hispanics, non-Hispanic blacks, and people with BMI ≥ 30 kg/m^2, to obtain information on family history that may contribute to reduction of incidence of type 2 diabetes, and early diagnosis of diabetes to help prevent or delay complications.

Acknowledgments

Disclaimer:The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Table 1

Crude prevalence of reported family history of diabetes by selected characteristics

	Prevalence percent (95% CI)	p-value
US population age 20 years and older		
Total	36.70 (35.05, 38.26)	
Age (years)		
20-39 (1)	31.89 (29.48, 34.29)	
40-59 (2)	40.75 (38.28, 43.23)	
≥60 (3)	37.28 (34.75, 39.81)	
Pairwise difference (1,2)		< 0.001
Pairwise difference (1,3)		0.001
Pairwise difference (2,3)		0.049
Sex		
Males	34.47 (32.57, 36.36)	< 0.001
Females	38.72 (36.71, 40.73)	
Race/ Ethnicity		
Non-Hispanic white (1)	33.61 (31.82, 35.40)	
Hispanic (2)	41.11 (37.68, 44.54)	
Non-Hispanic black (3)	48.92 (45.92, 51.91)	
Other * (4)	36.72 (32.28, 41.15)	
Pairwise difference (1,2)		< 0.001
Pairwise difference (1,3)		< 0.001
Pairwise difference (1,4)		0.157
Pairwise difference (2,3)		0.002
Pairwise difference (2,4)		0.128
Pairwise difference (3,4)		< 0.001
BMI (kg/m^2)		
< 25 (1)	28.92 (26.11, 31.74)	
25-30 (2)	35.10 (33.09, 37.12)	
≥ 30 (3)	44.30 (41.68, 46.92)	
Pairwise difference (1,2)		< 0.001
Pairwise difference (1,3)		< 0.001
Pairwise difference (2,3)		< 0.001
Education		
< high school	42.10 (39.0, 45.21)	< 0.001
≥ high school	35.51 (33.92, 37.11)	
Income to poverty ratio		
< 1	40.68 (37.53, 43.83)	0.005
≥ 1	35.74 (33.95, 37.53)	
Physically activity		
Not active	37.03 (35.18, 38.87)	0.376
Active	35.50 (32.52, 38.49)	

	Prevalence percent (95% CI)	p-value
Hypertension		
Yes (1)	41.76 (38.99, 44.54)	< 0.001
No (2)	33.54 (31.57, 35.51)	

*Non-Hispanic Asians, non-Hispanic multiracial, and non-Hispanic other race.

Table 2

Estimates of prevalence ratios from polytomous logistic regression when populations having diagnosed diabetes (DD), undiagnosed diabetes (UD), and prediabetes (PD) were compared to the population not having any of these conditions

	Prevalence Ratio Estimates (95% CI) by outcome		
	DD	**UD**	**PD**
Reported family history			
No †			
Yes	4.27 (3.57, 5.12)	2.03 (1.56, 2.63)	1.26 (1.09, 1.44)
Age (years)			
20-39 †			
40-59	7.50 (5.56, 10.13)	5.93 (3.76, 9.35)	2.33 (1.97, 2.76)
≥60	26.87 (19.39, 37.23)	16.33 (10.38, 25.68)	5.11 (4.16, 6.28)
Sex			
Females †			
Males	1.96 (1.64, 2.34)	2.79 (2.06, 3.79)	1.61 (1.38, 1.88)
Race/ Ethnicity			
Non-Hispanic white †			
Hispanic	1.89 (1.55, 2.30)	2.22 (1.57, 3.15)	1.23 (1.03, 1.47)
Non-Hispanic black	1.75 (1.42, 2.16)	1.98 (1.36, 2.87)	1.43 (1.17, 1.74)
Other	3.34 (2.56, 4.34)	4.24 (2.44, 7.38)	1.47 (1.18, 1.85)
BMI (kg/m^2)			
< 25 †			
25-30	1.93 (1.55, 2.41)	2.02 (1.21, 3.37)	1.40 (1.13, 1.73)
≥ 30	6.60 (5.31, 8.21)	8.19 (4.65, 14.41)	2.52 (1.99, 3.21)
Income to poverty ratio			
≥ 1 †			
< 1	1.46 (1.14, 1.87)	1.24 * (0.86, 1.79)	1.10 * (0.91, 1.33)
Education			
≥ high school †			
< high school	1.68 (1.40, 2.03)	1.87 (1.44, 2.43)	1.53 (1.25, 1.88)
Physically activity			
Active †			
Not active	1.37 (1.05, 1.80)	1.43 (1.01, 2.02)	0.91 * (0.78, 1.08)
Hypertension			
No			
Yes	3.53 (2.76, 4.50)	1.99 (1.48, 2.66)	1.51 (1.22, 1.87)

† Reference group

* PRs are “not significant at 0.05 level”

Table 3

Prevalence of diagnosed diabetes (DD), undiagnosed diabetes (UD), prediabetes (PD), adjusted odds ratios, and population attributable fractions (PAFs) of reported family history for population subgroups. Prevalence of UD, adjusted odds ratios, and PAFs are based on the population that does not have DD, and prevalence of PD, adjusted odds ratios, and PAFs are based on the population that does not have DD or UD

	Prevalence (95% CI) by outcome			Adjusted OR			PAF%			Number Impacted (in thousands)		
	DD	UD	PD	DD	UD	PD	DD	UD	PD	DD	UD	PD
US population age 20 years and older												
Total	9.26 (8.61, 9.91)	3.45 (3.03, 3.87) 333.873.87)33.873.84)	40.55 (38.47, 42.62) . 6250)	3.59	1.77	1.28	48.66	20.59	4.87	10,098	1,443	3,875
Age (years)												
20-39	1.69 (1.35, 2.03)	1.04 (0.72, 1.35)	24.78 (22.26, 27.31)	3.32	2.27	***	42.53	28.34	***	587	236	***
40-59	9.40 (8.18, 10.62)	4.09 (3.11, 5.07)	44.22 (41.43, 47.02)	3.34	1.90	1.30	48.81	25.21	5.48	3,876	789	1,781
≥60	19.49 (17.84, 21.15)	6.45 (5.50, 7.40)	62.40 (58.51, 66.30)	3.88	1.52	1.42	51.78	13.95	3.97	5,834	419	1,078
Sex												
Males	9.49 (8.66, 10.32)	4.40 (3.65, 5.15)	44.90 (42.09, 47.71)	3.89	1.68	***	49.90	17.60	***	5,102	755	***
Females	9.04 (8.28, 9.80)	2.56 (2.06, 3.05)	36.54 (34.08, 38.99)	3.31	1.95	1.41	47.18	25.37	7.91	4,964	686	2,981
Race/ Ethnicity												
Non-Hispanic white	8.29 (7.48, 9.11)	2.84 (2.29,3.40)	39.76 (37.09, 42.44)	3.38	1.78	1.29	44.48	19.46	4.70	5,560	765	2,510
Hispanic	9.62 (8.18, 11.07)	4.66 (3.75, 5.56)	41.48 (38.51, 44.45)	4.67	***	***	60.17	***	***	1,844	***	***
Non-Hispanic black	13.27 (12.32, 14.22)	4.56 (3.34, 5.78)	46.59 (43.35, 49.84)	3.63	***	***	56.27	***	***	1,905	***	***
Other	11.18 (8.85, 13.52)	5.09 (3.48, 6.71)	37.08 (32.47, 41.69)	4.58	3.62	***	56.77	46.35	***	1,013	335	***
BMI (kg/m^2)												
< 25	3.52 (2.93, 4.11)	1.33 (0.77, 1.90)	28.20 (24.76, 31.64)	4.77	3.29	***	52.16	38.75	***	1,257	342	***
25-30	7.05 (6.21, 7.89)	2.67 (2.08, 3.26)	40.47 (37.09, 43.84)	3.98	2.37	***	51.08	31.00	***	2,636	564	***
≥ 30	15.24 (14.02, 16.46)	6.17 (5.18, 7.16)	52.91 (50.13, 55.68)	3.21	1.43	1.32	49.48	14.81	5.10	6,209	638	1,766
Education												
< high school	13.69 (12.07, 15.31)	5.46 (4.60, 6.32)	51.22 (47.16, 55.27)	3.43	***	***	50.52	***	***	2,706	***	***
≥ high school	8.31 (7.57, 9.06)	3.05 (2.60, 3.50)	38.47 (36.31, 40.63)	3.69	1.91	1.25	48.81	22.86	4.43	7,504	1,182	2,804
Income to poverty ratio												
< 1	10.72 (9.22, 12.22)	3.76 (2.92, 4.60)	39.56 (35.44, 43.68)	2.97	1.72	***	44.42	21.20	***	1,729	259	***

	Prevalence (95% CI) by outcome			Adjusted OR			PAF%			Number Impacted (in thousands)		
	DD	UD	PD	DD	UD	PD	DD	UD	PD	DD	UD	PD
≥ 1	8.87 (8.08, 9.66)	3.41 (2.84, 3.99)	40.04 (37.78, 42.30)	3.73	1.78	1.33	49.39	20.35	5.62	8,224	1,189	3,721
Hypertension												
Yes	18.35 (17.04, 19.67)	6.06 (5.36, 6.76)	56.61 (52.84, 60.39)	3.38	1.52	***	49.89	16.0	***	7,783	673	***
No	3.70 (3.13, 4.27)	2.09 (1.60, 2.58)	32.56 (30.46, 34.66)	4.14	2.23	1.30	51.31	28.40	5.80	2,642	797	2,477
Physically active												
Yes	6.04 (5.03, 7.04)	2.44 (1.73, 3.15)	40.63 (36.79, 44.46)	3.63	***	***	48.29	***	***	1,607	***	***
No	10.31 (9.57, 11.05)	3.79 (3.30, 4.29)	40.51 (38.29, 42.74)	3.61	1.81	1.22	49.15	21.17	3.93	8,561	1,217	2,323

*** Not estimated due to not having a significant odds ratio