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Quantifying the Impact of Adverse Social Conditions on Diabetes in America: A National Analysis of US Adults

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An abstract of
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A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health in
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## Abstract

Diabetes is one of the top 10 leading causes of death affecting about 30 million Americans. Social determinants of health, such as education and income, have been identified as factors that influence an individual's diabetes status. Specifically, adults with lower levels of education and income are more likely to develop diabetes. Education and income may therefore present important leverage points for policy interventions to prevent diabetes nationally. The purpose of this study was to quantify the potential impact of two social conditions – educational attainment and annual family income – on the burden of diabetes nationally. We report the fraction of prevalent diabetes cases that could be prevented if all Americans were exposed to optimal social conditions, and examine which racial/ethnic groups stand to benefit the most from improvements in these conditions. We conducted a secondary data analysis of participants ≥20 in the 2013-2014 National Health and Nutrition Examination Survey (NHANES). Taking into account the prevalence of each social condition and the association between the social condition and diabetes, we computed the hypothetical fraction of prevalent diabetes that could be prevented (i.e., the population attributable fraction) if all adults achieved a college degree or higher and earned an annual family income of 100,000 or above. We found that 43% of prevalent diabetes cases could be prevented if all Americans achieved a college degree or higher, whereas 15% of prevalent diabetes cases could be prevented if all Americans were exposed to an annual family income of 100,000 or above. Hispanic and non-Hispanic Black Americans were seen to benefit the most from achievement of these optimal social conditions, with PAFs of about 51% and 18.0% respectively for education, and 18.0% and 18.4% respectively for income. Results from this study exemplify that modifiable conditions in the social environment may prove to be very impactful in addressing the growing diabetes prevalence.

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# Chapter 1: Introduction

## Problem Definition

Diabetes mellitus (DM) is one of the top 10 leading causes of death in the United States, resulting in almost 80,000 deaths annually (Centers for Disease Control and Prevention [CDC], 2016). Those who have been diagnosed with diabetes are at an increased risk for many health complications that can affect the eyes, skin, nerves, and various other parts of the body (American Diabetes Association [ADA], 2017a). Individuals and society face both direct and indirect costs including direct medical costs and loss of productivity. In 2012, the estimated cost of diagnosed diabetes was $245 billion, with $69 billion being a result of lost productivity (ADA, 2013). Furthermore, medical expenditures among people with diagnosed diabetes is 2.3 times higher than what expenditures would be if they did not have this diagnosis. Moreover, the 2012 estimated cost of diabetes is a $3 billion increase from what was spent in 2007 (ADA, 2013), illustrating the continued growth of diabetes cases and cost throughout time. Diabetes has presented itself as a debilitating disease in need of intervention to stem its growing prevalence and cost on both individuals and society.

### Diabetes Epidemiology

In 2012, 12.3% of the US adult population had diabetes and 25.2% of this population were not aware of their diabetes diagnosis. Additionally, diabetes prevalence has greatly increased over time in every racial/ethnic group, by all education levels, in both sexes, and in all poverty income groups (Menke, Casagrande, Geiss, & Cowie, 2015), and is estimated to affect 53.1 million Americans by 2025 (CDC, 2014; Rowley & Bezold, 2012).

Though diabetes is a growing problem for all Americans, the disparity in diabetes prevalence between racial/ethnic groups, education levels, and social economic strata continues to be disproportionate, with poor, less educated, and minority populations carrying the highest burden of disease. In 2012, non-Hispanic Blacks (20.6%), non-Hispanic Asians (16.5%), and Hispanic Americans (18.7%) had higher rates of total diabetes when compared to non-Hispanic Whites (9.5%). Additionally, those with less than a high school degree and in the lowest poverty income tertile had the highest rate of total diabetes (18.6% and 17.8% respectively) when compared to those having greater than a high school degree and belonging to the highest poverty income tertile (9.7% and 8.0% respectively) (Menke, Casagrande, Geiss, & Cowie, 2015). Furthermore, disparities in access to care have also exasperated disparities in diabetes prevalence, with minority populations being more likely to be uninsured (Nelson, Chapko, Reiber, & Boyko, 2005), and to have higher diabetes rates when uninsured, in comparison to their White counterparts (Hastings & Hawkins, 2010). Since diabetes has been seen to be patterned by these social conditions, it is important to understand the role of the social, political, and economic environment when setting out to alleviate this public health issue.

## Social Determinants of Health

Social determinants of health are conditions within the environment where people are born, live, work and learn that can affect a wide range of health outcomes such as poor school systems, economic resources, and racial discrimination (Braveman, Egerter, & Williams, 2011; Healthy People 2020, 2017a). These conditions can be social, economic, or physical, and may exist within environmental settings such as churches, neighborhoods, and the workplace (Healthy People 2020, 2017a). Healthy People 2020, a

10-year national plan for improving the health of all Americans (Healthy People 2020, 2017b) has identified social determinants of health as an important issue to address and see achievable gains by the year 2020. The goal of this 2020 topic is to "create social and physical environments that promote good health for all", and places importance on understating how populations experience conditions in the social environment, and how these conditions impact health (Healthy People 2020, 2017a).

Despite national level goals to address these disparities in socio-economically disadvantaged populations however, very little progress has been made to close these gaps (United States Department of Health and Human Services [HHS], 2013) and evidence suggests that these dipartites are very costly to society. In a recent economic analysis, authors found that if all adult Americans experienced the same level of mortality and illness as college graduates, there would be a one trillion-dollar total economic benefit (Braveman & Egerter, 2008). These substantial costs both to the individual and society highlight the need to address health disparities across the nation.

## Education, Income, and Health Care Access as Social Determinants of Health

Educational attainment, annual income, and health care access are all conditions affected by the social environment. These factors become social determinants when they are conceptualized in the context of an individual's *access* to these potentially health promoting determinants (Braveman, & Egerter, 2008; Braveman, Cubbin, Egerter, Williams, & Pamuk, E. 2010; Braveman, Egerter, & Williams, 2011). Additionally, these factors have also been shown to be affected by socioeconomic status and race/ethnicity, which has been seen to determine how access to resources is distributed. It is then important to understand how these conditions are affected by the socio-political environment and its relation to diabetes prevalence.

Disparities in Educational Attainment

In 2015, 88% of adults had a high school diploma or degree, while 33% of adults held a bachelor’s degree or higher. These rates varied by race/ethnicity however, with Asians and non-Hispanic Whites being more likely to hold a bachelor’s degree or higher when compared to their Hispanic and non-Hispanic Black counterparts. The percent of the population earning a bachelor’s degree or higher for Non-Hispanic Blacks and Hispanics was 23% and 16% respectively, in comparison to 33% and 54% in the non-Hispanic White and Asian populations respectively (Ryan & Bauman, 2016). Additionally, non-Hispanic Blacks ranked lowest in 6-year graduation rates (46%), followed by Hispanics (55%), non-Hispanic Whites (67%) and Asian (72%) populations (Shapiro et al., 2017).

Educational attainment is a factor that has been conceptualized as a social determinant of health (Braveman et al., 2011; Williams, Costa, Odunlami, & Mohammed, 2008). Higher levels of educational attainment have been associated with health-promoting behaviors, such as proper nutrition, exercise, and proper health disease and management (Barbeau, Krieger, & Soobader, 2004). Those who have achieved higher levels of education are also more likely to receive preventative care and less likely to experience adverse health outcomes (Hummer & Lariscy, 2011; Ross & Wu, 1995). Conversely, those with lower educational achievement are more likely to suffer from a range of diseases such as heart disease, asthma, and diabetes, as well as suffer an earlier death than those who have achieved higher levels of education (Borrell, Dallo, & White, 2006; Hummer & Lariscy, 2011; Kimbro, Bzostek, Goldman, & Rodriguez, 2008; Ross & Wu, 1995; Telfair & Shelton, 2012). Furthermore, educational attainment is patterned by race/ethnicity, with non-Hispanic Blacks and Hispanics being more likely to belong to disadvantaged schools, and are therefore more likely to achieve lower levels of education and feel the effects of adverse health outcomes (Rouse & Barrow, 2006). These adverse health effects have been illustrated in a 2011 study where authors found that higher educational attainment was associated with a lower prevalence of diabetes (Choi et al., 2011), and in a 2006 study which found that individuals with less than a high school degree were 1.6 times more likely to have diabetes than those individuals with at least a bachelor's degree (Borrell, Dallo, & White, 2006).

Disparities in Income

In 2016, the median annual household income was $59,039, which represented a statistically significant increase from the following year (United States Census Bureau, 2017). Despite these gains however, when stratified by race/ethnicity, clear disparities still exist. In 2010, the median household income was highest among Asian and non-Hispanic White populations ($57,518 and $48,977 respectively), while Hispanic and non-Hispanic Black populations achieved the lowest median incomes in that year ($32,241 and $30,134 respectively) (United States Census Bureau, 2017).

Access to economic resources such as income provides a wide range of health-promoting opportunities to individuals. Factors such as spending power, housing, work exposures, diet, and medical care provide opportunity to engage in health-promoting behaviors. (Winkleby, Jatulis, Frank, & Fortmann, 1992). Studies have shown that economic resources predict health and its determinants, with more positive health effects with increasing income being observed in randomized and natural experiments (Herd, Goesling, & House, 2007; Kawachi, Adler, & Dow, 2010). Along the income gradient, health-related outcomes generally follow a step-wise pattern, with those earning an income below poverty level generally experiencing the worst health. Furthermore, when assessing diabetes prevalence by family income, results of the 2010 study showed that as family income increases, the prevalence of diabetes decreases, with individuals with the lowest prevalence of disease earning greater than 400% of the Federal Poverty Line (Braveman, Cubbin, Egerter, Williams, & Pamuk, 2010).

Disparities in Health Care Access

Medical care and the healthcare system are the least understood as a social determinant of health, however when conceptualized as who has access to these health-promoting services and institutions it is helpful to view it in the context of the larger social climate. As of 2016, 12.3% of adults were uninsured. Of those adults who were uninsured, 26% were “poor” and 23% were “near poor”. Additionally, of those who were uninsured, 24.7% were Hispanic, 15.1% were non-Hispanic Black, 8.5% were non-Hispanic White, and 7.8% were Asian (Martinez, Zammitti, & Cohen, 2017). The rates of the uninsured can be understood in the context of who is more likely to have access to care and who, more importantly, is more likely to have access to this care on a continual and routine basis.

Race/ethnicity which presents itself within institutions as racism and discrimination have seen to shape who is granted access to such services (Braveman, Egerter, & Williams, 2011). Numerous studies have shown that those who are uninsured are more likely to be low income and belong to a minority population, in-turn making access to health care more difficult for non-Hispanic Black and Hispanic populations (Nelson, Chapko, Reiber, & Boyko, 2005, Hastings & Hawkins, 2010). This has had implications for health outcomes, with diabetes found to be highest among those who are uninsured (Hastings & Hawkins, 2010).

## Problem Justification

Many studies have assessed the effects of social determinants on the prevalence of diabetes, however there remains many gaps in the literature. Namely, though many studies have assessed the relationship between educational attainment and diabetes prevalence, fewer have assessed how annual family income and access to health care affect the prevalence of diabetes in the US adult population. Furthermore, annual family income has rarely been studied as its own variable, many times being assessed in conjunction with education and other factors to create one SES variable (Wi et al. 2016; Adler& Ostrove, 1999; Doshi, Smalls, Williams, Wolfman, & Egede, 2016). The role health care access has in prevalent diabetes is also an area that needs further exploration with a clearer definition of what it means to have access to care. Furthermore, there is a need to focus not only on reducing clinical markers of disease, but methods to slow the rate of prevalent diabetes as well, through modifications to the environments in which we work live and play.

Therefore, to have the biggest impact, more studies are needed to assess how *modifying* these social conditions will result in reductions of prevalent diabetes cases, and the reduction of disparities across population groups. There is a need to quantify the influence of social determinants of health on diabetes prevalence; without addressing this gap in the literature, we may over-estimate the role of proximal risk factors in diabetes prevention. If it is determined that exposure to optimal social conditions such as the attainment of a graduate education, earning within the highest income bracket, and equitable access to health care contribute to a lower diabetes prevalence across any or all racial/ethnic groups, this has implications for policies regarding the ways in which resources are distributed. Results from the study will provide justification for the potential health impact of policies aimed at achieving equity in education, annual income, and health care access, as well as increasing access to these resources for all Americans.

## Theoretical Framework

To understand the influence of educational attainment, annual income, and access to health care on prevalent diabetes, it is helpful to apply the Social Determinants of Health (SDOH) conceptual framework proposed by Braveman and colleagues (2011). The SDOH framework highlights, first, that health-related behaviors and receipt of medical care do not occur in a vacuum. Instead, these factors, known as downstream determinants, are shaped by living and working conditions that can influence health both directly and indirectly, known as upstream determinants.

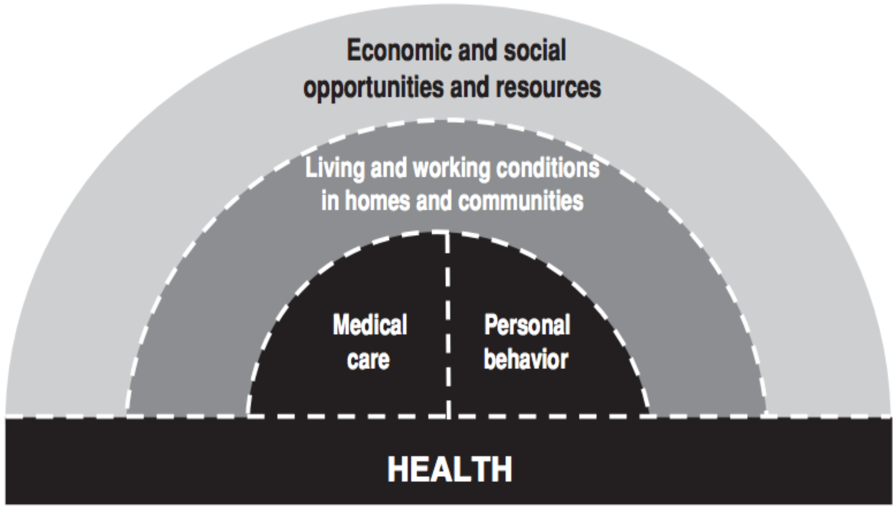


**Figure 1: Social Determinants of Health Framework: Upstream and Downstream Determinants (Braveman et. al., 2011)**

Within the framework, downstream determinants are understood as factors that are the most proximal to the individual and have the potential to determine health outcomes. These are factors such as smoking, exercising, and other health-related attitudes, beliefs, or behaviors. However, in isolation, addressing these factors may only temporarily solve the health issue and do little to address socioeconomic disparities that determine who has access to health promoting programs, interventions, and receipt of care. Conversely, upstream determinants are conceptualized as fundamental causes that set-in motion causal pathways that facilitate health effects through downstream factors. Upstream determinants are characteristics of the larger social, political, and economic environment that influence who, when, and where resources are allocated, which in-turn have effects on health outcomes through their influence on downstream determinants. The SDOH framework highlights how health is shaped not only by our personal health decisions and living and working conditions, but also by even more upstream determinants within the socio-political environment that influence an individual's access to health-promoting conditions and healthy choices (Braveman et al., 2011)

Diabetes diagnoses are influenced by a variety of factors that are not only proximal to the individual, such as diet, exercise, and medical care, but more distal ones as well, such as education and income, and the large social context that determines who has access to these resources. As has been summarized earlier, educational attainment has seen to influence health knowledge and literacy, which then influences the downstream determinants of nutrition, exercise, and health disease management that have a direct effect on health (Barbeau, Krieger, & Soobader, 2004). Similarly, income has been seen to predict health through downstream determinants such as access to housing, characteristics of the neighborhood environment, nutrition, and stress (Braveman, Egerter, & Williams, 2001). Health care access is the only downstream determinant that is of interest in this study, and, within the context of this framework, has a direct effect on health outcomes (Williams, Costa, Odunlami, & Mohammed, 2008). The most distal sphere within this framework explains the relationship of economic and social opportunities and resources on downstream determinants and health. Within the context of this study, race/ethnicity will be examined as a factor within the social environment that influences an individual's access to education, income, and health care, and its direct effect on health through chronic stress related to experiences with racism and discrimination (Rouse & Barrow, 2006).

Efforts to reduce diabetes prevalence, should be focused not only on proximal causes, but additionally on fundamental causes, with the goal of modifying the social and contextual environments such that all Americans are exposed to the same optimal conditions.

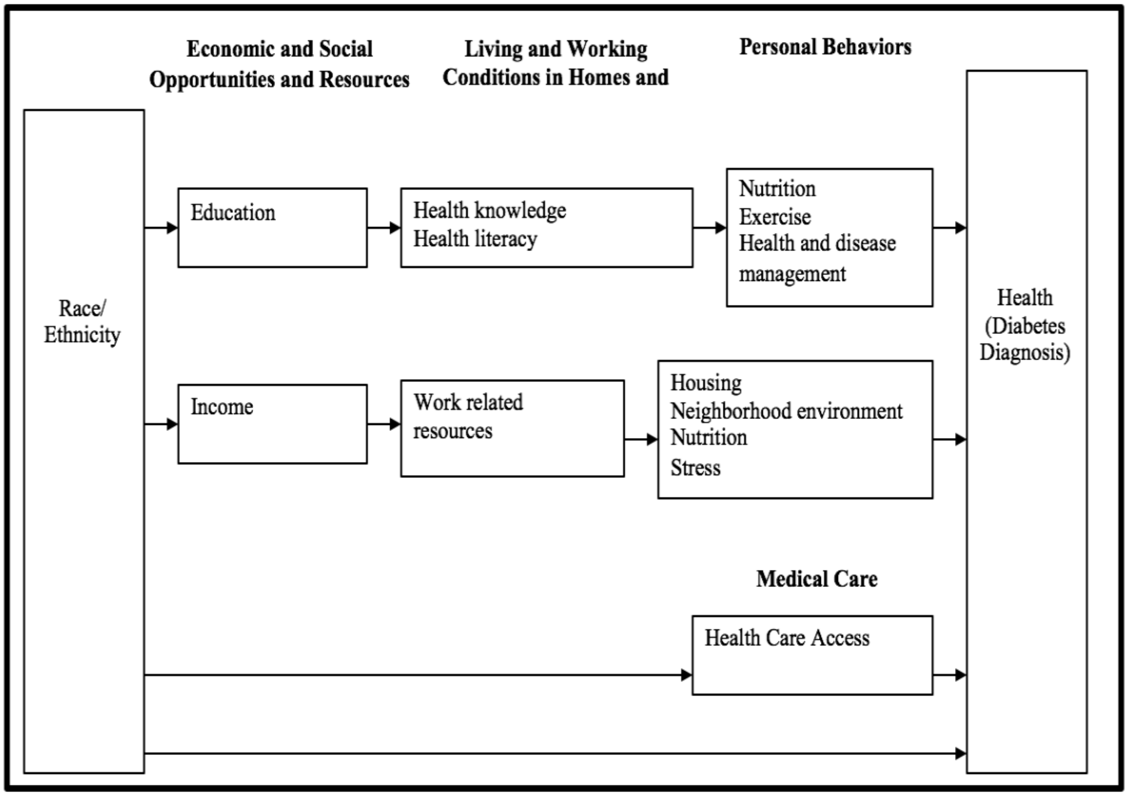


**Figure 2: Pathways linking education, income, health care access, and race/ethnicity to health (Braveman et al., 2011)**

## Purpose of the Study

The purpose of this study is to estimate the fraction of prevalent diabetes cases that could be prevented nationally if all Americans were exposed to optimal social conditions. To do so, the study sought to quantify the impact of three upstream social conditions: 1) educational attainment, 2) annual family income, and 3) health care access. The impact of each social condition will also be explored within each racial/ethnic category to determine which groups stand to benefit the most from exposure to optimal social conditions. With this study, it is hoped to be able to provide upper bounds of estimates of the potential reduction of diabetes that may be achieved by improvements in social environment, thereby providing rationale for further exploration into the role that the social environment plays in health outcomes.

## Research Questions

1. What fraction of prevalent diabetes cases can be prevented nationally if all Americans were exposed to optimal social conditions?

2. What racial/ethnic groups will stand to benefit the most from exposure to optimal social conditions when compared to all other major racial/ethnic groups in the United States?

# Chapter 2: Literature Review

## Introduction

Type 2 diabetes mellitus inflicts a great public health burden across all populations, affecting about 30.3 million Americans (CDC, 2017). Those who have been diagnosed with this chronic disease are at risk for many adverse and life threatening complications such as stroke, kidney disease, hypertension, and nerve damage (ADA, 2017a). To alleviate this burden of disease, attention justifiably has mostly been given to clinical and/or behavioral risk factors such as obesity, body mass index (BMI), hemoglobin A1c (HbA1c), smoking, and physical inactivity (Yang, Hall, Piccolo, Maserejian, & McKinlay, 2015). However, much of the literature suggests that conditions of the social environment, such as educational attainment, income level or socioeconomic status, and healthcare access, can and do contribute to the incidence of disease, and create health diminishing environments that sustain and increase their prevalence (Williams, Costa, Odunlami, & Mohammed, 2008).

The following sections will detail the relationship between diabetes and the three social conditions of interest: 1) educational attainment, 2) annual family income, and 3) health care access. The literature will document the relationship between the social conditions and diabetes as it is understood broadly, which will include not only prevalent diabetes, but incident diabetes and diabetes care, management, and outcomes as well, with the goal of presenting the most robust picture of the health problem of interest in this paper. The review will begin with the literature on educational attainment, then will move to income and SES, and lastly health care access. This represents the amount of literature existing on each topic from greatest to least, and moving from distal to more proximal determinants as understood within the context of the Social Determinants of Health framework. Finally, this section will end with a review of risk factor modification and race/ethnicity in the diabetes literature.

## Education and Diabetes

The relationship between educational attainment and diabetes has been the most clearly documented in the literature out of the three social conditions of interest. A 2014 study conducted by Whitaker and colleagues (2014) examined data from a nationally representative survey (National Center for Health Statistics, 2005, 2011) to assess the relationship between educational attainment and self-reported diabetes in adult U.S. men 18 and over. Results suggested that for all men with less than a bachelor's degree, there was an increased odds of reporting a diabetes diagnosis, with those men having less than a high school diploma having the highest odds of reporting a diabetes diagnosis (odds ratio [OR] = 2.28, 95% confidence interval [CI] = 2.14, 2.43) when compared to their counterparts with a bachelor's degree or higher. Specifically, Non-Hispanic White and Hispanic men with less than a high school education were seen to consistently, after adjustment, have higher odds of diabetes when compared to their counterparts who had a bachelor's degree or higher. However, non-Hispanic Black men did not appear to have an association between reporting a diabetes diagnosis and educational attainment. Authors of the study cited numerous variables such as residential segregation, racism, and perceived masculinity that were not accounted for in the study however (Whitaker et al., 2014). These factors were hypothesized as possible explanations as to why no association was found between educational attainment and self-reported diabetes diagnosis in non-Hispanic Black men, despite documented disparities in education and other social factors in this community (Menke, Casagrande, Geiss, & Cowie, 2015; Gaskin, Dinwiddie, Chan, & McCleary, 2012; Moody, Ayers, Stewart, Covinsky, & Inouye, 2005). They can also be understood in the context of this study as part of the social environment and seen to be distal and/or downstream determinants in the context of the SDOH framework, which are oftentimes hard to conceptualize and control for within studies.

In a 2005 study, authors furthered our understanding of this relationship by examining the association between lower socioeconomic position (SEP) and incident diabetes in a large county in California. Authors assessed data from the Alameda County Study (ACS) which collected information on predictors of health and physical functioning in an adult population (N=6,928) residing in the county in 1965. In this longitudinal study, educational attainment was one of three variables used to assess SEP. Results suggested that educational attainment was associated with increased diabetes risk, with those having <12 years of education having a 50% excess risk of incident diabetes compared with those with >12 years of education. This excess risk remained high even when adjustments were made for age, demographics (gender, race/ethnicity, etc.), behavioral covariates (physical activity, smoking, etc.) and BMI (Maty, Everson-Rose, Haan, Raghunathan, & Kaplan, 2005).

Similarly, Choi et al. (2011) assessed the relationship between self-reported educational attainment and numerous chronic diseases in individuals enrolled in a national health screening initiative. Authors analyzed data from the National Kidney Foundation's Kidney Early Evaluation Program (KEEP), a free nationwide screening program implemented in 2000 (N=61,457). In the study, diabetes was assessed as one of the chronic disease outcomes of interest, and it was found that higher educational attainment was associated with a lower prevalence of the disease. Authors found an absolute difference of 13% in prevalence of diabetes between the lowest (High school graduate or below) and highest (4-year college graduate or above) education groups, and a clear step-wise pattern in the prevalence of diabetes at each educational level. Authors concluded that higher educational attainment was independently associated with a lower prevalence of diabetes in all age and race/ethnicity groups (Choi et al., 2011).

Lastly, Borrell and colleagues (2006) additionally investigated the relationship between education and prevalent diabetes in U.S. adults. Study authors examined data from the National Health Interview Survey (1997-2002) (N=187,233) and found an inverse relationship between educational attainment and the prevalence of diabetes. Individuals with less than a high school degree were found to be 1.6 (CI=1.4, 1.8) times more likely to have diabetes than those with at least a bachelor's degree. Though this relationship remained consistent, yet decreased, after adjustment for age, gender, survey year, marital status, health insurance, BMI, income, and race/ethnicity, only Whites and Hispanics were seen to have a significant relationship between diabetes and having less than a high school degree. Similar to what was found by Whitaker and colleagues (2014), Non-Hispanic Blacks were not found to have a significant relationship between the two, despite this population exhibiting the highest prevalence of diabetes regardless of their education level. Authors conclude that though educational attainment was found to be inversely associated with diabetes, it may have a different effect on diabetes health among different racial/ethnic categories. (Borrell, Dalo, & White, 2006).

The studies reviewed in this section present a relationship between education and diabetes through pathways such as health and disease management as presented in the

SDOH pathways in Figure 2. However, though these studies provided evidence for the relationship between educational attainment and diabetes, they presented clear limitations with small sample sizes and differing results among the various racial/ethnic groups highlight the need for further investigation.

## Income, Socioeconomic Status, and Diabetes

Income level has also been documented in the literature as a risk factor for diabetes, oftentimes presenting a step-wise pattern as individuals move up the income gradient (Menke, Casagrande, Geiss, & Cowie, 2015). However, as with educational attainment, though education is more often assessed on its own, income is often assessed as a combined SES variable. Additionally, a few studies have also assessed clinical markers of diabetes in those who have been diagnosed with the disease. It therefore was deemed important to review studies on income, SES, prevalent diabetes, and diabetes clinical risk factors since much of the literature assesses a combination of all of these factors.

### Income and Diabetes Management

Doshi and colleagues (2016) investigated the relationship between annual income and clinical risk factors that have been associated with diabetes – (HbA1c, LDL-C, DBP) (ADA, 2017b). Adults (N=358) were recruited from two primary care settings, and study authors found that there was a significant association between those earning an annual income less than $75,000 and lower LDL-C ($p$=.021) (Doshi, Smalls, Williams, Wolfman, & Egede, 2016), suggesting that the higher your income, the better able you are to manage diabetes.

Another study conducted by Berkowitz and colleagues (2014) examined the association between hypoglycemia – a clinical marker of diabetes – and income in an adult population. Study authors analyzed regional data collected from adult patients (N=14,357) via the Kaiser Permanente Northern California (KPNC) diabetes registry and found that reports of severe hypoglycemia were more common (11%) among low-income vs. high income groups. Specifically, incomes of less than $15,000 (OR 1.51 95%CI 1.19– 1.91) and incomes that ranged from $15,000– $24,999 (OR 1.57 95%CI 1.27–1.94) were found to be associated with increased hypoglycemia. Authors concluded that earning a low-income is an important risk factor for hypoglycemia and the management of diabetes (Berkowitz et al., 2014).

Though Doshi et al. (2016) and Berkowitz et al. (2014) have contributed to our understanding of how social factors may foster or inhibit the symptoms of disease, authors did not allow for a comparative analysis of the differences in income and other characteristics of those who have been diagnosed with diabetes and those who have not, since study samples were restricted to those who have already been diagnosed with the disease.

Prevalent Diabetes and Measures of SES and Income

Wi and colleagues (2016) investigated the relationship between SES and prevalent diabetes in a mixed rural-urban U.S. community. Study authors assessed data on medical care delivery from the Rochester Epidemiology Project (REP) which was conducted in a northern county in the U.S. SES was measured using the Housing-based index of Socioeconomic status (HOUSES) (Juhn et al., 2011), which matches the addresses of eligible study participants (N=88,010) to publicly available property data.

Four property feature variables – housing value, square footage of housing unit, number of bedrooms, and number of bathrooms – were used to formulate a standard HOUSES score, with higher HOUSES's scores indicating a higher SES. Authors found that SES measured by HOUSES was inversely associated with prevalent diabetes ($p<.001$), and it was concluded that in a mixed rural-urban setting health disparities in diabetes and other chronic disease prevalence still exist across SES (Wi et al., 2016).

An additional study conducted by Garcia et al. (2015) examined the association between neighborhood socioeconomic position (NSEP) and prevalent diabetes in an older Latino population. Neighborhood SEP was measured similarly to the way in which HOUSES scores were computed in the study conducted by Wi et al. (2016). Garcia and colleagues used addresses to match census tract-level socioeconomic variables to specific neighborhoods. Study authors included 6 different variables ranging from education level, poverty, and income, to household size, to compute NSEP scores, with higher scores indicating higher neighborhood SES (Zeki Al Hazzouri et al., 2011). Individual level SEP factors were also included in analyses, which included self-reported gross past-month household income data that was grouped into low (<$1,500) and high (≥$1,500). Longitudinal data from the Sacramento Area Latino Study on Aging (SALSA), which included 1,789 Mexican American participants recruited between 1998-1999 was assessed, and it was found that higher NSEP was associated with lower diabetes prevalence ($p$=.001). This relationship remained even after adjustment for BMI and other individual level factors. However, individual level gross past-month income was not seen to be significantly associated with diabetes prevalence, though there was a higher prevalence of those with diabetes in the low-income group in comparison to the high-income group (66.4% vs. 33.6%) (Garcia et al., 2015).

Lastly, Braveman and colleagues (2010) investigated the relationship between prevalent diabetes and income using a nationally representative sample of children and adults. Data for the study was obtained from five nationally representative sources: Period Linked/Birth Infant Death Data File (2000-2002), National Longitudinal Mortality Study (1988-1998), National Health Interview Survey (2001-2005), National Health and Nutrition Examination Survey (1999-2004), and Behavioral Risk Factor Surveillance System (2005-2007). Authors found that in adults, income was significantly associated with diabetes ($p=.006$), with those with the lowest income being consistently the least healthy. Authors additionally noted clear step-wise patterns that emerge in diabetes prevalence as individuals move up the income gradient; the higher the income, the lower the prevalence of diabetes. It is concluded that a wider range of socioeconomic factors needs to be addressed to better understand how factors in the social environment effect the health of populations (Braveman, Cubbin, Egerter, Williams, & Pamuk, 2010).

These studies present a picture of the relationship between income and diabetes. As per the framework presented in Figure 2, the aforementioned literature documents the potential pathway from income, to factors such as housing and neighborhood environment in the HOUSES and NSEP scores respectively, to diabetes outcomes. However, as with the limitations presented in the educational attainment section, many of these studies are limited in the make-up of their sample as well as the sample size. Additionally, there is a clear need for further studies that treat income as its own variable and to not combine it with other factors.

## Healthcare Access and Diabetes

Access to healthcare has been the least concretely studied of the three social conditions of interest. This is in part due to different definitions of what it means to have "access" to healthcare. Some studies have conceptualized this concept as health insurance coverage, usual source of care, continuity of care, and type of insurance, among other definitions. Authors have additionally studied both diabetes management and diabetes prevalence in relation to a healthcare access variable. For the purposes of this review, the following sections will cover all varying different aspects and definitions of health care access.

### Health Insurance Status and Diabetes Management

A 2005 study described the association between type of health insurance coverage and the quality of care provided to individuals with diabetes. Authors assessed the 2000 Behavioral Risk Factor Surveillance system (N=11,647) and found that diabetes patients who were uninsured were more likely to be non-Hispanic African American and Hispanic, and report lower incomes. The uninsured additionally were less likely to report annual exams and daily monitoring that is important for the management of their diabetes (e.g. HbA1c tests, and blood glucose monitoring) (Nelson, Chapko, Reiber, & Boyko, 2005). Similarly, using data from the Third National Health and Nutrition Examination Survey (N=1,400), Mainous and colleagues (2004) found a link between continuity of care at a usual site of care with better glycemic control among people with diabetes (Mainous, Koopman, Gill, Baker & Pearson, 2004). Toulose and Kodadek (2015) assessed archived medical record data (N=65) and found a significant relationship between continuous access to medication an improved HbA1c (p=.003), LDL (p=.0044) and systolic blood pressure (p=.025) (Toulouse & Kodadek, 2014).

Furthermore, in a 2010 study examining the extent to which a usual source of healthcare mediated the relationship between health insurance and diabetes in adult men, authors found similar results to Nelson et al. (2005), where diabetes was found to be highest among Hispanic and non-Hispanic African American men who were uninsured (6% and 5% respectively). Using data from the 2005 California Health Interview Survey (N=17,472), authors additionally found a significant relationship between health insurance status and diabetes for every racial group except non-Hispanic African American men. Overall, men in this study had an odds of probable diabetes when enrolled in public health insurance 2.14 times greater than those men without diabetes ([OR=2.14 ; CI=1.50,3.06, $p<0.05$). Hispanic and non-Hispanic White men additionally revealed a significant mediation effect (p=.00), showing that usual source of care mediated the relationship between health insurance status and diabetes. No significant effect was found in non-Hispanic African American and non-Hispanic Asian American men however. This finding is consistent with other studies that have been previously reviewed in this paper that did not find a significant relationship between diabetes and the predictor variable in the non-Hispanic African American population of interest (Hastings & Hawkins, 2010).

Though some of these studies do not provide an understanding of the direct relationship between healthcare access and prevalent diabetes, it lends insight into how access may affect the management of disease, and presents a possible pathway from race/ethnicity, to health care access, to diabetes outcomes and management (Figure 2). In sum, the aforementioned studies highlight that access to health care in any form (health insurance, access to medication, continuity of care) is related to improved health outcomes for those with diabetes.

## Risk Factor Modification

Risk factor modification is used in various studies with the goal of guiding prevention efforts. The aim of these studies is to provide an estimate of how many incident or prevalent diabetes cases could be prevented if various risk factors were either eliminated or reduced to their "best achievable level" (this variable is conceptualized in many different ways depending on the study and its goals). A few studies have estimated attributable fractions in the context of diabetes. In a 2014 study estimating race specific proportions of gestational diabetes mellitus (GDM) that were attributable to overweight and obesity, authors found the fraction of GDM cases attributable to obesity to be 12% among all races. For extreme obesity however, the fraction of attributable cases was highest among non-Hispanic African American women (18.1%) when compared to their non-Hispanic White and Hispanic counterparts (14.0% and 9.6% respectively); though non-Hispanic African American women were found to have the lowest risk ratio (2.6 vs. 3.4 for Hispanic women and 3.1 for non-Hispanic White women) between the extremely obese and normal weight individuals in this population (Cavicchia et al., 2014).

Similarly, Motamedi and colleagues (2012) conducted a systematic review of the literature to estimate the avoidable burden of incident diabetes related to multiple clinical risk factors in Iran. Study authors analyzed data from multiple studies to calculate potential impact fractions (PIF) (reducing the prevalence of a risk factor) and found the highest PIF (0.18) to be after a reduction in impaired fasting glucose and impaired glucose tolerance (Motamedi et al., 2012). In contrast, Imamura and colleagues (2016) estimated the population attributable fraction for type 2 diabetes from behavioral risk factors as opposed to clinical ones. Authors conducted a systematic review of the literature and meta-analysis to estimate how many diabetes cases could be prevented population wide, if the consumption of sugar sweetened beverages were reduced. Authors found that the consumption of sugar sweetened beverages, when not accounting for obesity status, would result in 2.6 million excess diabetes events, an attributable fraction of 11.9% across the population as a whole (Imamura et al., 2016).

**Race/Ethnicity and Diabetes**

Many of the studies that have been reviewed in this paper have stratified their analyses by race/ethnicity. Most of these studies have shown associations between race/ethnicity and diabetes, with non-Hispanic African Americans, non-Hispanic Asian Americans, and Hispanic populations having the highest prevalence of diabetes across all levels of education, income, and measures of health care access (Whitaker et al., 2014; Borrell, Dalo, & White, 2006; Hastings & Hawkins, 2010). Additionally, there seems to be differential effect of race when estimating the proportion of diabetes cases that can be prevented through modification (Cavicchia et al., 2014). In a 2015 study, examining data from the Boston Area Community Health III Survey (N=2,764), authors found that African Americans were 2.89 times more likely than White Americans to have type II diabetes mellitus (T2DM) specifically when living in economically disadvantaged environments (Piccolo, Duncan, Pearce, & McKinlay, 2015), such as ones characterized by low educational attainment, low income, and lack of access to healthcare. In the context of the SDOH framework, this may be explained by distal determinants in the social environment, such as racism and discrimination, making their way downstream, effecting more proximal determinants, and in turn effecting health outcomes. Though minority populations consistently exhibited higher prevalence's of diabetes and have shown to be at a greater risk for disease diagnosis however, it is not as clear how race/ethnicity effects the association between social conditions and diabetes prevalence, especially in non-Hispanic African American populations, meriting the need for further study.

## Summary

Social and environmental factors have clearly presented opportunities for the possible reduction in the prevalence of disease, specifically for diabetes. Interventions and other efforts that address these social determinants of health have seen to possibly reduce disparities in outcomes, especially among those populations who are the most disadvantaged (Williams, Costa, Odunlami, & Mohammed, 2008). Several studies have documented the relationship between diabetes prevalence and the three social conditions of interest: education, income, and healthcare access; however, these relationships warrant further investigation, especially in regards to minority populations. Furthermore, even fewer studies have considered social and environmental factors in their estimation of preventable fractions. The aim of this study is to build on the existing literature that is assessing the relationship between factors in the social environment and prevalent diabetes, and to estimate how many disease cases can be prevented if these modifiable risk factors were altered to their best achievable levels. Doing so may provide insight into how and where interventions should occur to improve the health of populations and decrease disparities in outcomes.

# Chapter 3: Methods

## Data Source

The current study is a secondary data analysis of the National Health and Nutrition Examination Survey (NHANES) designed to assess the health and nutritional status of adults and children in the United States. NHANES is a major program of the National Center for Health Statistics (NCHS), which is part of the Centers for Disease Control and Prevention (CDC). The purpose of the survey is to determine the prevalence of major diseases and their risk factors, and to assess the nutritional status of the nation and its association with health promotion and disease prevention.

NHANES is a cross-sectional study and has been conducted continuously since 1999; for the purposes of the current study, the 2013-2014 2-year survey data was assessed due to it being the most current data available at the start of the study. NHANES examines a nationally representative sample of 5,000 individuals each year and it includes a household screener, health interview, and examination component. The household screener is used to determine eligibility, the interview includes demographic, socioeconomic, dietary, and health-related questions, and the examination includes medical, dental, physiological measurements, and laboratory tests. (National Center for Health Statistics [NCHS], 2017). For the current study, the demographics, examination (Body Measures file) questionnaire, (Diabetes, Health Insurance, Hospital Utilization & Access to Care files), and laboratory (Glycohemoglobin and Plasma Fasting Glucose files) data files were used. A letter of determination was requested from the Emory University Institutional Review Board and it was determined that this study did not meet the definition of research with “human subjects”; therefore, no IRB review was required.

## Participants

<u>Sampling Design</u>

Participants are selected using a complex, multistage, probability sampling design. The purpose of this study design is to select participants that are representative of the civilian, non-institutionalized US population residing in the 50 states and the District of Columbia. In the first stage of the sampling selection, primary sampling units (PSU) were selected which consisted of 15 different counties throughout the US. The second stage consisted of a sample of area segments which were comprised of census blocks or a combination of blocks that were designed to produce approximately equal sample sizes per PSU. The third stage consisted of selecting dwelling units (DUs) which included households and non-institutionalized group quarters such as dormitories. In the final stage of sample selection, individuals residing inside the households or dormitories were selected based on sex, race, age, Hispanic origin, and income. This was to ensure that the target sample sizes by subdomain were achieved.

Additionally, certain populations were oversampled due to them being of “particular public health interest” (NCHS, 2017). These populations included Hispanics, non-Hispanic Asians, non-Hispanic Blacks, older adults aged 80 or over, and low income whites/others below 130% of the federal poverty level (Johnson, Dohrmann, Burt, & Mohadjer, 2014). In the 2013-2014 survey, 14,332 individuals were selected from 30 different survey locations. Of those, 10,175 completed the survey and 9,813 participated in the examination. Response rates of the interview and examination were 71% and 68% respectively (NCHS, 2015)

Study Participants

For the current study, participants consisted of all adults ≥20 years old who completed the 2013-2014 NHANES survey and had data available for all main variables and covariates (diabetes, annual household income, education level, race, age, sex, and BMI). NHANES participants <20 years old and/or with missing data were excluded from the sample. After elimination of 4,517 participants <20 years old, 394 participants with missing income data, 249 participants with missing BMI data, and seven participants with missing education data, 5,149 participants remained in the study sample to be analyzed.

## Procedures

In each of the 30 locations selected for the 2014-2013 survey, local health and government officials were notified of the upcoming survey. Households who were previously selected received a letter from the NCHS director, introducing the survey and providing the consent brochure and official consent form.

Health interviews were conducted in the participant's home and data were collected via Computer Assisted Personal Interviewing (CAPI), which allowed participants to manually enter their responses and privately respond to sensitive survey questions. Following the completion of the interview, participants were then asked to participate in the physical examination. The examination was conducted in a specially designed mobile examination center (MEC) that was equipped with state-of-the-art equipment for the physical exam. The physical exam was conducted by a physician while laboratory tests, X-rays, and other health measurements were conducted by highly trained medical personnel. All data was stored and processed in an advanced computer database to eliminate the need for paper forms and manual coding (NCHS, 2013).

## Measures

Definition of Variables

### Independent Variables (Social Conditions)

The independent variables of interest in this study are conceptualized as upstream, or distal, determinants as defined by the SDOH framework, as they are variables that are largely determined by social and/or institutional norms as opposed to individual behaviors or actions. The independent variables were defined as follows:

***Educational Attainment.*** Educational attainment was assessed using the highest education level achieved by respondents. Participants were asked “What is the highest grade or level of school you have completed or the highest degree you have received” and responses were categorized into five groups. For the purposes of this study however, education level was further categorized into four groups: Less than a high school education (completion of grades 9-11); high school or GED (completion of grade 12 and/or GED equivalent); some college or an associate’s degree (completion of an associate’s degree); and college graduate or above (completion of a bachelor’s degree or above).

***Income Categories***. Income was assessed using the annual household income variable in the survey which was reported as a range of value in dollars. It was then categorized into three groups: Earnings between $0 and $19,999; earnings between $20,000-$99,999, and earnings of $100,000 and over.

***Health Care Access.*** Health care access was assessed using the “routine place to go for healthcare” variable in the survey. Participants were asked “is there a place that you usually go when you are sick or need advice about your health" and answered either yes or no.

**Outcome Variable (Diabetes)**

***Diabetes.*** Prevalent diabetes was the main outcome of interest in the study. A definition a total diabetes, both diagnosed and undiagnosed, was used for this study which is consistent across all NHANES study years (Menke et al., 2015). It was defined by a glycohemoglobin ($A_{1c}$) level of 6.5% or greater, a fasting plasma glucose (FPG) level of 126 mg/dL or greater, and a self-diagnosis of diabetes from a doctor or healthcare provider. Self-diagnosis of diabetes was assessed with the question "other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes". Participants only needed to meet one of the three diabetes criteria to be counted as a prevalent diabetes case.

**Covariates**

Covariates were included in the study as possible confounders or modifying factors of interest. They may also be conceptualized as downstream, or proximal, determinants as defined by the SDOH framework, as they are behavioral factors and/or non-modifiable characteristics of the individual.

***Race/ethnicity.*** Five racial/ethnic categories were included in the study for analysis. These were self-reported categories and included: non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic (other Hispanic and Mexican Americans), and other.

***BMI/Weight categories.*** Body mass index (BMI) was included in the study as a possible confounding variable and was organized into three weight categories: Normal weight (BMI<25), overweight (BMI≥25<30), and obese (BMI≥30).

Lastly, age, defined in years, and gender, either male or female, were additionally included in analyses as covariates and possible confounders. All variables were included in analyses used to answer both research questions 1 & 2.

Definition of Optimal Social Conditions

The purpose of this study was to use the population attributable fraction equation to estimate the number of prevalent diabetes cases that could be hypothetically prevented nationally if everyone were exposed to the same optimal levels of educational attainment and income, as well as to determine which racial/ethnic groups would potentially benefit the most from these optimal exposures. Therefore, to conduct this analysis, optimal conditions were defined as achieving the highest education or income category in this study, and reporting the use of a routine provider. For educational attainment, that was defined as achieving a bachelor's degree or higher; for income, that was defined as earning an annual family income of $100,000 or greater, and for health care access, that was defined as answering "yes" to the question "is there a place that you usually go when you are sick or need advice about your health".

## Statistical Analysis

The analysis for the current study proceeded in three stages: 1) an assessment of the prevalence of each social condition, 2) the estimation of the measure of association between diabetes and the social conditions, and 3) the calculation of population attributable fractions (PAFs) to estimate the number of preventable cases. Further explanation of how each analysis contributed to each research question will be detailed in the following sections.

Preliminary Analyses

The first two stages of the analysis were treated as preliminary analyses that were needed to continue to the main analyses of the study, which was the calculation of PAFs.

**Univariate Analysis: Assessing Prevalence of Each Social Condition**

To answer both research questions, the prevalence of each social condition and covariate in the total population was found using PROC SURVEYFREQ and the appropriate published sample weights. The same SAS procedure was also used to calculate the prevalence of those with and without diabetes in each of the previously mentioned categories. Observed prevalence's will later be used in the PAF equation which will be explained later in this section.

Sample weights were used in this analysis and the subsequent analyses to account for unequal probabilities of selection and nonresponse from the original NHANES sampling design; thus, this allowed for estimates that were representative of the civilian, noninstitutionalized US population (Zipf et al., 2013). MEC exam weights were therefore used for all analysis due to this weight this accounting for the weight of the smallest subpopulation. All analyses were conducted using SAS 9.4.

**Multiple Logistic Regression: Assessing Measures of Association**

Multiple logistic regressions were conducted using PROC SURVEYLOGISTIC and were conducted for the total population and in each racial/ethnic category. This stage of analyses was conducted to quantify the impact of the three social conditions on diabetes prevalence. Odds ratios were outputted from each model to be used as the measure of association in the PAF calculations.

Eight separate models were created for the total population, four education and four income models, building from a crude model 1 to a fully adjusted model 4. A sequential approach was used to add control variables in the model, with each model becoming sequentially more complex than the last. The four education models included: Model 1: education adjusted for age and sex; Model 2: education adjusting for age, sex, and race; Model 3: education adjusted for age, sex, race, and BMI; and Model 4: education adjusted for age, sex, race, BMI, income and routine provider. The four income models included: Model 1: income adjusted for age and sex; Model 2: income adjusting for age, sex, and race; Model 3: income adjusted for age, sex, race, and BMI; and Model 4: income adjusted for age, sex, race, BMI, income and routine provider.

To determine the association between diabetes and education as well as diabetes and income in each race/ethnic category, additional models were created stratified by race/ethnicity. Five models were created for education and five for income, one for each of the five racial/ethnic categories in the study. Each model was fully adjusted; the education models included education adjusted for age, sex, race, BMI, routine provider, and income in each racial/ethnic category, while the income models included income adjusted for age, sex, race, BMI, routine provider, and education in each racial/ethnic category.

Following initial analyses, final models were not created or included in this study for health care access. This variable was dropped as a main independent variable and included in subsequent analyses only as a covariate. This was due to very few prevalent cases of diabetes among those who did not have a routine provider, which may be due to factors above and beyond what can be accounted for in the current analysis. Alternate ways to define healthcare access were also explored, such as the presence or absence of health insurance, and yielded similar results. It was determined that the data was not appropriate to test the hypothesis that health care access was functioning as a social determinant in the same way as the other two independent variables in the study.

Main Analysis

**Estimating Population Attributable Fractions**

To answer research questions 1 & 2, the population attributable fraction equation was used. Population attributable fraction (PAF) is defined as the proportional reduction in population disease or mortality that would occur if exposure to a risk factor were reduced to an alternate or ideal level of exposure (World Health Organization [WHO], 2017). The population attributable fraction associated with educational attainment and income category was defined as:

$$\mathbf{PAF} = \frac{\sum_{i=1}^{n} P_i \; OR_i \; - \; \sum_{i=1}^{n} P_i' \; OR_i}{\sum_{i=1}^{n} P_i \; OR_i}$$

where $P_i$ is the observed prevalence of exposure level *i*, P' is the "counterfactual" or optimal level of exposure level *i*, defined as the achievement of the optimal level of education or income, and $OR_i$ is the odds ratio, or measure of association, at exposure level *i* (WHO, 2017; Patel, Winkel, Ali, Narayan, & Mehta, 2015).

PAF's were calculated separately for each education level and income category for the total study population and was additionally stratified by race/ethnicity. The resulting attributable fractions in the total study population may then be interpreted two ways: As the proportion of prevalent diabetes cases that could hypothetically be prevented if everyone were to complete a bachelor's degree or higher in comparison to their observed level of educational attainment; and the proportion of prevalent diabetes cases that could hypothetically be prevented if everyone were to earn $100,000 or above in comparison to their observed income category. Furthermore, the resulting attributable fractions stratified by race/ethnicity may be interpreted two additional ways: As the proportion of prevalent diabetes cases that could hypothetically be prevented in each racial/ethnic category if everyone in that category were to complete a bachelor's degree or higher in comparison to their observed level of educational attainment; and the proportion of prevalent diabetes cases that could hypothetically be prevented in each racial/ethnic category if everyone in that category were to earn $100,000 or above in comparison to their observed income category.

# Chapter 4: Results

## Introduction

The purpose of this study is to estimate the fraction of prevalent diabetes cases that could be prevented nationally if all Americans were exposed to optimal social conditions. To do so, preliminary analyses were conducted to assess the prevalence of each social condition and the measure of association between diabetes and the social conditions in the total U.S. adult population. The impact of each social condition was also explored in each racial/ethnic category to determine which groups stand to benefit the most from exposure to optimal social conditions. These analyses were explored to answer the two primary research questions guiding the study: 1) What fraction of prevalent diabetes cases can be prevented nationally if all Americans were exposed to optimal social conditions, and 2) What racial/ethnic groups will stand to benefit the most from exposure to optimal social conditions when compared to all other major racial/ethnic groups in the United States.

The following sections will detail the results of both the preliminary and main amylases that were conducted for the study. The preliminary analyses included univariate analysis and logistic regression models, while the main analyses included the calculation of the population attributable fractions in the total population and each/racial ethnic category. Specifically, this chapter will detail, 1) sample characteristics of the study population, 2) odds of diabetes in the total population associated with each social condition, 3) odds of diabetes in the largest racial/ethnic categories associated with each social condition, 4) the attributable fraction of prevalent diabetes cases associated with each social condition in the total population, and 5) the attributable fraction of prevalent diabetes cases associated with each social condition in each racial/ethnic category.

## Sample Characteristics

**Table 1** provides demographic characteristics of the participants included in the analyses. Characteristics are presented for the total population and additionally by diabetes status. The overall diabetes prevalence amongst participants was 12.9% with an average age of 49.0 (SD=17.5). Of the 5,149 participants, 51.9% were female, 66.6% were non-Hispanic White, and 38% were obese with a BMI ≥ 30. Additionally, majority earned an annual household income between $20,000-$99,999, completed some college or an Associate’s degree (33%), and reported having a routine healthcare provider (84.2%).

Among those with diabetes, 51.5% were male, 62.6% were non-Hispanic White, 61.3% were obese, and the average age was 60.6% (SD=13.3). Furthermore, among those with diabetes, most participants earned an annual household income between $20,000-$99,999 (63.2%), completed some college or an Associate’s degree (36.8%), and reported having a routine healthcare provider (95.9%).

Conversely, among those without diabetes, 52.4% were female, 67.1% were non-Hispanic White, 34.5% were obese, and the average age was 46.7 (SD=17.3). Lastly among those without diabetes, most participants earned an annual household income between $20,000-$99,999 (56.6%), completed some college or an Associate’s degree (32.5%), and reported having a routine healthcare provider (82.5%).

**Table 1: Characteristics of US Adults Aged 20 Years or Over: National Health and Nutrition Examination Survey, 2013-2014**

| | Total | | With Diabetes | | Without Diabetes | |
|---|---|---|---|---|---|---|
| | Prevalence (%) | 95% CI | Prevalence (%) | 95% CI | Prevalence (%) | 95% CI |
| Overall Diabetes Prevalence | 12.9 | 11.6-14.3 | | | | |
| **Demographics** | | | | | | |
| Age (Mean ±SD) | 49.0 (±17.5) | 48.5-49.4 | 60.6 (±13.3) | 59.7-61.5 | 46.7 (±17.3) | 46.2-47.2 |
| Sex | | | | | | |
| Male | 48.1 | 46.8-49.4 | 51.5 | 47.3-55.8 | 47.6 | 46.4-48.8 |
| Female | 51.9 | 50.6-53.2 | 48.5 | 44.2-52.7 | 52.4 | 51.2-53.6 |
| Race/Ethnicity | | | | | | |
| Non-Hispanic | | | | | | |
| White | 66.6 | 59.5-73.6 | 62.6 | 54.5-70.7 | 67.1 | 60.2-74.1 |
| Black | 11.4 | 8.0-14.9 | 14.1 | 9.5-18.6 | 11.0 | 7.6-14.4 |
| Asian | 5.3 | 4.0-6.7 | 6.3 | 3.8-8.7 | 5.2 | 3.9-6.5 |
| All Hispanic | 14.0 | 9.2-18.8 | 14.6 | 8.2-21.0 | 13.9 | 9.3-18.6 |
| Other | 2.7 | 1.7-3.6 | 2.4 | 0.6-4.4 | 2.8 | 1.8-3.7 |
| **Health Factors** | | | | | | |
| Weight Status | | | | | | |
| Normal Weight (BMI<25) | 29.2 | 27.4-31.1 | 10.2 | 7.3-13.1 | 32.1 | 30.1-34.0 |
| Overweight (BMI ≥25<30) | 32.8 | 31.0-34.6 | 28.5 | 23.5-33.5 | 33.4 | 31.7-35.1 |
| Obese (BMI ≥ 30) | 38.0 | 36.0-39.9 | 61.3 | 55.4-67.2 | 34.5 | 32.7-36.3 |
| **Social Factors** | | | | | | |
| Income Category | | | | | | |
| $0-$19,999 | 17.8 | 13.7-22.0 | 21.3 | 17.0-25.5 | 17.3 | 12.9-21.7 |
| $20,000-$99,999 | 57.4 | 54.6-60.4 | 63.2 | 58.2-68.1 | 56.6 | 53.2-60.0 |
| $100,000 and over | 24.8 | 19.8-29.7 | 15.5 | 9.3-21.8 | 26.1 | 20.9-31.3 |
| Education Level | | | | | | |
| Less than High School | 14.7 | 11.5-18.0 | 21.7 | 16.4-27.0 | 13.8 | 10.6-17.0 |
| High School Graduate or GED | 21.8 | 18.9-24.6 | 24.3 | 20.7-27.9 | 21.4 | 18.3-24.5 |
| Some College or Associates Degree | 33.0 | 30.7-35.2 | 36.8 | 31.6-42.0 | 32.5 | 30.1-34.8 |
| College Graduate or Above | 30.5 | 26.2-34.6 | 17.2 | 13.0-21.5 | 32.3 | 28.0-36.8 |
| Routine Provider | | | | | | |
| Yes | 84.2 | 82.6-85.7 | 95.9 | 94.0-97.8 | 82.5 | 80.7-84.2 |
| No | 15.8 | 14.2-17.4 | 4.1 | 2.2-6.0 | 17.5 | 15.8-19.3 |

CI=confidence interval; BMI= body mass index; GED=general equivalency diploma

Missing data were as follows: income, n=372; education level, n=5; weight status, n=68

## Associations Between Social Conditions and Prevalent Diabetes

Relative Odds of Diabetes in the Total Population

**Tables 2-3** provide results of the unadjusted and adjusted education and income regression models for the total study population. The purpose of these initial analyses was to explore the measure of association between the social conditions of interest in the study and diabetes in the total U.S. adult population. Four different logistic regression models were used per social condition to examine these associations, in which a sequential approach was used to add control variables into the models. Each model became sequentially more complex building off a crude Model 1 that included one of the social conditions (education or income) and adjusted only for age and sex. Model 2 adjusted for age, sex, and race; Model 3 adjusted for age, sex, race, and BMI; and the final Model 4 adjusted for age, sex, race, BMI, routine provider and the social condition that was not the primary interest in the model (i.e. for the models examining the relationship between diabetes and educational attainment, income was controlled for in the final model 4).

### Association Between Educational Attainment and Diabetes

**Table 2** presents the association between diabetes and educational attainment within the total study population. Model 1 represents the model including education and adjusting for age and sex. Among adults with less than a high school education (odds ratio [OR]=2.98, 95% confidence interval [CI]= 2.16,4.13), adults who are high school graduates or have a GED (OR=2.25, 95% CI= 1.64,3.09), and adults with some college or an Associate's degree (OR=2.46, 95% CI=1.72,3.51) there was a significantly higher odds of diabetes compared with adults who are college graduates or above. In Model 2, those differences persisted even after adjustment for race. There was a significantly higher odds of diabetes among adults with less than a high school education (OR=2.62, 95% CI= 1.83,3.74), adults who are high school graduates or have a GED (OR=2.21, 95% CI= 1.60,3.05), and adults with some college or an Associate's degree (OR=2.45, 95% CI=1.69,3.55) when compared to adults who are college graduates or above. A similar pattern persisted in Model 3 with further adjustment for BMI. There was a significantly higher odds of diabetes among adults with less than a high school education (OR=2.49, 95% CI= 1.76,3.51), adults who are high school graduates or have a GED (OR=2.03, 95% CI= 1.41,2.30), and adults with some college or an Associate's degree (OR=2.15, 95% CI=1.46,3.18) when compared to adults who are college graduates or above. Lastly, in the fully adjusted Model 4 that additionally adjusts for routine provider and income, there persisted a significantly higher odds of diabetes among adults with less than a college degree compared to adults with a college degree or above. Among those adults with less than a high school education, the odds of diabetes was 2.44 times higher (95% CI=1.73,3.43) when compared to adults who are college graduates or above. Furthermore, among adults with a high school education or GED, the odds of diabetes was 1.92 times higher (95% CI=1.27,2.90) when compared to adults who are college graduates or above. Finally, among those adults with some college or an Associate's degree, the odds of diabetes was 2.06 times higher (95% CI=1.38,3.07) when compared to adults who are college graduates or above.

**Table 2. The Association Between Educational Attainment and Diabetes in US Adults Aged 20 Years or Over: National Health and Nutrition Examination Survey, 2013-2014 (n=5,149)**

| Education | Model 1, OR (95% CI) | Model 2, OR (95% CI) | Model 3, OR (95% CI) | Model 4, OR (95% CI) |
|---|---|---|---|---|
| Less than High School | 2.98 (2.16-4.13) * | 2.62 (1.83-3.74) * | 2.49 (1.76-3.51) * | 2.44 (1.73-3.43) * |
| High School Graduate or GED | 2.25 (1.64-3.09) * | 2.21 (1.60-3.05) * | 2.03 (1.41-2.30) * | 1.92 (1.27-2.90) * |
| Some College or Associates Degree | 2.46 (1.72-3.51) * | 2.45 (1.69-3.55) * | 2.15 (1.46-3.18) * | 2.06 (1.38-3.07) * |
| College Graduate or Above | 1.00 | 1.00 | 1.00 | 1.00 |

OR=odds ratio; CI=confidence interval; BMI= body mass index; GED=general equivalency diploma
Model 1: education adjusted for age and sex; Model 2: crude model additionally adjusted for race; Model 3: Model 2 additionally adjusted for BMI; Model 4: Model 3 additionally adjusted for routine provider and income.
*denotes a statistically significant relationship at alpha=0.05 ($p<0.05$).

**Association Between Annual Family Income and Diabetes**

**Table 3** presents the association between diabetes and income level within the study population. Models 1-4 follow the same pattern as the education models previously discussed. Model 1 represents the model including income and adjusted for age and sex. In this model, there was a significantly higher odds of diabetes among adults earning between $0-$19,999 (OR=2.02, 95% CI=1.27-3.22) and adults earning between $20,000-$99,999 (OR=1.80, 95% CI= 1.13,2.86) when compared to adults earning $100,000 and over. Model 2 was further adjusted for race with observed differences persisting after adjustment. In Model 2, there was a significantly higher odds of diabetes among adults earning between $0-$19,999 (OR=1.79, 95% CI=1.08-2.96) and adults earning between $20,000-$99,999 (OR=1.68, 95% CI= 1.03,2.73) when compared to adults earning

$100,000 and over. Model 3 was further adjusted for BMI. The stepwise pattern in odds ratios persisted however with changes in significance. Among adults earning between $0-$19,999 the odds of diabetes was significantly higher (OR=1.74, 95% CI=1.03,2.93) compared to adults earning $100,000 and over. Among adults earning between $20,000-$99,999, the odds of diabetes was 1.47 times higher (95% CI=0.87,2.48) compared to adults earning $100,000 or above, though the difference in odds were not significant. Finally, in the fully adjusted Model 4, adjusted for routine provider and education, the odds of diabetes was 1.35 times higher (95% CI=0.77,2.34) among adults earning between $0-$19,999 compared to adults earning $100,000 and over. Lastly, the odds of diabetes was 1.20 times higher (95% CI= 0.70,2.04) among adults earning between $20,000-$99,999 when compared to adults earning $100,000 and above. None of odds ratios in the final model were significant.

**Table 3. The Association Between Income Level and Diabetes in US Adults Aged 20 Years or Over: National Health and Nutrition Examination Survey, 2013-2014 (n=5,149)**

| Income | Model 1, OR (95% CI) | Model 2, OR (95% CI) | Model 3, OR (95% CI) | Model 4, OR (95% CI) |
|---|---|---|---|---|
| $0-$19,999 | 2.02 (1.27-3.22) * | 1.79 (1.08-2.96) * | 1.74 (1.03-2.93) * | 1.35 (0.77-2.34) |
| $20,000-$99,999 | 1.80 (1.13-2.86) * | 1.68 (1.03-2.73) * | 1.47 (0.87-2.48) | 1.20 (0.70-2.04) |
| $100,000 and over | 1.00 | 1.00 | 1.00 | 1.00 |

OR=odds ratio; CI=confidence interval; BMI= body mass index; GED=general equivalency diploma
Model 1: income adjusted for age and sex; Model 2: crude model additionally adjusted for race; Model 3: Model 2 additionally adjusted for BMI; Model 4: Model 3 additionally adjusted for routine provider and education.
*denotes a statistically significant relationship at alpha=0.05 (p<0.05).

Relative Odds of Diabetes in each Racial/Ethnic Category

**Tables 4-5** provide the results for the fully adjusted regression models for education and income stratified by race/ethnicity. The purpose of these preliminary analyses was to explore the association between diabetes and the social conditions of interest in each racial/ethnic category. One logistic regression model was used for each racial/ethnic category to examine these associations. This was a fully adjusted model that included one of the social conditions (education or income) and adjusted for age, sex, race, BMI, routine provider, and the other social condition that was not the main interest in the model (i.e. for the education models, income was included as a control variable, and vice versa).

**Association Between Educational Attainment and Diabetes by Race/Ethnicity**

**Table 4** presents the association between diabetes and educational attainment in each racial/ethnic group using a fully adjusted model. Among non-Hispanic White adults, there was a significantly higher odds of diabetes in those with less than a high school degree (OR=2.88, 95% CI= 1.86,4.46), those who are high school graduates or have a GED (OR=1.94, 95% CI=1.15,3.28), and those with some college or an Associate's degree (OR=2.56, 95% CI=1.62,4.05) when compared to those who are college graduates or above. Similarly, among non-Hispanic Black adults, the odds of diabetes was higher among those with less than a high school education (OR=1.14, 95% CI= 0.61,2.15) and those who are high school graduates or have a GED (OR=1.20, 95% CI= 0.71,2.03) compared to those who are college graduates or above. However, those with some college or an Associate's degree had an odds of diabetes 0.76 times lower (95% CI= 0.46-1.27) when compared to non-Hispanic Black adults who are college graduates or above. Results were not significant for any education level however. Among non-Hispanic Asians, the odds of diabetes was higher among those with less than a high school degree (OR=1.56, 95% CI= 0.48,5.05), those who are high school graduates or have a GED (OR=1.22, 95% CI= 0.58,2.59), and those with some college or an associate's degree (OR= 1.14, 95% CI= 0.54,2.38) compared to non-Hispanic Asian adults who are college graduates or above. However, similar to results found in non-Hispanic Black adults, the odds of diabetes was not significant for any education level. Among Hispanic adults, results were similar to non-Hispanic White and non-Hispanic Asian adults who had higher odds of diabetes compared to those who are college graduates or above. The odds of diabetes among Hispanic adults was higher among those with less than a high school education (OR=3.44, 95% CI= 1.10,10.76), those who are high school graduates or have a GED (OR=3.98, 95% CI=1.37,11.53), and those with some college or an Associate's degree (OR=2.37, 95% CI=0.74,7.56) compared to Hispanic adults who are college graduates or above. There was only a significant odds of diabetes among Hispanic adults with less than a high school education and Hispanic adults who have a high school degree or GED. Lastly, among those identifying as "Other" in the study population the odds of diabetes was 0.76 times lower (95% CI= 0.04,16,14) when compared to adults who have a college degree or above. Conversely, the odds of diabetes was higher among adults with a high school degree or GED (OR=1.50, 95% CI=0.09,24.85) and adults with some college or an Associate's degree (OR=3.00, 95% CI= 0.30,30.44) compared to adults who are college graduates or above. Results were not significant for any education level.

**Table 4. The Association Between Educational Attainment and Diabetes Stratified by Racial/Ethnic Category in US Adults Aged 20 Years or Over: National Health and Nutrition Examination Survey, 2013-2014**

| Education | NH-White OR, (95% CI) (n=2,258) | NH-Black OR, (95% CI) (n=1,061) | NH-Asian OR, (95% CI) (n=586) | All Hispanic OR, (95% CI) (n=1,090) | Other OR, (95% CI) (n=154) |
|---|---|---|---|---|---|
| Less than High School | 2.88 (1.86-4.46) * | 1.14 (0.61-2.15) | 1.56 (0.48-5.05) | 3.44 (1.10-10.76) * | 0.76 (0.04-16.14) |
| High School Graduate or GED | 1.94 (1.15-3.28) * | 1.20 (0.71-2.03) | 1.22 (0.58-2.59) | 3.98 (1.37-11.53) * | 1.50 (0.09-24.85) |
| Some College or Associates Degree | 2.56 (1.62-4.05) * | 0.76 (0.46-1.27) | 1.14 (0.54-2.38) | 2.37 (0.74-7.56) | 3.00 (0.30-30.44) |
| College Graduate or Above | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

OR=odds ratio; CI=confidence interval; BMI= body mass index; GED=general equivalency diploma
Each model was adjusted for age, sex; BMI, routine provider and income.
* denotes a statistically significant relationship at alpha=0.05 ($p<0.05$).

### Association Between Annual Family Income and Diabetes and by Race/Ethnicity

**Table 5** presents the association between diabetes and income in each racial/ethnic group using a fully adjusted model. Among, non-Hispanic White adults, the odds of diabetes was higher among those earning between $0-$19,999 (OR=1.69, 95% CI= 0.88,3.22) and among those earning between $20,000-$99,999 (OR=1.14, 95% CI= 0.55,2.37) compared to non-Hispanic White adults earning $100,000 and over. Similarly, among non-Hispanic Black adults, the odds of diabetes is higher among those earning between $0-$19,999 (OR=1.36, 95% CI= 0.56,3.32) and among those earning between $20,000-$99,999 (OR=1.33, 95% CI= 0.60,2.97) compared to non-Hispanic Black adults earning $100,000 and over. Following the same trend as non-Hispanic White and non-Hispanic Black adults, non-Hispanic Asian adults have a higher odds of diabetes among those earning between $0-$19,999 (OR=1.11, 95% CI= 0.33,3.71) and among those earning between $20,000-$99,999 (OR=2.18, 95% CI= 1.10,4.33) compared to non-Hispanic Asian adults earning $100,000 and over. Additionally, the odds of diabetes was statistically significantly higher for those earning within the middle income level, whereas no such significant association was found for those earning within the lowest income level. Conversely, among Hispanic adults, the odds of diabetes was lower for those earning between $0-$19,999 (OR=0.54, 95% CI= 0.25,1.19) and among those earning between $20,000-$99,999 (OR=0.71, 95% CI= 0.37-1.38) compared to Hispanic adults earning $100,000 and over. Lastly, similar to Hispanic adults, among those identifying as “Other”, the odds of diabetes was lower among those earning between $0-$19,999 (OR=0.56, 95% CI= 0.02,14.25) and among those earning between $20,000-$99,999 (OR=0.90, 95% CI= 0.08-10.30) compared to “Other” adults earning $100,000 and over.

**Table 5. The Association Between Income Level and Diabetes Stratified by Racial/Ethnic Category in US Adults Aged 20 Years or Over: National Health and Nutrition Examination Survey, 2013-2014**

| Income | NH-White OR, (95% CI) (n=2,258) | NH-Black OR, (95% CI) (n=1,061) | NH-Asian OR, (95% CI) (n=586) | All Hispanic OR, (95% CI) (n=1,090) | Other OR, (95% CI) (n=154) |
|---|---|---|---|---|---|
| $0-$19,999 | 1.69 (0.88-3.22) | 1.36 (0.56-3.32) | 1.11 (0.33-3.71) | 0.54 (0.25-1.19) | 0.56 (0.02-14.25) |
| $20,000-$99,999 | 1.14 (0.55-2.37) | 1.33 (0.60-2.97) | 2.18 (1.10-4.33) * | 0.71 (0.37-1.38) | 0.90 (0.08-10.30) |
| $100,000 and over | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

OR=odds ratio; CI=confidence interval; BMI= body mass index; GED=general equivalency diploma
Each model was adjusted for age, sex; BMI, routine provider and education.
* denotes a statistically significant relationship at alpha=0.05 ($p<0.05$).

## Population Attributable Fractions

**Table 6** presents the population attributable fraction (PAF) of prevalent diabetes cases associated with education and income in the total population and stratified by race/ethnicity. Results from these calculations answer the two research questions guiding the study.

<u>Population Attributable Fraction in the Total Population</u>

The top row of **Table 6** displays the PAF's of prevalent diabetes cases associated with education and income for the total population, and answers research question 1: *What fraction of prevalent diabetes cases can be prevented nationally if all Americans were exposed to optimal social conditions*.

PAF's were estimated using the odds ratio for the total population from the fully adjusted model 4, with the highest level of education and income as the reference group respectively. The prevalence of each education level and income category within the total population was used as the prevalence ($P_i$) in the PAF calculation. Among all US adults, the fraction of prevalent diabetes cases attributable to achieving less than a college degree was 43.3% (95% CI= 32.3, 53.8). Additionally, the fraction of prevalent diabetes cases attributable to earning an annual household income less than $100,00 was 14.8% (95% CI=-13.8, 39.7).

Population Attributable Fraction in Each Racial//Ethnic Category

The remaining rows of **Table 6** present the PAF's of prevalent diabetes cases associated with education and income in each racial/ethnic category, and answer research question 2: *What racial/ethnic groups will stand to benefit the most from exposure to optimal social conditions when compared to all other major racial/ethnic groups in the United States.*

The PAF was estimated using the same odds ratios and reference categories as the PAF for the total population, however the prevalence of each education level and income category specifically within each racial/ethnic category was used as the prevalence ($P_i$) in the calculation. Among non-Hispanic White adults, the fraction of prevalent diabetes cases attributable to achieving less than a college degree was 41.1%. Additionally, the attributable fraction was 47.8% among non-Hispanic Black adults, 40.0% among non-Hispanic Asian adults, 51.1% among Hispanic adults, and 44.2% among Other adults. The fraction of prevalent diabetes cases attributable to earning an annual household income less than $100,00 was 14.0% among on-Hispanic White adults, 18.4% among non-Hispanic Black adults, 11.9% among non-Hispanic Asian adults, 18% among Hispanic adults, and 16.2% among Other adults.

**Table 6: Population Attributable Fractions of Diabetes Associated with Achievement of Optimal Social Conditions in The Total Population and Stratified by Racial/Ethnic Category in US Adults Aged 20 or Over: National Health and Nutrition Examination Survey, 2013-2014**

| | **Population Attributable Fraction (95% CI), %** | |
|---|---|---|
| | **PAF associated with achieving < college degree** | **PAF associated with earning < $100,000** |
| **Total Population** | **43.3 (32.3-53.8)** | **14.8 (-13.8-39.7)** |
| **NH-White** | 41.1 | 14.0 |
| **NH-Black** | 47.8 | 18.4 |
| **NH-Asian** | 40.0 | 11.9 |
| **All Hispanic** | 51.1 | 18.0 |
| **Other** | 44.2 | 16.2 |

All attributable fractions based on the OR in their corresponding fully adjusted model 4

# Chapter 5: Discussion

## Introduction

The purpose of this study was to estimate the fraction of prevalent diabetes cases that could be prevented nationally if all Americans were exposed to optimal social conditions, and which racial/ethnic groups stand to benefit the most from the achievement of these optimal conditions. To do so, preliminary analyses were conducted to determine the prevalence of each social condition and the measure of association between diabetes and the social conditions in the total US adult population. The impact of the social conditions was also explored in the largest racial/ethnic categories.

In sum, this study provides evidence that the achievement of optimal social conditions may result in the prevention of prevalent diabetes cases in the US adult population. The population attributable fraction for education and income was about 43% and 15% respectively. This also varied by racial/ethnic group with non-Hispanic Black and Hispanic adults being seen to benefit the most from exposure to the optimal social conditions. Additionally, results support previous literature that has seen an association between diabetes and educational attainment, as well as diabetes and annual family income. For the total US adult population, results suggested there was an increased odds of diabetes when achieving less than a college degree and earning an annual family income of less than $100,000, compared to their counterparts who achieved these education and income levels, and this association varied greatly by racial/ethnic group.

The remainder of this chapter will provide a more detailed discussion of the findings from the preliminary and main analyses, provide the strengths and limitations of the study, and discuss the implications of the findings.

# Findings

<u>Preliminary Results</u>

## Relative Odds of Diabetes in the Total Population

***Association Between Educational Attainment and Diabetes*.** The association between diabetes and educational attainment was explored in this study as an antecedent to the main analyses, and specifically research question 1. This was explored through multiple logistic regression models that sequentially added control variables to each model. Analyses indicated that there was an increased odds of diabetes for all US adults with less than a college degree compared to their counterparts who were college graduates or above. These increased odds persisted, yet decreased, even after full adjustment. In the final model, US adults achieving less than a college degree were at least twice as likely to have a diabetes diagnosis as their counterparts with at least a college degree. Analyses additionally indicated that this relationship was significant across all models. In other words, there was a significant increased odds of diabetes that persisted even when adjusting for age, sex, race, BMI, routine provider, and income. These findings are consistent with previous research, which also found an increased odds of diabetes in US adults achieving less than a bachelor's degree, even after full adjustment (Borrell et al., 2006). The improved health outcomes of individuals as they move up the education gradient has been linked to many factors that have created health promoting environments for individuals. This has mainly been seen to be due to where education lies within the social environment. The persistent increased and significant odds of diabetes in this analysis provide evidence for the justification of the conceptualization of education as an upstream determinant in this study, and more importantly in the SDOH framework. The role of education as an upstream determinant allows it effects to be felt at every level, both distal and proximal to the individual, and influences one's occupation, earnings, household income, and freedom form economic hardships (Mirowsky & Ross, 2003). All these factors make it easier for individuals to make healthy lifestyle choices that decrease their odds of adverse health outcomes (Hummer & Lariscy, 2011; Ross & Wu, 1995; Mirowsky & Ross, 2005).

***Association Between Annual Family Income and Diabetes.*** The association between diabetes and annual family income was the second analysis that was explored as an antecedent to main analyses answering research question 1. This was explored using multiple logistic regression models in the same sequential manner as the educational attainment models. Similar to what was seen with the education models, analyses indicated there was an increased odds of diabetes for US adults earning less than an annual family income of $100,000 compared to their counterparts who earn $100,000 or over, across all models. This is consistent with past studies that have found a step-wise pattern of improved health outcomes as an individual moves up the income gradient (Braveman et al., 2010). However, the increased odds of diabetes in relation to income did not remain significant in the fully adjusted Model 4, unlike what was seen in the education models. This may be explained by the hypothesis that education is the more important determinant in terms of influencing health outcomes, as it has been seen to moderate the effect of earning a low income (Mirowsky & Ross, 1999). Though for this particular study income was conceptualized as an upstream determinant in the outermost circle of the Social Determinants of Health Framework, it may also be understood as on the causal pathway from education to the health outcome, which may also explain the insignificant results in Model 4.

**Relative Odds of Diabetes in Each Racial/Ethnic Category**

***Association Between Educational Attainment and Diabetes by Race/Ethnicity.*** The association between diabetes and educational attainment was additionally explored in each racial/ethnic category in this study. This preliminary analysis was conducted to explore the impact of each social condition and assess how it may differentially impact each racial/ethnic category. This step was also taken to specifically answer research question 2. Results are only discussed for the largest racial/ethnic categories in this study due to the inability to interpret meaningful results from the smaller populations.

Results indicated that there was an increased odds of diabetes among non-Hispanic Whites and Hispanic adults with less than a college education, compared to their counterparts who were college graduates or above. Additionally, odds of diabetes were much higher among non-Hispanic White and Hispanic adults compared to their non-Hispanic Black counterparts. These results are consistent with previous studies that have found an inverse relationship between educational attainment and diabetes status among Hispanic and non-Hispanic White populations and a stronger association for these populations than for non-Hispanic Blacks. (Borrell et al., 2006; Borrell et al., 2009). Within these populations, the differences in odds of diabetes between education groups may be explained by factors including access, or lack thereof, to care (Guendelman & Wagner, 2000), as well as engaging in healthier lifestyle practices that have seen to be associated with higher levels of education (Ross & Wu, 1995). Hispanic adults specifically, have been seen to be less likely than non-Hispanic Whites to have a regular primary care physician even when insured (Guendelman & Wagner, 2000; Hargraves, Cunningham, & Hughes, 2001), and are more likely to be uninsured when having a diabetes diagnosis (Nelson et al., 2005). Preventative practices such as healthy diets, exercise, and seeking care are known to be important factors in the prevention and management of diabetes (Hummer & Lariscy, 2011; Ross & Wu, 1995), yet have seen to be obstacles for those with lower levels of education.

Among non-Hispanic Black adults, results varied slightly from their Hispanic and non-Hispanic White counterparts. Results indicated that there was an increased odds of diabetes for those achieving less than some college or an associate's degree compared to their counterparts who were college graduates or above. However, those who achieved some college or an associates degree were not seen to be at an increased odds of diabetes compared to their counterparts who were college graduates or above. The association between diabetes and educational attainment among non-Hispanic Blacks was additionally not seen to be significant, though it was for their non-Hispanic White and Hispanic counterparts. This is consistent with previous studies however, that did not find a clear association between diabetes and educational attainment within this population (Whitaker et al., 2016). It is hypothesized that this may be due to several social determinants including residential segregation, poverty, and perceived racism, which were not controlled for in this study. Segregation and poverty have been seen to play a role in diabetes outcomes in non-Hispanic Blacks (LaVeist, Thorpe, Galarraga, Bower, & Gary-Webb, 2009), especially in the US context in which the country is distinctly segregated, which may foster varying health outcomes for different populations (White, Haas, & Williams, 2012). Furthermore, though race was included as a control variable in this study, perceived racism was not. Perceived racism has been defined by Dawn Dailey (2008) as “the subjective interpretation by the effected individual of an event, situation, or experience as negative, unjust, or undignified and one that solely occurs due to one's racial background” (Dailey, 2008). Perceived racism has been correlated with prevalent diabetes among a population of non-Hispanic Black men in the United States (Moody-Ayers, Stewart, Covinsky, & Inouye, 2005). Therefore, the inability to control for these variables may have affected the way in which education interacts with diabetes in this population. Future studies should examine these factors when examining the association between educational attainment and diabetes in non-Hispanic Black populations.

***Association Between Annual Family Income and Diabetes by Race/Ethnicity.*** The association between diabetes and annual family income in each racial/ethnic category was the last preliminary analyses conducted and is related to research question 2. Results indicated there was an increased odds of diabetes among non-Hispanic White and non-Hispanic Black adults earning less than $100,000 compared to their counterparts who earned $100,000 or above. This is consistent with past studies where non-Hispanic White and non-Hispanic Black populations presented a step-wise pattern of improved health outcomes as they moved up the income gradient. Those who earned lower incomes in the study were more likely to report having a diabetes diagnosis (Braveman et al., 2010; Garcia et al., 2015). In the current study however, results were not significant for either of these populations.

Conversely, Hispanic adults were not seen to be at an increased odds of diabetes when earning less than $100,000. This has been previously documented in the literature where improved health outcomes at higher levels of the income gradient were not as apparent for Hispanic Americans (Braveman et al., 2010; Morales, Lara, Kington, Valdez, & Escarce, 2002). Authors have suggested that results such as these may be a reflection of the "Hispanic Paradox", in which Hispanic Americans have persistently been seen to be in good health compared to their non-Hispanic counterparts, despite earning relatively low incomes (Patel, Eschbach, Ray, & Markides, 2004). Furthermore, the inability to control for Hispanic origin may have also affected results, with SES disparities in Hispanic populations being seen to vary by country of origin. (Sánchez-Vaznaugh, Kawachi, Subramanian, Sánchez,& Acevedo-Garcia, 2009). Future studies are needed to examine the unique characteristics of Hispanic populations that take into account potential differences between US born and foreign born adults.

Main Analyses

**Population Attributable Fraction in the Total Population**

This study was designed to assess the impact of social risk factors on prevalent diabetes cases in US adults. The first research question asked what fraction of prevalent diabetes cases could be prevented if all Americans were to achieve at least a college degree and if they earned an annual income of at least $100,000 or over. This question was answered by using the population attributable fraction equation to calculate the preventable cases associated with each of these social conditions. Results indicated about 43% of diabetes cases would be prevented if all adults achieved at least a college degree, and about 15% of diabetes cases would be prevented if all adults earned an annual family income of at least $100,000. Based on current knowledge, this is the first study to assess social determinants of health as a modifiable risk factor, however results are similar to other sturdies assessing applying this framework to diabetes, with attributable fractions ranging from >5% to 25% (Imamura et al., 2015; Motamedi et. al, 2012; Cavicchia et. al., 2014).

**Population Attributable Fraction in Each Racial/Ethnic Category**

The second purpose of this study was to examine which racial/ethnic categories stood to benefit the most from exposure to these optimal social conditions. This question was answered using the PAF equation that used the prevalence of each social condition specific to each group and the measure of association from the total population. When stratified by race/ethnicity, Hispanic adults were seen to potentially benefit the most from the achievement of a college degree, with non-Hispanic Black adults being the second most beneficial group with PAF's of about 51% and 48% respectively. Results vary slightly for income however, with non-Hispanic Black adults being seen to benefit slightly more than Hispanic adults from earning and annual family income of at least $100,000, with PAF's of 18.4% and 18.0% respectively. The attributable fractions for these populations are significantly higher than what has been observed for the total population. These results highlight the importance of examining the impact of these social conditions separately for different racial/ethnic categories. Without these stratified analyses, much of the picture of the difference in adverse diabetes outcomes that exists within these populations would have been lost. The difference in PAF's for each racial/ethnic category can be explained by the various factors that influence health outcomes that have been explained earlier in this chapter. Factors such as access to care, insurance status, racism, and healthy lifestyle choices all differentially affect each of these racial/ethnic categories which has been exemplified by these results.

## Strengths and Limitations

This study has several strengths. The first strength is the use of a nationally representative dataset. NHANES is a national survey that uses a complex survey design and weighting strategy to capture the most representative sample of the United States as possible. This design takes into account numerous races and locations across the United States, to produce both racial and regional generalizability. This is a strength compared to regional or state-based studies that are limited in their generalizability to the unique population that was sampled. The complex design of NHANES increases its generalizability, making it relevant to a larger population of people, and making it the biggest strength of this study.

A second strength of this study is its unique contribution to the literature. This study not only adds to the literature surrounding the association between diabetes and the two social conditions, it also contributes novel findings on the fraction of prevalent diabetes cases that are attributable to exposure to adverse social conditions. Based on current knowledge, this is the first study to use the population attributable fraction framework and apply it to modifiable risk factors that exist in the social environment. Majority of the risk factor modification literature that currently exists surrounding diabetes is in relation to clinical and/or behavioral risk factors (Cavicchia et al., 2014; Motamedi et al., 2005) and does not take into account more upstream determinants. This study provides evidence for further exploration in the role that upstream social determinants play in the cause or prevention of chronic disease.

Another strength of this study was the use of counterfactual measures that are relatively realistic. In previous studies, counterfactual levels have been set to total elimination for clinical and behavioral risk factors (Patel et al., 2015; Mehta, Patel, Ali, & Venkat Narayan, 2017), which is not always feasible or realistic. The counterfactual measures that were used in the current study were the optimal social conditions, which were determined to be achieving a college degree or above for educational attainment, and earning an annual family income of $100,000 or more for income. These levels are realistically attainable for a majority of Americans if everyone were given the same social and economic opportunities, a lot of which can be achieved through the alleviation of racism and systemic inequality.

Lastly, the use of a clinical definition of total diabetes that has been widely used in the literature is another strength of the study. Though a self-reported measure was also used, the clinical definition allowed for the capturing of as many diabetes cases as possible, which accounted for both diagnosed and undiagnosed diabetes. This hopefully acted as a minor correction for any self-repot cases that are more subject to error.

Despite the many strengths of this study however, there were a few limitations. The first limitation was the relatively small sample size in the stratified analyses. This limited the ability to produce meaningful results for the smaller racial/ethnic groups in the study, and produced slightly higher odds of diabetes in the non-Hispanic White, non-Hispanic Black, and Hispanic populations than what is typically seen in the literature (Whitaker et al., 2014; Borrell et al., 2006). This was mainly an issue for the stratified regression models, which also hindered the study's ability to use race specific odds ratios in the PAF calculations. This was another limitation and may have led to either an over or under estimation of the fraction of diabetes cases that may be prevented in relation to each social condition within the racial/ethnic categories. Furthermore, the use of odds ratios as a measure of may have also led to an overestimation of PAF's. Odds ratios are upper bounds and tend to overestimate risk ratios, which may have also lead to an over estimation of preventable diabetes cases.

The grouping of the income categories was also a limitation in this study. Only three categories were used in the study and they did not all have an equal range between the highest and lowest income in the category. This may have resulted in the variability of results. Future studies should expand on these categories with the goal of achieving a smaller range between the lower and upper bound of the category. This may hopefully may reduce the variability of the odds ratios and PAF's.

The use of self-reported measures was an additional limitation. Education and income were both self-reported which increased the chance of bias in the study. Though it may be unfeasible to verify education and income data, future studies may want to take this into account when measuring these variables. Additionally, since this study did not include original data collection, it was limited in its ability to analyze all possible confounders that may have impacted the results of the study. As has been stated earlier, variables such as segregation and perceived racism were not able to be controlled for since they were not included in the original NHANES study. Lastly, NHANES is a cross-sectional study which presented limitations such as the inability to determine the temporal order of the disease outcome.

## Implications and Recommendations

Despite these limitations, this study has many implications for public health research, practice, and policy. First, this study provides justification for further research into the role of upstream social determinants and their direct impacts on prevalent diabetes cases. Over the past few years, social determinants of health have been given greater attention in the literature, which has been clearly warranted, however few studies have set out to quantify the exact impact of these determinants. It is important to know, not only, the association between diabetes and its various risk factors, but realistically how much of the health burden can be alleviated if these factors were addressed at the population level. This has implications for both the individual and society. With the direct and indirect cost of diabetes including issues such as adverse health complications, as well as loss of productivity and rising medical expenditures, a decrease in the prevalence of the disease will not only save lives but decrease the financial burden placed on the health care industry.

Furthermore, findings indicated that there may be racial/ethnic disparities in the way in which social determinants influence an individual's odds of diabetes, and the burden they carry once diagnosed. This information is beneficial to various organizations and initiatives that have set out to address social determinants of health and health disparities, such as the Healthy People 2020 Social Determinants of Health Objective. This objective aims to not only create environments that promote good health for all Americans, but to understand how exactly specific populations differentially experience conditions in the social environment (Healthy People 2020, 2017a). As is shown in ***Figure 2***, this study hypothesizes that there may be both a direct and indirect impact of race/ethnicity on different racial/ethnic categories. The small, yet present, difference in PAFs within each racial/ethnic category exemplify that there is a potential difference in how various groups experience these conditions, and further research is needed to better understand the "how". A few of the results from the study seemed to be counterintuitive to our current understanding of the relative disadvantage experienced by minority populations. However, as was discussed earlier, issues such as racism, discrimination, segregation, poverty, and others of the like, need further investigation. Including these variables in future studies may shed light on how racial/ethnic populations differentially experience the effects of education and income.

Additionally, results from this study can be used to justify where and how resources should be allocated. In order to achieve health equity across all racial/ethnic groups, attention should be given first to the populations that need it the most. Braveman and Gruskin (2003) define health equity as "the absence of systematic disparities in health (or in the major social determinants of health) between groups with different levels of underlying social advantage/disadvantage, such as, wealth, power, or prestige". Inequities in health place certain populations who are already socially disadvantaged due to systematic inequalities, at a further disadvantage when it comes to their health (Braveman & Gruskin, 2003). Therefore, in order to achieve health equity, public health policy should be strategically tailored to target these populations that are already disadvantaged, and will most likely stay that way, without intervention, by virtue of their racial/ethnic status. Specifically, in regards to this study, policy should be created that provides resources that create greater access to higher education for minority populations, as well as legislation that works to alleviate the pat gap between White Americans and their minority counterparts.

The long history of systemic inequality that has existed within the US has made it very important and justifiable for public health professionals to focus on disadvantage populations. However, results from this study additionally support the need for access to these resources more broadly for *all* Americans, and for the inclusion of interventions that exist outside the "health" sector. Many social determinants of health are not what is typically deemed a health behavior, such as diet and exercise, and therefore have not been given the same weight as interventions that address these behaviors. However, results exemplify the need to include as many sectors as possible when aiming to improve the health of populations. Results from this study further this particular understanding of the SDOH framework; the idea that there are conditions at every level of the social environment, both within and outside the health care sector, that impact health outcomes, and should be prioritized in the same way that behavioral and clinical health interventions have been in the past.

Lastly, results from this study continue to advance our understanding of the SDOH framework in a few additional ways. Findings support the current conceptualization of the model as a whole; that is, that health behaviors and outcomes do not exist in a vacuum, yet are the result of the relationship between both upstream and downstream determinants (Braveman et al., 2011). This was exemplified when assessing the magnitude of association between the social conditions and diabetes prevalence, which showed differential associations based on which control variables were added to the model. Specifically, results support the understanding that upstream determinants impact health both directly and indirectly (Braveman et al., 2011). The upstream determinants in this study, education and income, had a direct impact on diabetes prevalence, which is exemplified in the PAF's associated with each social condition. Even after controlling for numerous other variables, the PAF's for education and income still remained relatively high. As Braveman and colleagues suggest, results support the notion that upstream determinants present one of the most important opportunities for intervention.

Conversely, results from the study challenge researchers to seek further understanding of the way in which race/ethnicity functions within the framework and where it should be placed, if at all, on the various casual pathways. This was highlighted in the stratified analysis assessing the magnitude of association between the social conditions and diabetes. Specifically, non-Hispanic Black and Hispanic populations have continued to have contradictory levels of risk that oppose our understanding of their disadvantaged social position, such as a lower odds of diabetes than their white counterparts. Race/ethnicity is a very broad term and may encompass numerous variables, such as perceived racism, poverty, and segregation, which may all function as their own distinct variable. These factors may have differential effects on populations due to either having a direct or indirect impact on health. Further researcher is needed to explore these relationships and possibly further expand on the idea of a distinct racial/ethnic causal pathway.

Lastly, though a considerable impact was seen in relation to income, results from the study may present a different conceptualization of income than was originally hypothesized. The association between income and diabetes was not as strong or significant as what was observed for education. Additionally, the PAF associated with income was markedly lower than the PAF for education. As was discussed earlier, this may be due to alternate hypotheses that place income lower on the causal pathway and/or on the same pathway as education. This begs the question of whether income, as a singular variable, is enough to be conceptualized as an upstream determinant in the same way as education. A combined SES variable, which is commonly used when assessing the impact of income, may be a better conceptualization of an upstream determinant whose impacts are not as effected by lower level determinants. Results challenge researchers to explore if income may be a more mid-level determinant, due to it being largely dependent on the achievement of certain levels of education, or if income can function as both upstream *and* further down the pathway, and in which circumstances would this be the case.

Diabetes is a major public health issue in the United States and effects populations differently. Additionally, social determinants of health have been seen to have both direct and indirect influences on diabetes outcomes. Determinants, such as income and education, that are upstream in the Social Determinants of Health framework have trickle down effects that influence social and economic conditions, access to resources, and personal behaviors. Disparities that exist at this level then, trickle down to individual populations and create the racial/ethnic disparities in health seen in diabetes burden and outcomes. Future studies should aim to take into account all these factors on the casual pathway, with the goal of reducing diabetes disparities in morbidity and mortality, and to improve the overall quality of life for all Americans.

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