Relationship of Neighborhood and Individual Socioeconomic Characteristics to Type 2 Diabetes, Hyperinsulinemia, and Impaired Fasting Glucose: The Atherosclerosis Risk in Communities Study, 1987-1998

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ABSTRACT

SERONDA A. JACKSON: Relationship of Neighborhood and Individual Socioeconomic Characteristics to Type 2 Diabetes, Hyperinsulinemia, and Impaired Fasting Glucose: The Atherosclerosis Risk in Communities Study, 1987-1998
(Under the direction of Gerardo Heiss)

Neighborhood socioeconomic characteristics are inversely related to the prevalence and incidence of coronary heart disease, but little is known about their association with diabetes. We investigated whether neighborhood- and individual- level socioeconomic characteristics are associated with Type 2 diabetes prevalence and incidence and the prevalence of hyperinsulinemia and impaired fasting glucose, whether neighborhood associations persisted after adjusting for individual level social class indicators, and whether the effects of individual level indicators varied across neighborhoods.

The study sample consisted of 10,721 African American and white men and women aged 45-64 at the baseline examination of the Atherosclerosis Risk in Communities study. Participants were sampled from four United States communities: Forsyth County, North Carolina; Washington County, Maryland; the northwestern suburbs of Minneapolis, Minnesota; and Jackson, Mississippi. Census tracts were used as proxies for neighborhoods. A summary score for neighborhood characteristics was constructed from indicators of wealth, income, education, and occupation from the 1990 U.S. Census. Age-adjusted multilevel models including neighborhood characteristics and individual level indicators (household income, education, and occupation) were fit separately for each race-gender group.

Individual income, education, and occupation were inversely associated with diabetes prevalence for all race-gender subgroups. There were no clear, consistent patterns of association between individual level indicators and hyperinsulinemia and impaired fasting glucose. Individual level indicators were generally inversely associated with diabetes incidence in most subgroups, except among African American men, in whom education and occupation were directly associated with diabetes incidence. Neighborhood characteristics were inversely associated with the prevalence of diabetes and impaired fasting glucose among women only. There was not a clear pattern of association between neighborhood characteristics and prevalence of hyperinsulinemia. Diabetes incidence was inversely related to neighborhood characteristics among whites only. There was a direct association for African American women and no clear pattern of association among African American men. Associations with individual level indicators did not vary systematically across neighborhoods.

Individual level socioeconomic indicators generally were associated with diabetes, hyperinsulinemia, and impaired fasting glucose in this biracial cohort. Living in disadvantaged neighborhoods was not consistently associated with increased prevalence of diabetes, hyperinsulinemia, or impaired fasting glucose or incidence of diabetes.

In memory of my grandparents Arlene Lane, Charlie Moffett, and Ruth and Fred Jackson and to my parents Delphine and Wayne Jackson; my siblings Mia, Jemia, Josepha, Phineas, and Laketa; the wind beneath my wings Samuel Lee Robinson II; and my golden friends from Coffee High School in Douglas, GA. My grandparents represent the giants upon whose shoulders I stand, without my parents I would not be, to my siblings I yield my shoulders upon which to stand, Sam inspired me by helping me to realize the beautiful genius that I am, and my friends continued to support me through all the years.

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1.0 Background

1.1 Introduction

There is a growing scientific literature of research linking the residential environment to health status, mortality, and health-related behaviors. Living in deprived neighborhoods has been associated with a greater prevalence and incidence of cardiovascular diseases (CVD) and a higher prevalence of risk factors for cardiovascular disease [1-2]. These associations have also been shown for risk factors of type 2 diabetes [3-5]. Insofar as risk factors for CVD and diabetes are similar and based on the common soil hypothesis of diabetes and atherosclerosis [6], it can be hypothesized that the prevalence of type 2 diabetes is also associated with factors that operate at the neighborhood level. An inverse relationship has been observed between individual socioeconomic status (SES) and the prevalence of type 2 diabetes in the United States and other industrialized countries [7-8]. However, studies of neighborhood-level SES and type 2 diabetes have resulted in inconsistent findings.

Diabetes is a major public health burden that is costly and leads to severe complications [9-10]. However, type 2 diabetes can be prevented [11-14] and successfully treated, thus a clear potential exists for reducing diabetes-related morbidity and mortality. This study takes a psycho-social perspective to investigating diabetes risk by considering whether contextual socio-economic factors at the neighborhood level as well as individual-level socio-economic factors are related to markers of hyperinsulinemia, impaired fasting blood glucose, and the development of diabetes. Findings from this study could provide information regarding the desirability of considering individual and/or neighborhood socio-economic factors for preventive strategies. A better understanding of whether particular neighborhood environments serve as pathways leading to diabetes may aid in the development of innovative approaches to community-level interventions.

1.2 Socioeconomic Status and Cardiovascular Disease

Neighborhood socioeconomic characteristics have been linked to cardiovascular diseases (CVD), primarily coronary heart disease (CHD), and several cardiovascular disease risk factors such as smoking, physical inactivity, and obesity [1-3, 15-16]. An inverse association of CVD and SES measured at the aggregate level has been demonstrated repeatedly [1, 17-20]. Early work by Lilienfeld examined the impact of community-level characteristics by ranking census tracts by socioeconomic status [21]. No differences were found in mortality rates for atherosclerotic mortality by SES. However, the lowest SES tracts had the highest rates of hypertensive disease with rates decreasing as SES increased.

Much of the literature relating CVD and SES has examined individual-level measures of SES. The Evans County Georgia Heart Study suggested an age-related crossover effect whereby older men with low SES had a lower incidence of CHD than those with high SES, while younger men with low SES had a higher incidence [22]. Among black men in the Charleston Heart Study, those with low SES had twice the rates of CHD and acute myocardial infarction (MI) as those with high SES [23]. In the Scottish Heart Study a significantly higher prevalence of coronary heart disease was associated with years of education, housing tenure, and occupational status [24].

Studies linking SES to CVD have used various measures such as education and occupation to operationalize SES. The Whitehall Study is one of the best-known examples of research linking occupation to CVD. While the Whitehall studies are best known for establishing the inverse association between employment grade and mortality, such relationships also hold for morbidity. Rose and Marmot reported a higher age-adjusted prevalence of angina pectoris and 10-year coronary mortality rate among men in the lowest employment grade than for those in the top administrative grade [15]. Similarly, a higher incidence rate for CHD was found among laborers and unemployed workers than among professionals in the Evans County Heart Study [22].

Education has been inversely related to the risk of CVD, including MI, CHD, and all-cause mortality [25-26]. Hinkle et al. [27] found that those with a college degree had a lower coronary disease incidence and death rate than those without a college degree. In men aged 35 to 59 in Finland, low income and education were associated with excess risk of death from ischemia and other diseases [28]. The US National Longitudinal Mortality Study found a similar inverse relationship between higher education and income and lower all-cause mortality [29]. In a study of Ontario men income, but not education, was a significant predictor of mortality; education was however, inversely related to high levels of coronary risk factors (i.e. weight, plasma cholesterol level, diastolic blood pressure, and smoking) [30].

1.3 Socioeconomic Status and Diabetes Risk Factors and Complications

Low socioeconomic status has been associated with risk factors for diabetes as well as the severity of diabetes-related outcomes. Diabetes risk factors such as physical inactivity, obesity, smoking, and low birth weight have been found associated with low SES in Western societies [3-4]. Similarly, studies in blacks have demonstrated that individuals with lower SES have greater levels of obesity, physical inactivity, and poor nutritional habits [5].

Studies from around the world have reported associations between diabetes complications and socioeconomic conditions. In the United States, the NHANES II and other large epidemiologic studies found associations between low socioeconomic status, expressed by income, education, or occupation, with high rates of diabetes and its long-term complications [31-32]. In the Somerset and Avon survey of health involving a sample of patients aged 35 and older from 40 general practices diabetic eye disease was most strongly associated with low socioeconomic position [33]. Diabetes mortality was strongly associated with income level in the National Longitudinal Mortality Study [34].

1.4 Socioeconomic Status and Prevalent Diabetes

Individual-level Measures

In the United States the nature of the association between diabetes and socioeconomic status has changed over time. A study conducted during the 1970's indicated that populations with greater social standing, affluence, and education had a higher prevalence of diabetes [35]. This may have been due, in part, to higher caloric intake and/or lower levels of physical activity in these groups. Later studies, however, found that diabetes prevalence was inversely associated with lower socioeconomic position [36].

Lower SES, along with obesity, physical inactivity, and positive family history of disease, is now well-established as a characteristic of individuals at high risk for type 2 diabetes (formerly known as non-insulin-dependent diabetes mellitus) [31]. Cowie and colleagues found reduced diabetes risk associated with greater education, after adjusting for family history, obesity, and other diabetes risk factors [37]. In the 1976-80 NHANES II persons with at least one year of college education had on average a 30% lower risk of type 2 diabetes compared to those with less than high school education. Similarly, in the 1989 National Health Interview Survey (NHIS) of a representative sample of non-institutionalized, civilian US adults' individual SES was associated with type 2 diabetes prevalence. After adjusting for age, individuals with type 2 diabetes were less likely to be unemployed and had lower educational levels and less income than those without type 2 diabetes [31]. The prevalence of diabetes in individuals with family incomes less than $10,000 was almost twice that in people with incomes of at least $35,000 (136.1 per 1000 vs. 68.9 per 1000) [38]. Additionally, an interaction between education and ethnicity was observed in a study of a rural San Luis Valley, CO population: compared to non-Hispanic whites, Hispanics with less than a high school education had nearly four times the diabetes prevalence. However, Hispanics with at least a high school education had no excess risk compared with non-Hispanic whites after controlling for relevant risk factors [39].

Like early studies in the U.S. a study in Asia also found a positive association between individual SES and type 2 diabetes. In rural and urban populations in Bangladesh, the highest prevalence of type 2 diabetes was observed among the rich and the lowest prevalence was observed among the poor, similar to the situation in North America in the 1970's [40]. Even after adjusting for WHR and BMI, a very high risk of type 2 diabetes persisted among the rich (OR=5.6, CI 2.96-10.66). This may have been because the rich are able to enjoy a more sedentary lifestyle.

Many of the studies on the association between diabetes and socioeconomic conditions have been conducted in Europe. The British Whitehall II study of civil servants assessed individual-level socioeconomic position, expressed in terms of occupational employment grade, which was inversely associated with diabetes prevalence. Diabetes was most common in lower grade male civil servants aged 35-55 years [41].

Aggregate-level Measures

European studies have also used aggregate-level measures to investigate relationships between SES and diabetes. In the Somerset and Avon survey of health the Townsend deprivation score derived by linking postcodes of residents to enumeration districts from the 1991 census was used as an indicator of area SES. Eachus and colleagues found no association between diabetes prevalence and aggregated scores for the deprivation index. Approximately equal frequencies of diabetes were found for deprived areas relative to more affluent areas [33]. However, this finding may reflect differential rates of self-reported diabetes for deprived versus affluent areas. In particular, asymptomatic diabetes may have been underestimated for more deprived areas, on the basis of lesser availability and use of preventive services.

A positive association was demonstrated between diabetes and deprivation indices in several other European studies. Using a validated diabetes registry and a well-defined population in Tayside, Scotland Evans, Newton, and colleagues found that the prevalence of type 2 diabetes varied by social and economic deprivation [42]. People in the most deprived areas were 1.6 times more likely to have type 2 diabetes than those in the least deprived areas. Additionally, in persons with diabetes BMI increased with increasing deprivation. This study utilized a material deprivation measure derived from the UK decennial census using postal code data for area characteristics. In another study in the United Kingdom Connolly and colleagues [43] observed a significant trend between the prevalence of type 2 diabetes and quintiles of deprivation. A high prevalence of type 2 diabetes among persons aged 40-69 years accounted for an elevated prevalence of diabetes in most deprived areas. Similarly, using two measures of deprivation based on the 1991 UK Census (the Townsend and Jarman indices) Meadows reported a significant correlation between deprivation and type 2 diabetes prevalence [44]. Another European study analyzed immigrants from South Asia living in The Hague. Among younger persons diabetes mellitus was more prevalent in those living in deprived areas than in those in more affluent areas. In these studies no information was available on individual SES; therefore, it was impossible to control for confounding [45].

1. 5 Socioeconomic Status and Incident Diabetes

Individual-level Measures

Relatively few studies have evaluated whether SES is associated with incident type 2 diabetes. In the Israeli Heart Disease Project 5-year incidence of diabetes was inversely related to level of education in men aged 40 or older [46]. Incidence rates were 63% higher in those with an elementary school education compared to those with more than high school education after adjusting for age and area of birth. Diabetes incidence in laborers and administrators was higher than that for professionals, technicians, and teachers. Similar to the Israeli project, studies of Mexican Americans have found that the incidence of diabetes decreased linearly with increasing SES among Mexican-American women [47-48].

Aggregate-level Measures

One known published aggregate level study of SES and incident diabetes found results similar to the studies of individual level measures. An ecological study of nine English towns described an inverse association between relative affluence of towns and incidence of type II diabetes [49]. Since this study only investigated community-level SES, it was not possible to distinguish between the effects of context and composition.

1.6 Pre-diabetic Conditions

The abnormal metabolic stages hyperinsulinemia and impaired glucose tolerance (IGT) are directly involved in the pathogenesis of diabetes [50]. Hyperinsulinemia is a deficiency in the body's ability to use insulin to break down glucose in the cells. It predisposes individuals to diabetes and CVD [51-53]. More than 60 million Americans are affected by hyperinsulinemia. It is estimated that one-quarter of them will develop type 2 diabetes [54]. Individuals with glucose values in the range between the levels for normoglycemia and diabetes are considered to have impaired glucose tolerance (IGT) or impaired fasting glucose (IFG). Having IGT and IFG is associated with a high risk of progression to type 2 diabetes. The risk ranges from 2.3 to 11% per year [50]. The cumulative incidence of diabetes mellitus among persons with impaired glucose tolerance is as high as 50% [55]. BMI, which increases monotonically with SES along with elevated fasting and post-load glucose levels, has been identified as a predictor of progression from IGT to type 2 diabetes [56]. IGT is common in the US with about 1.5 times the prevalence of type 2 diabetes [57]. An estimated 11.2% of adults between ages 20 and 74 have IGT.

Hyperinsulinemia and impaired glucose tolerance share many of the same risk factors as diabetes [50]. Obesity, high fat diet, and physical inactivity, all associated with low SES, are risk factors for IGT and IFG as well as diabetes [12, 58-59]. Obesity and physical inactivity may cause people who are genetically predisposed to type 2 diabetes to become more insulin resistant, leading to the development of IGT [60-61]. Hyperglycemia worsens as beta cell capacity becomes unable to compensate for the hyperinsulinemia, with overt diabetes the consequence of this progression [62-64]. Since IGT is the earliest stage of type 2 diabetes that can easily be detected, individuals with IGT should be targeted for intervention to prevent further development of type 2 diabetes [65].

Studies have shown an association between glucose intolerance and SES. A significant inverse association between grade of employment and the pre-diabetic condition glucose intolerance was found in the Whitehall Study [15]. A higher prevalence of glucose intolerance was found among civil servants at low employment grades. Similarly, a study in Hong Kong found that among Chinese men and women level of educational attainment and occupation were associated with increased risk for glucose intolerance [66]. We are not aware of studies investigating the impact of neighborhood SES on hyperinsulinemia or IFG.

1.7 Independence and Interaction

In previous studies assessing neighborhood and individual SES measures simultaneously, neighborhood characteristics were reported to remain associated with health outcomes such as mortality [67], chronic conditions [68], and poor health [69] independently of individuals' socioeconomic position. Relatively few studies, however, have jointly investigated the impact of the individual and social environments on CVD. Diez-Roux et al.

found that living in deprived neighborhoods was associated with a greater prevalence of coronary heart disease and with elevated levels of risk factors (i.e. prevalence of current smoking, systolic blood pressure, and serum cholesterol) [1]. These associations generally persisted after adjustment for individual-level factors. They later found that living in a disadvantaged neighborhood was also associated with a high incidence of coronary heart disease even after controlling for personal income, education, and occupation in the ARIC cohort [2]. Similarly, in a study conducted in the towns of Renfrew and Paisley in the west of Scotland, area-based and individual socioeconomic indicators were found to make independent contributions to less favorable cardiovascular disease risk factor profiles and mortality risk [70].

Some studies have noted cross-level effect modification between individual- and aggregate-level factors. Krieger found neighborhood effects on hypertension among non-working-class subjects [71]. Jones and Duncan found that as neighborhood deprivation increased, there was an increase in the reporting of heart disease symptoms among low- and middle-income adults [72]. However, among adults with high incomes there was an inverse relationship between deprivation and heart disease symptoms. These examples follow the "double jeopardy" hypothesis which suggests that living in disadvantaged communities may particularly affect the health of individuals with lower socioeconomic status [73]. Diez-Roux and colleagues found that for African-American men, low individual status was associated with high serum cholesterol in more affluent neighborhoods while low individual status was associated with low serum cholesterol in disadvantaged neighborhoods [1]. This may have been due to the "relative deprivation" hypothesis, which suggests that low SES individuals experience worse conditions in higher SES neighborhoods due to the inability to compete with higher SES neighbors for resources.

1.8 Demographic Differences

Studies have demonstrated that the strength of the association between neighborhood-level measures and health status varies according to age, gender, and ethnicity. An age difference was noted by Connolly and colleagues [43]. In a study of 4313 persons with diabetes identified from physicians' records the increased prevalence of type 2 diabetes in the 40-69 age band accounted for the increased prevalence of diabetes in the most deprived areas. Other studies have noted gender differences in associations. LeClere and colleagues found a stronger effect of the neighborhood on male mortality than on female mortality before age 65. Similarly, in a study conducted in Scotland, neighborhood deprivation scores were associated with high prevalence of angina among men [70]. Conversely, among women these aggregate-level scores were positively associated with the prevalence of angina and ischemia as well as body mass index. Differences between ethnic groups have also been observed. After adjusting for age and gender, Diez-Roux and colleagues found a stronger association between low education and the odds of coronary heart disease in whites (OR = 3.8, 95% CI 2.5-5.9) than in blacks (OR = 1.7, 95% CI 0.9-3.1) [74]. In another study, Diez Roux et al. found that levels of serum cholesterol increased with increasing neighborhood disadvantage among whites; however, among blacks, levels were highest in the intermediate category of neighborhood deprivation. This study also found among white women stronger neighborhood effects on coronary heart disease odds than among white men risk [1].

1.9 Possible Mechanisms

Neighborhood characteristics may affect diabetes through the physical and social environments. Socioeconomic characteristics of the neighborhood may affect the availability and accessibility of goods and health services. In disadvantaged neighborhoods adequate and high quality services may not be available even for individuals of higher SES who may be able to afford them. Therefore people would have to travel outside of their communities to access these resources [75]. Morland and colleagues found that poorer neighborhoods have fewer supermarkets which offer a wider and less expensive variety of foods [76]. In these communities they also found fewer households with access to private transportation, which presents additional barriers to accessing resources. Similarly, the transportation systems in disadvantaged neighborhoods may be unsafe or inadequate. Additionally, poorer neighborhoods generally have fewer recreational facilities available to residents [75]. The association between low socioeconomic status and obesity and physical inactivity may reflect, in part, the influence of such attributes of the community on the occurrence of diabetes [3].

The influence of the community on the social environment may also influence diabetes risk. Community characteristics impact social cohesion in the community, which is associated with the occurrence of crime. Fear of crime may in turn influence the freedom to travel in communities [73]. This further hinders access to services and prevents the health-promoting practice of walking for exercise. Neighborhood conditions also shape social interactions, norms, and values. Living in poorer communities may expose residents to more advertisements for cigarettes and fast food and to neighbors who are less likely to practice health-promoting behaviors [77, 73]. The neighborhood influence on unhealthy behavior is reflected in studies showing that living in deprived neighborhoods is independently associated with a greater likelihood of smoking [1, 78] and higher levels of serum cholesterol and systolic blood pressure [1].

The mechanisms by which neighborhood environments are related to diabetes risk are not clearly defined. Higher rates of diabetes and its complications in low SES groups have been attributed in part to obesity, physical inactivity, unavailability of resources, lack of access to health care, and delay in seeking medical attention [5]. The demonstrated association between SES and diabetes risk factors indicates that SES may be an important factor in the development of diabetes through these risk factors.

1.10 Summary

Numerous studies have shown that the neighborhood socioeconomic environment is related to health and mortality. Some studies have concluded that the association between neighborhood level factors and health outcomes is independent of the influence of individual socioeconomic position. This suggests that attributes of the actual neighborhoods may affect health. Most prior studies examined a single geographic or administratively-defined level of SES and were not able to distinguish between the effects of context and composition. Ecological studies, on the other hand, are not able to evaluate the role of individual-level indicators as confounders, mediators, or modifiers. Failure to adjust for individual SES leaves the possibility that individual characteristics may account for observed associations at the neighborhood-level. Thus, neighborhood level socioeconomic characteristics need to be investigated using appropriate techniques that permit distinction between neighborhood and individual effects.

In investigating the effect of SES on diabetes, this project will build on prior research in three ways. First, whereas most prior studies have considered either individual-level or group-level SES, this research will investigate the influence of SES on diabetes at both levels simultaneously. Next, while most previous work has been cross-sectional in nature, this research will be based on a longitudinal design by examining the incidence of type 2 diabetes over a twelve-year period. Finally, SES at the level of the neighborhood could contribute more to diabetes risk for some subgroups than others. For example, the daily activities of women may be more dependent on the neighborhood environment than men's. Thus, due to gender differences in roles, lifestyles, stress coping mechanisms and health-seeking behavior, women might respond more strongly to neighborhood SES than men. Therefore, this research will look for differences in neighborhood-level SES effect across the four race/ethnicity and gender subgroups. Furthermore, studies documenting an association between impaired glucose tolerance and socioeconomic conditions have been conducted in countries other than the USA, leaving open the question of whether such relations also apply in populations in the United States. This study will attempt to answer this question.

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2.0 Statement of Hypotheses

2.1 Study Question

The objectives of this study were: 1) to evaluate the relationship between neighborhood- and individual-level socioeconomic status and pre-diabetic conditions (hyperinsulinemia and impaired fasting glucose) and type 2 diabetes; 2) to quantify the influence of neighborhood socioeconomic conditions after adjusting for individual-level SES indicators and vice versa; and 3) to determine whether the effects of individual-level factors vary in the context of neighborhoods. It is hypothesized that independent, inverse associations exist between unfavorable neighborhood and individual-level socioeconomic conditions and the prevalence of hyperinsulinemia and impaired fasting glucose and the prevalence and incidence of type 2 diabetes. Neighborhood and individual-level indicators are hypothesized to interact in shaping these outcomes. The study questions were addressed in a bi-ethnic (black and white) cohort of men and women aged 45-64 years at baseline and followed for an average of 9 years. Due to differences in the distribution of socioeconomic characteristics between subgroups, gender- and race-specific analyses were performed.

2.2 Specific Aims and Hypotheses

1. This research estimated the association between neighborhood-level and individual-level socioeconomic characteristics and the prevalence of hyperinsulinemia (indexed by fasting insulin levels), impaired fasting glucose, and type 2 diabetes.

a. We tested the hypothesis that neighborhood-level and individual-level socioeconomic characteristics are inversely related to prevalence of hyperinsulinemia, impaired fasting glucose, and type 2 diabetes.
b. In addition, we expected associations between neighborhood level characteristics and prevalence of hyperinsulinemia, impaired fasting glucose, and type 2 diabetes to persist after controlling for individual level characteristics, and vice versa.
c. Furthermore, we expected the association between individual level factors and hyperinsulinemia, impaired fasting glucose, and type 2 diabetes to be greater in disadvantaged neighborhoods.

2. This research estimated the association between neighborhood-level and individual-level socioeconomic characteristics and the incidence of type 2 diabetes over a maximum of 9 years of follow up.
    a. We investigated whether the cumulative incidence of type 2 diabetes was inversely related to neighborhood-level and individual-level socioeconomic characteristics.

2.3 Rationale

An inverse association has been found between SES and cardiovascular diseases. However, the strength of the association varies across SES indices. Many previous studies investigated a single indicator of SES. With economic status being a function of a composite of factors, multiple SES indicators should be utilized to determine the most relevant indicator.

Most prior studies also examined a single level of SES and were not able to distinguish between the effects of context and composition. This study investigated the impact of three individual level measures and four neighborhood characteristics combined into a composite score. Hierarchical multilevel techniques were used to examine both prevalence and incidence of outcomes. This method enabled distinction between neighborhood and individual effects and investigation of their roles as confounders or modifiers.

The cross-sectional nature of most previous studies does not permit the exclusion of potential reverse causality, with socioeconomic status being a function of diabetes, rather than diabetes being a function of socioeconomic status. In addition to examining the association of SES and prevalence of pre-diabetic conditions and type 2 diabetes, the prospective nature of the ARIC study provided the opportunity to investigate the temporal relationship between socioeconomic status and the development of type 2 diabetes.

Subgroup analyses were needed due to gender and racial disparities in socioeconomic status and rates of disease. This study utilized analyses of a large bi-ethnic cohort, which enabled gender and race/ethnicity subgroup analyses. Given the racial/ethnic differences in socioeconomic status in the US and the higher prevalence of type 2 diabetes and its sequelae in blacks, the main study questions were addressed separately in blacks and whites.

3.0 Methods

3.1 Study Design

This study was a secondary analysis of data collected as part of the Atherosclerosis Risk in Communities (ARIC) Study, which consists of a closed cohort of approximately 16,000 middle-aged men and women. Study participants underwent comprehensive baseline and follow-up clinical examinations. Non-clinical data were gathered via comprehensive questionnaires. Following the baseline examinations conducted between 1987 – 1989 participants were followed for up to 9 years in 3-year cycles. This study utilized both cross-sectional and prospective components to jointly investigate individual and neighborhood socioeconomic characteristics to determine the independent and interactive role of the social environment on pre-diabetic conditions (hyperinsulinemia and impaired fasting glucose) and type 2 diabetes.

3.2 Study Population

The Atherosclerosis Risk in Communities (ARIC) cohort, sponsored by the National Heart Lung and Blood Institute (NHLBI), is a prospective study of the etiology and natural history of subclinical and clinically manifest atherosclerosis. The cohort includes 15,792 men and women ages 45 to 64 years at baseline between 1987-1989 who completed a home interview and clinic examination. Follow-up visits occurred approximately every three years through the beginning of January 1999. Nearly 4,000 people were probability sampled from each of four US communities: Forsyth County, NC; Jackson, MS; Minneapolis, MN; and

Washington County, MD. Eighty-five percent of participants from Forsyth County and nearly all participants from Minneapolis, MN and Washington County, MD were white. African Americans were oversampled in Forsyth County and exclusively sampled in Jackson to provide sufficient power to investigate findings by ethnicity. Further details on the study design, response rates, and methods have been published elsewhere[1]. This study used data from the baseline visit (1987-89), visit 2 (1990-92), visit 3 (1993-95), and visit 4 (1996-98).

3.3 Data Collection

Assessment of Baseline Characteristics

All ARIC field centers used standardized data collection protocols[2]. General health information was collected on participants' health history and current health status during the baseline home interview. Trained research personnel recorded information on known cardiovascular risk factors, family medical history, smoking status, alcohol consumption, income, education, and employment status during structured, face-to-face interviews.

The clinical examination included a general physical assessment, blood pressure collection, anthropometry measurement, and other cardiovascular assessments. Participants were asked to fast overnight (>8 hours) before morning blood collection. They were also asked to refrain from smoking and consuming alcohol or caffeine on the day of the examination. Blood specimens were drawn from the antecubital vein of seated patients and shipped to a central laboratory. Serum glucose was assessed by a modified hexokinase/glucose-6-phosphate dehydrogenase procedure. Standard radioimmunoassay was used to determine serum insulin level using an Insulin Kit (Cambridge Medical Diagnosis, Billerica, MA). Detailed procedures for blood collection have been reported elsewhere[3, 4].

Dependent Variables

The main outcomes of interest were type 2 diabetes, hyperinsulinemia, and impaired fasting glucose. Prevalent type 2 diabetes was defined based on American Diabetes Association (ADA) cutpoints of fasting glucose levels ≥ 126 mg/dl (7 mmol/l) after at least 8 hours of fasting, a nonfasting glucose level ≥ 200 mg/dl (11.1 mmol/l), self-reported use of insulin or oral hypoglycemic agents and/or report of physicians-diagnosed diabetes. A baseline fasting glucose level between 110-126 mg/dl was an indication of impaired fasting glucose. Hyperinsulinemia was defined at baseline as the upper 20th percentile of fasting insulin levels. Participants free of diabetes at baseline who were classified as diabetic at visits 2, 3, or 4 were considered to have incident diabetes.

For the cross sectional analyses, the outcome variable is coded as 1 if the individual is diabetic at baseline. Outcome variables for hyperinsulinemia, and impaired glucose metabolism are defined similarly. Because we have wide intervals between visits, rather than using interval censoring, the method derived by Duncan and colleagues[5] were utilized to approximate time to development of diabetes mellitus. Linear interpolation was used to determine the time of onset for individuals in whom incident diabetes was based on glucose measurements. For those with classification based on physician diagnosis or medication use, the midpoint between the last visit free of diabetes and the first visit at which diabetes was classified was used.

Independent Variables: Individual Level

Information on personal education, income, and occupation was obtained during the baseline home interview. During data collection the level of education attained was categorized as high school not completed, high school or general equivalency diploma completed, one to three years of college, four years of college completed, and some graduate or professional school. The literature gives no indication of an association between cardiovascular diseases and smaller increments of education; thus for this study educational level was categorized into three levels based on the highest grade level completed (less than high school, high school completed, greater than high school). Information on the current or most recent occupation was collected for employed, unemployed, and retired participants and coded according to census criteria. Six categories of occupational groups were formed: executive, managerial, and professional; technical, sales, and administrative support; farming, forestry, and fishing; precision production, craft, and repair; and homemakers[6]. In these analyses occupation was examined as homemakers (category VII), manual occupations (categories III-VI), and nonmanual occupations (categories I-II) as the referent. Total combined family income was selected from eight categories: under $5,000; $5,000 to $7,999; $8,000 to $11,999; $12,000 to $15,999; $16,000 to $24,999; $25,000 to $34,999; $35,000 to $49,999; and $50,000 or more. Three levels of income were created based on the center-specific tertiles.

Independent Variables: Neighborhood Level

Participants were linked to their neighborhood of residence by their home address reported at baseline. Census tracts were used as proxies for neighborhoods. Though the population of census tracts varies widely, in 1990 an average of 4,000 persons resided in each. Indicators of neighborhood socioeconomic conditions were selected from the 1990 US Census. An index of neighborhood socioeconomic characteristics was developed based on factor analyses of multiple variables as reported elsewhere[7, 8]. Factor analysis is a statistical technique used to identify subsets of variables that can meaningfully combine into a summary score.

Six indicators were chosen to represent the following dimensions: education (percentage of adults aged 25 or older who had completed high school and the percentage of adults aged 25 or older who had completed college), occupation (percentage of persons aged 16 or older employed in executive, managerial, or specialty occupations), and wealth/income (median value of housing unit; percentage of houses receiving interest, dividend, or net rental income; and median household income). Neighborhood indicators were combined into a summary neighborhood index based on the work of Diez Roux and colleagues[7]. Median value of housing was log transformed due to having an extremely skewed distribution. This transformation increases the consistency of the index across geographic areas[9]. For each variable a z score for each census tract was calculated by subtracting the overall mean (across all tracts in the sample) and dividing by the standard deviation[7, 8]. This measure reflects the deviation of the value of each variable from the mean. The z scores for each of the six variables were summed to form the neighborhood summary score. An increasing score signified an increase in neighborhood socioeconomic advantage.

In each ARIC center subjects were divided into three tertiles, or roughly equal groups, according to the summary scores for their neighborhoods. Center-specific categories were formed due to variation in socioeconomic status across the United States as illustrated in table 1.

3.4 Analysis Plan

The basic framework of this study is illustrated in figure 3.1. There is not a conventionally- accepted, comprehensive theory to describe the processes that putatively link individual-level socioeconomic status with disease outcomes, nor the complex mechanisms linking neighborhood context with an individual's health. However, several potential pathways have been suggested. Two main pathways were explored. One pathway suggests that individual socioeconomic characteristics (SEC) is estimated through educational achievement, income and occupational status, and is influenced by age, race, and gender. Individual socioeconomic characteristics in turn affect the individual environment and ultimately individual health through social, psychological, behavioral, and biological experiences. It is suggested that neighborhood social conditions affect individual's health through the ecometrics of the community environment and that the socioeconomic context of the community also shapes individual's socioeconomic position. While it is well established that an individual's health status may impact his/her socioeconomic condition, this study will examine the pathways from community context and individual socioeconomic position to diabetes outcomes.

The overview of the analysis plan is simplified by restricting it to a binary dependent variable (i.e. the occurrence of diabetes, hyperinsulinemia, and impaired glucose metabolism) using data in which individuals are nested (or clustered) in neighborhoods. Individuals in the same cluster tend to be more similar in their outcome measures because they share the same environment. Therefore, knowing the outcome for one observation in the cluster can help us predict the outcome for other individuals to the extent that individuals are correlated. This suggests that every observation is not independent, which violates one of the most basic assumptions underlying traditional least squares modeling.

For cross-sectional analyses, hierarchical logistic modeling and for time-to-event analyses hierarchical proportional hazards modeling were used to appropriately model outcomes as a function of variables at the individual and neighborhood level. Within this modeling framework, one can evaluate the effect on the outcome of covariates at any level of the hierarchy and interactions among covariates measured at different levels. Hierarchical modeling corrects for biases in parameter estimates and corresponding standard errors resulting from the correlation between individuals in neighborhoods.

This study involves individuals nested within neighborhoods. Therefore, multilevel, or hierarchical, analyses were employed to *deal with* possible correlation between individuals within neighborhoods. Multilevel analyses involving two-levels (in our case individuals nested within neighborhoods) can be conceptualized as the following two stage system of equations:

<u>Level 1 (Individual level)</u>

A separate individual level regression is defined for each neighborhood:

(1) $Y_{ij} = \beta_{0j} + \beta_{1j} I_{ij} + \beta_{2j} A_{ij} + \varepsilon_{ij}$ $\varepsilon_{ij} \sim N(0, \sigma^2)$

Y_{ij} = Outcome variable for *i*th individual in *j*th neighborhood

I_{ij} = individual level socioeconomic indicator for *i*th individual in *j*th neighborhood

β_{0j} = neighborhood specific intercept

β_{1j} = neighborhood specific effect of the individual level variable

A_{ij} = baseline age for *i*th individual in *j*th neighborhood

Individual level errors (ε_{ij}) are assumed to be independent and identically distributed with mean 0 and variance σ^2. The same independent variables are used in all neighborhoods, but regression coefficients are allowed to vary from one neighborhood to another.

<u>Level 2 (Neighborhood level)</u>

Neighborhood-specific regression coefficients are modeled as a function of neighborhood-level variables.

(2) $\beta_{0j} = \gamma_{00} + \gamma_{01}N_j + \mu_{0j}$ $\mu_{0j} \sim N(0, \tau_{00})$

(3) $\beta_{1j} = \gamma_{10} + \gamma_{11}N_j + \mu_{1j}$ $\mu_{1j} \sim N(0, \tau_{11})$ $\text{cov}(\mu_{0j}, \mu_{1j}) = \tau_{10}$

(4) $\beta_{2j} = \gamma_{20}$

N_j = neighborhood level socioeconomic characteristics

γ_{00} = common intercept across groups

γ_{01} = effect of neighborhood level predictor on group-specific intercepts

γ_{10} = common slope associated with the individual level socioeconomic variables across neighborhoods

γ_1 = effect of neighborhood level factors on the group specific slopes

β_{2j} = the coefficient for age is assumed to be constant across neighborhoods

With the inclusion of an error term (μ_{0j}) in the level 2 equation, the model allows for sampling variability in the group specific coefficient and for the effect of other neighborhood-level factors that may not have been included.

The final mixed effects model is derived by substituting equations 2, 3, and 4 into equation 1.

(5) $$Y_{ij} = \gamma_{00} + \gamma_{01}N_j + \gamma_{10} I_{ij} + \gamma_{11}N_j I_{ij} + \gamma_{20} A_{ij} + \mu_{0j} + \mu_{1j}I_{ij} + \varepsilon_{ij}$$

In cross-sectional analyses parameter estimates were obtained from SAS GLIMMIX. Fixed effect estimates can be interpreted in much the same way as those from the standard logistic model. For example, the odds of having the response (e.g., diabetes) for individuals with a household income of $50,000 versus those with an income of $15,000 would be $\exp[\beta_2(50-15)]$. This fixed effect is the average effect of income across census tracts. Including a random effect for income allows a unique effect for each census tract in addition to the fixed effect. The addition of the tract-specific effects makes the model more accurate than the fixed effect model only.

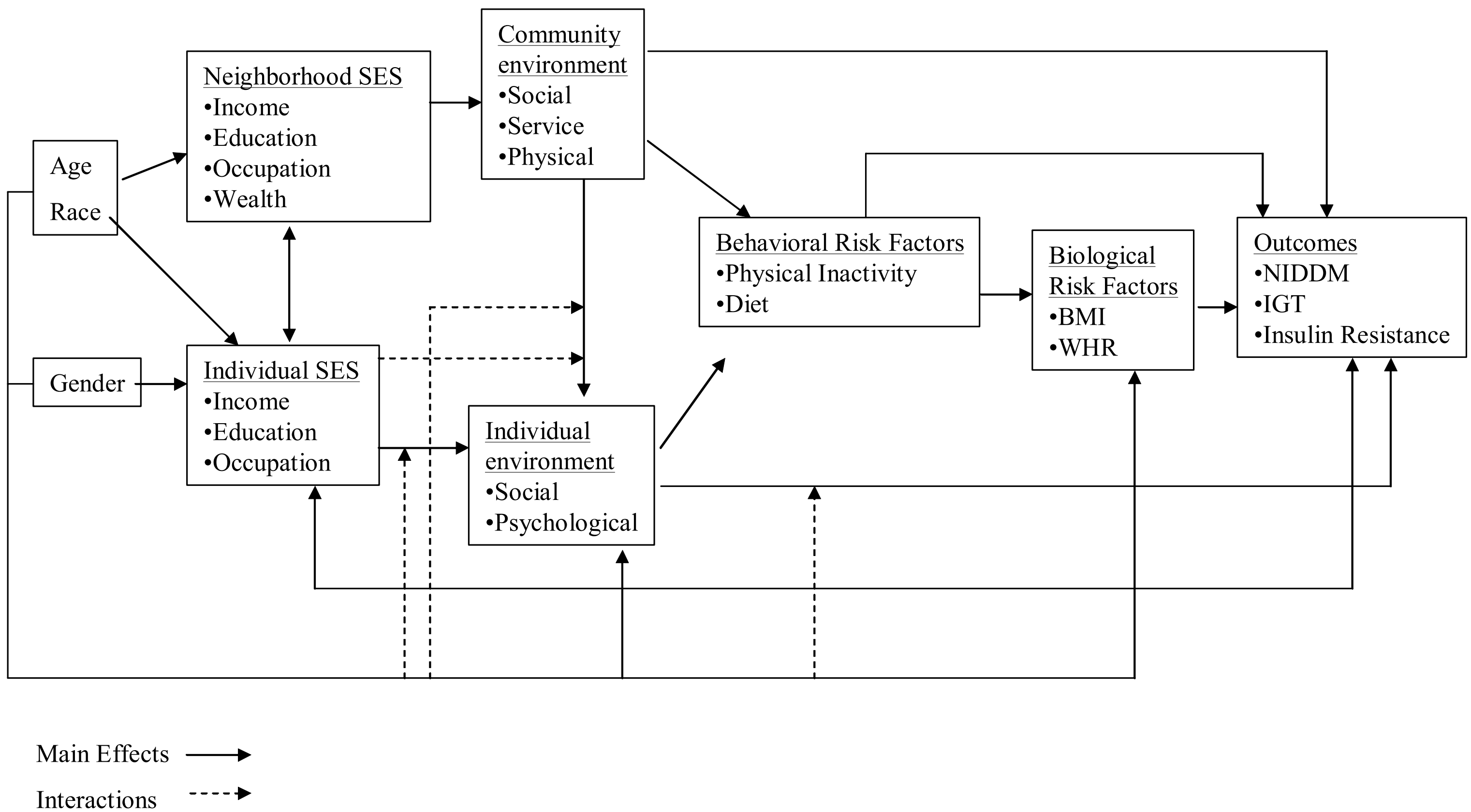
For prospective analyses Poisson regression was used to estimate age-adjusted incidence rates per 1,000 person-years. Cox proportional hazards regression was used to estimate hazard ratios (HR) and 95% confidence intervals (CI) relating diabetes incidence at the two lowest levels of the individual or neighborhood socioeconomic characteristics factors to the highest level, after controlling for age. To examine the combined effects of individual and neighborhood characteristics, gender-specific rates for nine cross-classified categories of neighborhood and individual socioeconomic characteristics were estimated. The COVSANDWICH option in SAS PROC PHREG was used to account for within-neighborhood correlation of outcomes in longitudinal analyses.

Table 3.1. Distribution of neighborhood level factors by ARIC field centers, 2000

	Washington Co., MD	Forsyth Co., NC	Hennepin Co., MN	Jackson, MS
percentage of adults aged 25 or older who had completed high school, 2000	77.8	82.0	90.6	79.1
percentage of adults aged 25 or older who had completed college, 2000	14.6	28.7	39.1	27.1
median value of housing unit, 2000	$115,000	$114,000	$143,400	$64,400
median household income, 1999	$40,617	$42,097	$51,711	$30,414

Source: Quick Facts from the US Census Bureau[10]

Figure 3.1. Conceptual framework for the association of neighborhood and individual socioeconomic characteristics with type 2 diabetes, hyperinsulinemia, and impaired fasting glucose



Adapted from Robert, 1999[11]

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4.0 Relationship of Neighborhood and Individual Socioeconomic Characteristics to Type 2 Diabetes, Hyperinsulinemia, and Impaired Fasting Glucose in Whites. The Atherosclerosis Risk in Communities Study, 1987-1998

4.1 Introduction

A wealth of research demonstrating an association between individual socioeconomic status (SES) and health has accumulated over several decades. There also is growing evidence that links the residential environment to health outcomes and health behaviors[1-4]. Some studies have found that living in socioeconomically disadvantaged areas is inversely related to health independent of individual socioeconomic position [2, 5-9]. For type 2 diabetes the direction of association has been inconsistent[10-13]. Studies conducted in the early 1970's and a more recent study in Bangladesh indicated that populations with higher levels of SES had greater prevalence of diabetes [12, 14]. Other studies, however, found increased prevalence among those of lower socioeconomic position [15-18]. Most studies investigating the association of aggregate-level measures of SES and diabetes were conducted in Europe. One study known to us found no association between area deprivation and prevalence of Type 2 diabetes [19] while others observed a positive association [20-22].

Fasting hyperinsulinemia (an indicator of insulin resistance) and impaired fasting glucose are directly involved in the pathogenesis of Type 2 diabetes [23]. Two studies have reported associations between glucose intolerance and individual level education or occupation [24, 25]. Another study indicated that neighborhood socioeconomic characteristics are inversely related to components of the insulin resistance syndrome [26]. We know of no studies directly investigating the relationship between neighborhood level factors and hyperinsulinemia or impaired fasting glucose.

Prior research on socioeconomic characteristics and diabetes has investigated the influence of socioeconomic characteristics (SEC) either at the individual- or at the neighborhood-level, without considering their putative joint influence. We examined the independent and interactive effects of individual- and neighborhood-level socioeconomic factors on diabetes prevalence and incidence. The influence of socioeconomic characteristics on prevalent hyperinsulinemia and impaired fasting glucose as well as on the progression to diabetes from these pre-diabetic conditions was also examined.

4.2 Materials and Methods

Study Population

This report is based on the white examinees of the Atherosclerosis Risk in Communities (ARIC) study. ARIC is a prospective investigation of atherosclerosis in four U.S. communities (Forsyth County, North Carolina; Jackson, Mississippi; Washington County, Maryland; and the northwestern suburbs of Minneapolis, Minnesota). The ARIC cohort is composed of 15,792 black and white men and women aged 45 to 64 years at baseline, 1987-1989, selected from a probability sampling of the four communities. Three samples represent the geographic distribution of the communities with Washington County and the Minneapolis suburbs virtually all white and Forsyth County 85% white. In Jackson, MS only African Americans were sampled. A detailed description of the study design, methods, and response rates is available elsewhere [27].

Of the 11,374 white men and women ages 45-64 in the ARIC cohort 11,137 were linked to their neighborhood of residence by their home address at baseline (1987-1989). Participants were excluded sequentially due to missing census tract information (n=504), diabetes status missing (n=23), missing education (n=11), income missing (n=456), and occupation missing (n=373). Due to differences in socioeconomic status, particularly regarding occupation and income, as well as the inability to determine whether disease impacted occupational status, those who were retired at baseline (n=1,617) were also excluded from analyses. Though homemakers did not report having a job outside the home, they were not significantly different from other participants with regards to other individual socioeconomic factors. Thus homemakers were retained in the dataset and categorized as a separate occupation group. Because there was only one man that identified himself as a homemaker, he was excluded from analyses. The final sample size for cross-sectional analyses was 8,152 (3,747 men, 4,405 women). For the pre-diabetic conditions hyperinsulinemia and impaired fasting glucose (IFG), the 3,410 men and 4,063 women without diabetes at the baseline examination were included in analyses. These 7,473 individuals also composed the sample for incident calculations.

Definition of Variables

During a baseline interview cohort members self-reported information on demographic characteristics such as age, race, gender, household income, education, and most recent occupation. Total family income in U.S. dollars was selected from the following eight listed categories: (<$5,000; $5,000-$7,999; $8,000-$11,999; $12,000-$15,999; $16,000-$23,999; $24,000-$34,999; $35,000-$49,999; and ≥ $50,000). For analyses income tertiles were constructed based on the distribution within each region, or ARIC center. For North Carolina (NC) and Maryland (MD) the tertiles were as follows: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. For Minnesota (MN) the lowest tertile was <$35,000, middle: $35,000-49,999; highest: ≥ $50,000. Three levels of income were created based on the center-specific tertiles. Educational level was categorized into three levels based on the highest grade level completed (less than high school, high school completed, greater than high school). Occupation was coded according to the 1980 Census Alphabetical Index of Occupations [28] and categorized as follows: I) executive, managerial, and professional specialty occupations; (II) technical, sales, and administrative support; (III) service occupations; (IV) farming, forestry, and fishing occupations; (V) precision production, craft, and repair occupations; and (VI) operators, fabricators, and laborers (VII) homemakers. In these analyses occupation was examined as homemakers (category VII), manual occupations (categories III-VI), and nonmanual occupations (categories I-II) as the referent.

Participants were linked to a neighborhood of residence by their home address reported at baseline by means of geocoding [29]. Census tracts - subdivisions of counties with an average population of 4,000 persons – were used as proxies for neighborhoods [30-32]. Indicators of neighborhood socioeconomic conditions were obtained from the 1990 U.S. Census. Six indicators were chosen to represent the following dimensions: education (percentage of adults aged 25 or older who had completed high school and the percentage of adults aged 25 or older who had completed college), occupation (percentage of persons aged 16 or older employed in executive, managerial, or specialty occupations), and wealth/income (median value of housing unit; percentage of houses receiving interest, dividend, or net rental income; and median household income). These indicators were selected and used to develop a neighborhood summary score based on factor analyses reported elsewhere [5, 33]. Neighborhood factors were summarized into a composite neighborhood score, which was used as the main indicator of the neighborhood socioeconomic environment. A z score for each census tract was estimated for each variable by subtracting the overall mean (across all tracts in the sample) and dividing by the standard deviation. This measure reflects the deviation of the value of each variable from the mean. The z-scores for each of the six variables were summed to form the neighborhood summary score. Neighborhood summary SES scores for census tracts in this sample ranged from -11.91-13.44 for NC, -14.13-16.57 for MN and -14.85-21.65 for MD. An increasing score signifies an increase in neighborhood socioeconomic advantage. Three categories of z-scores were formed based on tertiles of the distribution by geographic region. The intervals from lowest to highest were as follows: for NC, (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44);) for MN, (-14.23, -3.23), (-3.22, 2.46), and (2.47, 16.57; and for MD, (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65). The scores in the lowest third correspond to the most disadvantaged neighborhoods while scores in the highest third correspond to the most advantaged neighborhoods.

At baseline participants underwent clinical examinations with all measurements collected according to a standardized protocol [34]. Participants were asked to fast overnight (>8 hours) prior to the clinical examination. They were also asked to refrain from smoking and consuming alcohol or caffeine on the day of the examination. At all study sites blood was drawn from seated patients and sent to a central laboratory for assay. Prevalent Type 2 diabetes was defined according to the American Diabetes Association criteria [35]. Patients who met any of the following criteria were considered to have diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/L), nonfasting glucose ≥ 200 mg/dl (11.1mmol/L), self-reported physician diagnosis, or self-reported use of medications for diabetes. Participants with a baseline fasting glucose level between 110-126 mg/dl (6.1 – 7.0mmol/L) were considered to have impaired fasting glucose. Hyperinsulinemia was defined at baseline as the upper 20th percentile of fasting glucose. Participants with incident diabetes were free of diabetes at baseline and later classified as diabetic during follow-up.

For incident diabetes classified on the basis of a glucose value, incident date was estimated by linear interpolation using glucose values from the ascertaining visit and the previous visit. The time at which 7.0mmol/l was reached for subjects who had been told by a physician they had diabetes or who were on diabetic medication was estimated using information from all diabetic subjects who had been unaware of their status [36].

Statistical Analyses

All analyses were performed separately by gender due to large differences in the distribution of socioeconomic characteristics. All models were adjusted for age at baseline as a continuous variable. Due to the nesting of individuals within neighborhoods, mixed effects models with a random intercept for each neighborhood were fit using a SAS Macro (GLIMMIX, SAS Institute Inc., Cary, North Carolina) in the cross-sectional analyses in order to account for potential within-neighborhood correlations in outcomes [37]. Type 2 diabetes, hyperinsulinemia, and impaired fasting glucose were identified as binary dependent variables.

For prospective analyses Poisson regression was used to estimate age-adjusted incidence rates per 1,000 person-years. Cox proportional hazards regression was used to estimate hazard ratios (HR) and 95% confidence intervals (CI) relating diabetes incidence at the two lowest levels of the individual or neighborhood socioeconomic characteristics factors to the highest level, after controlling for age. To examine the combined effects of individual and neighborhood characteristics, gender-specific rates for nine cross-classified categories of neighborhood and individual socioeconomic characteristics were estimated. The COVSANDWICH option in SAS PROC PHREG was used to account for within-neighborhood correlation of outcomes in longitudinal analyses [38].

4.3 Results

4.3.1 Cross-sectional analyses

Individual-level Attributes

After exclusions the final sample of participants consisted of 8,152 individuals distributed among 236 census tracts. Fifty-four percent were women. Both men and women had a mean age of 53 years (Table 4.1). Most men reported incomes in the highest level (41%) while most women (36%) reported incomes in the middle level. Nearly 46% of men reported having more than a high school education, and approximately half of the women reported having completed high school. Nearly sixty percent of men and women reported having professional jobs. Over 20% of men and women reported a known family history of Type 2 diabetes.

The age-adjusted prevalence of Type 2 diabetes was marginally higher in men (8.7%) than in women (7.5%). Among men and women the age-adjusted prevalence of Type 2 diabetes decreased with increasing individual economic characteristics (Tables 4.2a and 4.2b). The prevalence was highest among those with incomes in the lowest income level, less than high school education, and manual occupations (for men), homemakers (for women). For women the prevalence doubled from nearly 5.5% to 11% for each socioeconomic characteristic. Among women this pattern was also documented for the prevalence of hyperinsulinemia and impaired fasting glucose (Table 4.2b). Among men by contrast, the patterns for pre-diabetic conditions were inconsistent (Table 4.2a).

Table 4.3 shows the age-adjusted prevalence odds ratios of diabetes and pre-diabetic conditions associated with individual-level characteristics. Among men the prevalence odds of having diabetes was fifty percent higher for those in the lowest individual-level income tertile relative to those in the highest tertile (age-adjusted 1.51 [1.12, 2.05]) and for those with less than a high school education (1.50 [1.10-2.05]) compared to those with college education. The prevalence odds were also higher for those completing high school (1.32 [1.02-1.69]) and manual versus nonmanual occupations (1.42 [1.14-1.78]). For women the odds were twice as high for those in the lowest categories relative to the highest -- for income (2.62 [1.89, 3.62]), education (2.31 [1.68, 3.17]), and occupation (2.15 [1.65, 2.79]). Though there was a slight attenuation in magnitude of the association after adjustments for neighborhood-level social class indicators, individual disadvantage remained associated with Type 2 diabetes prevalence. The pattern of higher prevalence odds in lower levels of socioeconomic characteristics compared to the highest level persisted among women for hyperinsulinemia and impaired fasting glucose. For men associations between individual-level socioeconomic factors and hyperinsulinemia and IFG were inconsistent.

Neighborhood-level Attributes

Increased neighborhood disadvantage was generally associated with increased age-adjusted prevalence of Type 2 diabetes, hyperinsulinemia, and IFG in women (Table 4.2b).

For men the prevalence was highest in the intermediate category of neighborhood characteristics (Table 4.2a). There was an inverse association between neighborhood socioeconomic characteristics and the prevalence odds of diabetes, hyperinsulinemia, and IFG for women (Table 4.3). In the lowest category of neighborhood socioeconomic characteristics there was nearly a 40-50 percent increase in prevalence above those in the most advantaged neighborhoods. In men the odds of having diabetes were increased for lower and intermediate levels of neighborhood relative to the highest level. However, the highest prevalence odds were found in the intermediate category (1.37 [1.04, 1.81] versus 1.24 [0.93, 1.64] the lowest category). For hyperinsulinemia and IFG there was a very small association with neighborhood characteristics. Table 4.4 shows the prevalence odds ratios for the lower levels of neighborhood characteristics compared to the highest level. The prevalence odds of diabetes were 30 and 50 percent greater in more disadvantaged neighborhoods than in the more advantaged neighborhoods for men and women respectively. Associations decreased after adjusting for individual level factors. For men the attenuation was the same after adjusting for each individual-level factor separately. However, the influence of neighborhood socioeconomic characteristics attenuated most after the adjustment for personal income in women.

Individual and Neighborhood Associations

The strength of the association of the odds ratio between individuals in the lowest income category relative to the highest income category increased with increasing neighborhood SEC among white men. There was not a consistent linear trend in this association among white women (Figure 4.1), nor was there a consistent pattern of association between lower individual and neighborhood-level groups relative to the highest individual and neighborhood group (Table 4.5)

4.3.2 Longitudinal analyses

Individual-level Attributes

Over an average of 8.7 years of follow-up 1,078 new cases of diabetes occurred among the 7,473 participants free of diabetes at baseline. The incidence was 20.3 in men and 20.9 in women. In general, an inverse age-adjusted association was observed between diabetes incidence and individual-level socioeconomic characteristics factors (Table 4.6). Having lower income, education, or manual occupations was associated with nearly 25, 50, and 15 percent higher risk than having the highest levels of individual factors in men (Table 4.7). For women there was no association for the lowest level of income and being a homemaker tended to be protective. However, these associations were not statistically significant. There was a 53 percent higher risk for those with less than high school education compared to those who were college-educated. Adjustment for neighborhood level factors did not significantly influence the impact of individual level factors.

Trajectories of temporal change in BMI indicated no consistent pattern by socioeconomic level or gender. Among women those in the lowest categories of socioeconomic characteristics had the highest baseline BMI (27.2 to 28.4 kg/m2) (Table 4.8). Those in the highest categories had the greatest increase over time, statistically significant for income and occupation. Among white males there was no consistent pattern in the BMI trajectories by socioeconomic characteristics. Those with the lowest levels of income and occupation had the highest baseline BMI, 27.68 kg/m2 and 27.53 respectively. Those with the middle income and lowest occupation had the greatest increase over time (0.13 kg/m2). For education (27.54 kg/m2) and neighborhood characteristics (27.56 kg/m2) those in the middle categories had the highest baseline BMI and the greatest increase over time (0.13 kg/m2). These changes were not statistically significant.

Neighborhood-level Attributes

The incidence of diabetes generally increased with decreasing neighborhood socioeconomic characteristics ranging from 19.4 to 21.1 cases per 1,000 person-years from the most to the least advantaged neighborhoods in men and 19.8 to 22.9 cases per 1,000 person-years in women (Table 4.6). Hazard ratios for Type 2 diabetes associated with neighborhood socioeconomic characteristics indicate a slight increase risk for those in the lowest neighborhood tertile (1.05[0.80, 1.39] for men, 1.16 [0.86, 1.58] for women) (data not shown). This association did not persist after adjustment for individual-level factors. There was no association observed for those in the middle neighborhood tertile compared to those in the highest tertile.

Individual and Neighborhood Associations

There was no clear pattern of a joint effect between individual socioeconomic factors and neighborhood socioeconomic characteristics in their association with Type 2 diabetes incidence (Figure 4.2) among women. Among white women the strength of the association of the hazard ratio between individuals in the lowest income category relative to the highest income category was strongest in the most advantaged neighborhoods. The risk of diabetes for those in the lowest income category relative to the highest income category decreased with increasing neighborhood status. Hazard ratio estimates indicated no consistent pattern of association between lower individual and neighborhood-level groups relative to the highest individual and neighborhood group (Table 4.9)

4.4 Discussion

Our findings support those of other studies that found low neighborhood socioeconomic characteristics to be associated with higher diabetes prevalence [10, 18, 20-22]. Both neighborhood and individual level socioeconomic factors were inversely associated with diabetes prevalence. The odds of diabetes was fifty percent higher for men and twice as high for women in the lowest versus the highest levels of individual socioeconomic characteristics. Similarly, the odds were 30-50 percent greater in more disadvantaged neighborhoods. Though neighborhood effects were no longer statistically significant after adjustment for individual-level factors, a modest association remained.

Previous studies failed to consider the potential interplay between neighborhood level factors and individual-level factors in their association with type 2 diabetes. The availability of census data linked to personal data allowed us to investigate the impact of neighborhood independently of the individual factors and vice versa. Though the association of individual-level socioeconomic characteristics factors with diabetes was stronger, some influence of the neighborhood factors was suggested by our data. Neighborhood disadvantage was associated with increased diabetes prevalence after adjusting for individual level factors although the association was no longer statistically significant. Neighborhood characteristics accounted for a fifteen percent increase in prevalence odds after adjusting for all individual factors simultaneously and more than a twenty percent increase when adjusted for separate individual factors. For men there was nearly a fifty percent increase in risk of diabetes prevalence for all individual level factors in the lowest relative to the highest categories even after adjusting for neighborhood effects. For women this increase was two-fold. Associations comparing the prevalence odds of diabetes in the lowest income category to the prevalence odds in the highest income category did not show a consistent pattern among women. Among men, as neighborhood characteristics increased the disparity between the prevalence odds for those with low income relative to high income increased. This may be partly explained by the lack of resources available to either the "poor" or the "rich". The excess difference in the prevalence odds in more advantaged neighborhoods may suggest that resources are available in these neighborhoods but they are not accessible to those of lower income. Explanations for gender-differences are not clear.

We know of only one other study on the relationship between neighborhood socioeconomic factors and Type 2 diabetes incidence. Our findings agree with those of the collaborative study of diabetes incidence from nine British towns [39] in that we demonstrate an inverse association between neighborhood advantage and Type 2 diabetes incidence after considering the contribution of individual-level factors. Type 2 diabetes was more likely to develop over nine years in men and women who lived in the most disadvantaged neighborhoods than in those who lived in the most advantaged neighborhoods. Barker's study of diabetes incidence and socioeconomic conditions investigated geographic areas as the unit of analysis and thus did not address whether geographic variations were due to differences among the residents of the various areas. In that study the mean incidence of Type 2 diabetes was 23 per 100,000 population for the 'worse' towns compared to 10 per

100,000 for the 'better' towns. Standardization for social class reduced the incidences to 19.6 and 7.5 per 100,000 population in 'worse' and 'better' towns respectively [39].

Few studies have investigated the association of socioeconomic characteristics with metabolic abnormalities. In our data there was an inverse association between socioeconomic characteristics and hyperinsulinemia and impaired fasting glucose (IFG) in women only. Among men there was no consistent trend in prevalence across socioeconomic characteristics categories. These findings could suggest that the mechanisms linking socioeconomic characteristics with Type 2 diabetes differ from those of pre-diabetic conditions, although such an inference is speculative and has to be considered with caution.

Additional analyses examining differences in diabetes classification based on prior external classification compared to elevated glucose levels during the ARIC screening did not indicate a significant difference in access to care for this population. However, examination of those lost to follow-up by the final visit relative to those that participated in all visits indicated a significant difference by socioeconomic characteristics. Generally most of those that attended all visits were in higher SES categories. Among women more of those that were lost were in the lowest income category and lowest neighborhood tertile. This differential loss may have obscured patterns of findings.

Among the strengths of this study are the availability of confirmed prevalent disease and the interpolation of onset time for incident cases instead of interval censoring. Rather than relying on self-reported diagnosis of diabetes, comprehensive clinical examinations were conducted utilizing standardized procedures during each year of the study. Because we had wide intervals between visits, linear interpolation was used to determine approximate time to development of Type 2 diabetes for individuals in whom incident diabetes was based on glucose measurements. For those with classification based on physician diagnosis or medication use, the midpoint between the last visit free of diabetes and the first visit at which diabetes was classified was used.

This study utilized hierarchical modeling techniques to correct for biases in parameter estimates and corresponding standard errors resulting from the correlation between individuals nested in neighborhoods. These methods enabled us to more appropriately model outcomes as a function of variables at the individual and neighborhood level. Within this modeling framework, we were able to evaluate the independent effects on the outcome of factors measured on multiple levels of the hierarchy as well as interactions between these factors.

A strength of this study is that it is based on a large, population-based sample drawn from three diverse areas representing a range of socioeconomic conditions in the US. However, there was limited variability in socioeconomic characteristics within each area; this may have diluted the ability to observe the impact of neighborhoods in this study. Because neighborhood scores for more disadvantaged areas in one region may have been in the range of more advantaged areas in another region, adjustments were made to incorporate variability between regions. Nonetheless, it is important to mention that ours was not a sample drawn from regionally (or nationally) defined frames, which imposes constraints to the wider generalizability of our findings.

While the use of census tracts as proxies for neighborhoods has been supported in other studies [30-32], inferences regarding neighborhood effects may be weakened by the use of administratively defined units since this may not be the best operational definition of neighborhood. However, since the specific mechanisms through which neighborhoods influence diabetes are not clearly understood, the most theoretically relevant neighborhood definition for this study is not clear. The ambiguity of defining the most relevant area and the availability of census information make census tracts the most practical alternative for this relatively large study linking individual and area data in such diverse geographic areas.

In this study aggregate census measures were used as proxies for neighborhood characteristics, yet associations were observed even with these crude proxies. The z-score is an indirect marker of neighborhood attributes, thus the impact of other neighborhood factors needs to be explored. Socioeconomic characteristics have been associated with established risk factors for diabetes, such as physical inactivity and obesity [25, 40-42]. Studies have found that neighborhoods differ in the availability of food stores [43] and in the availability and cost of healthful foods [44-46]. Diet has also been found to be associated with neighborhood environments [40]. Patterns of physical activity may differ by neighborhood environment due to variation in availability and access to safe, quality recreational facilities [47-49] and perceived safety. The findings that individual socioeconomic characteristics and to some degree also neighborhood socioeconomic characteristics are related to the burden of diabetes suggest that diabetes prevention strategies may need to consider the socioeconomic context of their target populations. To what degree socioeconomic barriers at the level of residential areas influence the community burden of type 2 diabetes in addition to individual-level factors deserves heightened attention by public health scientists.

Table 4.1. Neighborhood and individual socioeconomic characteristics at baseline by center and gender. Atherosclerosis Risk in Communities study, 1987-1989: White men and women

Characteristics	Men	Women
No. (%)	3747 (45.96)	4405 (54.04)
Age, yrs, mean (SD)	53.3 (5.20)	53.17 (5.38)
Family History of Diabetes	836 (22.31)	1091 (24.77)
Individual Income[a]		
Lowest Tertile	744 (19.86)	1527 (34.67)
Middle Tertile	1485 (39.63)	1607 (36.48)
Highest Tertile	1518 (40.51)	1271 (28.85)
Individual Education		
< High School	578 (15.43)	677 (15.37)
High School Completed	1446 (38.59)	2205 (50.06)
College	1723 (45.98)	1523 (34.57)
Individual Occupation		
Homemakers [b]	---	953 (21.63)
Manual occupations	1453 (38.78)	859 (19.50)
Nonmanual occupations	2294 (61.22)	2593 (58.86)
No. of neighborhoods (census tracts)	209	201
Neighborhood Score [c], mean (SD)	0.10 (5.45)	-0.09 (5.39)

[a] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000

[b] One male homemaker was excluded due to insufficient numbers.

[c] A summary value for each census tract was created from the sum of z scores for six indicators of income/wealth, education, and occupation.

Table 4.2a. Age-adjusted prevalence (95% CI) of type 2 diabetes, hyperinsulinemia, and impaired fasting glucose[a] by individual and neighborhood socioeconomic characteristics. Atherosclerosis Risk in Communities study, 1987-1989: White men

	Type 2 Diabetes	**Hyperinsulinemia**	**Impaired Fasting Glucose**
No. participants (%)			
Individual Income[b]			
Lowest Tertile	10.2 (8.1, 12.8)	28.5 (25.1, 32.1)	15.2 (12.5, 18.2)
Middle Tertile	9.3 (7.9, 10.9)	26.1 (23.8, 28.5)	15.6 (13.7, 17.6)
Highest Tertile	7.3 (6.0, 10.9)	27.0 (24.7, 29.4)	15.8 (14.0, 17.8)
Individual Education			
< High School	11.3 (8.7, 14.5)	25.5 (21.6, 29.8)	14.4 (11.3, 18.2)
High School	9.4 (8.0, 11.1)	27.6 (25.2, 30.1)	17.1 (15.1, 19.2)
College Education	7.4 (6.2, 8.7)	26.9 (24.7, 29.1)	14.4 (12.8, 16.3)
Individual Occupation			
Manual occupations	10.4 (8.9, 12.1)	25.2 (22.9, 27.6)	15.7 (13.8, 17.8)
Nonmanual occupations	7.6 (6.6, 8.8)	28.0 (26.1, 29.9)	15.5 (14.0, 17.1)
Neighborhood SEC [c]			
Lowest Tertile	9.2 (7.7, 11.0)	27.3 (24.8, 30.0)	14.8 (12.9, 17.1)
Middle Tertile	9.8 (8.3, 11.7)	27.3 (24.7, 30.0)	16.1 (14.1, 18.4)
Highest Tertile	7.1 (5.8, 8.7)	26.2 (23.7, 28.7)	15.7 (13.8, 17.9)

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes. Hyperinsulinemia: the upper 20[th] percentile of the distribution of fasting glucose at baseline. Impaired fasting glucose: baseline fasting glucose level between 110-126 mg/dl.

[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000

[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23),
(-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

Table 4.2b. Age-adjusted prevalence (95% CI) of type 2 diabetes, hyperinsulinemia, and impaired fasting glucose[a] by individual and neighborhood socioeconomic characteristics. Atherosclerosis Risk in Communities study, 1987-1989: White women

	Type 2 Diabetes	**Hyperinsulinemia**	**Impaired Fasting Glucose**
No. participants (%)			
Individual Income[b]			
Lowest Tertile	10.68 (9.13, 12.46)	19.5 (17.3, 21.8)	7.7 (6.3, 9.5)
Middle Tertile	7.02 (5.86, 8.40)	19.0 (17.1, 21.1)	7.3 (6.1, 8.8)
Highest Tertile	4.14 (3.14, 5.43)	14.6 (12.6, 16.8)	6.9 (5.5, 8.5)
Individual Education			
< High School	11.89 (9.41, 14.90)	25.1 (21.5, 29.1)	9.9 (7.5, 12.9)
High School	7.42 (6.38, 8.61)	18.3 (16.7, 20.1)	7.8 (6.7, 9.0)
College Education	5.43 (4.39, 6.69)	14.7 (13.0, 16.7)	5.9 (4.7, 7.3)
Individual Occupation			
Homemaker	11.03 (8.98, 13.48)	22.5 (19.6, 25.7)	10.8 (8.7, 13.4)
Manual Occupations	9.38 (7.59, 11.54)	17.2 (14.7, 20.1)	7.4 (5.7, 9.5)
Nonmanual Occupations	5.46 (4.65, 6.42)	17.0 (15.6, 18.6)	6.4 (5.5, 7.5)
Neighborhood SEC [c]			
Lowest Tertile	8.4 (7.1, 10.0)	20.6 (18.5, 22.8)	8.2 (6.8, 9.8)
Middle Tertile	8.1 (6.8, 9.7)	18.7 (16.7, 21.0)	8.0 (6.6, 9.6)
Highest Tertile	5.8 (4.7, 7.2)	15.0 (13.2, 16.9)	6.0 (4.9, 7.5)

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes. Hyperinsulinemia: the upper 20th percentile of the distribution of fasting glucose at baseline. Impaired fasting glucose: baseline fasting glucose level between 110-126 mg/dl.

[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.

[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23),
(-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

Table 4.3. Age-adjusted prevalence odds ratios of type 2 diabetes[a] by socioeconomic characteristics and gender. Atherosclerosis Risk in Communities study, 1987-1989: White men and women

	Men (N=3747)		**Women (N=4405)**	
	Age-adjusted	**Adj. for Neighborhood**	**Age-adjusted**	**Adj. for Neighborhood**
Individual Income [b]				
Lowest Tertile	1.51 (1.12, 2.05)	1.47 (1.07, 2.02)	2.62 (1.89, 3.62)	2.52 (1.81, 3.52)
Middle Tertile	1.30 (1.00, 1.69)	1.27 (0.97, 1.67)	1.70 (1.22, 2.37)	1.66 (1.19, 2.33)
Highest Tertile	1.0	1.0	1.0	1.0
Individual Occupation				
Homemaker [c]	----	----	2.15 (1.65, 2.79)	2.14 (1.64, 2.78)
Manual Profession	1.42 (1.14, 1.78)	1.39 (1.10, 1.76)	1.72 (1.30, 2.28)	1.66 (1.25, 2.20)
Nonmanual Profession	1.0	1.0	1.0	1.0
Individual Education				
Less than High School	1.50 (1.10, 2.05)	1.46 (1.06, 2.02)	2.31 (1.68, 3.17)	2.19 (1.58, 3.03)
High School Completed	1.32 (1.02, 1.69)	1.29 (0.99, 1.67)	1.39 (1.06, 1.82)	1.34 (1.02, 1.76)
College	1.0	1.0	1.0	1.0

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes.

[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.

[c] 1 male homemaker was excluded due to small numbers.

Table 4.4. Prevalence odds ratios[a] of type 2 diabetes by neighborhood socioeconomic characteristics and gender. Atherosclerosis Risk in Communities study, 1987-1989: White men and women

	Men	**Women**
Age-adjusted	1.30 (1.02, 1.67)	1.47 (1.10, 1.97)
Adjusted for income	1.21 (0.93, 1.56)	1.23 (0.92, 1.63)
Adjusted for occupation	1.21 (0.94, 1.56)	1.42 (1.08, 1.87)
Adjusted for education	1.21 (0.94, 1.56)	1.28 (0.97, 1.69)
Adjusted for all individual factors	1.15 (0.89, 1.50)	1.15 (0.88, 1.51)

[a] Odds ratios are based on lowest and middle tertiles versus highest neighborhood tertiles (ref).

Table 4.5. Age-adjusted prevalence odds ratios[a] of type 2 diabetes by individual income[b] and neighborhood characteristics[c]. Atherosclerosis Risk in Communities study, 1987-1989: White men and women

Men						
Income Level	**Neighborhood Level**	**Estimate**	**Std error**	**T value**	**Pr > |t|**	**Interaction Pr > |t|**
Lowest	Lowest	-0.5965	0.4122	-1.45	0.1479	0.6256
Lowest	Middle	-0.2333	0.4003	-0.58	0.5600	
Middle	Lowest	-0.3416	0.3458	-0.99	0.3233	
Middle	Middle	-0.2342	0.3221	-0.73	0.4672	

Women						
Income Level	**Income Level**	**Income Level**	**Income Level**	**Income Level**	**Income Level**	**Income Level**
Lowest	Lowest	-0.0219	0.4276	-0.05	0.9591	0.5157
Lowest	Middle	-0.1209	0.3935	-0.31	0.7587	
Middle	Lowest	-0.4106	0.4440	-0.92	0.3551	
Middle	Middle	-0.0114	0.3919	-0.03	0.9767	

[a] Odds ratios assess the prevalence of type 2 diabetes in the lowest individual income category relative to the highest income category.
[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000.
MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.
[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23), (-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

Table 4.6. Incidence of type 2 diabetes by gender. Atherosclerosis Risk in Communities study, 1989-1998: White men and women

Characteristics	Persons at Risk (n)	Person-Years	Incident Cases (n)	Incidence Rate [a]
<u>Men</u>				
Individual Characteristics				
Income[b]				
Lowest Tertile	659	4,424	110	24.9
Middle Tertile	1,343	9,555	202	21.1
Highest Tertile	1,408	10,011	175	17.5
Education				
< High School	508	3,332	98	29.4
High School	1,308	9,216	191	20.7
College Education	1,594	1,444	198	17.3
Occupation				
Manual Occupations	1,295	8,912	206	23.1
Nonmanual Occupations	2,115	15,079	281	18.6
Neighborhood SES[c]				
Lowest Tertile	1,108	7,672	162	21.1
Middle Tertile	1,111	7,764	159	20.5
Highest Tertile	1,191	8,555	166	19.4
<u>Women</u>				
Individual Characteristics				
Income[b]				
Lowest Tertile	1,351	9,050	196	21.7
Middle Tertile	1,492	10,518	227	21.6
Highest Tertile	1,220	8,734	168	19.2
Education				
< High School	585	3,803	94	24.7
High School	2,037	4,174	314	22.2
College Education	1,441	10,326	183	17.7
Occupation				
Homemakers	833	5,706	120	21.0
Manual Occupations	777	5,243	121	23.1
Nonmanual Occupations	2,453	17,354	350	20.2
Neighborhood SEC [c]				
Lowest Tertile	1,374	9,308	213	22.9
Middle Tertile	1,298	9,145	183	20.0
Highest Tertile	1,391	9,849	195	19.8

[a] Age-adjusted incidence rate per 1,000 person-years.

[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000

[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23), (-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

Table 4.7. Hazard ratios of type 2 diabetes[a] by individual-level socioeconomic characteristics and gender. Atherosclerosis Risk in Communities study, 1989-1998: White men and women

	Men (N=3,747)		**Women (N=4,405)**	
	Age-adjusted	**Adj. for Neighborhood**	**Age-adjusted**	**Adj. for Neighborhood**
Individual Income [b]				
Lowest Tertile	1.23 (0.91, 1.65)	1.24 (0.91, 1.69)	1.01 (0.76, 1.34)	0.97 (0.72, 1.30)
Middle Tertile	1.24 (0.96, 1.60)	1.25 (0.97, 1.60)	1.13 (0.87, 1.47)	1.10 (0.85, 1.43)
Highest Tertile	1.0	1.0	1.0	1.0
Individual Occupation				
Homemaker [c]	----	----	0.95 (0.71, 1.28)	0.96 (0.71, 1.28)
Manual Profession	1.13 (0.90, 1.42)	1.13 (0.89, 1.43)	1.10 (0.81, 1.49)	1.07 (0.79, 1.46)
Nonmanual Profession	1.0	1.0	1.0	1.0
Individual Education				
Less than High School	1.52 (1.16, 1.99)	1.54 (1.16, 2.05)	1.53 (1.07, 2.20)	1.51 (1.05, 2.17)
High School Completed	1.15 (0.91, 1.45)	1.17 (0.92, 1.49)	1.27 (1.00, 1.62)	1.27 (1.00, 1.60)
College	1.0	1.0	1.0	1.0

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes.

[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.

[c] One male homemaker was excluded due to insufficient numbers.

Table 4.8. Baseline body mass index (BMI) and slope of change in BMI over time. Atherosclerosis Risk in Communities study, 1987-1989: White men and women

	Men			**Women**		
	Baseline BMI (kg/m^2)	**Change over Time (kg/m^2)**	**P-value[c]**	**Baseline BMI (kg/m^2)**	**Change over Time (kg/m^2)**	**P-value[c]**
Income[a]						
Lowest Level	27.68	0.12	0.19	27.34	0.17	<0.0001
Middle Level	27.48	0.13		26.62	0.20	
Highest Level	27.30	0.12		25.57	0.21	
Education						
< High School	27.47	0.13	0.34	28.44	0.17	0.05
High School	27.54	0.13		26.56	0.19	
> High School	27.37	0.12		25.74	0.19	
Occupation						
Homemaker[b]				27.21	0.13	<0.0001
Manual	27.53	0.13	0.064	27.06	0.19	
Nonmanual	27.39	0.12		26.16	0.21	
Neighborhood Characteristic						
Lowest Level	27.48	0.13	0.96	27.21	0.16	0.24
Middle Level	27.56	0.13		26.53	0.13	
Highest Level	27.32	0.12		25.93	0.18	

[a] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000. MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000
[b] One male homemaker was excluded due to insufficient numbers.
[c] P-value for interaction between socioeconomic characteristics and time.

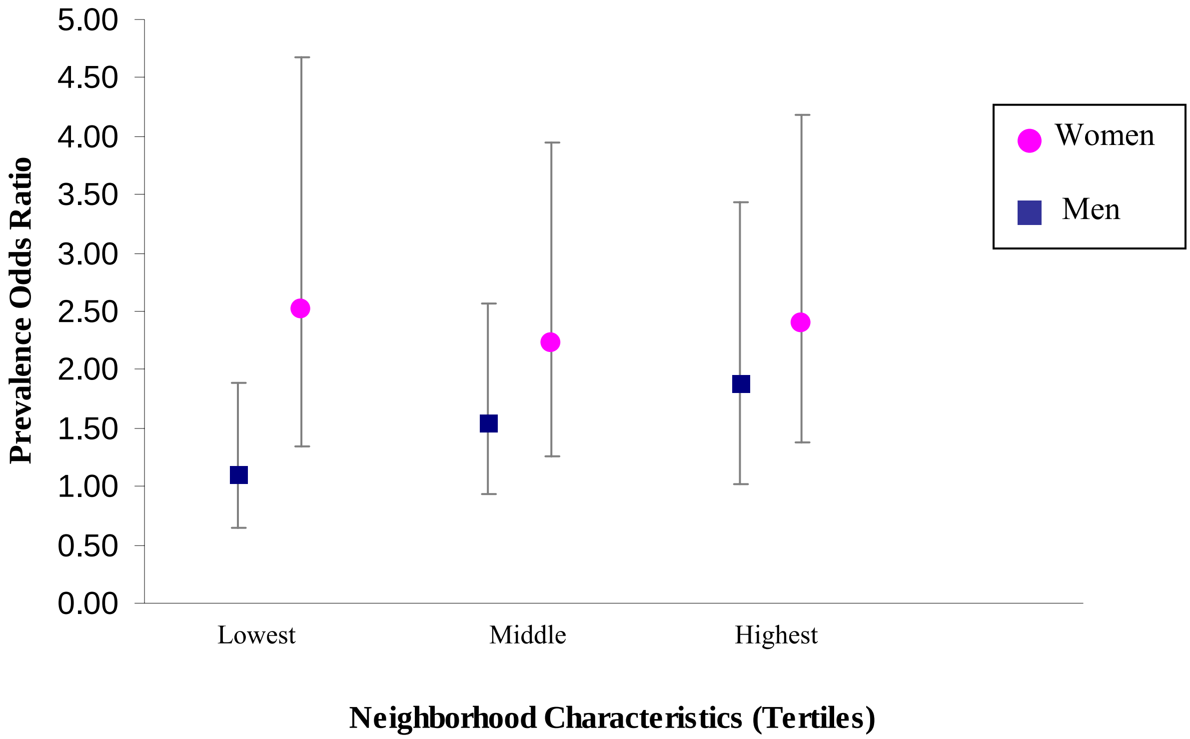
Table 4.9. Age-adjusted incidence estimates[a] for type 2 diabetes by individual income[b] and neighborhood characteristics[c]. Atherosclerosis Risk in Communities study, 1987-1989: White men and women

			Men			
Income Level	**Neighborhood Level**	**Estimate**	**Std error**	**T value**	**Pr > |t|**	**Interaction Pr > |t|**
Lowest	Lowest	-0.1138	0.3658	-0.3112	0.7559	0.4737
Lowest	Middle	-0.1436	0.3606	-0.3982	0.6908	
Middle	Lowest	-0.1010	0.2978	-0.3391	0.7348	
Middle	Middle	0.2719	0.2472	1.0998	0.2725	

			Women			
Income Level	**Neighborhood Level**	**Estimate**	**Std error**	**T value**	**Pr > |t|**	**Interaction Pr > |t|**
Lowest	Lowest	-0.5655	0.3615	-1.5640	0.1191	0.1522
Lowest	Middle	-0.5585	0.3677	-1.5189	0.1301	
Middle	Lowest	0.1291	0.3853	0.3352	0.7377	
Middle	Middle	-0.1940	0.3674	-0.5281	0.5979	

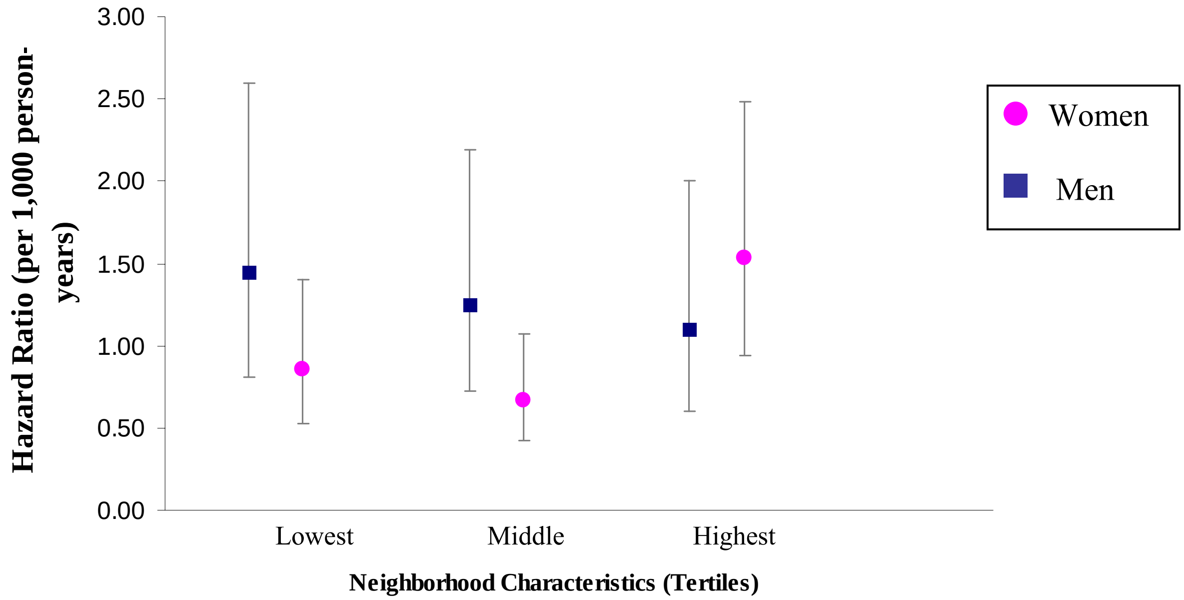
[a] Estimates are assessed at the interaction of the indicated levels relative to the highest level of both SES indicators.
[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000.
MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.
[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23), (-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

Figure 4.1. Age-adjusted prevalence odds ratios[a] of type 2 diabetes by individual income[b] and neighborhood characteristics[c] in whites. Atherosclerosis Risk in Communities study, 1987-1989



[a] Odds ratios assess the prevalence of type 2 diabetes in the lowest individual income category relative to the highest income category.
[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000.
MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.
[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23), (-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

Figure 4.2. Age-adjusted hazard ratios[a] of type 2 diabetes by individual income[b] and neighborhood characteristics[c] in whites. Atherosclerosis Risk in Communities study, 1989-1998



[a] Hazard ratios assess the prevalence of type 2 diabetes in the lowest individual income category relative to the highest income category.
[b] Income categories: NC & MD: lowest: <$24,000; middle: $24,000-49,999; highest: ≥ $50,000.
MN: lowest: <$35,000, middle: $35,000-49,999; highest: ≥ $50,000.
[c] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized using center-specific tertiles. The intervals from lowest to highest were (-11.91, -2.55), (-2.54, 1.04), and (1.05, 13.44) for NC; (-14.23, -3.23), (-3.22, 2.46), and (2.47, 16.57) for MN; and (-14.85, -1.17), (-1.16, 2.06), and (2.07, 21.65) for MD.

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5.0 Relationship of Neighborhood and Individual Socioeconomic Characteristics to Type 2 Diabetes, Hyperinsulinemia, and Impaired Fasting Glucose in African Americans. The Atherosclerosis Risk in Communities Study, 1987-1998

5.1 Introduction

There is well documented evidence of an excess prevalence of type 2 diabetes among African Americans compared to their white counterparts[1-4] with Type 2 diabetes more than 50% more common among African Americans[5]. In the United States the prevalence of type 2 diabetes is higher for all racial/ethnic minority groups than for non-Hispanic whites[6, 7]. Though the prevalence of type 2 diabetes is increasing in all population groups, there is a greater rate of increase in minority groups[8]. The explanation for this differential is unclear.

The prevalence of diabetes varies with socioeconomic status, and in the United States socioeconomic status is strongly associated with race. There is documented evidence of the association between socioeconomic status and type 2 diabetes[9-13]. While the association of socioeconomic status with diabetes is not clearly understood, the greatest excess prevalence of type 2 diabetes among African Americans has been found in individuals with lower socioeconomic status[14]. There is a growing literature linking poor neighborhood socioeconomic conditions with elevated rates of cardiovascular disease[15-18]. Studies of the association between socioeconomic status and diabetes at the aggregate level have been conducted primarily in other countries and findings have been inconsistent[19-23]. In this study we investigated the independent and interactive effects of individual socioeconomic factors and neighborhood socioeconomic characteristics (SEC) on diabetes and pre-diabetic conditions in a sample of middle-aged African Americans.

5.2 Materials and Methods

Study Population

This report is based on the African American participants in the Atherosclerosis Risk in Communities (ARIC) study. ARIC is a prospective investigation of atherosclerosis in four U.S. communities (Forsyth County, North Carolina; Jackson, Mississippi; Washington County, Maryland; and the northwestern suburbs of Minneapolis, Minnesota). The ARIC cohort is composed of 15,792 black and white men and women aged 45 to 64 years at baseline, studied from1987-1989, selected from a probability sampling of the four communities. Three samples represent the geographic distribution of residents of these communities with participants from Washington County and the suburbs of Minneapolis virtually all white. Eighty-five percent of the participants from Forsyth County were white. African Americans only were sampled in Jackson, MS, and this sample specifically was used for this study. A detailed description of the study design, methods, and response rates is available elsewhere[24].

A total of 3,683 African Americans in Jackson, MS completed the baseline interview. All except two were linked to their neighborhood of residence by their home address. Approximately five percent (n=193) were excluded due to missing tract level information. Diabetes status was unknown for three percent (n=104) of participants who were necessarily excluded. An additional ten percent of persons were excluded on the basis of missing individual level socioeconomic data for education (n=8), income (n=349), and occupation (n=22). Due to differences in socioeconomic status, particularly regarding occupation and income, as well as the inability to determine whether diabetes influenced occupational status or vice versa, 426 retired participants were also excluded from analyses. Though homemakers did not report having jobs outside the home, they were not significantly different from other participants with regard to other individual socioeconomic factors. Thus, homemakers were retained in the dataset and categorized as a separate occupation group. As only ten men self-identified as homemakers, these individuals were also excluded from analyses. The final sample size for cross-sectional analyses was 2,569 (875 men, 1,694 women). For the pre-diabetic conditions hyperinsulinemia and impaired fasting glucose (IFG), the 737 men and 1,347 women without diabetes at the baseline examination were included in analyses. Analyses for incident diabetes also included these 2,084 individuals.

Definition of Variables

Information on demographic characteristics such as age, race, gender, household income, education, and most recent occupation were obtained during the baseline interview of the ARIC study conducted between 1987 and 1989. Total family income in U.S. dollars was selected from the following eight listed categories: (<$5,000; $5,000-$7,999; $8,000-$11,999; $12,000-$15,999; $16,000-$23,999; $24,000-$34,999; $35,000-$49,999; and ≥ $50,000). Approximate tertiles of income were constructed based on the distribution within the population. The categories were as follows: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000. Educational level was categorized into three levels based on the highest grade level completed (less than high school, high school completed, greater than high school). Occupation was coded according to the 1980 Census Alphabetical Index of

Occupations[25] and categorized as follows: I) executive, managerial, and professional specialty occupations; (II) technical, sales, and administrative support; (III) service occupations; (IV) farming, forestry, and fishing occupations; (V) precision production, craft, and repair occupations; and (VI) operators, fabricators, and laborers (VII) homemakers. In our analyses occupation was evaluated as three categories: homemakers (category VII), manual occupations (categories III-VI), and nonmanual occupations (categories I-II). Nonmanual occupations served as the reference category.

Participants were linked to a neighborhood of residence by their home address reported at baseline by means of geocoding[26]. Census tracts were used as proxies for neighborhoods[27-29]. Tracts are subdivisions of counties with an average population of 4,000 persons. Indicators of neighborhood socioeconomic conditions were obtained from the 1990 U.S. Census. Six indicators were chosen to represent the following dimensions: education (percentage of adults aged 25 or older who had completed high school and the percentage of adults aged 25 or older who had completed college), occupation (percentage of persons aged 16 or older employed in executive, managerial, or specialty occupations), and wealth/income (median value of housing unit; percentage of houses receiving interest, dividend, or net rental income; and median household income). These indicators were selected and used to develop a neighborhood summary score based on factor analyses reported elsewhere[18, 30]. Neighborhood factors were summarized into a composite neighborhood score, which was used as the main indicator of the neighborhood socioeconomic environment. A z score for each census tract was estimated for each variable by subtracting the overall mean (across all tracts in the sample) and dividing by the standard deviation. This measure reflects the deviation of the value of each variable from the mean. The z-scores for each of the six variables were summed to form the neighborhood summary score. Neighborhood scores for census tracts in this sample ranged from -8.91 to 22.31. An increasing score signifies an increase in neighborhood socioeconomic advantage. Three categories of z-scores were formed based on tertiles of the distribution by geographic region. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31). The scores in the lowest third correspond to the most disadvantaged neighborhoods while scores in the highest third correspond to the most advantaged neighborhoods.

At baseline participants underwent clinical examinations with all measurements collected according to a standardized protocol[31]. Participants were asked to fast over night (>8 hours) prior to the clinical examination. They were also asked to refrain from smoking and consuming alcohol or caffeine on the day of the examination. At all study sites blood was drawn from seated patients and sent to a central laboratory for assays. Prevalent type 2 diabetes was defined according to current American Diabetes Association criteria[32]. Patients who met any of the following criteria were considered to have diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/L), nonfasting glucose ≥ 200 mg/dl (11.1mmol/L), self-reported physician diagnosis, or self-reported use of medications for diabetes. Participants with a baseline fasting glucose level between 110-126 mg/dl (6.1 – 7.0mmol/L) were considered to have impaired fasting glucose. Hyperinsulinemia was defined at baseline as the upper 20th percentile of fasting glucose. Participants with incident diabetes were free of diabetes at baseline and later classified as diabetic during follow-up.

For incident diabetes classified on the basis of a glucose value, the incident date was estimated by linear interpolation using glucose values from the ascertaining visit and the previous visit. The time to reach 7.0mmol/l for subjects who had been told by a physician they had diabetes or who were on diabetic medication was estimated using information from all diabetic subjects who had been unaware of their status[33].

Statistical Analyses

All analyses were performed separately by gender due to large differences between genders in the distribution of socioeconomic characteristics. All models were adjusted for age at baseline as a continuous variable. Due to the nesting of individuals within neighborhoods, mixed effects models with a random intercept for each neighborhood were fit using a SAS Macro (GLIMMIX, SAS Institute Inc., Cary, North Carolina) in the cross-sectional analyses in order to account for potential within-neighborhood correlations in outcomes[34]. Type 2 diabetes, hyperinsulinemia, and impaired fasting glucose were identified as binary dependent variables.

For prospective analyses Poisson regression was used to estimate age-adjusted incidence rates per 1,000 person-years. Cox proportional hazards regression was used to estimate hazard ratios (HR) and 95% confidence intervals (CI) relating diabetes incidence at the two lowest levels of the individual or neighborhood socioeconomic factors to the highest level, after controlling for age. To examine the combined effects of individual and neighborhood characteristics gender-specific rates for nine cross-classified categories of neighborhood and individual socioeconomic status were estimated. The COVSANDWICH option in SAS PROC PHREG was used to account for within-neighborhood correlation of outcomes in longitudinal analyses[35].

5.3 Results

5.3.1 Cross-sectional analyses

Individual-level Attributes

Characteristics of the 875 men and 1,694 women are shown in Table 5.1. The majority of men were classified in the highest income level (41.6 %) while the majority of women (45.8 %) were classified in the lowest level of household income. Men and women were similar with regards to education with only five percent more men than women having completed college. Forty-one percent of men and women reported having less than a high school education. With only 33% of men and women having nonmanual occupations, the remaining men held manual occupations and nearly twenty percent of women were homemakers.

An inverse association between the age-adjusted prevalence of type 2 diabetes and individual indicators of socioeconomic status was observed for all African Americans (Table 5.2). Overlapping confidence intervals indicated that there was no statistically significant difference with increasing levels of income and education. However, there was a statistically significant difference in type 2 diabetes prevalence between the highest and lowest levels of all indicators. Proportions ranged from 13 to 22 percent for income and education and from 13 to 31 percent for occupation. Gender-specific analyses indicated an inverse association between the age-adjusted prevalence of type 2 diabetes and individual level indicators of socioeconomic status. There was no statistically significant difference in the prevalence of type 2 diabetes between levels of individual indicators among men. The prevalence in the lowest socioeconomic group was more than double the prevalence in the highest category among women, ranging from 12 to 25, 13 to 25, and 13 to 30 from the highest to the lowest levels of income, education, and occupation, respectively. However, these associations were often not significant.

There was no consistent pattern of association between individual level factors and the prevalence of hyperinsulinemia (Table 5.3) or impaired fasting glucose (Tables 5.4). While the prevalence in the lowest level of each indicator was generally higher than the prevalence in the highest level for all participants, this difference was only significant for occupation. Women tended to have an inverse association between most individual level socioeconomic factors and hyperinsulinemia. For education and occupation the prevalence in the lowest categories was nearly 30% while it was closer to 20% in the highest categories. Among men the prevalence of hyperinsulinemia increased with increasing levels of income and occupation. In men the prevalence of impaired fasting glucose was inversely associated with individual education and occupation increasing from 16 percent in the highest categories to 18 percent in the lowest. Women tended to have an inverse association between income and education and impaired fasting glucose.

Table 5.5 presents the age-adjusted prevalence odds ratios of type 2 diabetes for lower levels of socioeconomic characteristics compared to the highest level. For men prevalence odds ratios indicated modest increases in the prevalence of type 2 diabetes for the lowest levels of individual income (OR=1.23, 95% CI=0.77, 1.95), occupation (OR=1.12, 95% CI=0.75, 1.67), and education (OR=1.28, 95% CI=0.82, 1.99) relative to the highest levels. However, none of these associations met nominal levels of statistical significance. There was no association in the middle level of income (OR=1.00, 95% CI=0.64, 1.55). For women there were significant increases in the prevalence odds of type 2 diabetes in the lower and middle groups of individual socioeconomic indicators compared to the highest level. For income and education the prevalence odds of type 2 diabetes in the lowest categories were double those in the highest categories (OR=2.32, 95% CI=1.59, 3.38 and (OR=1.99, 95% CI=0.1.42, 2.77, respectively). The odds for homemakers was nearly three times the odds for nonmanual workers (OR=2.94, 95% CI=2.06, 4.21). For the middle levels of income, occupation, and education there were 80, 65, and 40 percent increases respectively over the higher levels. This association was not statistically significant for education. After adjustment for neighborhood there were slight attenuations in these associations for men and women.

Neighborhood-level Attributes

The men in this study represented 43 census tracts and the women resided in 51 tracts. Of note, the women lived in neighborhoods that were considerably poorer (Table 5.1). The highest prevalence of diabetes cases occurred in neighborhoods with the lowest socioeconomic summary score, 18.6 and 22.55 percent for men and women, respectively (Table 5.2). However, there was no clear pattern of association between type 2 diabetes prevalence and level of neighborhood disadvantage for men. For women there was an inverse association between neighborhood socioeconomic characteristics and type 2 diabetes prevalence (Table 5.2). The prevalence in the lowest neighborhood tertile was 23% while the prevalence in the highest tertile was only 15%.

Neighborhood prevalence odds ratios are indicated in Table 5.6. Men in the most disadvantaged neighborhoods were nearly 44% more likely to have diabetes than those in the more advantaged neighborhoods (OR=1.44, 95% CI=0.97, 2.17). There was a 24% increase for women (OR=1.24, 95% CI=0.85, 1.79). Adjustment by either individual level factor attenuated the association to about 15% in women.

There was not a clear pattern of association between the level of neighborhood disadvantage and the prevalence of hyperinsulinemia (Table 5.3) and impaired fasting glucose (Table 5.4). For men the prevalence of hyperinsulinemia tended to increased with increasing neighborhood advantage. The prevalence was 10 percent in the lowest tertile and 17 percent in the highest. There was no discernible pattern of association for impaired fasting glucose. Among women the prevalence of impaired fasting glucose varied directly with neighborhood disadvantage and, ranging from 11 to 14 percent.

Individual and Neighborhood Associations

Among black men and women there were no consistent linear patterns across neighborhoods in the prevalence odds ratios for those with lower income relative to those with higher income. There was a 27% reduction in the odds of diabetes for low income men relative to high income men in most disadvantaged neighborhoods. In more advantaged neighborhoods the prevalence odds of diabetes in women with low income were nearly four times the prevalence odds of women with high income (Figure 5.1). Additional analyses to quantify the interaction effect indicated no consistent pattern of association between lower individual and neighborhood-level groups relative to the highest individual and neighborhood group (Table 5.7)

5.3.2 Longitudinal analyses

Individual-level Attributes

A total of 548 incident cases of type 2 diabetes occurred during the follow-up period among the 2,084 participants. Age-adjusted incidence rates were 47.3 per 1,000 person-years among black men and 48.3 per 1,000 person-years among black women. For women the incidence of type 2 diabetes decreased with increasing income and occupational level (Table 5.8). Associations for black men followed no consistent pattern. Adjustments for neighborhood characteristics tended to increase the strength of associations between individual level factors and type 2 diabetes incidence (Table 5.9). Among men the likelihood of developing diabetes was stronger for those in the middle income category (HR=1.19, 95% CI = [0.80, 1.77]) than for those in the lowest category (HR=1.16, 95% CI = [0.72, 1.88]). Women having the lowest income compared to the highest income were characterized by a 34% higher risk of developing diabetes. The risk of developing diabetes was 13% higher for women with a high school education compared to those with more than high school. Among African American men the risk of developing type 2 diabetes tended to be less for those that did not have more than a high school education. However, these associations were not statistically significant.

Among African American males the baseline body mass index (BMI) ranged from 27 to 28.4 kg/m2. Though differences were relatively small, men in the highest categories of socioeconomic characteristics had the highest BMI and generally had the greatest change in BMI over time (0.09 kg/m2). The amount of change over time was inversely related to income levels among African American women. The differences in the changes over time by levels of socioeconomic characteristics were statistically significant. Among African

American females those in the lowest categories of socioeconomic characteristics had the highest baseline BMI. The greatest changes in BMI over time were in the highest categories of the socioeconomic characteristics. The changes in BMI over time by levels of socioeconomic characteristics were statistically significant for all individual-level socioeconomic characteristics (Table 5.10).

Neighborhood-level Attributes

For men there was no obvious linear pattern of association between neighborhood socioeconomic status and the incidence of diabetes (Table 5.8). The highest rate (50.6 per 1,000 person-years) was found in the middle tertile of neighborhood socioeconomic characteristics. For women the incidence of diabetes was inversely associated with neighborhood disadvantage. Rates increased from 43.2 in the lowest tertile to 51.4 in the highest SEC tertile. Hazard ratios indicated a protective effect for those living in the most disadvantaged neighborhoods compared to those in the more advantaged neighborhoods (data not shown). The hazard ratios were 0.85, 95% CI=0.65, 1.10 for black men and women combined.

Individual and Neighborhood Associations

The hazard ratio of diabetes in African American men and women with low income relative to men and women with high income did not differ across neighborhoods. For men and women in the most disadvantaged neighborhoods there was a reduction in the risk of diabetes for those with low income relative to those with high income. However, differences were not statistically significant (Figure 5.2). Hazard ratios indicated no consistent pattern of association between lower individual and neighborhood-level groups relative to the highest individual and neighborhood group (Table 5.11)

5.4 Discussion

Our study implicates individual and neighborhood socioeconomic factors as related to the distribution of type 2 diabetes prevalence. In our cross-sectional analysis of a cohort of African Americans we found that type 2 diabetes prevalence was associated with individual socioeconomic factors for both men and women. There was a decrease in prevalence with increasing levels of income, education, and occupation. However, there was not a clear pattern across genders of consistent linear trends in associations between neighborhood-level characteristics and diabetes prevalence. The highest prevalence of diabetes invariably occurred, however, in the most disadvantaged neighborhoods. Among women there was an inverse association between neighborhood socioeconomic characteristics and the prevalence of type 2 diabetes. In contrast, prevalence among men did not decrease monotonically with increasing neighborhood advantage. Stronger neighborhood effects were found in women. In men neighborhood effects were generally small and not statistically significant. Stronger effects of neighborhood level variables in women than in men have also been observed for CHD prevalence[15]. The reasons for these gender differences require further investigation. In our study, the effects of individual level income on the distribution of type 2 diabetes did not vary consistently across neighborhoods.

Contrary to our expectations the incidence of diabetes did not vary inversely with neighborhood disadvantage. Among women, diabetes incidence varied directly with neighborhood advantage, while no discernible pattern was observed among men. In both groups the incidence of type 2 diabetes was lowest in the poorest neighborhoods. This conclusion is similar to findings of lower CHD rates in the poorest sectors of nonindustrialized countries where those in poorer areas had not yet experienced the results of high-fat diets and the stress of industrialization[36, 37]. A lower incidence of diabetes in poorer neighborhoods may also reflect "survival of the fittest" or survivor bias. Due to the high mortality of African Americans living in poor neighborhoods, our sample may only include a relatively healthy sample.

In the past few years several studies have suggested a relationship between characteristics of the neighborhood environment and health outcomes. These associations have been disseminated as ostensibly independent of the influence of individual level factors[38-40]. Neighborhood characteristics may be associated with the prevalence and development of type 2 diabetes through characteristics of the neighborhood such as lack of access to services, proper nutrition, and recreational facilities. Neighborhood differences in the availability and price of food have been documented [41-42]. However, the specific mechanisms through which neighborhood characteristics are associated with diabetes require further exploration. Several studies conducted abroad have investigated the association of neighborhood socioeconomic characteristics on diabetes prevalence[19-21, 23, 43] and incidence[44-45]. Studies in the United States have investigated the impact of neighborhood on health behaviors and complications in people with diabetes. However, to our knowledge the present report is among the first to investigate the effects of neighborhood socioeconomic characteristic on the distribution and development of diabetes and related outcomes in African Americans.

To our knowledge the present report is also one of the first studies to investigate the effects of neighborhood characteristics on the prevalence of hyperinsulinemia and impaired fasting glucose while accounting for individual factors. Strong risk factors for glucose intolerance as well as type 2 diabetes, such as obesity and physical inactivity, have been associated with neighborhood deprivation [15, 46-48]. Few studies have investigated the role of neighborhood environments, however, on the distribution of metabolic abnormalities such as insulin resistance and impaired fasting glucose. Neighborhood characteristics may influence the development of these conditions through psychosocial pathways or their influence on health-related behaviors linked to physical activity and diet[49-50]. Sources of chronic stress such as poverty, violence, and noise, which tend to vary across neighborhoods, also may be related to the development of these conditions. In our study we found inverse associations between individual income and education and neighborhood socioeconomic characteristics and impaired fasting glucose for women. For men we observed inverse associations with education and occupation for IFG. Among women we found inverse associations between individual education and occupation and hyperinsulinemia. Results for women were similar to those of other reporting inverse associations between the prevalence of glucose intolerance and grade of employment and level of education[46, 51]. For African American men in our study the prevalence of hyperinsulinemia tended to vary directly with levels of individual income and occupation and levels of neighborhood socioeconomic status. These differences may be due in part to the smaller sample size for men. Though other studies have also reported inconsistencies in findings between genders in this population, gender differences in the present study should be interpreted with caution.

While the distribution of type 2 diabetes tended to vary inversely with socioeconomic characteristics among women, patterns were less consistent among men. Other studies have noted inconsistent patterns in the associations of socioeconomic factors and health outcomes among blacks[15, 30, 52]. In a study of neighborhood characteristics on CHD outcomes and risk factors Diez-Roux and colleagues found the highest age-adjusted prevalence of serum cholesterol in the intermediate category of neighborhood characteristics among Jackson participants[15]. Like our study, that study also observed more consistent patterns for Jackson women than for Jackson men.

Additional analyses were conducted to examine differences by SES in the process by which participants were identified as diabetics. There was little difference in the degree to which ARIC participants were classified as diabetics based on a diagnosis by a health practitioner prior to entry into the study compared to those not previously diagnosed and classified as diabetics because of elevated glucose levels during the ARIC examination. This suggests little difference in access to health care by SES for this population. An exception was noted for African American women, in whom those with less than high school education more often reported being diabetic based on a prior diagnosis external to the ARIC study. Conceivably, the notoriously higher prevalence of type 2 diabetes in African American women may have resulted in greater awareness among healthcare practitioners and a higher frequency of screening for elevated blood glucose.

Examination of cohort members who did not attend subsequent ARIC examination visits relative to those who participated in all visits indicated a considerable and statistically significant difference by socioeconomic characteristics. Men who attended all ARIC examination visits were in higher SES groups than those who were unable or unwilling to attend re-examination visits. Among women, those in higher SES groups more often refused or were unable to attend all re-examinations . This gender difference may have influenced our findings to a modest degree, although if present, the effect would have been detectable only in men.

A potential limitation of this study is the use of census tracts as proxies for neighborhoods. As an administratively defined unit it may offer a less than perfect operational definition of neighborhood. It may be more appropriate to investigate neighborhood effects utilizing a more detailed sociological construct that considers social networks and interactions. However, other studies have suggested that census tracts are reasonable indicators of the socioeconomic environment[29]. Furthermore, our study utilized more precise geographic areas than utilized in previous studies.

Analyses in this study were limited by the relatively small sample size, particularly in men. Jackson, MS is arguably well representative of poor, southern, urban communities. Nevertheless, since results were based on African Americans living in a single locale in the South, our findings may not be generalizable to similar groups and areas. Due to the small sample size and homogeneity of this population further research of larger, more heterogeneous populations in other regional contexts is recommended.

A significant strength of this study was the use of hierarchical modeling techniques. These methods allowed us to assess the interplay between individual and neighborhood-level factors. The observed associations remained generally consistent after adjusting for the other level. Significant individual- and neighborhood-level associations were observed for prevalent diabetes among women. These associations remained significant after adjustment for neighborhood variables. Additionally, the longitudinal component of this study enabled conclusions to be drawn regarding causal relations between socioeconomic characteristics and the development of type 2 diabetes. Neighborhood characteristics did not consistently influence the development of diabetes in the expected direction.

Additional strengths of this study include the availability of confirmed prevalent disease and the methods utilized for classification of disease. Whereas some previous studies solely relied on self-reported diagnosis of diabetes, we conducted standardized comprehensive clinical examinations. To improve the precision of estimating time-to-event data, we interpolated the onset time for incident cases rather than utilizing interval censoring. For individuals for whom incident diabetes was classified based on glucose measurements, we used linear interpolation to determine the approximate time to development of type 2 diabetes. For those with classifications based on physician diagnosis or medication use, the midpoint between the last visit free of diabetes and the first visit at which diabetes was classified was used for determinations.

Our findings are not conclusive regarding the effects of neighborhood characteristics on the distribution of diabetes. Associations between neighborhood characteristics and prevalent diabetes were moderate and not generally statistically significant. However, associations remained after adjustment for all individual level factors, even after adjustment for all individual level factors simultaneously to minimize residual confounding. To better understand whether neighborhood factors are related to diabetes, further studies examining specific neighborhood processes in a larger more heterogeneous population are recommended.

Table 5.1. Neighborhood and individual socioeconomic characteristics at baseline by gender. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

Characteristics	Men	Women	All
No. (%)	875 (34.06)	1694 (65.94)	2569
Age, yrs, mean (SD)	52.6 (5.35)	52.6 (5.40)	52.6 (5.38)
Individual Income [a]			
Lowest Level	217 (24.80)	776 (45.81)	993 (38.65)
Middle Level	294 (33.60)	511 (30.17)	805 (31.34)
Highest Level	364 (41.60)	407 (24.03)	771 (30.01)
Individual Education			
< High School	355 (40.57)	702 (41.44)	1057 (41.14)
High School	224 (25.60)	499 (29.46)	723 (28.14)
> High School	296 (33.83)	493 (29.10)	789 (30.71)
Individual Occupation			
Homemakers [b]	---	297 (17.53)	297 (11.56)
Manual	583 (66.63)	828 (48.88)	1411 (54.92)
Nonmanual	292 (33.37)	569 (33.59)	861 (33.51)
No. of neighborhoods (census tracts)	43	51	54
Neighborhood Score, mean (SD)	0.55 (5.86)	-0.29 (5.3)	0.00019 (5.51)

[a] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000
[b] 10 male homemakers were excluded due to insufficient numbers.
[c] A summary value for each census tract was created from the sum of z scores for six indicators of income/wealth, education, and occupation.

Table 5.2. Age-adjusted prevalence (95% CI) of type 2 diabetes[a] by individual and neighborhood socioeconomic characteristics. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

	Men	Women	All
No. cases (%)	138 (15.77)	347 (20.48)	485 (18.88)
Individual Income [b]			
Lowest Level	16.23 (11.63, 22.20)	24.58 (21.49, 27.96)	22.73 (20.07, 25.64)
Middle Level	15.24 (11.53, 19.87)	19.18 (15.96, 22.88)	17.59 (15.09, 20.39)
Highest Level	14.68 (11.32, 18.82)	11.51 (8.56, 15.31)	13.05 (10.76, 15.75)
Individual Education			
< High School	17.53 (13.71, 22.15)	24.78 (21.48, 28.40)	22.35 (19.76, 25.18)
High School	14.65 (10.54, 20.00)	18.26 (15.04, 21.98)	17.22 (14.60, 20.21)
> High School	14.07 (10.49, 18.63)	13.15 (10.34, 16.58)	13.48 (11.21, 16.14)
Individual Occupation			
Homemakers [c]		30.98 (25.57, 36.97)	30.98 (25.57, 36.97)
Manual	16.03 (13.23, 19.29)	20.40 (17.74, 23.35)	18.59 (16.61, 20.75)
Nonmanual	14.51 (10.88, 19.08)	12.63 (10.07, 15.73)	13.32 (11.17, 15.81)
Neighborhood SEC [d]			
Lowest Tertile	18.61 (14.22, 23.99)	22.55 (19.15, 26.35)	21.30 (18.54, 24.35)
Middle Tertile	13.11 (9.68, 17.53)	21.36 (18.06, 25.07)	18.62 (16.09, 21.44)
Highest Tertile	15.38 (11.73, 19.92)	14.75 (11.92, 18.12)	15.03 (12.73, 17.66)

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes.

[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000

[c] 10 male homemakers were excluded due to insufficient numbers.

[d] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Table 5.3. Age-adjusted prevalence (95% CI) of hyperinsulinemia[a] by individual and neighborhood socioeconomic characteristics. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

	Men	Women	All
No. cases (%)	102 (13.84)	315 (23.39)	417 (20.01)
Individual Income [b]			
Lowest Level	8.97 (5.50, 14.28)	27.26 (23.62, 31.24)	23.10 (20.31, 26.35)
Middle Level	11.29 (7.84, 15.99)	20.05 (16.45, 24.20)	16.93 (14.26, 19.98)
Highest Level	18.64 (14.61, 23.46)	20.65 (16.45, 25.59)	19.75 (16.78, 23.09)
Individual Education			
< High School	12.14 (8.75, 16.61)	26.40 (22.58, 30.62)	21.35 (18.53, 24.48)
High School	10.63 (6.95, 15.93)	22.72 (18.90, 27.07)	18.87 (15.92, 22.23)
> High School	19.10 (14.65, 24.51)	19.76 (16.11, 24.01)	19.58 (16.69, 22.85)
Individual Occupation			
Homemakers [c]		30.27 (24.00, 37.39)	30.37 (24.11, 37.44)
Manual	12.14 (9.52, 15.36)	22.10 (19.07, 25.47)	17.88 (15.76, 20.22)
Nonmanual	17.33 (13.10, 22.58)	21.63 (18.14, 25.58)	20.22 (17.44, 23.31)
Neighborhood SEC [d]			
Lowest Tertile	9.95 (6.56, 14.83)	23.85 (19.99, 28.19)	19.48 (16.56, 22.77)
Middle Tertile	14.78 (10.89, 19.74)	24.40 (20.59, 28.67)	20.88 (18.00, 24.09)
Highest Tertile	17.06 (12.92, 22.19)	22.49 (18.83, 26.63)	20.52 (17.68, 23.68)

[a] Hyperinsulinemia: the upper 20th percentile of the distribution of fasting glucose at baseline.
[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000
[c] 10 male homemakers were excluded due to insufficient numbers.
[d] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Table 5.4. Age-adjusted prevalence (95% CI) of impaired fasting glucose[a] by individual and neighborhood socioeconomic characteristics. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

	Men	**Women**	**All**
No. cases (%)	127 (17.23)	175 (12.99)	302 (14.49)
Individual Income [b]			
Lowest Level	16.56 (11.76, 22.83)	16.50 (13.54, 19.96)	16.71 (14.13, 19.66)
Middle Level	19.83 (15.29, 25.31)	10.85 (8.19, 14.25)	14.20 (11.74, 17.08)
Highest Level	16.27 (12.51, 20.89)	9.64 (6.85, 13.42)	12.83 (10.43, 15.67)
Individual Education			
< High School	18.36 (14.14, 23.50)	14.23 (11.31, 17.76)	15.72 (13.24, 18.57)
High School	17.25 (12.45, 23.41)	13.24 (10.25, 16.93)	14.68 (12.05, 17.77)
> High School	16.37 (12.25, 21.54)	10.65 (7.97, 14.08)	12.84 (10.48, 15.65)
Individual Occupation			
Homemakers [c]		13.52 (9.20, 19.42)	13.58 (09.27, 19.45)
Manual	17.88 (14.72, 21.55)	12.18 (9.85, 14.98)	14.67 (12.72, 16.86)
Nonmanual	16.21 (12.11, 21.35)	13.19 (10.45, 16.52)	14.24 (11.89, 16.97)
Neighborhood SEC [d]			
Lowest Tertile	15.54 (11.15, 21.25)	14.06 (10.99, 17.81)	14.54 (11.95, 17.59)
Middle Tertile	18.81 (14.43, 24.15)	13.05 (10.16, 16.61)	15.25 (12.74, 18.15)
Highest Tertile	17.22 (13.06, 22.37)	11.10 (8.47, 14.41)	13.37 (11.03, 16.11)

[a] Impaired fasting glucose: baseline fasting glucose level between 110-126 mg/dl.

[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000

[c] 10 male homemakers were excluded due to insufficient numbers.

[d] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Table 5.5. Age-adjusted prevalence odds ratios of Type 2 diabetes[a] by individual-level socioeconomic characteristics and gender. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

	Men (N=875)		**Women (N=1,694)**		**All (N=2,569)**	
	Age-adjusted	**Adjusted for Neighborhood**	**Age-adjusted**	**Adjusted for Neighborhood**	**Age-adjusted**	**Adjusted for Neighborhood**
Income [b]						
Lowest Level	1.23 (0.77, 1.95)	1.14 (0.70, 1.84)	2.32 (1.59, 3.38)	2.24 (1.54, 3.27)	1.87 (1.42, 2.46)	1.79 (1.36, 2.37)
Middle Level	1.00 (0.64, 1.55)	0.96 (0.61, 1.50)	1.82 (1.22, 2.70)	1.78 (1.20, 2.65)	1.38 (1.03, 1.84)	1.34 (1.00, 1.79)
Highest Level	1.0	1.0	1.0	1.0	1.0	1.0
Education						
< High School	1.28 (0.82, 1.99)	1.21 (0.77, 1.91)	1.99 (1.42, 2.77)	1.92 (1.38, 2.69)	1.71 (1.31, 2.23)	1.65 (1.26, 2.16)
High School	1.04 (0.63, 1.71)	0.99 (0.60, 1.65)	1.39 (0.97, 1.99)	1.35 (0.94, 1.94)	1.27 (0.95, 1.70)	1.24 (0.92, 1.66)
> High School	1.0	1.0	1.0	1.0		1.0
Occupation						
Homemaker [c]	----	----	2.94 (2.06, 4.21)	2.88 (2.01, 4.13)	2.88 (2.09, 3.97)	2.80 (2.03, 3.87)
Manual	1.12 (0.75, 1.67)	1.07 (0.72, 1.61)	1.65 (1.21, 2.25)	1.61 (1.18, 2.20)	1.40 (1.10, 1.80)	1.37 (1.07, 1.75)
Nonmanual	1.0	1.0	1.0	1.0	1.0	1.0

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes

[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000

[c] 10 male homemakers were excluded due to small numbers.

Table 5.6. Prevalence odds ratios of type 2 diabetes by neighborhood socioeconomic status and gender. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

Prevalence odds ratios [a]	**Men (N=875)**	**Women (N=1,694)**	**All (N=2,569)**
Age-adjusted	1.44 (0.97, 2.17)	1.24 (0.85, 1.79)	1.32 (0.98, 1.78)
Adjusted for income	1.42 (0.93, 2.16)	1.14 (0.82, 1.61)	1.21 (0.91, 1.60)
Adjusted for occupation	1.44 (0.95, 2.16)	1.16 (0.81, 1.65)	1.25 (0.93, 1.67)
Adjusted for education	1.41 (0.93, 2.14)	1.15 (0.81, 1.63)	1.24 (0.93, 1.65)
Adjusted for all individual factors	1.40 (0.92, 2.13)	1.11 (0.79, 1.57)	1.19 (0.90, 1.58)

[a] Odds ratios compare lowest neighborhood tertile to middle and highest tertiles combined as the reference category.

Table 5.7. Age-adjusted prevalence odds ratios[a] of type 2 diabetes by individual income[b] and neighborhood characteristics[c]. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

Men						
Income Level	**Neighborhood Level**	**Estimate**	**Std error**	**T value**	**Pr > |t|**	**Interaction Pr > |t|**
Lowest	Lowest	-0.8598	0.5903	-1.46	0.1456	0.4066
Lowest	Middle	-0.0733	0.6302	-0.12	0.9074	
Middle	Lowest	0.1712	0.5604	0.31	0.7601	
Middle	Middle	0.5690	0.5824	0.98	0.3288	

Women						
Income Level	**Neighborhood Level**	**Estimate**	**Std error**	**T value**	**Pr > |t|**	**Interaction Pr > |t|**
Lowest	Lowest	-0.6221	0.4900	-1.27	0.2044	0.3414
Lowest	Middle	-0.6018	0.4564	-1.32	0.1875	
Middle	Lowest	0.0438	0.5298	0.08	0.9341	
Middle	Middle	-0.2170	0.4924	-0.44	0.6596	

[a] Odds ratios assess the prevalence of type 2 diabetes in the lowest individual income category relative to the highest income category.
[b] Individual income categories: lowest: <\$12,000; middle: \$12,000-24,999; highest: ≥ \$25,000.
[c] Summary scores for neighborhood socioeconomic characteristics were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Table 5.8. Incidence of type 2 diabetes by gender. Atherosclerosis Risk in Communities study, 1989- 1998: African American men and women

	Men				Women				All			
Characteristics	**Persons at Risk (n)**	**Person-Years**	**Incident Cases (n)**	**Incidence Rate [a]**	**Persons at Risk (n)**	**Person-Years**	**Incident Cases (n)**	**Incidence Rate [a]**	**Persons at Risk (n)**	**Person-Years**	**Incident Cases (n)**	**Incidence Rate [a]**
Income [b]												
Lowest Level	177	917	43	46.9	568	2,958	160	54.1	745	3,876	203	52.4
Middle Level	249	1,430	72	50.3	413	2,254	103	45.7	662	3,685	175	47.5
Highest Level	311	1,799	81	45.0	366	2,081	89	42.8	677	3,881	170	43.8
Education												
< High School	290	1,650	65	39.4	508	2,716	130	47.9	798	4,366	195	44.7
High School	192	1,089	53	48.7	407	2,184	107	49.0	599	3,273	160	48.9
> High School	255	1,408	78	55.4	432	2,395	115	48.0	687	3,803	193	50.7
Occupation												
Homemakers[c]					194	972	51	52.4	194	972	51	52.4
Manual	487	2,724	123	45.1	653	3,499	173	49.4	1140	6,224	296	47.6
Nonmanual	250	1,422	73	51.3	500	2,823	128	45.3	750	4,246	201	47.3
Neighborhood SEC[d]												
Lowest Tertile	216	1,194	49	41.0	442	2,475	107	43.2	658	3,669	156	42.5
Middle Tertile	251	1,384	70	50.6	434	2,346	118	50.3	685	3,730	188	50.4
Highest Tertile	270	1,569	77	49.1	471	2,472	127	51.4	741	4,042	204	50.5

[a] Age-adjusted incidence rate per 1,000 person-years

[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000

[c] 10 male homemakers were excluded due to small numbers.

[d] Summary scores for neighborhood socioeconomic characteristics (SEC) were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Table 5.9. Hazard ratios of type 2 diabetes[a] by individual-level socioeconomic characteristics and gender. Atherosclerosis Risk in Communities study, 1989-1998: African American men and women

	Men (N=1,658)		**Women (N=426)**		**All (N=2,084)**	
	Age-adjusted	**Adjusted for Neighborhood**	**Age-adjusted**	**Adjusted for Neighborhood**	**Age-adjusted**	**Adjusted for Neighborhood**
Income [b]						
Lowest Level	1.05 (0.68, 1.62)	1.16 (0.72, 1.88)	1.26 (0.89, 1.80)	1.34 (0.92, 1.95)	1.18 (0.90, 1.55)	1.26 (0.93, 1.71)
Middle Level	1.14 (0.76, 1.70)	1.19 (0.80, 1.77)	1.04 (0.79, 1.36)	1.03 (0.79, 1.34)	1.06 (0.82, 1.38)	1.09 (0.83, 1.42)
Highest Level	1.0	1.0	1.0	1.0	1.0	1.0
Education						
< High School	0.75 (0.46, 1.20)	0.78 (0.49, 1.25)	1.06 (0.72, 1.54)	1.15 (0.79, 1.69)	0.92 (0.68, 1.25)	0.96 (0.71, 1.29)
High School	0.92 (0.64, 1.34)	0.97 (0.66, 1.43)	1.13 (0.86, 1.50)	1.15 (0.87, 1.53)	1.04 (0.83, 1.32)	1.07 (0.86, 1.34)
> High School	1.0	1.0	1.0	1.0	1.0	1.0
Occupation						
Homemakers [c]	----	----	0.92 (0.55, 1.52)	0.91 (0.53, 1.56)	0.86 (0.54, 1.37)	0.90 (0.57, 1.43)
Manual	0.89 (0.67, 1.18)	0.92 (0.69, 1.23)	1.16 (0.85, 1.58)	1.26 (0.91, 1.75)	1.05 (0.85, 1.29)	1.08 (0.88, 1.32)
Nonmanual	1.0	1.0	1.0	1.0	1.0	1.0

[a] Type 2 diabetes: fasting glucose level ≥ 126 mg/dl (7mmol/l), nonfasting glucose ≥ 200 mg/dl (11.1mmol/l), self-reported physician diagnosis, or self-reported use of medications for diabetes

[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000

[c] 10 male homemakers were excluded due to insufficient numbers.

Table 5.10. Baseline body mass index (BMI) and slope of change in BMI over time. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

	Men			Women		
	Baseline BMI (kg/m^2)	**Change over Time (kg/m^2)**	**P-value[c]**	**Baseline BMI (kg/m^2)**	**Change over Time (kg/m^2)**	**P-value[c]**
Income[a]						
Lowest Level	27.01	0.09	0.64	31.51	0.10	<.0001
Middle Level	27.69	0.08		31.22	0.16	
Highest Level	28.41	0.07		29.32	0.19	
Education						
< High School	27.49	0.08	0.77	31.79	0.09	<.0001
High School	27.60	0.07		31.01	0.16	
> High School	28.37	0.09		29.52	0.19	
Occupation						
Homemaker[b]	--------			32.11	0.07	<.0001
Manual	27.61	0.07	0.52	31.35	0.13	
Nonmanual	28.24	0.09		29.62	0.19	
Neighborhood Characteristic						
Lowest Level	27.76	0.07	0.09	31.28	0.12	0.13
Middle Level	27.83	0.06		31.18	0.14	
Highest Level	27.85	0.10		30.20	0.16	

[a] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000

[b] 10 male homemakers were excluded due to small numbers.

[c] P-value for interaction between socioeconomic characteristics and time.

Table 5.11. Age-adjusted incidence estimates[a] for type 2 diabetes by individual income[b] and neighborhood characteristics[c]. Atherosclerosis Risk in Communities study, 1987-1989: African American men and women

Men						
Income Level	**Neighborhood Level**	**Estimate**	**Std error**	**T value**	**Pr > |t|**	**Interaction Pr > |t|**
Lowest	Lowest	-0.2196	0.5651	-0.3886	0.6990	0.0062
Lowest	Middle	-0.9190	0.5387	-1.7060	0.0938	
Middle	Lowest	0.5410	0.5311	1.01868	0.3129	
Middle	Middle	1.0639	0.4172	2.54984	0.0137	

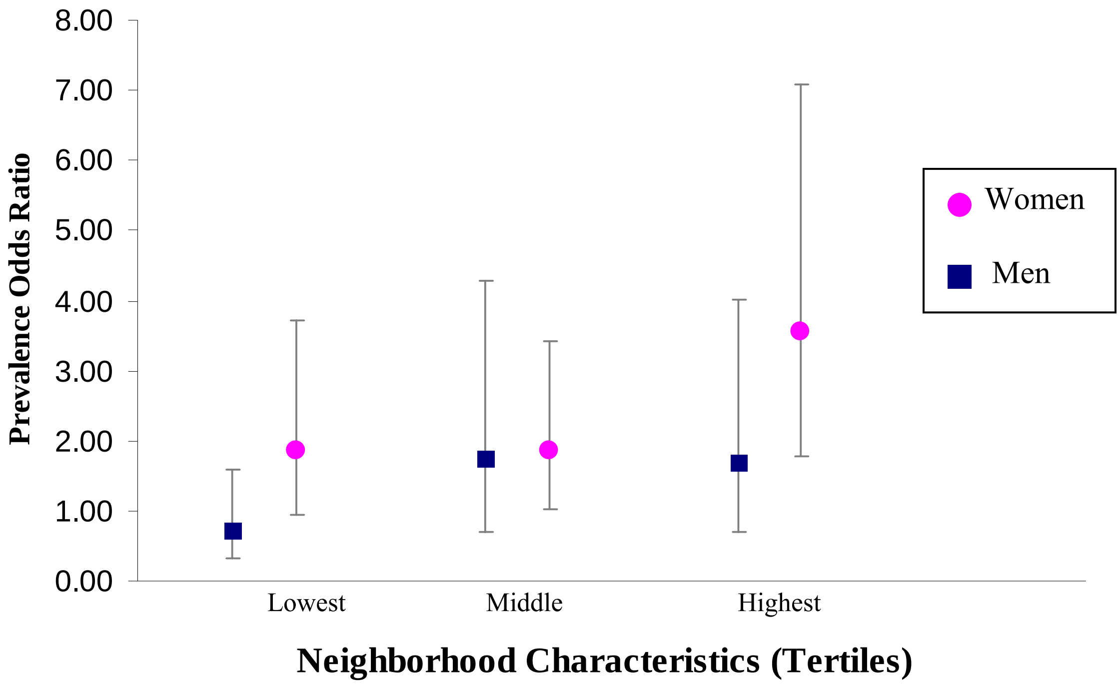
Women						
Income Level	**Income Level**	**Income Level**	**Income Level**	**Income Level**	**Income Level**	**Income Level**
Lowest	Lowest	-0.8307	0.3139	-2.7333	0.0085	0.1008
Lowest	Middle	-0.2851	0.2904	-0.9818	0.3307	
Middle	Lowest	-0.3565	0.3304	-1.0789	0.2855	
Middle	Middle	-0.0025	0.2771	-0.0093	0.9925	

[a] Estimates are assessed at the interaction of the indicated levels relative to the highest level of both SES indicators.

[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000.

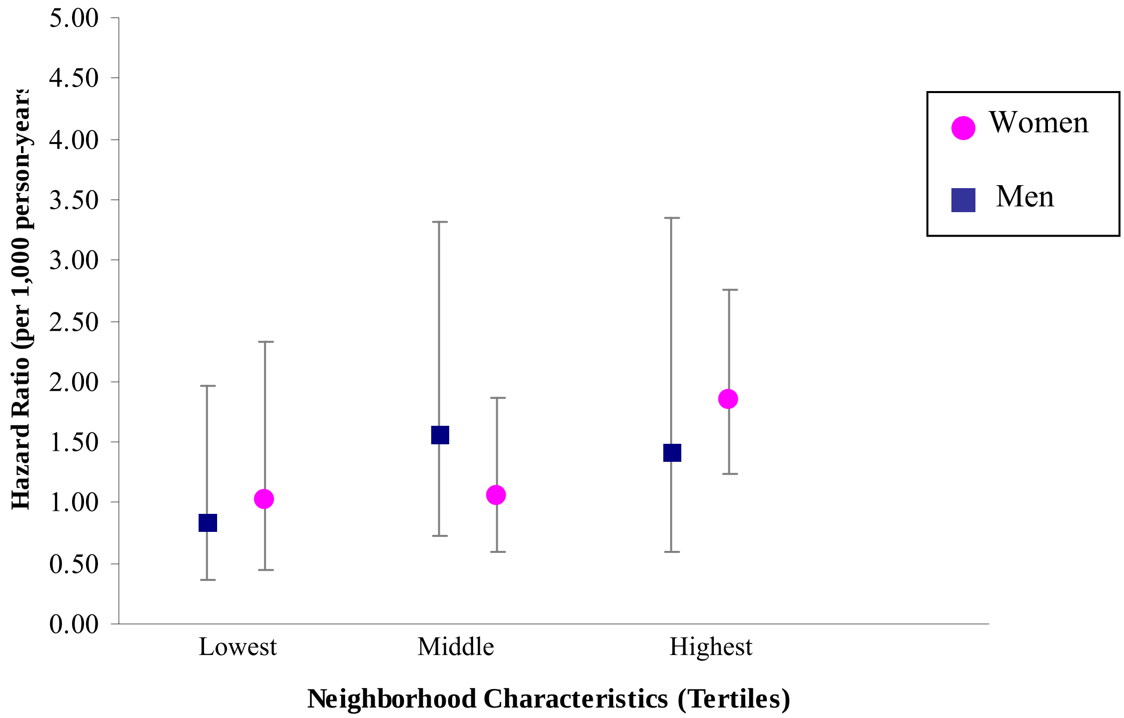
[c] Summary scores for neighborhood socioeconomic characteristics were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Figure 5.1. Age-adjusted prevalence odds ratios[a] of type 2 diabetes by individual income[b] and neighborhood characteristics[c] in African Americans. Atherosclerosis Risk in Communities study, 1987-1989



[a] Odds ratios assess the prevalence of type 2 diabetes in the lowest individual income category relative to the highest income category.
[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000.
[c] Summary scores for neighborhood socioeconomic characteristics were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

Figure 5.2. Age-adjusted hazard ratios[a] of type 2 diabetes by individual income[b] and neighborhood characteristics[c] in African Americans. Atherosclerosis Risk in Communities study, 1989-1998



[a] Hazard ratios assess the prevalence of type 2 diabetes in the lowest individual income category relative to the highest income category.
[b] Individual income categories: lowest: <$12,000; middle: $12,000-24,999; highest: ≥ $25,000.
[c] Summary scores for neighborhood socioeconomic characteristics were categorized by tertiles. The intervals from lowest to highest were (-8.81, -3.46), (-3.45, 2.02), and (2.01, 22.31).

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6.0 Discussion

6.1 Overview

This is one of the first studies in the U.S. to investigate the association of neighborhood and individual level socioeconomic factors with the prevalence of type 2 diabetes, hyperinsulinemia, and impaired fasting glucose, and the incidence of type 2 diabetes. Analyses were conducted among African American and white participants of the Atherosclerosis Risk in Communities (ARIC) study. Census tracts were used as proxies for neighborhoods and hierarchical analyses were used to account for the nested nature of the data. The next sections summarize the findings, strengths, and weaknesses of the study. Public health implications and areas for future research are also addressed.

6.2 Summary of findings

Cross-sectional Analyses

In this study patterns of association between socioeconomic characteristics and type 2 diabetes prevalence generally were similar to those from previous European studies. Inverse associations were observed between the prevalence of type 2 diabetes and all individual socioeconomic indicators in all race-sex groups. All individual level indicators produced similar rates of diabetes within each race-sex group. Greater prevalence of diabetes was observed among African Americans than among whites, with the greatest prevalence found among African American women. Inverse associations were observed between neighborhood characteristics and type 2 diabetes prevalence for women only. There was no consistent pattern observed for men regardless of race. Thus, it is possible that the behavioral and psychosocial characteristics of men in more disadvantaged neighborhoods differ from those of women. However, explanations for these findings are speculative. The lack of a statistically significant association between socioeconomic factors and the odds of prevalent disease among African American men also may reflect the smaller number of participants in this group relative to other race-sex groups.

Pre-diabetic Conditions

No consistent patterns of association were observed for fasting hyperinsulinemia nor impaired fasting glucose. Both individual and neighborhood level factors were inversely associated with the prevalence of impaired fasting glucose (IFG) among white women. For African American women neighborhood characteristics and all individual level factors except occupation were inversely associated with IFG prevalence. No clear or consistent patterns were observed for African American or white males. Findings for hyperinsulinemia suggested inverse associations between all socioeconomic factors and the prevalence of hyperinsulinemia among white women. Inverse associations with hyperinsulinemia prevalence were observed for education and occupation among African American women. There were no clear patterns observed for other factors. Findings among women were similar to other studies that found inverse associations between prevalence of glucose intolerance and grade of employment and level of education[1, 2] and one that observed an inverse relationship between neighborhood socioeconomic score and a summary Insulin Resistance Syndrome (IRS) score [3]. Among white men the prevalence of hyperinsulinemia tended to vary directly with increasing income and inversely with occupation. However, differences between levels of these factors were not significant. Patterns observed among African American men were not consistent. However, the largest prevalence tended to occur in the highest levels of socioeconomic factors, similar to a study that found a positive association between neighborhood score and the IRS score in African American men of relatively low individual level characteristics [3]. The inconsistencies in these findings could suggest that the mechanisms linking socioeconomic characteristics with type 2 diabetes differ from those of pre-diabetic conditions, although such an inference is speculative and has to be considered with caution.

Prospective Analyses

All individual level socioeconomic factors were inversely related to the incidence of diabetes among whites, except occupation in white women. The greatest incidence was observed for non-manual occupations among white women. Among African American women diabetes incidence varied inversely with income and occupation. Among African American men by contrast, diabetes incidence increased with increasing levels of education and occupation. These findings suggest the influence of mechanisms similar to John Henryism in which individuals exert a strong personality predisposition to actively cope with psychosocial environmental stressors. However, previous studies have only associated this effect with elevated blood pressure[4]. The contrasting findings in African American men warrant replication, as well as additional investigation of the attributes that may link higher levels of education and occupation to diabetes incidence. Lifestyle factors offer themselves as a source of testable hypotheses in this regard. For all groups except African American men, longitudinal analyses relating socioeconomic characteristics to the development of type 2 diabetes over nine-years of follow-up confirmed the cross-sectional findings.

Among whites there was a direct association between incidence of type 2 diabetes and neighborhood disadvantage. Findings among whites support those of Barker and colleagues. In a collaborative study of diabetes incidence from nine British towns they found that type 2 diabetes was more likely to develop over two years in men and women who lived in the most disadvantaged neighborhoods than in those who lived in the most advantaged neighborhoods after considering the contribution of individual-level factors[5]. Among African Americans there was no consistent pattern of association between type 2 diabetes incidence and neighborhood characteristics. The incidence of type 2 diabetes decreased for women living in more disadvantaged neighborhoods, while there was no clear pattern of association among African American men. For both men and women the incidence of type 2 diabetes was lowest in the poorest neighborhoods. The lower incidence in poorer neighborhoods may reflect to some degree selective survival. Due to the high mortality of African Americans living in poor neighborhoods and selective attrition due to other factors related to socioeconomic status, our re-examined cohort may be disproportionately healthy.

6.3 Strengths and Limitations

Our study is unprecedented in utilizing hierarchical modeling to investigate the impact of neighborhood characteristics on type 2 diabetes after controlling for individual level factors. To our knowledge this study also is one of the first to evaluate the gender-specific associations between individual and neighborhood-level socioeconomic characteristics and diabetes in a biracial, population-based sample of individuals within the

United States. Furthermore, it provides an analysis of the association of socioeconomic characteristics with hyperinsulinemia and impaired fasting glucose, which is infrequently examined. Because this study was both cross-sectional and longitudinal in nature we were able to address the patterns in the prevalence of diabetes and of impairments of glucose metabolism, as well as the temporal relationship between socioeconomic characteristics and the development of type 2 diabetes.

This study has several methodological strengths including the definition of variables and the use of hierarchical modeling. Diabetes status was classified based on the availability of confirmed prevalent disease and interpolation of time to disease onset. Whereas several previous studies solely relied on self-reported diagnosis of diabetes, to minimize the potential for measurement error this study utilized standardized definitions based on comprehensive clinical examinations. To increase precision in estimating time-to-event the interpolation of onset time for incident cases was utilized instead of interval censoring. For individuals in whom incident diabetes was based on glucose measurements linear interpolation was used to determine approximate time to development of type 2 diabetes. For those with classification based on physician diagnosis or medication use the midpoint between the last visit free of diabetes and the first visit at which diabetes was classified was used.

This report is based on a large, population-based sample drawn from four diverse areas representing a range of socioeconomic conditions in the US and utilized hierarchical modeling techniques due to its nested nature. These methods enabled us to more appropriately model outcomes as a function of variables at the individual and neighborhood level. They also allowed corrections for biases in parameter estimates and corresponding standard errors resulting from the correlation between individuals nested in neighborhoods.

Within this modeling framework, we were able to evaluate the independent effects on the outcome of factors measured on multiple levels of the hierarchy and to assess the interplay between individual and neighborhood level factors. By simultaneously controlling for all individual level factors we were able to minimize the possibility of residual confounding on neighborhood effects, whereas most other known studies of the neighborhood impact on type 2 diabetes have investigated a single level.

6.4 Potential Limitations

Despite our large, population-based sample of diverse areas in the U.S. there was limited variability in socioeconomic characteristics within each area; this may have diluted the ability to observe the impact of neighborhoods in this study. Importantly, the sample of African Americans in this study represented a single locale in the South and was further limited by relatively small sample size. Thus, findings may not be generalizable to other groups and areas. Lastly, it is important to mention that ours was not a sample drawn from regionally (or nationally) defined frames, which imposes additional constraints on the generalizability of our findings.

While the use of census tracts as proxies for neighborhoods has been supported in other studies [6-8], inferences regarding neighborhood effects may be weakened by the use of administratively defined units since this may not be the best operational definition of neighborhood. However, since the specific mechanisms through which neighborhoods influence diabetes are not clearly understood, the most theoretically relevant neighborhood definition for this study is not established. The ambiguity of defining the most relevant area and the availability of census information make census tracts the most practical alternative for this relatively large study linking individual and area data in such diverse geographic areas.

Aggregate census measures were used as proxies for neighborhood characteristics, yet some associations were observed even with these crude proxies. Since the z-score construct derived for this study is an indirect and possibly heterogeneous marker of neighborhood attributes, the impact of other neighborhood factors should be explored in future research.

6.5 Public Health Implications

Type 2 diabetes is a costly public health burden that leads to severe complications. . Neighborhood associations suggest that risk factors for diabetes such as physical inactivity and diet are more common in disadvantaged neighborhoods [9-11]. The findings that individual socioeconomic characteristics and to some degree also neighborhood socioeconomic characteristics are related to the burden of diabetes suggest that diabetes prevention and intervention strategies should be targeted at disadvantaged individuals, and possibly also at disadvantaged neighborhoods. The differential effects between the two race-ethnic groups and between the genders provide a motivation for future research. The degree to which socioeconomic barriers at the level of neighborhood areas influence the community burden of type 2 diabetes in addition to individual-level factors would deserve heightened attention by public health scientists.

6.6 Recommendations

Findings from this study add to the growing body of literature relating neighborhood level socioeconomic characteristics to health outcomes. Most previous studies of diabetes were conducted abroad. Because our results are equivocal, additional studies in the US are recommended. Further, African Americans in this sample were sampled from a single, southern locale. Though whites were sampled from three diverse areas, large urban areas were under-represented. Therefore, these findings need to be confirmed in other geographic areas. Additionally, a more comparable sample of African Americans by sample size and geographic area is suggested to enhance comparisons by race.

Due to the potential impact of socioeconomic factors during the life course, these findings should be confirmed in longitudinal studies that consider the influence of these factors from childhood. Moreover, future studies should seek to identify the specific mechanisms through which neighborhoods impact diabetes. Therefore, investigations of associations with other neighborhood characteristics are suggested. Furthermore, rather than relying on the use of administratively defined units, analyses based on operational definitions of neighborhoods are suggested.

6.7 References

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