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LIFE COURSE SOCIOECONOMIC STATUS, RACE,
AND KIDNEY FUNCTION ACROSS THE ADULT LIFE SPAN

A Dissertation in

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ABSTRACT

Chronic kidney disease (CKD), an umbrella term for various disorders associated with kidney damage and progressive decline in kidney function, is currently a public health concern in the United States. An unhealthy pattern of kidney functioning among relatively healthy individuals, indicated by steeper age-related decrements in kidney function, is a risk factor for faster progression to CKD. This dissertation utilized the life course framework to examine the role of life course socioeconomic status (SES) and race on creating disparities in kidney functioning across the adult life span among relatively healthy Black and white American adults. This dissertation included a systematic review and three empirical papers. The systematic review (Chapter 2) surveyed the current state of the literature and found the lack of utilization of the life course framework on empirical studies examining SES and racial disparities in kidney disease. The first empirical paper (Chapter 3) examined the association between parental education, a proxy for socioeconomic context in early life, and age-related decrements in kidney function and whether the association was conditional on race. In addition, this paper examined racial differences in the life course pathways from parental education to kidney functioning in adulthood through current SES and health-related risk factors. Building on the findings from the first empirical paper, the second empirical paper (Chapter 4) identified and examined the association between intergenerational educational mobility and kidney functioning across adulthood and whether the association was conditional on race. The third empirical paper (Chapter 5) explored the association between multiple indicators of subjective indicators of SES across the life course and kidney functioning across the adult life span. Using latent class analysis, this paper identified the heterogeneity of SES mobility patterns based on multiple indicators of subjective SES across the life course. This paper also examined the association between different patterns of subjective SES mobility and age-related decrements in kidney

function and whether the association was conditional on race. Taken together, incorporating the life course framework into the study of disparities in kidney functioning provided novel understandings of how social factors across the life course contribute to the development of risk for accelerated aging kidney functioning and progression to CKD.

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Chapter 1

General Introduction

Chronic Kidney Disease

Chronic kidney disease (CKD) is currently a public health concern in the United States. CKD refers to the various disorders associated with damage to kidney structure and the progressive decline in kidney function (Levey et al., 2009). The progression of CKD is divided into five stages, in which stage 1 is characterized by kidney damage with normal filtration and the final stage (end-stage renal disease/ESRD) is characterized by kidney failure in which transplantation or dialysis is required for survival (Levey & Coresh, 2012; Levey et al., 2009). Approximately 15% of U.S. adults are expected to have CKD; around 6-7% of adults who suffer from CKD are in stage 3 or higher (Murphy et al., 2016; Saran et al., 2018). Currently around 800,000 individuals in the U.S. receive dialysis treatment and more than 200,000 CKD individuals are living with a kidney transplant (Center for Disease Control and Prevention, 2021). The burden of CKD is higher among individuals from lower socioeconomic background and member of the U.S. minority groups. For example, the prevalence of CKD among non-Hispanic Black adults (16%) is higher than the prevalence among non-Hispanic white adults (13%) (Center for Disease Control and Prevention, 2021). The prevalence of CKD in the U.S. is projected to continously grow over the next decade and the burden of the disease will heavily impact the minority groups and those from lower socioeconomic background (Hoerger et al., 2015). Actions are needed, including the development of interventions to reduce the burden of CKD and related complications (Office of Disease Prevention and Health Promotion [ODPHP], n.d.). In order to do that, there must be a clear and comprehensive understanding of how social factors, including socioeconomic status (SES) and race create disparities in CKD. However, there is a lack of focus on utilizing the life course framework to examine how SES and race affect disparities in CKD (Shoham et al., 2005). This dissertation utilized the life course framework to examine the role of life course socioeconomic status (SES) and race on creating disparities in kidney functioning across the adult life span among relatively healthy Black and white American adults. In the next sections, I will briefly decribe important conceptual frameworks to understanding the association between SES, race, and disparities in kidney disease across adulthood.

Health Disparities

Health disparities refers to *systematic* and *avoidable* differences in health and determinants of health due to the unequal distribution of wealth, power, and prestige between the underprivileged social groups (e.g., low social position) and more privileged groups (Braveman, 2006). Given that more wealth, power, and prestige are positively associated with the ability to optimally avoid health risks and minimize the detrimental impact of disease, the underprivileged social groups systematically experience poorer health than the more privileged groups (Braveman, 2006; Link & Phelan, 1995). Health disparities are not only evident between the most underprivileged and the most privileged group; health disparities can be observed along the continuum or different strata of wealth, power, and prestige, forming what is known as the *health gradient* (Adler et al., 1994; Adler & Stewart, 2010). Health disparities are unnecessary and avoidable (i.e., through policies) which make disparities in health *unfair* and *unjust* (Adler & Stewart, 2010; Braveman, 2006; Braveman et al., 2011). The fundamental principle that motivates the commitment to reduce and eventually eradicate disparities in health and determinants of health is referred to as *health equity* (Braveman, 2014). Understanding health disparities as part of pursuing health equity requires a formulation of criteria to define social position or social strata to determine the socially underprivileged and more privileged groups.

Life Course Socioeconomic Status and Health Disparities in Adulthood

The most common way to analyze social position or social strata is usually done by examining disparities in valued and scarce resources, both material and social (i.e., income, education, social status). This group of valued resources is usually referred to as socioeconomic status or SES (Carpiano et al., 2008). Understanding the interaction between exposure to health risks and resources across the life course would advance our knowledge regarding socioeconomic disparities in health. To gain a better understanding of socioeconomic inequality and health disparities throughout the life course requires knowledge from both the life span development theory and the life course paradigm. Relevant to understanding socioeconomic disparities in health is the concept of plasticity and early life programming and age differences in evolutionary selection benefits (i.e., senescent as the product of the absent of evolutionary selection benefits) from the life span development theory to explain the higher proportion of chronic diseases across adulthood (Baltes, 1997; Kirkwood, 2003). Furthermore, the life course paradigm focuses on the embedding of one's life into social structures across the life course (Diewald & Mayer, 2009). Of interest in the study of socioeconomic disparities in health is the concept of cumulative dis/advantage across the life course.

Life Span Development Framework

The persistent rate of chronic diseases in the early to mid-twentieth century, combined with the difficulties of changing adult risk factors encouraged scholars to shift the focus from identifying and preventing adult risk factors to investigate whether the etiology of chronic disease in adulthood started early in life (Kuh & Smith, 2004). The developmental origin of health and disease (DOHaD) is a major theoretical framework which focuses on understanding early life as a critical period in the development of health and disease. Through the DOHaD lens, early life is viewed as a plastic period in which the physiological system is continuously adjusted to the predicted future environment (through gene-environment interactions) based on the information received from the environment as part of the human adaptive process (Gluckman & Hanson, 2006). The risk for chronic disease in adulthood is elevated when there is a mismatch between predicted and actual environment. This level of mismatch is significantly higher in the context of early life adversity (Gluckman & Hanson, 2006). Furthermore, as individuals get older and pass the reproductive age, the benefit of evolutionary selection is lower, giving rise to the increased prevalence of chronic diseases among this population (Baltes, 1997; Kirkwood, 2003). Thus, the consequence of developmental mismatch is more apparent in midlife and older adulthood (Gluckman & Hanson, 2006). DOHaD provides a theoretical underpinning on the importance of early life as a critical/sensitive period for the development of health and disease across adulthood. Multiple studies have documented that low social status is a strong predictor of markers of adversity in early life relevant to health disparities in adulthood, including prematurity and low birth weight (Martinson & Reichman, 2016; Parker et al., 1994). Thus, it is critical to understand the influence of social position in early life as an integral part of health disparities in adulthood.

Cumulative Dis/Advantage

The life course paradigm focuses on the interdependencies in social systems that provide structural constraints and opportunities on guiding one's life at various stages across the life course (Diewald & Mayer, 2009; Elder Jr & Giele, 2009; Mayer, 2018). The life course paradigm is the study of human embedding into social structures and institutions by participating in social roles at different levels of social systems (Diewald & Mayer, 2009). At its core, it is a study of tension between structural forces and human agency on navigating one's life across the life course; the tighter the interdependences among social systems on navigating one's life, the smaller the room left for an individual's agency on influencing their life course (Diewald & Mayer, 2009; Elder Jr & Giele, 2009).

Related to the life course paradigm is the concept of cumulative dis/advantage (CDA) across the life course (Dannefer, 2018; DiPrete & Eirich, 2006; O'Rand, 2009). Formally, CDA is defined as a systemic tendency that a favorable relative hierarchy plays as a resource to generate further gains (Dannefer, 2018; DiPrete & Eirich, 2006). CDA is often depicted as "the rich get richer, the poor get poorer", although the patterns of accumulation across the life course are more complicated than that (O'Rand, 2009). CDA contributes conceptually to the study of social inequality across the life course by providing a framework on the cumulation processes. There are three main components of cumulative processes that are highly correlated with each other (O'Rand, 2009): 1) social selection, 2) cumulative exposure, and 3) trajectories of continuity (i.e., persistence of change).

The social selection process refers to the anchoring of one's life trajectories in initial conditions (O'Rand, 2009). Related to socioeconomic inequality, parental social position determines a child's social position, which in turn will determine access to resources later in life, such as educational attainment, and education, in turn, will determine one's earning potential throughout adulthood. In addition, one's health status early in life also has been shown to not only influence health status later in life but socioeconomic attainment in adulthood as well (Haas, 2006).

Cumulative exposure refers to the adding effect of multiple and highly related adverse social positions; thus, a small difference early in life will accumulate across the life course and be significantly bigger in the later stages of the life (O'Rand, 2009). The chain of systemic socioeconomic adversity across the life course (low childhood social position → low education

→ low adult social position) gives rise to the staggering health disparities in midlife and older adulthood.

Finally, the trajectories of continuity refer to the heterogeneity of the cumulative process due to different impacts of the interactions between social force and personal agency (O'Rand, 2009). While the majority of individuals have a persistent level of social position across their life course (i.e., high or low across the life course), a smaller number of individuals may change the course of their trajectories (i.e., either downward or upward).

Empirical Applications

The life course approach in understanding how socioeconomic inequality leads to health disparities in adulthood can be summarized in three ways (Galobardes et al., 2006; Loucks et al., 2010): 1) the critical/sensitive period framework (i.e., a specific stage of life is considered a critical/sensitive period in which the experience of socioeconomic adversity will lead to an adverse outcome); 2) the accumulation framework (i.e., focus on the accumulation of socioeconomic adversity across the life course), and 3) the social mobility framework. Figure 1.1 provides a graphic representation of the three ways to examine the association between life course SES and health disparities in adulthood.

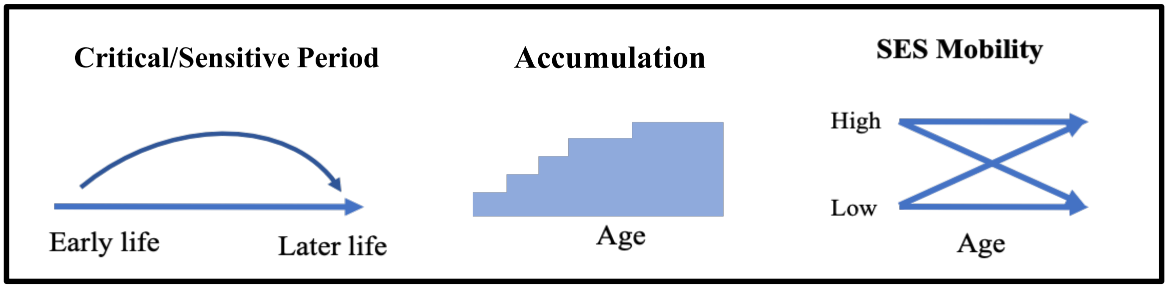


Figure **1.1**: Three ways to examine the association between life course SES and health in adulthood

Intersectionality Between SES and Race

In addition to SES, there are other indicators of stratification in the society that are also relevant to understanding health disparities, such as race. Understanding the dynamics between SES and race and their impact on health will certainly provide a better understanding of disparities therein. The framework to study the meaning and relationship between SES and race as a set of stratification criteria is known as *intersectionality* (Hankivsky & Christoffersen, 2008). Understanding the intersectionality between SES and race as important social stratification criteria is critical to better understanding disparities in kidney functioning across adulthood.

Following Williams and Sternthal (2010), race is defined as a sociocultural construct that reflects geographical origins, traditions and cultural norms, and the sociohistorical background of certain groups. Race captures stigmatization and marginalization (especially in the context of the US society) that have significant consequences for every aspect of life relevant to health (Williams, 1999; Williams et al., 2010; Williams et al., 2016; Williams & Sternthal, 2010). Race is closely related to socioeconomic inequality, in which racial minorities occupy the lower rung of social position due to exploitation, marginalization, and alienation in the social relations of production (Williams et al., 2010; Williams & Sternthal, 2010). However, the impact of race on health is not fully explained by SES (Williams, 1999; Williams et al., 2010; Williams et al., 2016; Williams & Sternthal, 2010). The direct impact of race on health can be explained through the lens of racism and discrimination, a systematic effort to exploit, alienate, and marginalize certain groups based on race (Williams, 1999). In the United States, Black individuals have a long history of racism and discrimination that contribute to disparities in health (Williams, 1999; Williams et al., 2010; Williams et al., 2016; Williams & Sternthal, 2010). For example, racial segregation in the US is a direct consequence of racist policies (Rothstein, 2017) that have a strong impact on patterning health outcomes based on race (Kramer & Hogue, 2009; Williams et al., 2010). Taken together, examining both SES and race as a set of stratification criteria is critical to better understand the ways social factors create disparities in kidney disease.

Dissertation: Life Course SES, Race, and Disparities in Kidney Functioning

This dissertation seeks to advance our understanding of the association between life course SES, race, and kidney functioning across adulthood. This dissertation especially focuses on the patterns of age-related decrements in kidney function as a window to examine the impact of SES and race on differentiating the kidney aging process throughout the adult life span. The rate of decline in kidney function is a robust indicator of progression to CKD as well as the detrimental impacts of the disease (Peralta et al., 2011; Peralta et al., 2013; Shlipak et al., 2009). While kidney function declines across adulthood as part of a normal aging process, a pattern of faster decline may indicate a pathological sign of an early progression to CKD.

This dissertation includes one systematic review and three empirical studies. The systematic review (Chapter 2) focuses on exploring the current state of empirical literature that examines SES, race, and kidney disease in the United States. Williams et al. (2010) laid out recommendations regarding domains and focus of research in which empirical studies are needed to capture the complexities of how SES and race create health disparities. The current state of literature on the association between SES, race, and kidney disease was examined based on these recommended areas of research. The first empirical study (Chapter 3) utilizes the sensitive period and accumulation frameworks (Figure 1.1) to examine the association between parental education and age-related decrements in kidney function and the life course pathways from parental education to kidney functioning in adulthood through current SES and health-related risk factors. The second and third empirical studies utilized the mobility framework (Figure 1.1) by examining the heterogeneity of SES across the life course and its association with age-related decrements in kidney function across adulthood. The second empirical study (Chapter 4) focuses on intergenerational educational mobility as a way to look at SES mobility across the life course, while the third empirical study (Chapter 5) examines SES mobility based on multiple indicators of subjective SES across the life course. Taken together, this dissertation comprehensively examined the multiple ways to examine the association between life course SES and kidney functioning across the adult life span and how this association may be conditional on race.

Chapter 2

A Systematic Review of Empirical Studies on Socioeconomic Status, Race, and Kidney Disease Across Adulthood

Introduction

Reducing the burden of chronic kidney disease (CKD) and related complications is one of the goals of the Healthy People 2030 framework (ODPHP, n.d.), the U.S. national blueprint for public health goals. One of the major challenges to achieving this goal is the persistent socioeconomic and racial/ethnic disparities in CKD. According to the United States Renal Data System (2020), the prevalence of CKD is higher among individuals from lower levels of SES. For example, between 2015-2018, the prevalence of CKD among those who did not have high school degree was 19.5%, significantly higher than the prevalence among individuals with some college degree or higher (13.1%). CKD is also higher among those with income below the poverty line (17.4%) compared to individual with income above it (14.4%). Similarly, racial and ethnic disparities in CKD in the U.S. have been well-documented. According to the Center for Disease Control (2021), the prevalence of CKD among non-Hispanic Black adults (16%) is higher compared to non-Hispanic white adults (13%). It is also estimated that 14% of Hispanic adults have CKD (Center for Disease Control, 2021). Addressing these disparities is critical in order to achieve the goal of reducing the burden of CKD in the United States.

Effectively addressing these disparities in CKD requires a comprehensive understanding of how SES and race/ethnicity independently and cumulatively impact the development and progression of the disease (Williams et al., 2010; Williams et al., 2016). The fundamental cause theory (FCT) is a useful theoretical framework to understanding the complexity of how SES and factors related to race/ethnicity create health disparities. The persistence of SES differences in health over time, despite advancement in medical technology and efforts to eliminate disease risk factors, indicate that SES is indeed a fundamental cause of health disparities (Link & Phelan, 1995). Higher SES is associated with more wealth, power, and prestige which are positively associated with the ability to optimally avoid health risks and minimize the detrimental impact of disease. As a consequence, individuals from lower levels of SES systematically experience poorer health than the more privileged groups.

Similarly, systemic racism is also a fundamental cause of health disparities, manifested by persistent racial and ethnic disparities in health (Phelan & Link, 2015). Through racist policies (e.g., segregation), individuals from racial/ ethnic minority backgrounds in the U.S. are marginalized from the mainstream social institutions which lowers their access to gain and accumulate material and social resources (i.e., lower SES). As previously mentioned, lower material and social resources means a lower ability to avoid health risks and minimize the damaging impact of disease. In addition, systemic racism is also manifested by the unfair daily treatment experiences of individuals from racial and ethnic minority backgrounds. For example, there is a well-documented evidence showing that, when compared to white adults, Black adults reported higher levels of day-to-day discrimination regardless of their SES level, which may have a direct impact on health and well-being (Surachman et al., 2021). Thus, racial disparities in health are a consequence of systemic racism that works through both SES- and non-SES related factors.

Based on FCT, SES and race related factors work in a complex way to create health disparities, including kidney disease. More than a decade ago, Williams et al. (2010) laid out a blueprint consisting of four major guidelines for empirical research that examines SES, race, and health (see details in Table 2.1): a) unpacking the social context to explore all aspects of social context across the life course; b) focusing on migration and health; c) exploring the complex interaction between genetic and environmental factors on disparities in health; and d) better understanding the influence of health care systems on health disparities. Together, these directions aim to create a new paradigm of an integrative science of social determinants of health that focuses on the accumulation of advantages and disadvantages, across the life course and across generations, for creating socioeconomic and racial disparities in health (Williams et al., 2010).

Table **2.1**: Four major domains and priority research areas for each domain to better understand SES and racial disparities in health

Direction	Research Priority
Comprehensively unpacking social context	• Go beyond income and education to fully capture SES differences across racial groups • Focus on multiple levels of SES, including focus on area-based SES with the goal to capture segregation and its impact on health • Focus on capturing SES across the life course • Examine the role of stigmatization and discrimination • Explore all the possible social environments in which racial differences exist, including disparities in work place (i.e., hazard exposure and likelihood of injury), exposure to community violence, and history of incarceration
Focus on migration and health	• Understand specific context for specific immigrant population • Explore the role of the reception factors in the current social context • Comprehensively examine social and environmental resources and risk factors among the immigrant population, including stressors and strain associated with adaptation, cultural values, and family ties
Focus on the interaction between gene and environment	• Focus on examining genetic contribution based on direct tests of genetic traits • Focus on gene-environment research • Focus on the potential role of epigenetic effects

Direction	Research Priority
Comprehensively unpacking health care systems as social context	• Focus on the role of insurance coverage and access to care on creating racial disparities in health • Explore the role of prevention-oriented care on reducing racial disparities in health • Examine a better understanding of how health care systems and other social contexts work together on creating disparities in health

Source: adapted from Williams et al. (2010)

In the field of nephrology, scholars have made specific recommendations similar to the points above to advance our understanding regarding SES and racial disparities in kidney disease. In their review, Patzer and McClellan (2012) developed a multilevel framework of disparities in kidney disease that incorporate multiple levels of SES (individual- and community-level SES) across the life course, genetic factors, and lifetime risk factors in order to fully understand the role of race and SES in the context of kidney disease. Beaulieu and Levin (2009) emphasized the lack of exploration on mechanisms and pathways that link SES to kidney disease. Similarly, Bruce et al. (2015) called for researchers to integrate psychosocial factors, especially psychosocial stress, as a possible pathway that links socioeconomic inequality to disparities in kidney disease. In addition, a narrative review by Shoham et al. (2005) argues for the need to better understand the role of life course SES on the development and progression of CKD.

Current Systematic Reviews

In the past few decades, there has been a growing interest in understanding the role of SES and race on creating disparities in kidney disease. This systematic review was intended to document and synthesize the current state of empirical knowledge on the topic. The ultimate goal was to identify areas of strength and weakness in the current state of the literature, especially on multiple aspects related to (Williams et al., 2010): 1) methods to unpack social contexts including different ways to examine SES, stigmatization and discrimination, and socioenvironmental factors associated with socioeconomic and racial disparities in kidney disease, 2) analysis on the role of migration on health, especially on the unique psychosocial factors associated with migrant population that may influence health, 3) analysis focusing on the interaction between gene and environment, 4) analysis in health care system as a unique social context that contributes to SES and racial disparities in kidney disease, and 5) the variability of kidney disease indicators as the main outcomes.

Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). Below is detailed explanation regarding inclusion criteria, search strategy, selection process, and analysis used in this systematic review.

Inclusion Criteria

Six inclusion criteria were used to identify relevant articles (see Table 2.2 for rationale): 1) the article had to be indexed in PubMed/MEDLINE, 2) the article must be an empirical study, 3) the article focused on kidney disease in adulthood, broadly defined (from pre-CKD to survival post-transplantation), as the main outcome, 4) the goals of the article must focus on examining the role of both SES and race/ethnicity on disparities in kidney disease, 5) the article addressed the U.S. context, and 6) the article must be written in English.

Table **2.2**: Inclusion criteria and rationale for a systematic review of articles on SES, race, and disparities in kidney disease

Inclusion Criteria	Rationale
The article was indexed in PubMed/MEDLINE	The PubMed/MEDLINE database is the major and most frequently used database for medical and public health research. Focusing the search on PubMed/MEDLINE would help identify relevant articles from a broad range of medical- and public health-related fields looking at SES and racial/ethnic disparities in kidney disease.
The article was empirical study (i.e., was not review, meta-analysis, or editorial papers)	The goal of this systematic review was to compile and analyze studies that empirically tried to address the intersectionality between SES and race on kidney disease in adulthood.
The article focused on kidney disease in adulthood as the main outcome, including pre-CKD, CKD stage 1-4, end-stage renal disease, transplantation, and mortality due to kidney disease	Socioeconomic and racial/ethnic disparities in kidney disease in adulthood have been documented throughout the continuum of kidney disease outcome in adulthood, from pre-CKD to mortality due to kidney disease. This systematic review was intended to comprehensively document empirical studies examining SES and racial/ethnic disparities in this broad outcome of kidney disease across adulthood.
The goals of the article must focus on examining the role of both SES and race/ethnicity in kidney disease	Both SES and factors related to race/ethnicity are fundamental causes of disparities in health, including kidney disease across adulthood. It is critical to document and examine the intricate mechanism of how both SES and factors related to race/ethnicity creates disparities in kidney disease across adulthood. Thus, the goal of this review was to document and analyze empirical studies that examine the intersectionality between SES and race/ethnicity on creating disparities in kidney disease across adulthood.
The article addressed the U.S. context	SES and race/ethnicity related factors are fundamental causes of disparities in health, and there is consistent evidence of them worldwide. However, the exact mechanisms of how SES and race/ethnicity as social contexts in the development and progression of kidney disease is certainly dependent on larger/macro structural factors, including historical, social, and economic factors. Thus, this review focused on empirical studies addressing disparities in kidney disease across adulthood in the United States.
The article was written in English	For mainly practical reasons, articles included in this review must be written in English.

Search Strategy

The initial search for relevant empirical papers on PubMed/MEDLINE database was conducted on April 5, 2021. The following keywords were used during the search: ("socioeconomic status" OR "social class" OR "social status" OR "socioeconomic position") AND (race OR ethnicity) AND ("kidney function" OR "kidney disease" OR "renal function" OR "renal disease").

Selection Process

The article selection process is summarized in Figure 2.1. The initial search resulted in 227 articles. The first-stage screening indicated that 175 articles met the criteria of empirical papers (i.e., using a qualitative or quantitative method to test hypotheses), while 52 review, editorial, and commentary articles were excluded. The second-stage screening identified articles that focused on relevant kidney disease in adulthood as the outcome of the analysis. Out of 175 articles screened, 89 met the criterion and 86 articles were excluded from further consideration. Among the 86 excluded articles were 3 that focused on pediatric kidney disease. The third-stage screening determined whether the articles focused on both SES and race/ethnicity as the main predictors of the analysis. Articles met this criterion if there was a statement in the paper, whether in the title, abstract, or introduction, that indicated the focus of the study was on the link between both SES and race/ethnicity on kidney disease outcome in adulthood (i.e., both SES and race/ethnicity were the primary focus). A primary focus on race/ethnicity should include both racial or ethnic group comparisons or a within racial- or ethnic minority analysis. Articles that included SES and race/ethnicity as covariates for their analyses were excluded from further consideration (i.e., SES and race/ethnicity were a secondary focus). Among the 89 articles screened in this stage, 44 met the criterion and 45 were excluded. Among the articles that did not meet the criterion: a) in 20 articles, race/ethnicity was the primary focus but SES was secondary; b) in 11 articles, SES was the primary focus but race/ethnicity was secondary; and c) in 14 articles, both SES and race/ethnicity were the secondary focus. The final screening excluded articles that focused on a non-U.S. context and were not written in English. Of the 44 articles included in this final stage of screening, 27 met the criteria.

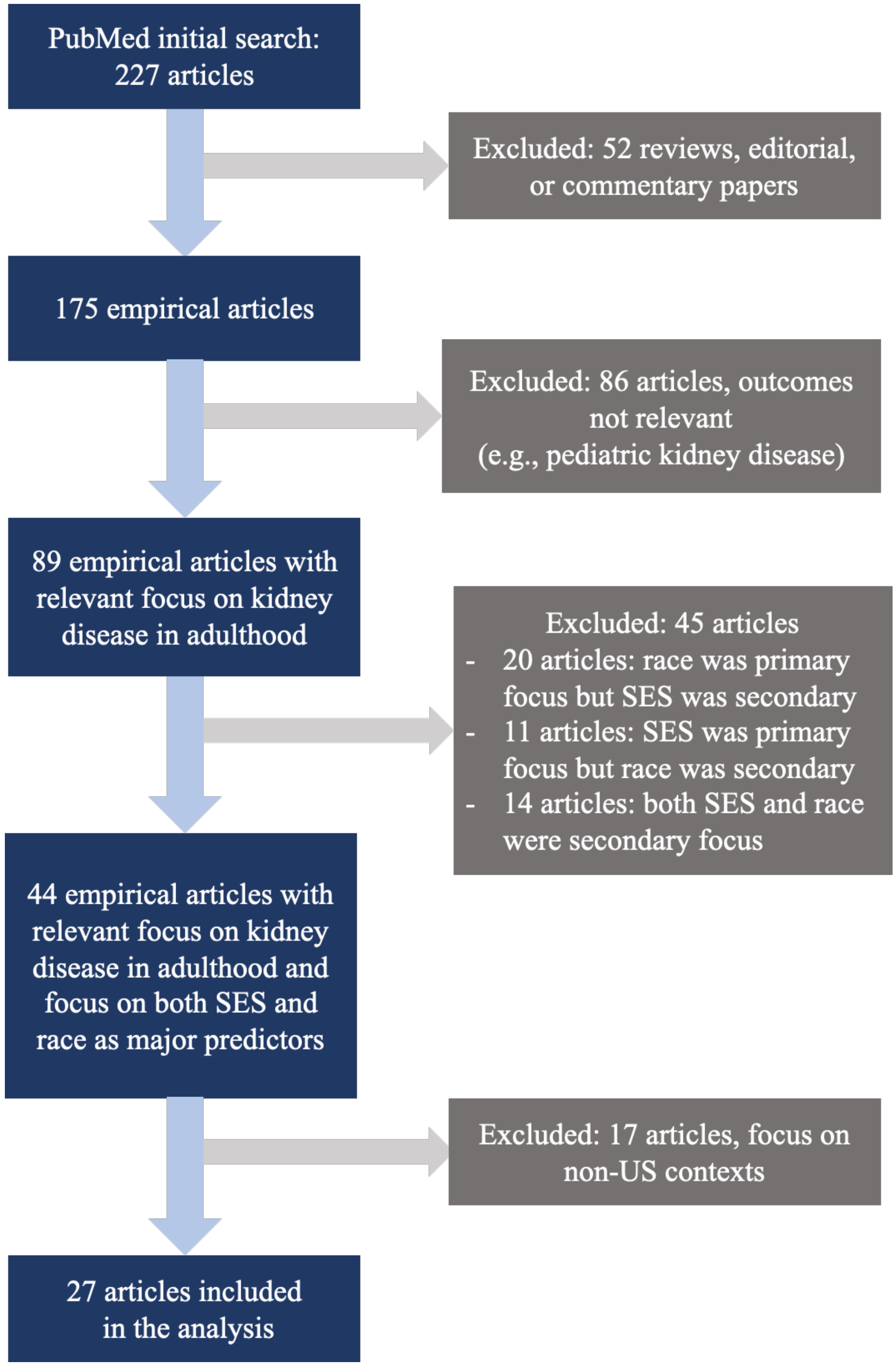


Figure **2.1**: Selection process of the articles in the current systematic review

Analysis

Once the relevant articles that met all of the inclusion criteria were identified, each article was read and the relevant information was recorded using a standard form (see Appendix A). The information was then synthesized and summarized covering multiple topics, including: 1) methods to unpack social contexts including different ways to examine SES, stigmatization and discrimination, and socioenvironmental factors associated with socioeconomic and racial disparities in kidney disease, 2) analysis on the role of migration on health, especially on the unique psychosocial factors associated with migrant population that may influence health, 3) analysis focusing on the interaction between gene and environment, 4) analysis in health care system as a unique social context that contributes to SES and racial disparities in kidney disease, and 5) the variability of kidney disease indicators as the main outcomes.

Results

General Information of the Articles

The list of articles included in the systematic review is presented in Table 2.2. The articles were published across a three-decade periods (1990-2020), in which the article by Byrne et al. (1994) was the earliest publication that examined both SES and race in kidney disease. There was a growing pattern of publication numbers per decade in this topic for the last three decades (Figure 2.2). The majority of the articles (56%) were published in the last decade (2011-2020; Figure 2.2) and they represent a broad discipline of academic journals, including nephrology (15 articles), transplantation (1), (non-nephrology) medicine (6), epidemiology (1), and other (1). Among the nephrology journals, most of the articles (*n* = 9) were published in the American Journal of Kidney Disease (AJKD). Finally, the majority of the articles (*n* = 18) utilized data from national or regional cohort studies. There were 12 population-based cohort studies identified among these articles (see Table 2.3). Among the identified cohort studies, the Chronic Renal Insufficiency Cohort Study (CRIC) and the Dialysis Outcomes and Practice Patterns Study (DOPPS) are studies that specifically investigated the development and progression of CKD. The majority of the cohort studies identified in these articles investigated the development and risk factors of cardiovascular disease, such as the Jackson Heart Study, the Atherosclerosis Risk in Communities (ARIC) study and the Reasons for Geographic and Racial Differences in Stroke (REGARDS) study. Among the articles that did not utilize data from cohort studies, 6 articles analyzed data from kidney disease-related national registry data, including the United States Renal Data System (USRDS) and the Scientific Registry of Transplant Recipients (SRTR). The rest of the articles analyzed data from single-center studies and one article was a qualitative study based on focus group discussion.

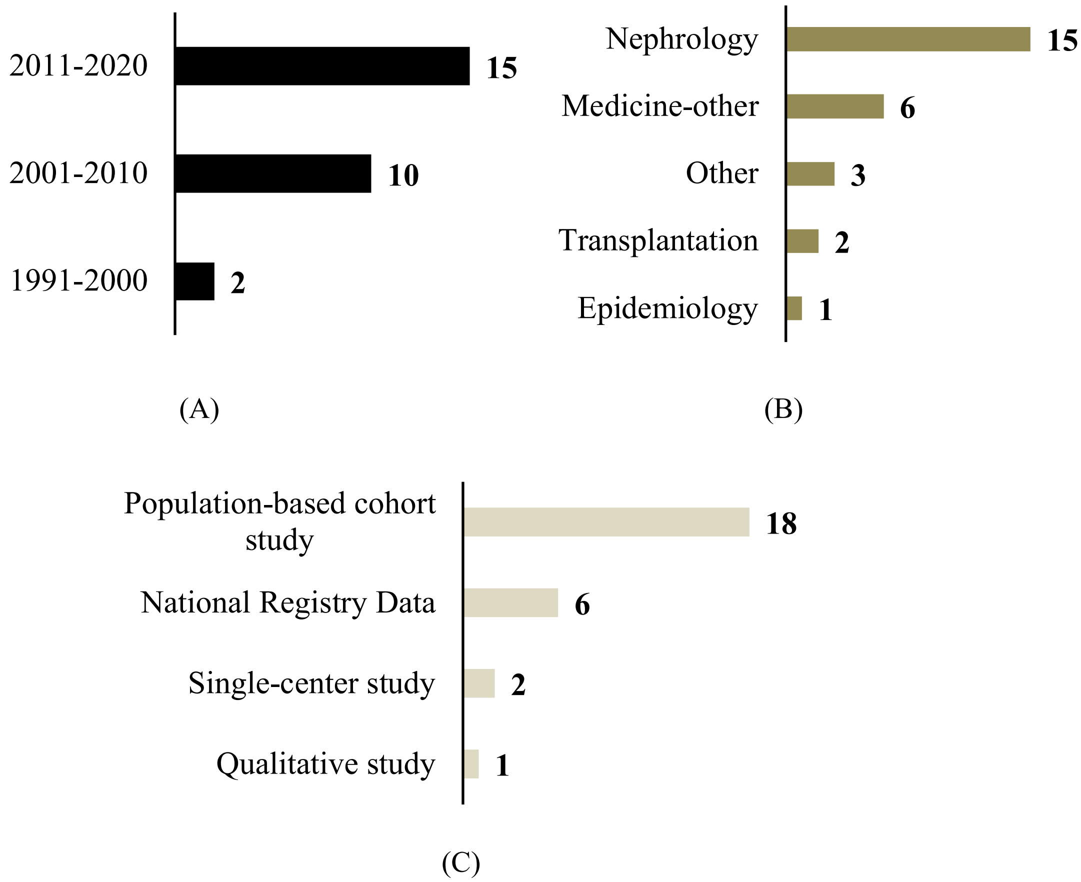


Figure **2.2**: Number of publications per decade (A), discipline of journals where articles were published (B), and the source of data for the analysis (C)

Table **2.3**: List of articles included in the systematic review (*N* = 27)

No	First Author[a]	Socioeconomic Status	Racial comparison	Outcome	Study	Journal
1	Arvelakis et al. (2019)	Area-level SES: median household income based on ZIP code	Black and white	Survival after kidney transplantation	A single-center study at the Recanati-Miller Transplantation Institute at Mount Sinai Medical Center	Clin Transplant
2	Assari (2016)	Individual-level SES: education and income	Black and white	Mortality due to renal disease	The Americans' Changing Lives (ACL)	J Nephropathol
3	Bruce et al. (2010)	Individual-level SES: education and annual household income (income to poverty ratio)	Black only	CKD status based on eGFR and presence of albuminuria	The Jackson Heart Study	Am J Kidney Dis
4	Byrne et al. (1994)	Area-level SES: median family income based on ZIP code	Black and white	Incidence rate of ESRD	A single-center study in NYC	Am J Kidney Dis
5	Crews et al. (2010)	Individual-level SES: household income	Black and white	CKD status based on eGFR	The Healthy Aging in Neighborhoods of Diversity Across the Lifespan (HANDLS)	Am J Kidney Dis
6	Eisenstein et al. (2009)	a. Individual-level SES (type of insurance coverage and employment status) b. Area-level SES based on ZIP code (% of Black population, median household income, average house value, and urban/ rural characteristic) c. Dialysis facility characteristics (e.g., patient-to-nurse ratio and number of treatments per patient per week)	Black and other	Survival of hemodialysis patients	The United States Renal Data System (USRDS)	Am J Med
7	Fedewa et al. (2014)	a. Individual-level SES (household income, education, and health insurance status) b. Area-level SES based on ZIP code (poverty rate and Gini index)	Black and white	All-cause mortality, ESRD incidence, and eGFR	The Reasons for Geographic and Racial Differences in Stroke (REGRADS) Study	BMC Nephrol

No	First Author[a]	Socioeconomic Status	Racial comparison	Outcome	Study	Journal
8	Golestaneh et al. (2020)	a. Individual-level SES: education b. Area-level SES: percentage of Black population, percentage of poor households, percentage of household with higher education	Non-Hispanic Black, non-Hispanic white, Hispanic, and other	Hospitalization incidence rate among dialysis patients	The Dialysis Outcomes and Practice Patterns Study (DOPPS)	Am J Kidney Dis
9	Gutiérrez et al. (2010)	Individual-level SES: annual household income, highest formal education, and employment status	Black and white	Serum phosphate, urinary albumin, calcium, and serum creatinine	The Chronic Renal Insufficiency Cohort (CRIC) Study	J Am Soc Nephrol
10	Hicken et al. (2019)	Area-level SES: neighborhood problems (e.g., lack of food shopping and heavy litter problem) and neighborhood cohesion (e.g., people in the neighborhood can be trusted and people in the neighborhood getting along)	Black, Chinese, Hispanic, and white	eGFR decline and annualized change in eGFR	The Multi-Ethnic Study of Atherosclerosis (MESA)	Am J Kidney Dis
11	Johnson et al. (2014)	Individual-level SES: education, employment status, health insurance status, and annual income	Black only	Risk for CKD	-	BMC Nephrol
12	Lipworth et al. (2012)	Individual-level SES: education and annual household income	Black and white	ESRD diagnosis	The Southern Community Cohort Study (SCCS)	PLoS One
13	Merkin et al. (2005)	a. Area-level SES based on ZIP code (e.g., median household income and median value of housing) b. Individual-level SES: family income, education, and occupation	Black and white	Incident of progressive CKD	The Atherosclerosis Risk in Communities (ARIC) Study	Am J Kidney Dis
14	Moghani Lankarani and Assari (2017)	Individual-level SES: education, income, and employment status	Non-Hispanic Black and white	Mortality due to renal disease	The Americans’ Changing Lives (ACL) Study	J Diabetes Investig
15	Murphy et al. (2020)	Individual-level SES: education, household income, and employment status	Black and white	Time to kidney transplantation listing	Prospective Cohort on Aging and Kidney Failure linked to the Scientific Registry of Transplant Recipients (SRTR)	Clin J Am Soc Nephrol
16	Nair et al. (2020)	Individual-level SES: education, insurance status, and annual income	Black and non-Hispanic white	eGFR and ESRD incident	Southern Community Cohort Study (SCCS)	J Health Care Poor Undeserved

No	First Author[a]	Socioeconomic Status	Racial comparison	Outcome	Study	Journal
17	Nee et al. (2013)	Area-level SES: median household income based on ZIP code	Black and non-Black	Allograft loss, all-cause mortality, and death-censored graft survival	The United States Renal Data System (USRDS)	Transplantation
18	Nguyen et al. (2018)	Individual-level SES: education and annual family income	Caribbean Black in the US	Report of CKD diagnosis by physicians	The National Survey of American Life (NSAL): Coping with Stress in the Twenty-First Century	Race Soc Probl
19	Peralta et al. (2006)	Individual-level SES: education, annual income, and occupational class	Ancestry-informative markers and genotype and self-report race	eGFR and annual rate of eGFR change	The Cardiovascular Health Study (CHS)	J Am Soc Nephrol
20	Perneger et al. (1995)	Individual-level SES: education, annual household income, and access to health care (e.g., use of preventive services and health insurance status)	Black, white, and other	Diagnosis of ESRD	Unnamed population-based, case-control study	Arch Intern Med
21	Shoham et al. (2007)	a. Individual-level SES across the life course: - R's social class at age 30, 40, and 50 - Father's social class at age 10 b. area-based SES at age 10, 30, 40, and 50 based on ZIP codes	Black and white	CKD status based on eGFR	The Life Course Socioeconomic Status (LCSES) ancillary study of The Atherosclerosis Risk in Communities (ARIC) Study	Am J Kidney Dis
22	Vart et al. (2015)	Individual-level SES: income-to-poverty ratio	Black, Mexican American, white, and other	CKD status based on eGFR	The National Health and Nutrition Examination Survey (NHANES)	Am J Epidemiol
23	Vart et al. (2020)	Individual-level SES: education and income-to-poverty ratio	Non-Hispanic Black, Mexican American, non-Hispanic white, and other	CKD stage 3 and 4 (based on eGFR)	The National Health and Nutrition Examination Surveys (NHANES)	JAMA Netw Open
24	Ward (2007a)	Individual-level SES: medical insurance status Area-level SES: 7 indicators based on ZIP codes	Native American, API, Black, Hispanic, white, and other	a. kidney laboratory indicators: eGFR,	The United States Renal Data System (USRDS)	J Rheumatol

No	First Author[a]	Socioeconomic Status	Racial comparison	Outcome	Study	Journal
				serum albumin, and hematocrit b. pre-dialysis uses of epoetin		
25	Ward (2007b)	Individual-level SES: medical insurance status Area-level SES: 7 indicators based on ZIP codes	Native American, API, Black, Hispanic, white, and other	Age at which ESRD treatment began	The United States Renal Data System (USRDS)	Arch Intern Med
26	Ward (2008)	Area-level SES: 7 indicators based on ZIP codes	API, Black, Hispanic, Native American, white, and other	Incidence of ESRD	The United States Renal Data System (USRDS)	Am J Kidney Dis
27	Young et al. (2016)	Individual-level SES: income and education	Black only	Rapid kidney function decline	The Jackson Heart Study	Am J Kidney Dis

Note: a = listed alphabetically

Table **2.4**: List of population-based cohort studies mentioned in the articles

No	Study Name	Description	Year	Participants	*N* at Baseline	Age at baseline	Kidney Markers	Public Access
1	Americans' Changing Lives (ACL) Study (https://acl.isr.umich.edu/)	The Americans' Changing Lives study addresses how social, psychological, behavioral, medical, and environmental factors affect health outcomes and health changes over the adult life course	1986-ongoing	Adults in the continental US		25 and older	Mortality due to renal disease	Yes (mortality data are restricted)
2	Atherosclerosis Risk in Communities (ARIC) Study (https://sites.cscc.unc.edu/aric/)	The ARIC study is designed to investigate the causes of atherosclerosis and its clinical outcomes, and variation in cardiovascular risk factors, medical care, and disease by race, gender, and location.	1987-ongoing			45-64	Multiple serum and urine biomarkers	By request
3	Cardiovascular Health Study (CHS; https://chs-nhlbi.org/)	The Cardiovascular Health Study (CHS) is an NHLBI-funded observational study of risk factors for cardiovascular disease in which participants underwent annual extensive clinical examinations	1989-ongoing	Older adults in four regions: Sacramento, CA Hagerstown, MD, Forsyth County, NC, and Pittsburgh, PA	5,201	65 and older	Multiple serum and urine biomarkers	By request
4	Chronic Renal Insufficiency Cohort (CRIC) Study (http://www.cristudy.org/)	The CRIC study aims to advance the understanding of factors that contribute to the progression of CKD and promote the development of strategies to reduce the burden of kidney disease	2003-ongoing		3939	21-74	Multiple serum and urine biomarkers	By request

No	Study Name	Description	Year	Participants	*N* at Baseline	Age at baseline	Kidney Markers	Public Access
5	Healthy Aging in Neighborhoods of Diversity Across the Lifespan (HANDLS) Study (https://handls.nih.gov/)	The HANDLS study addresses the need to understand the sources of persistent health disparities in overall longevity, cardiovascular disease, and cerebrovascular disease by disentangling the relationship between race, socioeconomic status, and health outcomes	2004-ongoing	Black and white adults drawn from neighborhoods in Baltimore City	3,720	30–64	Multiple serum and urine biomarkers	By request
6	Jackson Heart Study (https://www.jacksonheartstudy.org/)	The primary objective of the Jackson Heart Study is to investigate the causes of cardiovascular disease (CVD) in African Americans and to learn how to best prevent this group of diseases in the future	1998-ongoing	Black adults living in the Jackson, Mississippi, metropolitan area of Hinds, Madison, and Rankin Counties		35-84	Multiple serum and urine biomarkers	By request
7	The Multi-Ethnic Study of Atherosclerosis (MESA) Study (https://www.mesa-nhlbi.org/)	The MESA study focuses on the characteristics of subclinical cardiovascular disease and the risk factors that predict progression to clinically overt cardiovascular disease or progression of the subclinical disease	2000-2020	Black, Hispanic, Chinese American, and white adults from Baltimore County, MD, Chicago, IL, Forsyth County, NC, LA County, CA, and St. Paul, MN	6,814	45-84	Multiple serum and urine biomarkers	By request

No	Study Name	Description	Year	Participants	*N* at Baseline	Age at baseline	Kidney Markers	Public Access
8	National Health and Nutrition Examination Survey (NHANES) Study (https://www.cdc.gov/nchs/nhanes/index.htm)	The National Health and Nutrition Examination Survey (NHANES) is a program of studies designed to assess the health and nutritional status of adults and children in the United States. The survey is unique in that it combines interviews and physical examinations	1971-ongoing	US children and adults	~28,000	1-74	Cystatin C	By request
9	National Survey of American Life (NSAL)	The NSAL study aims to investigate the nature, severity, and impairment of mental disorders among national samples of the black and non-Hispanic white (*n* = 1,006) populations in the U.S.		Black, Black Caribbean, and non-Hispanic white in the US	6,199		Self-report of CKD diagnosis	NA
10	Reasons for Geographic and Racial Differences in Stroke (REGRADS) Study (https://www.uab.edu/soph/regardsstudy/)	The REGARDS study focuses on understanding geographic and racial/ethnic (African-American vs. white) differences in stroke	2003-ongoing	Black and white adults, 30% from the Stroke Belt, 20% from the Stroke Buckle, and the remainder from elsewhere in the continental U.S	30,239	45 and older e	Multiple serum and urine biomarkers	By request
11	The Southern Community Cohort Study (SCCS; https://www.southerncommunitystudy.org/)	The SCCS aims to address many unresolved questions about the root causes of cancer health disparities, with its findings expected to help prevent and reduce the burden of cancer among all populations	2002-2009	Adults (mostly Black and white) from (mostly) Alabama and other southern states	84,797	40-79	Multiple serum and urine biomarkers	By request

No	Study Name	Description	Year	Participants	*N* at Baseline	Age at baseline	Kidney Markers	Public Access
12	Dialysis Outcomes and Practice Patterns Study (DOPPS; https://www.dopps.org/)	A prospective cohort study of hemodialysis practices based on the collection of observational longitudinal data for a random sample of patients from dialysis facilities in a representative and random sample of units in twenty countries.	-	-	-	-	Multiple serum and urine biomarkers	By request

Unpacking Social Context

Income and Education as the Most Common Indicators of SES

Based on the types of SES indicators, articles could be divided into three different categories: 1) those that included individual- or household-level SES (i.e., individual or family as the unit of the measure, for example participant's education), 2) articles that included area- or neighborhood-level SES (i.e., area/neighborhood as the unit of the measure, for example percentage of poor family in a ZIP code area), and 3) articles that included both individual- and area-level SES. The majority of the articles (n = 15) included individual- or household-level SES (Figure 2.3), while the rest included area- or neighborhood-level SES (n = 5) or a combination of both (n = 7). Income (utilized in 17 articles) and education (n = 16 articles) are the most commonly used individual-level SES found among the articles. Other individual-level SES indicators include access to or type of health insurance (n = 7), employment status (n = 5), and occupational-based social class (n = 2).

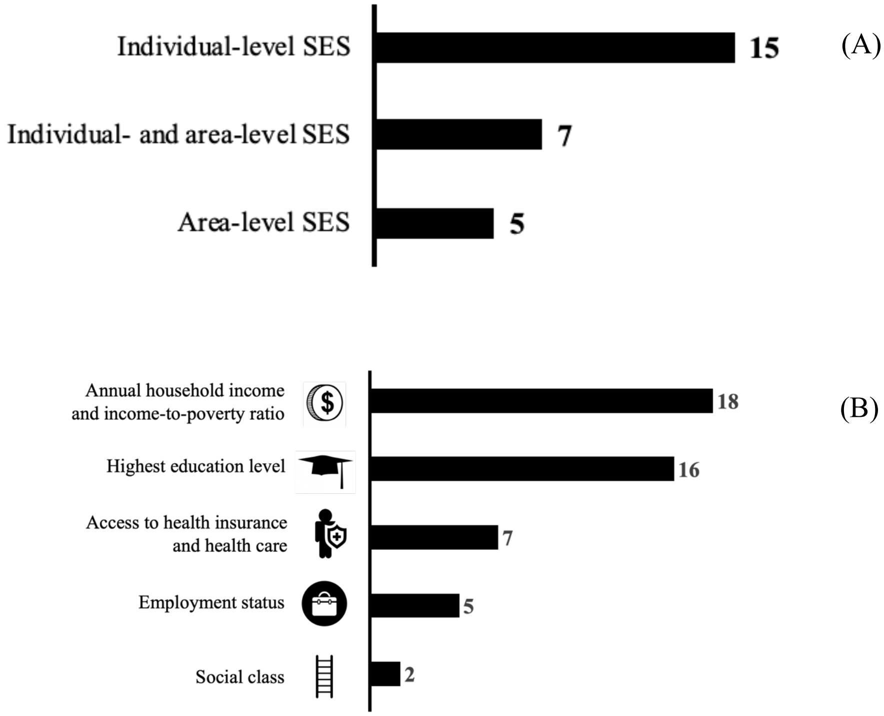


Figure **2.3**: Breakdowns of SES domains (A) and different indicators of individual-level SES (B)

Income. Income was the most common indicators of individual-level SES used among the articles, 11 of which specified it as annual household/family income. There were three different ways in which annual income was utilized in the analyses: a) as a continuous variable, b) as a categorical variable, and c) as a relative proportion to the federal poverty line or as an annual income to poverty ratio. There was a high level of heterogeneity in terms of the operationalization of annual income as a categorical variable. First, the number of categories vary, ranging from two (e.g., <50K vs. ≥50K) to six categories, with four as the most common number of categories. Second, there was a high degree of variability in terms of the reference group when utilizing categorical annual income. For example, among articles that utilized dichotomous annual income, Lipworth et al. (2012) used annual income lower than US$15K as the cutoff, while Murphy et al. (2020) used US$50K as the cutoff.

Among all articles that transformed annual income to an income-to-poverty ratio (IPR), a categorical variable was used instead of a continuous variable to reflect the grouping of individuals based on their relative income compared to the absolute standard of poverty line. However, the operationalization of IPR categorical variable vary across the studies, mainly due to the arbitrary of poverty line in the United States (Iceland, 2005). The number of IPR categories included two, three, and four categories. In addition, authors chose different cutoffs of IPR in their respective analyses. For example, Bruce et al. (2010) and Vart et al. (2020) used IPR of less than one to indicate a lower level of SES, while Crews et al. (2010) used an IPR less than 1.25. In a different study, Vart, Gansevoort, Crews, et al. (2015) categorized IPR into tertiles, in which an IPR less than or equal to 1.36 indicated lower level of SES. All the articles that utilized IPR mentioned that the IPR calculation was adjusted for family or household size and the year in which data were collected.

Education. Similar to income, education was also a commonly found individual-level SES indicator among the articles. In articles that utilized education to gauge individual-level SES, 12 used categorical variable of credential education level, such as no high school degree versus graduated from high school or higher, and 4 articles used the number of years of education completed. Among the articles that used the categorical variable of credential education level, there was variability in terms of the number of categories, ranging from two to five. Despite this heterogeneity, all the articles consistently used no high school diploma as the criterion for the lowest level of education.

Other Indicators of Individual-Level SES

In addition to income and education, other indicators of individual-level SES included access to and/or type of health insurance (see the section about the health care system), employment status, and occupation-based social class. Peralta et al. (2006) identified occupational social class based on Census Bureau occupation codes and divided them into white collar (e.g., professional, administrative, or sales), blue collar (e.g., craftsman, machine operator, or farming), and other (e.g., housewife). Shoham et al. (2007) followed a theory-based framework to identify occupational social class based on capital ownership, job control, and skill level and divided participants into working and non-working class.

Exploration on Area-Level SES

Among the reviewed articles, 12 included area-level SES. The majority of the articles that examined area-level SES utilized census-derived information based on ZIP codes. There was a high degree of variability in terms of neighborhood/areal-level information utilized and used in the analyses. A data-driven method to create an index score of area-level SES was the most often utilized approach to examine area-level SES. For example, Shoham et al. (2007) generated 15 indicators based on ZIP code, including median home value, mean income level, unemployment, number of people living per room, percent high school and college educated, percent professional, and percent home ownership. Principal component analysis (PCA) involving these indicators was then conducted to select indicators to calculate an area-level SES index. In this specific analysis, the area-level SES index was based on the summation of *z* scores which were based on four indicators, including household income, percent professional or managerial occupations, percent with at least a high school education, and mean home value. In another study by Ward (2008), PCA resulted in the identification of seven indicators to create area-level SES index: 1) median household income, 2) percent with income less than 200% poverty line, 3) median house value, 4) median monthly rent, 5) mean education level, 6) percent adults 25 and older with college degree, and 7) percent employed persons with a professional occupation. Finally, in an analysis by Merkin et al. (2005), PCA resulted in six indicators to construct an area-level SES index: 1) median household income, 2) median house value, 3) percent household with interest, dividend, or rental income, 4) percent adults 25 and older with a high school diploma, 5) percent adults 25 and older with a college degree, and 6) percent employed persons with a professional occupation.

Finally, a study by Hicken et al. (2019) used a different indicator of area-level SES, namely neighborhood problems and neighborhood social cohesion. Neighborhood problems was based on participants' reports of seven community problems: 1) lack of adequate food shopping in the neighborhood, 2) lack of parks or playgrounds in the neighborhood, 3) excessive noise in the neighborhood, 4) poor sidewalks in the neighborhood, 5) heavy traffic or speeding cars in the neighborhood, 6) trash and litter problems in the neighborhood, and 7) violence problems in the neighborhood. Neighborhood social cohesion indicated social capital in the community. In this particular study, it was measured based on participants' assessments of five indicators, including: 1) close knit neighborhood, 2) people in the neighborhood do not get along, 3) people willing to help their neighbors, 4) people in the neighborhood can be trusted, and 5) people in the neighborhood do not share the same values.

Focus on SES Across the Life Course

An article by Shoham et al. (2007) was the only analysis that included SES information across the life course. Individual-level SES, indicated by occupational social class, was collected at ages 30, 40, and 50. In addition, information regarding area-level SES employed a community SES index at ages 10, 30, 40, and 50.

Focus on Discrimination

The article by Nguyen et al. (2018) was the only article that included discrimination in their analysis. They utilized the Everyday Discrimination Scale developed by Williams et al. (1997) to assess daily discrimination. This scale included 9 items of daily instances of bias that are commonly experienced by individuals from minority backgrounds, including being treated with less respect than other people and being called names or insulted.

Focus on Migration and Health

Racial and ethnic groups found in the articles include Black (found in 26 articles), white (20), Hispanic (5), Native American (3), Asian and Pacific Islander/API (3), Mexican American (2), Chinese American (1), and Caribbean Black (1). In terms of racial and/or ethnic comparisons, almost half of the articles compared Black to white adults (13 articles). An analysis by Nguyen et al. (2018) is the only article that focused on migration and disparities in kidney outcomes. The article examined the interaction between the length of U.S. residency and the experience of discrimination on the risk of CKD.

Focus on Genetic Factors

The analysis by Peralta et al. (2006) was the only article that utilized genetic information. The article focused on contrasting the genetic African ancestry information and self-report of race on the risk of CKD. Genetic African ancestry was examined by genotyping 24 bi-allelic markers related to ancestry information to generate genetic estimate of each participant's ancestry. The study demonstrated that self-reported race (i.e., race as a social construct) was a better predictor of risk for CKD rather than the genetic African ancestry information (Peralta et al., 2006).

Unpacking Access to Health Care and the Health Care System

As mentioned earlier, some articles also utilized insurance access as an indicator of SES that specifically tapped into health care access. In those articles, some studies simply divided participants into those with and without access to health insurance. Other articles further differentiated participants with access to health insurance based on the type of the insurance, such as public (e.g., Medicaid) versus private health insurance. All studies that utilized information regarding employment status used a dichotomous variable to divide employed and unemployed participants. In addition, an article by Ward (2007a) utilized information regarding the pre-dialysis use of epoetin as a marker of health care access.

Multiple articles on disparities in hemodialysis focused on the area-level context of dialysis facilities. For example, Eisenstein et al. (2009) utilized multiple indicators related to dialysis facility characteristics including ownership type (non-profit vs. for-profit), median hemodialysis patients per clinic, median number of treatments per patient per week, availability of in-home dialysis service, total nurses, percent RN of total nursing staff, patient-to-nurse ratio, and patient-to-total-staff ratio. In a different study, Golestaneh et al. (2020) utilized census-derived information based on the ZIP code of the dialysis facility, focusing on the percentage of residents who self-identified as Black.

Focus on the Disease Process

Markers of Kidney Function and Kidney Disease

The most common marker of kidney function used in the analyses was estimated glomerular filtration rate (eGFR; n = 13). In the majority of the articles that used eGFR, it was assessed based on serum creatinine (n = 11) and few articles (n = 2) mentioned eGFR based on serum cystatin C. Furthermore, the majority of articles that used eGFR reported using the MDRD formula. Six articles reported urine-based markers of kidney function (5 articles used urine albumin and 1 used urine electrolytes). Among analyses involving ESRD patients, ESRD diagnosis was used as an indicator. Finally, 1 study utilized self-report of CKD as the outcome.

Kidney Disease Outcomes

The articles included in the review covered a broad range of outcomes across the continuum of CKD progression, covering the pre-CKD stage to post-transplantation and mortality (see Figure 2.4). The majority of the articles focused on examining the risk of CKD and ESRD (n = 16). The least represented stage was the pre-CKD stage (n = 1).

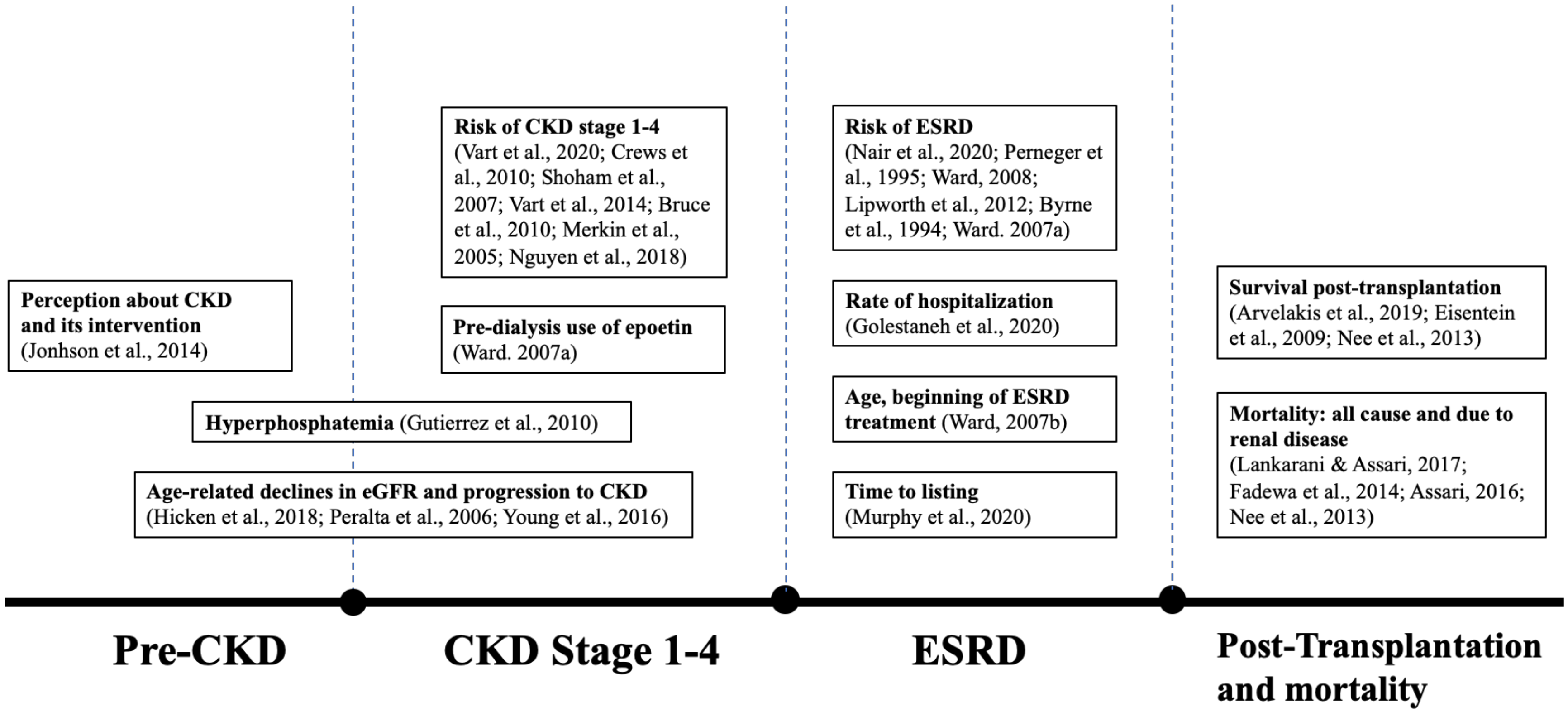


Figure **2.4**: Distribution of the articles across the continuum of kidney disease outcomes

Discussion

More than a decade ago, Williams et al. (2010) laid out research priorities to advance our understanding of the interplay between SES and race on creating health disparities. This systematic review examined the current state of the literature on the association between SES, race, and kidney disease across adulthood. The ultimate goal of this review was to assess research gaps in the understanding of socioeconomic and racial disparities in kidney disease by comparing empirical studies on this topic to the points of research priorities raised by Williams et al. (2010). In this review, 27 studies met the inclusion criteria, in which articles must focus on the spectrum of kidney disease in adulthood, SES and race were the primary predictors, and the analysis must focus on the U.S. context.

There have been growing interests on the examination of how SES and race link to disparities in kidney disease during adulthood. The challenges of persistent socioeconomic and racial disparities in CKD and ESRD in the U.S. have led to mounting attention from researchers, policy makers, and public health practitioners on trying to address these problems. For example, Healthy People 2020 marked the inclusion of kidney disease-specific goals for the first time. In this review, the mounting interests in this topic is clearly depicted by the increasing number of publications over the past two decades. One factor that potentially contributes to this growth is the increasing number of cohort-based studies involving adults from diverse racial backgrounds as well as markers of kidney function. For example, the National Health and Nutrition Examination Survey (NHANES), a national study involving the U.S. civilian population conducted by the National Center for Health Statistics, has included measures of kidney function since NHANES III (1988-1994).

Unpacking Social Context

The major recommendation from Williams et al. (2010) was to move beyond strictly using income and education in order comprehensively unpack the social context regarding socioeconomic and racial disparities in health. While education is a reliable and convenient measure of SES, it has different meaning across different racial groups. For example, Black adults with similar levels of education to their white counterpart earn lower income and accumulate less wealth (Williams & Mohammed, 2009). Thus, relying solely on education may not be able to capture the socioeconomic context that leads to racial disparities in kidney disease. In this review, some articles included novel theory-driven SES measures. For example, Shoham et al. (2007) utilized the method developed by Wright (2005) to examine social class based on three dimensions, including ownership, control, and skill level. In addition, despite the increasing utilization of subjective SES in public health and health disparities research (Operario et al., 2004; Zell et al., 2018), none of the articles reviewed included subjective SES in their analysis.

Multiple articles followed the recommendation to examine area-level SES and its association with kidney disease. Some articles combined both individual-level SES and area-level SES, tapping into the multilevel influence of SES on kidney disease (Patzer & McClellan, 2012). Inclusion of area-based SES on the study of socioeconomic and racial disparities in kidney disease is critical, especially to capture the context of segregation as a result of racist policy in the United States (Rothstein, 2017; Williams et al., 2010). Some studies in this review utilized measures that tapped into the idea of segregation and how it may link to disparities in kidney outcomes. For example, Golestaneh et al. (2020) used information regarding racial composition of the area where hemodialysis facilities were located. Furthermore, Williams et al. (2010) mentioned that in order to examine the detrimental impact of segregation on health, it should also be a priority to systematically assess conditions under which segregation may have positive effects on health. In their analysis, Hicken et al. (2019) examined both neighborhood problems and neighborhood cohesion to comprehend both area-level strain and resources.

In 2005, Shoham et al. (2005) made a case for the need to incorporate the life course framework to better understand socioeconomic disparities in health. In a more recent review, Patzer and McClellan (2012) also recommended the examination of exposure to socioeconomic advantage and disadvantage across the life course to better understand racial disparities in kidney disease. The need to incorporate life course SES in the study of health disparities in CKD is motivated by the well-documented evidence that early life is a critical period for kidney disease in adulthood (Kett & Denton, 2010; Luyckx & Brenner, 2010) and the mounting knowledge regarding the accumulation of risks and resources across the life course (Ben-Shlomo & Kuh, 2002). However, only one article in this review incorporated the life course framework in their analysis. I believe this is a major gap in the field and it should be a priority to incorporate the life course framework in future investigations of disparities in kidney disease.

Other Important Gaps

Based on this reviews, other noticeable gaps include the lack of focus on migration and health, the interaction between genetics and environment, and the lack of focus on exploring psychosocial factors linked to disease development and progression. The article by Nguyen et al. (2018) set a good example on tapping into the complexity of the migration experience through the lens of discrimination and its impact on the risk of kidney disease. Future studies should also examine social and environmental resources and risk factors among immigrant populations, including stressors and strain associated with adaptation, cultural values, and family ties. Furthermore, future studies should also focus on assessing the role of epigenetics and the interaction between genetic and environmental factors that may contribute to socioeconomic and racial disparities in kidney disease. The growing knowledge regarding the link between epigenetics and disease programming in early life may inform research on socioeconomic and racial disparities in health (Nistala et al., 2011). Finally, the exploration regarding the role of psychosocial factors linked to the development and progression of kidney disease is still in the early stages of its development. Future studies should systematically examine important psychosocial factors that contribute to CKD advancement. Bruce et al. (2015), for example, introduced a framework of how psychosocial stress can have an impact on the development and progression of kidney disease.

Conclusion

Eliminating SES and racial disparities in CKD is an integral part of the ultimate goal to reducing the burden of CKD in the United States. The growing numbers of empirical studies that examined socioeconomic and racial disparities in adult kidney disease in the past three decades have certainly advanced our understanding on the intersectionality between SES and race on creating disparities in CKD. However, more works are needed, especially to fully unpack the multilevel (across ecological contexts and across the life course) and multidimensional (involving biological, psychological, and social dimensions) nature of social context associated with SES and race that relevant to the development and progression of CKD. These massive works would certainly require cross-field collaborations to tackle the complexity of how SES and race create disparities in CKD.

Chapter 3

Life Course Pathways from Parental Education to Age-Related Decrements in Kidney Function among Black and white American Adults

Introduction

Early life is a critical period for kidney development with long-term implications for kidney health and functioning in adulthood (Kett & Denton, 2010). Nephrogenesis occurs primarily between 9-36 weeks of gestation (Rosenblum et al., 2017) and it takes up to two years for kidneys to be functionally mature postnatally (Kett & Denton, 2010). Kidney programming during this period, especially through lower nephron endowment (the kidney's functional unit), is recognized as the developmental antecedent of several chronic conditions in adulthood, including chronic kidney disease (CKD), a major public health concern in the United States and worldwide (Kett & Denton, 2010). Furthermore, abnormal programming of kidney regulation and structure in early life is associated with adverse birth outcomes, including preterm birth and low birth weight (Gurusinghe et al., 2017). Adverse birth outcomes are profoundly influenced by social factors, especially SES, making kidney function important to consider as a possible mediator on the path to adult health disparities. Parental education level, an indicator of familial SES during fetal development and childhood is linked to lower nutrient intake, higher exposure to environmental toxicants, more psychological stressors, and reduced access to high quality parental care, all factors known to increase the likelihood of adverse birth outcomes and compromises in child development (Aizer & Currie, 2014).

The Multi-Hit Model of Disparities in Kidney Function Across Adulthood

Figure 3.1.A illustrates the multi-hit etiological model of disparities in adult kidney functioning, which could increase the likelihood of progressing to CKD (Nahas, 2010): 1) early life programming of kidney structure and regulation, 2) age-related changes in kidney structure and functioning, and 3) occurrence of other health-related risk factors, including obesity, hypertension, and diabetes that may accelerate renal dysfunction and senescence. Specifically, exposure to a number of factors associated with being raised in lower SES families can be the first risk that increases the likelihood of exposure to a second hit later in adulthood. Lower nephron endowment at birth can contribute to compensatory hyperfiltration in adulthood and a dysregulation of the renin-angiotensin-aldosterone system (RAAS), which has been recognized as one of the paths to hypertension in adulthood (Dötsch et al., 2012; Singh & Denton, 2015). Furthermore, low birth weight in a premature or small-for-gestational age infant that is followed by catch-up growth increases the probability of obesity, metabolic syndrome, and type 2 diabetes (Desai et al., 2013). Thus, exposure to early and later risk factors can accentuate the normal kidney aging process, which increases the chance of developing CKD (Surachman, Daw, et al., 2020; Vart, Gansevoort, Crews, et al., 2015).

Questions remain, however, regarding the specific ways that SES contributes to the known disparities in kidney health and how exposure to risk factors in childhood summate with other social factors and poor health in adulthood. The life course framework indicates that socioeconomic inequalities in early life, even small ones, may accumulate and engender greater risk in adulthood (Dannefer, 2020). The accumulation of socioeconomic (dis)advantage reflects a chain of risk associated with SES across the life course (Ben-Shlomo & Kuh, 2002). Parental education level captures early childhood SES context, as it is associated with the ability to generate and provide material and psychosocial resources associated with children's optimal development (Evans, 2004; Ross & Mirowsky, 2011). Furthermore, lower parental education has also been linked to lower educational attainment and income among children, initiating a path to transgenerational influences (Dannefer, 2020). This transmission and funneling of risk over time has become accentuated in the United States as the avenues for upper mobility have become more limited (Chetty et al., 2014). Thus, in addition to direct effects on the kidney that may already be initiated during the prenatal period, parental education level may influence the propensity for obesity and unhealthy diets, contributing to the chance of poor kidney functioning in adulthood. In addition, kidney health and disease in adulthood have been directly linked to other health conditions, including hypertension and diabetes (Surachman, Daw, et al., 2020; Vart, Gansevoort, Joosten, et al., 2015).

Are SES Disparities in Kidney Disease Conditional on Race?

There is well-established evidence of Black-white racial disparities in the three factors of the multi-hit model. First, adverse birth outcomes, especially premature births, continue to be more common among Black women (Fang et al., 1999; Gage et al., 2013). Second, there is clear evidence of racial disparities in kidney functioning across adulthood (Costello-White et al., 2015; Peralta et al., 2011). While kidney function will continuously decline in all adults (Weinstein & Anderson, 2010), longitudinal studies show faster age-related decreases in kidney function among Black relative to white adults (Peralta et al., 2011; Peralta et al., 2013). In addition to a higher chance of developing CKD (Peralta et al., 2011), declining kidney function is associated with increased cardiovascular disease (Shlipak et al., 2009) and overall mortality (Rifkin et al., 2008). Using cross-sectional data, Costello-White et al. (2015) found racial differences in estimated glomerular filtration rate (eGFR), a proxy of kidney function, when comparing Black Americans, white Americans, and Japanese adults, which were particularly pronounced when focusing on clearance patterns in the middle-aged adults. The younger Black adults were more likely to show signs of renal hyperfiltration (RHF), which has been associated with fatty liver disease, hypertension and diabetes (Kanbay et al., 2019). Individuals with RHF tend to show earlier age-related decline in renal clearance, and a faster progression to later stages of CKD (Low et al., 2018). Third, there is well-established evidence for many other Black-white racial disparities in health-related risk factors in adulthood that contribute to the development of CKD, including obesity (Wang & Beydoun, 2007), hypertension (Musemwa & Gadegbeku, 2017), and diabetes (Gaskin et al., 2014).

The racial disparities observed between Black and white individuals in the three factors in the multi-hit model mentioned above provide support for the *weathering* hypothesis (Geronimus et al., 2006). According to this hypothesis, Black individuals may tend to show an early health deterioration due to more frequent exposure to social and environmental stressors across their life course (Geronimus et al., 2006). An earlier health deterioration among Black women is one of the main contributors to Black-white racial disparities in adverse birth outcomes (Geronimus, 1996), in addition to more limited access to high quality prenatal care. Furthermore, the higher prevalence of RHF among Black adults can be viewed as part of adaptive response to early renal deterioration (e.g., nephron loss) due to hypertension, which will also activate maladaptive renal and hemodynamic response that will ultimately contribute to progressive declines in kidney function and CKD (Helal et al., 2012).

Systemic racism is a fundamental cause of the racial disparities in health between Black and white adults (Phelan & Link, 2015). There are at least two different pathways in which societal racism creates racial disparities in health: through racial differences in income, education and social status across the life course and through racial disparities in non-SES related factors (Phelan & Link, 2015; Surachman et al., 2021). The pervasive historical inequality in socioeconomic opportunities due to structural barriers driven by racism continues to cause SES inequalities between Black and white individuals, including differences in educational attainment (Phelan & Link, 2015; Williams et al., 2019). However, race is not a simple proxy of SES, indicating that racial disparities in health cannot be fully explained by SES and both factors can independently influence health (Kawachi et al., 2005). There are also non-SES related factors that contribute to racial disparities in health, including discrimination and stigmatization (Phelan & Link, 2015). A study by Cobb et al. (2020) showed that daily experiences of discrimination, which are more common among Black adults, were associated with a higher risk of CKD, independent of SES. Thus, when considering the association between parental education and race on age-related decrements in kidney function, it would follow the additive (both parental education and race are independently linked to the age-related decrements in kidney function), but not necessarily an interactive pattern (i.e., the impact of parental education on kidney function appears to be conditional on race).

Finally, we anticipated that there could be Black-white differences with respect to the life course pathway from parental education to kidney functioning in adulthood. Relative to white adults, Black adults have been constrained from achieving positions that provide higher income and thereby blocked from accumulating wealth across generations, even when able to attain similar levels of education (Williams & Sternthal, 2010). Furthermore, according to the *diminishing return hypothesis*, even when achieving higher SES, Black adults often do not enjoy the health benefits experienced by white adults (Williams et al., 2010). Multiple studies have provided support for the Diminishing Return hypothesis when examining the link between SES, race, and multiple health outcomes, including inflammatory physiology (Surachman et al., 2021; Surachman, Rice, et al., 2020) and blood pressure (Assari, 2019). However, a systematic consideration of how parental education level contributes to the influence on early rearing conditions on later kidney health among Black and white adults has not been considered previously.

The Current Study

In summary, the regulation and functioning of the adult kidney may be traced back to earlier life events and linked to the socioeconomic environment during childhood. Using cross-sectional data from young and older adults, this analysis tested three hypotheses related to the influence of parental education on the age-related decrements in eGFR, a marker of renal clearance, and the life course pathways from parental education to age-related decrements in adult kidney function:

H1: Lower parental education would be associated with less healthy profiles of kidney function, especially reflected by renal hyperfiltration in middle-aged adults (Figure 3.1.B).

H2: Both parental education and race would be associated with age-related decrements in kidney function. However, the association between parental education and age-related decrements in kidney function across adulthood may not be conditional on race.

H3: The association between parental education and age-related decrements in kidney function in adulthood would be mediated by the participants' current SES and health-related risk factors, which include obesity, hypertension, and type 2 diabetes. However, the exact pathways could be different between Black and white adults due to well-established evidence of diminishing returns when considering the beneficial links between SES and health among Black adults.

This analysis adds to new knowledge about the developmental origins and life course pathways contributing to the progression to kidney disease in adulthood.

(A)

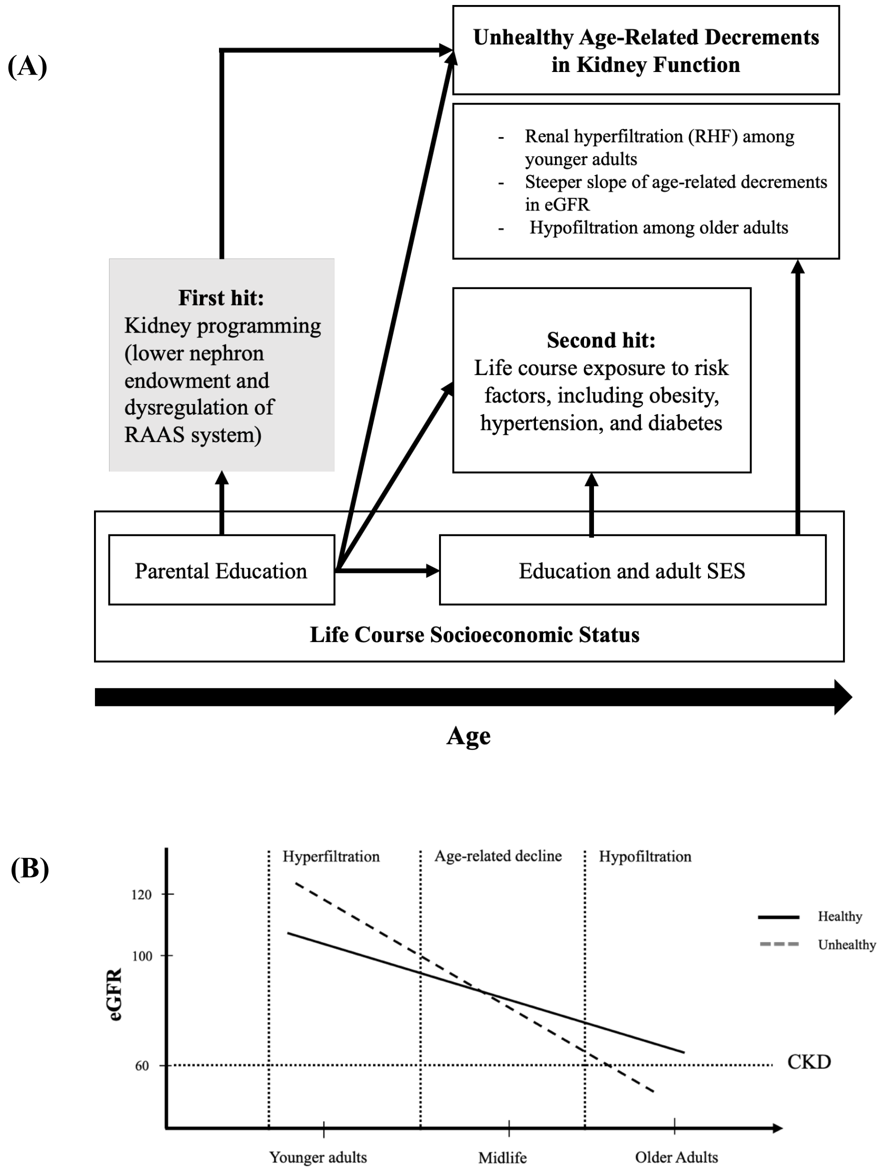


Figure **3.1**: A life course model of risk from parental education to age-related declines in kidney function through contemporaneous adult SES and health factors. Variables in the white boxes were included in the current analysis (A). Unhealthy age-related profiles of kidney function across adulthood are characterized by elevated eGFR among younger adults followed by a steeper decline clearance rates that can progress to Stages 3-5 chronic kidney disease (CKD) among older adults (B)

Methods

Participants and Procedures

Data from Midlife in the United States (MIDUS), a national study examining factors associated with age-related changes in health and well-being across the adult life course, were used to evaluate racial differences in the eGFR of middle-aged and older adults (Brim et al., 2019). MIDUS began in 1995-1996 (MIDUS 1) and included 7108 English-speaking adults (ages 25-74) from the continental United States, recruited through random digit dialing (RDD). Approximately a decade later (2004-2005), a longitudinal follow up was conducted (MIDUS 2) and included 4963 longitudinal participants (70% longitudinal retention rate; 75% mortality-adjusted retention rate). Similar to the protocol in MIDUS 1, participants in MIDUS 2 were contacted first by phone for a baseline interview and then asked to complete self-administered questionnaires by mail (SAQs; response rate = 81%).

To increase the minority representation among MIDUS 2 participants, a supplemental sample consisting mostly of Black adults was recruited from Milwaukee County, WI during 2005-2006. The Milwaukee Oversample included 592 adults (ages 35-85; 70.7% response rate) who completed in-person baseline interviews, and the majority also completed the SAQs (SAQ response rate = 67.2%). In addition, new biomarker assessments were introduced in MIDUS 2, (Biomarker Project). Biological indicators of health were assessed including serum creatinine which provided an indicator of kidney function. The MIDUS 2 Biomarker Project (2004-2009) included 1255 participants from the national sample and Milwaukee Oversample who had completed both baseline interviews and the SAQs.

In 2011-2014, additional participants were recruited through RDD to participate in the MIDUS Refresher study (MIDUS R). The main goal was to broaden the age range, in particular to increase the number of younger participants now that the original MIDUS participants had gotten older. Recruitment was designed to reflect sociodemographic characteristics of MIDUS 1 samples (Kirsch & Ryff, 2016; Surachman et al., 2019). MIDUS R included 3577 adults (response rate 59%; ages 25-74) who completed baseline phone interviews. Similar to MIDUS 2, participants in MIDUS R were then asked to complete SAQs by mail (response rate = 73%). With the same goal of achieving more racial diversity, an additional sample consisting mostly of Black adults was recruited from Milwaukee County, WI (MIDUS R Oversample 2012-2013). It included 508 adults (response rate = 47.7%; ages 25-64) who completed in-person interviews, and the majority also completed SAQs (58.9%). Finally, biomarkers were also assessed in MIDUS R during 2012-2016. The MIDUS R Biomarker Project included 863 participants selected from the national sample and Milwaukee Oversample of MIDUS R who completed the baseline interview and SAQs.

Biomarker Assessment Protocol

Participants in both MIDUS 2 and MIDUS R Biomarker Projects stayed overnight at one of the three clinical research units (CRUs) located either in Madison, WI, Washington DC, or Los Angeles, CA. The CRU site for each participant was based on the one that imposed the least travel burden. Fasted blood samples to determine serum creatinine levels were collected on the morning of the second day before participants had breakfast. Blood samples were collected by trained phlebotomists, spun in refrigerated centrifuges, and frozen sera stored in ultracold freezers until analyzed using standardized procedures (Weinstein et al., 2018). All serum creatinine tests were conducted with a colorimetric assay in the same CLIA clinical laboratory (Unity Meriter Labs, Madison, WI).

Analytic Sample

More detailed information on the participant selection process is presented in Figure 3.2. In brief, the analytic sample included participants who completed the Biomarker Projects of MIDUS 2 and MIDUS R. Out of a potential pool of 2118 participants (MIDUS 2 = 1255, MIDUS R = 863), 1930 were selected who self-identified as non-Hispanic Black (*n* = 369) and non-Hispanic white (*n* = 1561). Participants with missing information for either serum creatinine (*n* = 20) or parental education (*n* = 49) were excluded. The final sample included 1861 adults (non-Hispanic Black adults = 326, non-Hispanic white adults = 1535).

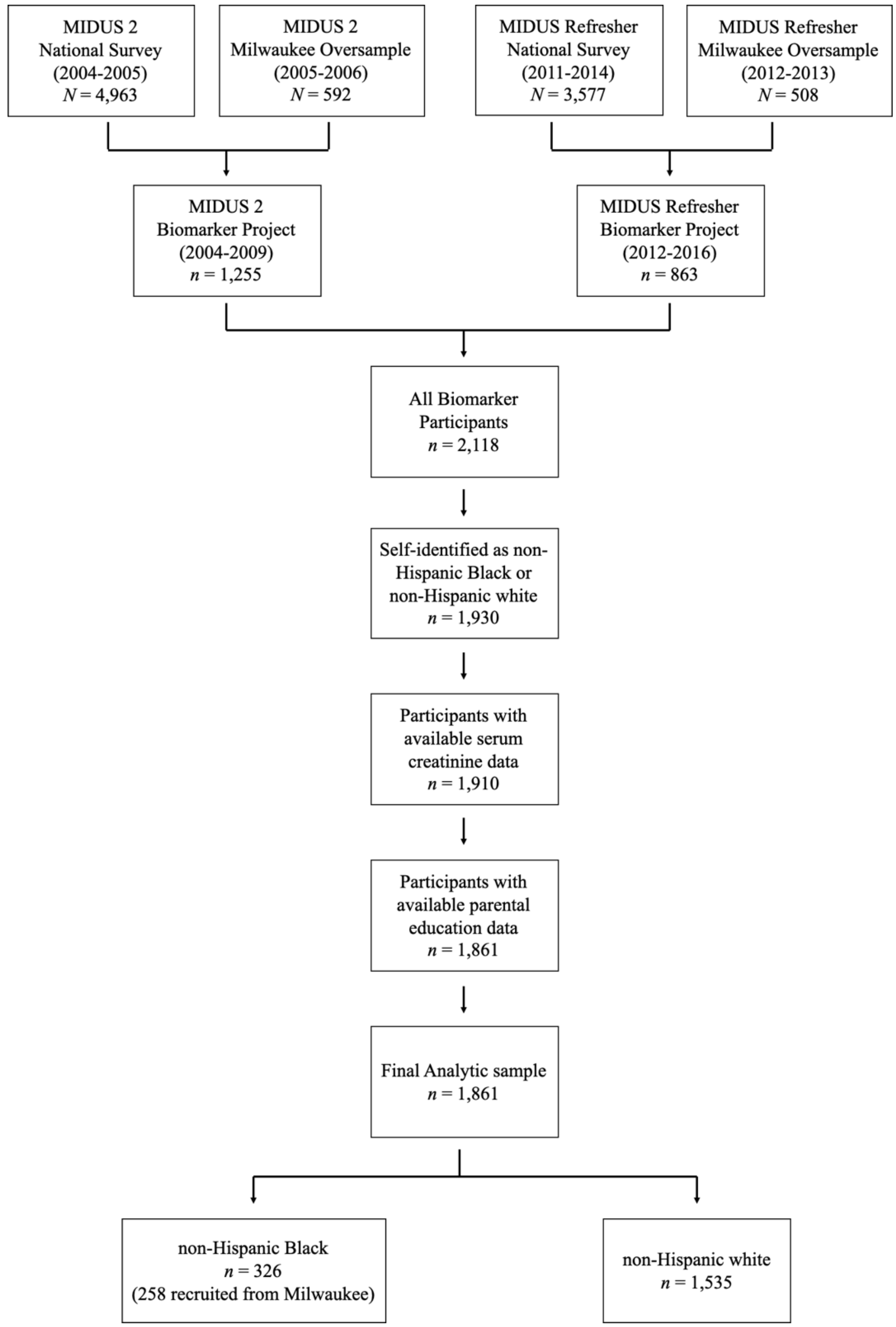


Figure **3.2**: Flow chart indicating the selection process for inclusion of the analytic sample (MIDUS = Midlife in the United States)

Measures

Parental Education

As part of the baseline interview, participants reported the highest level of formal education of their father or male household head and their mother or female household head. Educational attainment was scored on a 12-point scale (1=no school/some grade school [1-6 years]; 6=1 to 2 years of college, no degree yet; 12=Ph.D., Ed.D., MD etc.). If information on the father's highest level of education level was not available, the mother's or female household head's highest level of education was substituted. In the cases when both father's and mother's education levels were available, only father's education level was used. Parental education was then categorized as a binary variable: no high school/GED degree (coded as 0) and graduated from high school/GED or higher (coded as 1).

Current Socioeconomic Status

Current SES was a composite score (0-10) based on five indicators (Surachman, Daw, et al., 2020): (1) participant's educational attainment (graduated from high school/GED=0, some college=1, bachelor's degree or higher=2); (2) household size-adjusted household income-to-poverty ratio (<150%=0; ≥150%, <300%=1; ≥300%=2); (3) perception of current financial status (low=0; medium=1; high=2); (4) perception of the availability of sufficient money to meet needs (not enough=0; enough=1; more money=2); and (5) perception of hardship with respect to paying bills (difficult=0; not very difficult=1; not at all difficult=2).

Health-Related Risk Factors

Health-related risk factors included several indicators associated with worse kidney function. These factors included: 1) obesity (BMI≥30 kg/m^2=1, otherwise coded as 0); 2) hypertension (systolic and diastolic BP≥140/90 or self-report of diagnosis of hypertension by physician=1, otherwise coded as 0); and 3) insulin resistance (HbA1c≥6.5% or fasting blood glucose≥126 mg/dL or self-reported diagnosis of type 2 diabetes by a physician=1, otherwise coded as 0).

Age

Participants reported their birth dates during the Biomarker Project. Thus, each participant's age (years) was based on age at the time of blood sample collection.

Kidney Function

Estimated glomerular filtration rate (eGFR) was calculated from serum creatinine using the CKD-EPI formula (Levey & Stevens, 2010). The CKD-EPI formula takes age, sex, and race into consideration when calculating eGFR. Serum creatinine was assayed from overnight fasted blood collected during the Biomarker Project using Roche Cobas Analyzer (Unity Meriter Lab, Madison, WI). The assay range was 0.06-30.5 mg/dL, with an inter-assay CV of 2.08%. across the 2 phases of MIDUS.

Covariates

As indicated by Bolignano et al. (2014), sex is an important factor to consider when evaluating the aging kidney. We included sex (0 = female, 1 = male) as a covariate in the analysis. In addition, study cohort (0 = MIDUS Refresher, 1 = MIDUS 2) was also included as a covariate in the analysis.

Statistical Analysis

Multiple linear regression and regression-based moderated mediation analyses were utilized to examine the main hypotheses. eGFR was first regressed on age. The inverse association between age and eGFR indicative of the normal age-related decrement in eGFR was characterized by higher eGFR among younger participants and a lower eGFR in older participants. To examine the potential influence of parental education, parental education as a binary variable (HS=0, HS/higher=1) and its interactions with age were entered into the model predicting eGFR (Model 1), controlling for sex and 2 MIDUS phases (MIDUS 2 = 1, MIDUS Refresher = 0). A significant interaction between age and parental education would indicate that age-related decrements in eGFR were influenced by parental education. Further, the possibility of a three-way interaction between age, parental education, and race was tested (Model 2). A significant three-way interaction would indicate that the influence of parental education on age-related decrements in eGFR was conditional on race. To examine possible mediation by current SES and health-related risk factors, we included current SES (score) and each of the health-related risk factors (as a binary variable) and their interactions with age into the model (Model 3).

Regression-based moderated mediation analysis was utilized to examine life course pathways from parental education to the age-related decrements in eGFR among Black and white participants. The hypothesized moderated mediation model is presented in Figure 3.3.

(A)

(B)

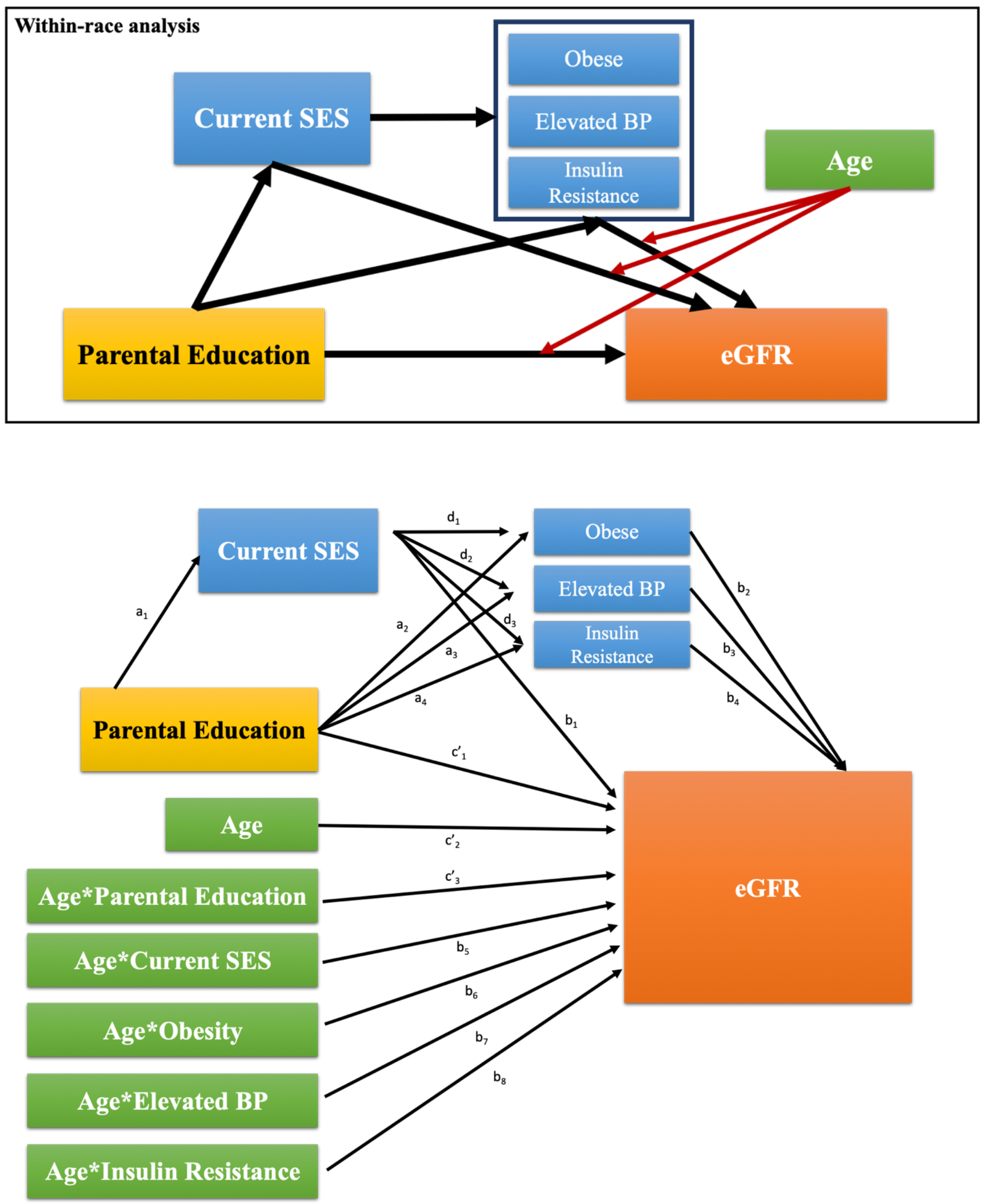


Figure **3.3**: The hypothesized moderated mediation model (A) and the breakdown of all the regression paths in the hypothesized model (B)

As seen in Figure 3.3.B, eGFR was regressed on age, parental education, current SES, obesity, elevated BP, and insulin resistance. In addition, age was also moderating the prediction of eGFR by parental education, current SES, obesity, elevated BP, and insulin resistance. Thus, the regression formula predicting kidney function can be written as follows:

$$eGFR_j = b_0 + b_1 Current\ SES_j + b_2 Obese_j + b_3 Elevated\ BP_j + b_4 Insulin\ Resistance_j + b_5 Age_j * Current\ SES_j + + b_6 Age_j * Obese_j + b_7 Age_j * Elevated\ BP_j + b_8 Age_j * Insulin\ Resistance_j + c'_1 Parental\ Educ_j + c'_2 Age_j + c'_3 Age_j * Parental\ Educ_j + e_j$$ (**Equation 1**)

where b_o was the regression intercept, and b_i represents the slope for each predictor on predicting eGFR. Furthermore, current SES, obesity, elevated BP, and insulin resistance were regressed on parental education. In addition, obesity, elevated BP, and insulin resistance were regressed on current SES. The regression formulas predicting current SES, obese, elevated BP, and insulin resistance were:

$$Current\ SES_j = a_{01} + a_1 Parental\ Educ_j + e_j$$ (**Equation 2**)
$$Obese_j = a_{02} + a_2 Parental\ Educ_j + d_1 Current\ SES_j + e_j$$ (**Equation 3**)
$$Elevated\ BP_j = a_{03} + a_3 Parental\ Educ_j + d_2 Current\ SES_j + e_j$$ (**Equation 4**)
$$Insulin\ Resist_j = a_{04} + a_4 Parental\ Educ_j + d_3 Current\ SES_j + e_j$$ (**Equation 5**)

where a_{oi} was the intercepts for each respective model, and a_i represents the slope for the association between parental education and current SES, obese, elevated BP, and insulin resistance. Finally, d_i represents the slope for the association between current SES and health-related risk factors. Next, we substituted current SES, obese, elevated BP, and insulin resistance in **Equation 1** with **Equation 2**, **3**, **4**, and **5** respectively:

$$eGFR_j = b_0 + b_1(a_{01} + a_1 Parental\ Educ_j) + b_2\left(a_{02} + a_2 Parental\ Educ_j + d_1(a_{01} + a_1 Parental\ Educ_j)\right) + b_3\left(a_{03} + a_3 Parental\ Educ_j + d_2(a_{01} + a_1 Parental\ Educ_j)\right) + b_4\left(a_{04} + a_4 Parental\ Educ_j + d_3(a_{01} + a_1 Parental\ Educ_j)\right) + b_5 Age_j(a_{01} + a_1 Parental\ Educ_j) + b_6 Age_j\left(a_{02} + a_2 Parental\ Educ_j + d_1(a_{01} + a_1 Parental\ Educ_j)\right) + b_7 Age_j\left(a_{03} + a_3 Parental\ Educ_j +\right.$$

$d_2(a_{01} + a_1 Parental\ Educ_j)\Big) + b_8 Age_j \Big(a_{04} + a_4 Parental\ Educ_j + d_3(a_{01} + a_1 Parental\ Educ_j)\Big) + c'_1 Parental\ Educ_j + c'_2 Age_j + c'_3 Age_j * Parental\ Educ_j + e_j$
(**Equation 6**)

Furthermore, **Equation 6** can be transformed into the following equation:

$eGFR_j = b_0 + a_{01}b_1 + a_1b_1 Parental\ Educ_j + a_{02}b_2 + a_2b_2 Parental\ Educ_j + a_{01}b_2d_1 + a_1b_2d_1 Parental\ Educ_j + a_{03}b_3 + a_3b_3 Parental\ Educ_j + a_{01}b_3d_2 + a_1b_3d_2 Parental\ Educ_j + a_{04}b_4 + a_4b_4 Parental\ Educ_j + a_{01}b_4d_3 + a_1b_4d_3 Parental\ Educ_j + a_{01}b_5 Age_j + a_1b_5 Age_j * Parental\ Educ_j + a_{02}b_6 Age_j + a_2b_6 Age_j * Parental\ Educ_j + a_{01}d_1b_6 Age_j + a_1d_1b_6 Age_j * Parental\ Educ_j + a_{03}b_7 Age_j + a_3b_7 Age_j * Parental\ Educ_j + a_{01}d_2b_7 Age_j + a_1d_2b_7 Age_j * Parental\ Educ_j + a_{04}b_8 Age_j + a_4b_8 Age_j * Parental\ Educ_j + a_{01}d_3b_8 Age_j + a_1d_3b_8 Age_j * Parental\ Educ_j + c'_1 Parental\ Educ_j + c'_2 Age_j + c'_3 Age_j * Parental\ Educ_j + e_j$ (**Equation 7**)

In turn, **Equation 7** can be simplified into the form of parental education predicting eGFR ($eGFR_j = b_0 + b_1 CSES_j$):

$eGFR_j = (b_0 + a_{01}b_1 + a_{02}b_2 + a_{01}b_2d_1 + a_{03}b_3 + a_{01}b_3d_2 + a_{04}b_4 + a_{01}b_4d_3 + a_{01}b_5 Age_j + a_{02}b_6 Age_j + a_{01}d_1b_6 + a_{03}b_7 Age_j + a_{01}d_2b_7 + a_{04}b_8 Age_j + a_{01}d_3b_8 + c'_2 Age_j) + (a_1b_1 + a_2b_2 + a_1b_2d_1 + a_3b_3 + a_1b_3d_2 + a_4b_4 + a_1b_4d_3 + a_1b_5 Age_j + a_2b_6 Age_j + a_1d_1b_6 Age_j + a_3b_7 Age_j + a_1d_2b_7 Age_j + a_4b_8 Age_j + a_1d_3b_8 Age_j + c'_1 + c'_3 Age_j) CSES_j + e_j$ (**Equation 8**)

Based on **Equation 8**, there was one direct effect from childhood SES on kidney function, conditional on age:

$$Direct\ effect = (c'_1 + c'_3 Age_j) Parental\ Educ_j$$

In addition, there were seven indirect effects, conditional on age. The first conditional indirect effect was through current SES (Parental education → current SES → eGFR, conditional on age):

$$Indirect\ Effect_1 = (a_1b_1 + a_1b_5 Age_j) Parental\ Educ_j$$

The second indirect effect was through obese (Parental education → obese → eGFR, conditional on age):

$$Indirect\ Effect_2 = (a_2b_2 + a_2b_6Age_j)Parental\ Educ_j$$

The third indirect effect was through elevated BP (Parental education → elevated BP → eGFR, conditional on age):

$$Indirect\ Effect_3 = (a_3b_3 + a_3b_7Age_j)Parental\ Educ_j$$

The fourth indirect effect was through insulin resistance (Parental education → insulin resistance → eGFR, conditional on age):

$$Indirect\ Effect_4 = (a_4b_4 + a_4b_8Age_j)Parental\ Educ_j$$

The fifth indirect effect was through current SES and obese (Parental education → current SES → obese → eGFR, conditional on age):

$$Indirect\ Effect_5 = (a_1d_1b_2 + a_1d_1b_6Age_j)Parental\ Educ_j$$

The sixth indirect effect was through current SES and elevated BP (Parental education → current SES → elevated BP → eGFR, conditional on age):

$$Indirect\ Effect_6 = (a_1d_2b_3 + a_1d_2b_7Age_j)Parental\ Educ_j$$

The seventh indirect effect was through current SES and insulin resistance (Parental education → current SES → insulin resistance → eGFR, conditional on age):

$$Indirect\ Effect_6 = (a_1d_3b_4 + a_1d_3b_8Age_j)Parental\ Educ_j$$

Conditional direct and indirect effects were tested by dividing age into three different groups, younger (age = –1 *SD*), middle (age = mean age), and older (age = +1 *SD*). The statistical significance of these indirect effects was tested using bootstrapping procedures. Unstandardized indirect effects were computed for each of 10,000 bootstrapped samples, and the 95% confidence intervals were calculated by determining the indirect effects at the 2.5th and 97.5th percentiles. The mediated moderation analysis was conducted in M*plus* version 8.1.

Results

Table 3.1 provides a descriptive summary on the sociodemographic and health characteristics of the participants. Black participants were younger, more likely to have parents without a high school degree, less likely to have attended college, and reported being in a lower SES category currently. A higher percent of the Black participants had a larger BMI indicative of obesity, and had high blood pressure, and/or met criteria for type 2 diabetes compared to their white counterparts. Finally, Black adults had significantly a higher mean eGFR level (M = 101.8 mL/min/1.73 m^2, SD = 23.4) when compared to white participants (M = 88.7, SD 17.1). The difference in mean eGFR was driven by the higher values in younger adults, which were indicative of renal hyperfiltration (Figure 3.4.A). In addition, younger participants raised by families with lower parental education had a significantly higher mean eGFR compared to younger participants who reported childhood backgrounds in families with higher parental education (Figure 3.4.B). Zero-order correlations between variable of interests (across all participants and within each racial group) are presented in Appendix B.

Table **3.1**: Sociodemographic and health characteristics of the Black (*n* = 326) and white (*n* = 1535) participants in the analytic sample (*N* = 1861)

	Black adults	White adults	*P* value [a]
Age, *M* (*SD*)	49.1 (11.6)	54.3 (12.5)	< .001
< 50, *n* (%)	167 (51.2)	577 (37.6)	
50-64, *n* (%)	131 (40.2)	605 (39.4)	< .001
≥ 65, *n* (%)	28 (8.6)	353 (23.0)	
Female, *n* (%)	223 (68.4)	791 (51.5)	< .001
Parents without high school degree, *n* (%)	153 (46.9)	467 (30.4)	< .001
Current SES, score, *M* (*SD*)	3.65 (2.62)	6.25 (0.07)	< .001
Participants without college education, *n* (%)	123 (37.7)	297 (19.3)	< .001
Household income-to-poverty ratio < 150%, *n* (%)	108 (33.1)	150 (9.8)	< .001
Lower current financial status, *n* (%)	193 (59.2)	435 (28.3)	< .001
Not enough money to meet needs, *n* (%)	175 (53.7)	289 (18.8)	< .001
Hard to pay bills, *n* (%)	198 (60.7)	421 (17.4)	< .001
Health-related risk factors			
Obese, *n* (%)	197 (60.4)	596 (38.8)	< .001
Elevated BP, *n* (%)	199 (61.0)	752 (49.0)	< .001
Insulin resistance, *n* (%)	107 (32.8)	229 (14.9)	< .001
eGFR, mL/min/1.73 m^2, *M* (*SD*)	101.8 (23.4)	88.7 (17.1)	< .001
eGFR < 60 mL/min/1.73 m^2, *n* (%) [b]	17 (5.2)	77 (5.0)	*n.s.*
eGFR > 120 mL/min/1.73 m^2, *n* (%) [c]	85 (26.1)	32 (2.1)	< .001
MIDUS 2, *n* (%)	183 (56.1)	954 (62.1)	*n.s.*
Milwaukee Oversample, *n* (%)	245 (95)	13 (5)	< .001

Note: [a] Significant difference between Black and white participants. Significance of mean age, mean current SES, and mean eGFR based on t tests. Other comparisons were based on Chi-square tests. [b] eGFR < 60 mL/min/1.73 m^2 is one of the clinical criterions for compromised renal clearance and an indicator of Stage 3 CKD when low. [c]eGFR > 120 mL/min/1.73 m^2 is commonly used as an indicator of renal hyperfiltration. eGFR = estimated glomerular filtration rate; MIDUS = Midlife in the United States.

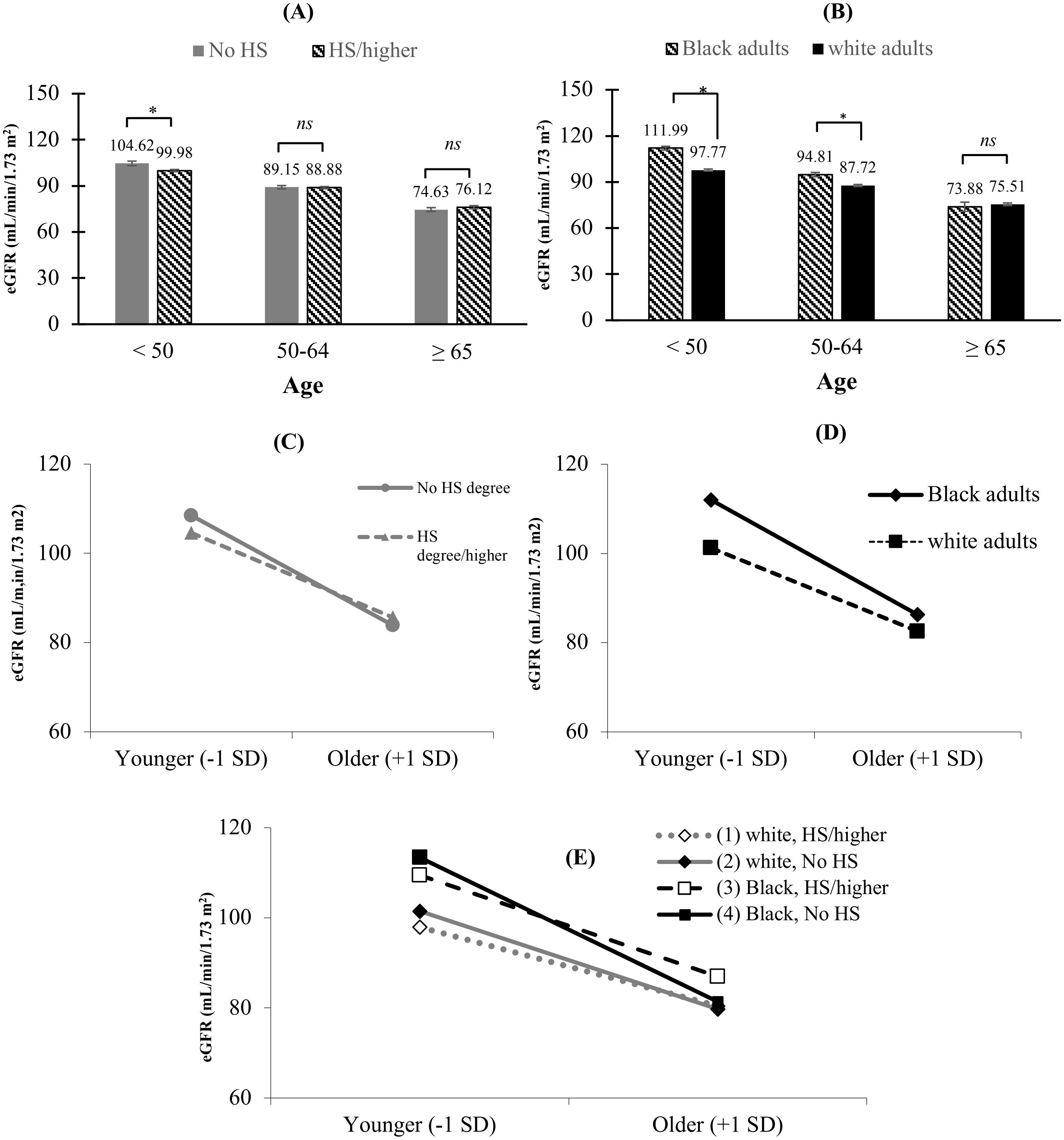


Figure **3.4**: (A) Kidney function (eGFR) in 3 age categories based on parental education. Among younger adults, eGFR among participants with lower parental education was significantly higher for those from families with higher parental education ($p < .05$; Bonferroni correction applied). However, eGFR was not significantly influenced by parental education in the middle and older age groups (B) Among younger and middle age groups, Black participants had a significantly higher eGFR ($p < .05$; Bonferroni correction applied). However, among older participants, eGFR was not significantly different between Black and white participants. (C) Lower parental education was associated with steeper age-related decline in the -eGFR ($p < .01$). (D) Similarly, race was significantly larger age-related changes in eGFR ($p < .01$). (E) Three-way interaction between age, race, and parental education was not significant ($p > 0.05$), although younger Black adults raised by less educated families had the highest eGFR

Parental Education and Age-Related Decrements in eGFR

Multiple linear regression analysis was used to examine whether parental education was associated with age-related differences eGFR. Age was negatively associated with eGFR, indicating a declining age pattern in creatinine clearance across adulthood (*B* = -0.84, *SE* = 0.03, $p < .001$, 95%CI = -0.90, -0.78). The mean eGFR decreased by 0.84 mL/min/1.73 m^2 per year. Controlling for sex and the two MIDUS phases, there was a significant interaction between participant age and parental education when evaluating the eGFR of all participants (Table 3.2, Model 1; *B* = 0.24, *SE* = 0.07, $p < .001$, 95%*CI* = 0.12, 0.37). The inverse age-eGFR association between age and eGFR among participants with lower parental education was significantly steeper when compared to participants raised by families with a higher parental educational attainment (Figure 3.4.C). Among younger adults, lower parental education was associated with a slightly higher eGFR relative to those how reported higher parental education. Conversely, among older adults, lower parental education tended to be was associated with a lower eGFR.

Parental Education, Race, and Age-Related Differences in eGFR

The interaction between age and parental education remained significant after adding race and the interaction between race and age into the model (Table 3.2, Model 2; *B* = 0.38, *SE* = 0.15, $p = .013$, 95%*CI* = 0.08, 0.68). Further, the interaction between age and race on eGFR was statistically significant (Table 3.2, Model 2; *B* = 0.41, *SE* = 0.13, $p < .01$, 95%*CI* = 0.16, 0.66. The age-related decrement in eGFR among Black participants was significantly steeper compared to white participants (Figure 3.4.D). The eGFR of the younger Black adults was elevated relative to similarly aged white adults. However, the eGFR of the older Black participants did not differ from the older white participants. This pattern indicated that the steeper slope of the age-related differences among Black relative to white adults was driven primarily by the higher eGFR values of the younger Black adults. Closer examination indicated there were 117 participants who met the RHF criteria of an eGFR > 120 mL/min/1.73 m^2. The majority (*n* = 101, 86.3%) were younger than 50 years. The proportion of Black participants who met RHF criteria (*n* = 85; 72.6%) was significantly higher than that of white participants (*n* = 32; 27.4%). Finally, among both Black and white participants who met the criteria of RHF, the majority in both races were younger than 50 years (81.2% among Black adults, 100% among white adults).

The three-way interaction for age, race, and parental education did not attain statistical significance (Table 3.2, Model 2; *B* = -0.22, *SE* = 0.17, *p* = .20, 95%*CI* = -0.55, 0.12). This suggested that the differences in age-related differences in eGFR related to parental education were not conditional on race (Figure 2E). As hypothesized, the association between parental education, race, and parental education followed the additive pattern, rather than the interactive pattern. After adding current SES, the 3 health-related risk factors (obesity, hypertension, and insulin resistance), and their interactions with age, the interaction between age and parental education was reduced to non-significance (Table 3.2, Model 3; *B* = 0.29, *SE* = 0.16, *p* = .07, 95%*CI* = -0.02, 0.59). This suggests that the link between parental education and age-related differences in eGFR may be mediated by current SES and overall health. Lower SES in adulthood was also indicative of a steeper age-related difference in eGFR between younger and older adults (Table 3.2, Model 3; *B* = 0.03, *SE* = 0.01, *p* = .03, 95%*CI* = 0.01, 0.05). Similarly, meeting criteria for type 2 diabetes was associated with a larger difference in in eGFR between younger and older adults (Table 3.2, Model 3; *B* = -0.30, *SE* = 0.08, *p* < .001, 95%*CI* = -0.47, -0.14).

Table **3.2**: Summary from linear regression analysis predicting eGFR among Black (n = 326) and white (n = 1,535) adults

	Model 1: Parental education and age-related decrement in eGFR		Model 2: Parental education, race, and age-related decrement in eGFR		Model 3: Full Model	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Intercept	**93.92 (1.22)*****	**91.53, 96.32**	**98.70 (1.60)*****	**95.57, 101.84**	**98.03 (1.77)*****	**94.56, 101.49**
Age (centered)	**-1.02 (0.05)*****	**-1.23, -0.92**	**-1.29 (0.11)*****	**-1.51, -1.07**	**-0.96 (0.13)*****	**-1.22, -0.71**
Sex	-0.28 (0.74)	-1.73, 1.17	0.43 (0.72)	-0.99, 1.85	0.87 (0.74)	-0.59, 2.32
Study cohort	-0.61 (0.76)	-2.11, 0.88	-1.09 (0.75)	-2.55, 0.37	-0.96 (0.76)	-2.45, 0.53
Parental educ. (no HS=0, HS/higher=1)	**-2.42 (0.82)****	**-4.03, -0.82**	0.99 (1.87)	-2.68, 4.67	**-6.24 (1.53)*****	**-9.24, -3.23**
Age*Parental education	**0.24 (0.07)*****	**0.12, 0.37**	**0.38 (0.15)***	**0.08, 0.68**	0.25 (0.13)	-0.01, 0.51
Race (Black=0, white=1)			**-6.88 (1.48)*****	**-9.78, -3.98**	1.73 (1.90)	-1.99, 5.46
Age*Race			**0.41 (0.13)****	**0.16, 0.66**	0.29 (0.16)	-0.02, 0.59
Three-way interaction						
Race*Parental education			-2.30 (2.09)	-6.40, 1.80	-2.51 (2.12)	-6.67, 1.64
Age*Race*Parental education			-0.22 (0.17)	-0.55, 0.12	-0.19 (0.17)	-0.52, 0.15
Current SES (centered)					-0.26 (0.15)	-0.55, 0.02
Age*Current SES					**0.03 (0.01)***	**0.01, 0.05**
Obese (0 = No, 1 = yes)					0.43 (0.77)	-1.08, 1.95
Age*Obese					-0.02 (0.06)	-0.14, 0.11
Elevated BP (0 = No, 1 = yes)					**-1.83 (0.80)***	**-3.40, -0.26**
Age*Elevated BP					-0.13 (0.06)	-0.25, 0.01
Insulin resistance (0 = No, 1 = yes)					**2.85 (1.03)***	**0.84, 4.87**
Age*Insulin resistance					**-0.30 (0.08)*****	**-0.47, -0.14**
F	170.02		110.33		58.71	
Adj. R^2	.31		.34		.35	

Note: $*p < .05$; $** p < .01$; $***p < .001$

Life Course Pathways from Lower Parental Education to Unhealthy Profiles in Kidney Function Among Black and white Adults

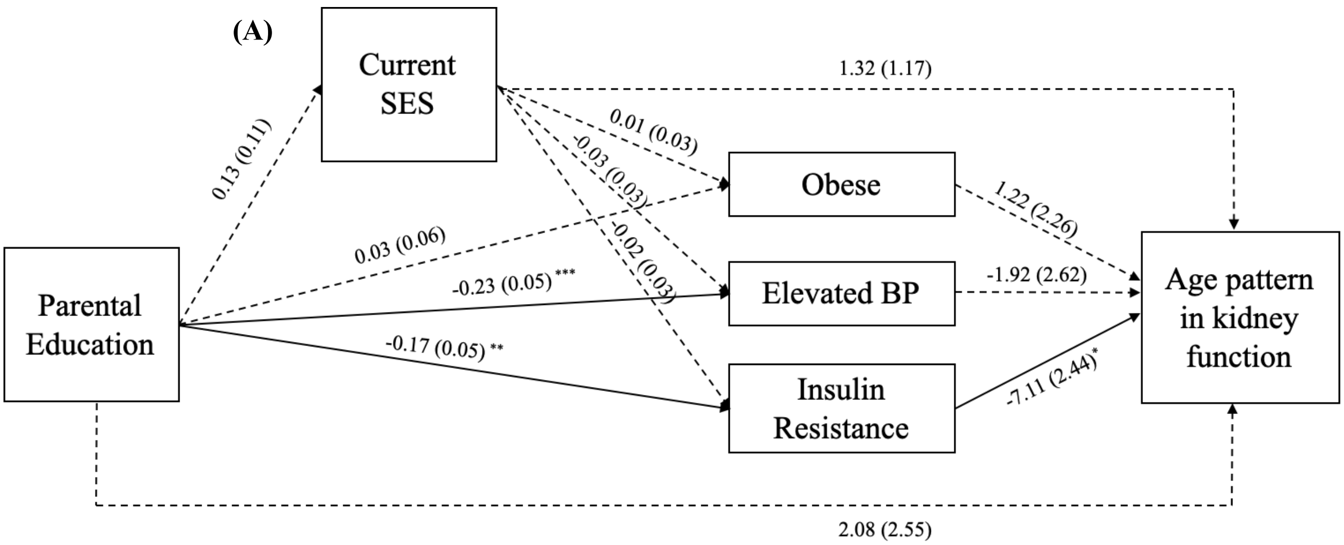
A regression-based moderated mediation analysis was conducted to examine the pathways from parental education level during childhood to the renal clearance patterns seen in middle-aged and older adult Life course pathways assessed separately for each racial group.

Parental Educational Attainment and eGFR Among Black Adults

Results from the moderated mediation analysis for the Black group are presented in Figure 3.5.A. Lower parental education was associated with the likelihood of hypertension among the black participants (B = -0.23, SE = 0.05, $p < 0.001$) as well glucoregulatory indices of insulin resistance (B = -0.17, SE = 0.05, $p < 0.01$). In turn, insulin resistance was associated with a larger difference in eGFR between the younger and older adults (B = -7.11, SE = 2.74, p = .010). The indirect effect analysis indicated the mediation through insulin resistance was driven primarily by the significant effect and higher eGFR among younger adults (B = -2.03, SE = 1.03, p = .04), and was not evident among older participants (B = 0.44, SE = 0.58, $p > .05$). Thus, the pathway from familial context and status during childhood to a less healthy age pattern in renal clearance appeared to be associated with the more common occurrence of type 2 diabetes among the Black participants (Figure 3.5.B). The significant effects of parental education and familial conditions during childhood did not appear to be mediated by the current SES of the participants as parental education level was not associated with current SES among the Black participants (B = 0.13, SE = 0.11, p = .24).

Parental Educational Attainment and eGFR Among White Adults

The moderated mediation analysis for the white participants is presented in Figure 3.6.A. Lower parental education during childhood was associated with lower current SES ($B = 0.30$, $SE = 0.06$, $p < 0.001$). Further, low parental education was also associated with a likelihood of being overweight in adulthood ($B = -0.08$, $SE = 0.03$, $p = .004$), being hypertensive ($B = -0.16$, $SE = 0.03$, $p < 0.001$), and meeting criteria for type 2 diabetes ($B = -0.06$, $SE = 0.02$, $p = .005$). Current SES was also associated with obesity ($B = -0.07$, $SE = 0.01$, $p < .001$), hypertension ($Est = -0.03$, $SE = 0.01$, $p = .036$), and insulin resistance ($B = -0.04$, $SE = 0.01$, $p < .001$). The unhealthy patterns of high BP ($B = -1.77$, $SE = 0.84$, $p = .035$) and insulin resistance ($B = -2.77$, $SE = 1.36$, $p = .041$) linked with the age-related changes in eGFR. Thus, among white adults, the pathways to kidney health appeared to reflect both the connection between childhood and adult SES as well as the general association between low SES and overall poor health. The indirect effect analysis indicated that both the social and obesity-related physiological pathways were statistically significant in younger and older adults (Figure 3.6.B). Among white participants, the higher eGFR among younger adults and lower eGFR among older adults resulted in the appearance of stronger influence of age, with a steeper decline.



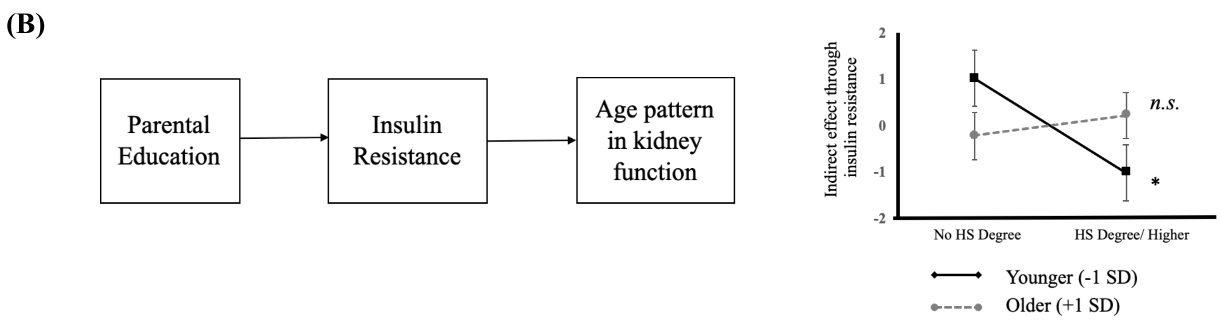


Figure **3.5**: (A) Moderated mediation analysis predicting age-related decrements in eGFR among Black adults. Solid lines indicate significant paths and dashed lines indicating non-significant paths. Path coefficients are the unstandardized estimates (standard error in parentheses). (B) There was significant indirect path from parental education to age-related decrements in eGFR through insulin resistance indicative of Type 2 diabetes, but only among younger Black participants (age -1 *SD*). This finding suggests that lower parental education, through insulin resistance, was linked to elevated eGFR among younger Black participants. Note: *$p < .05$; ** $p < .01$; ***$p < .001$

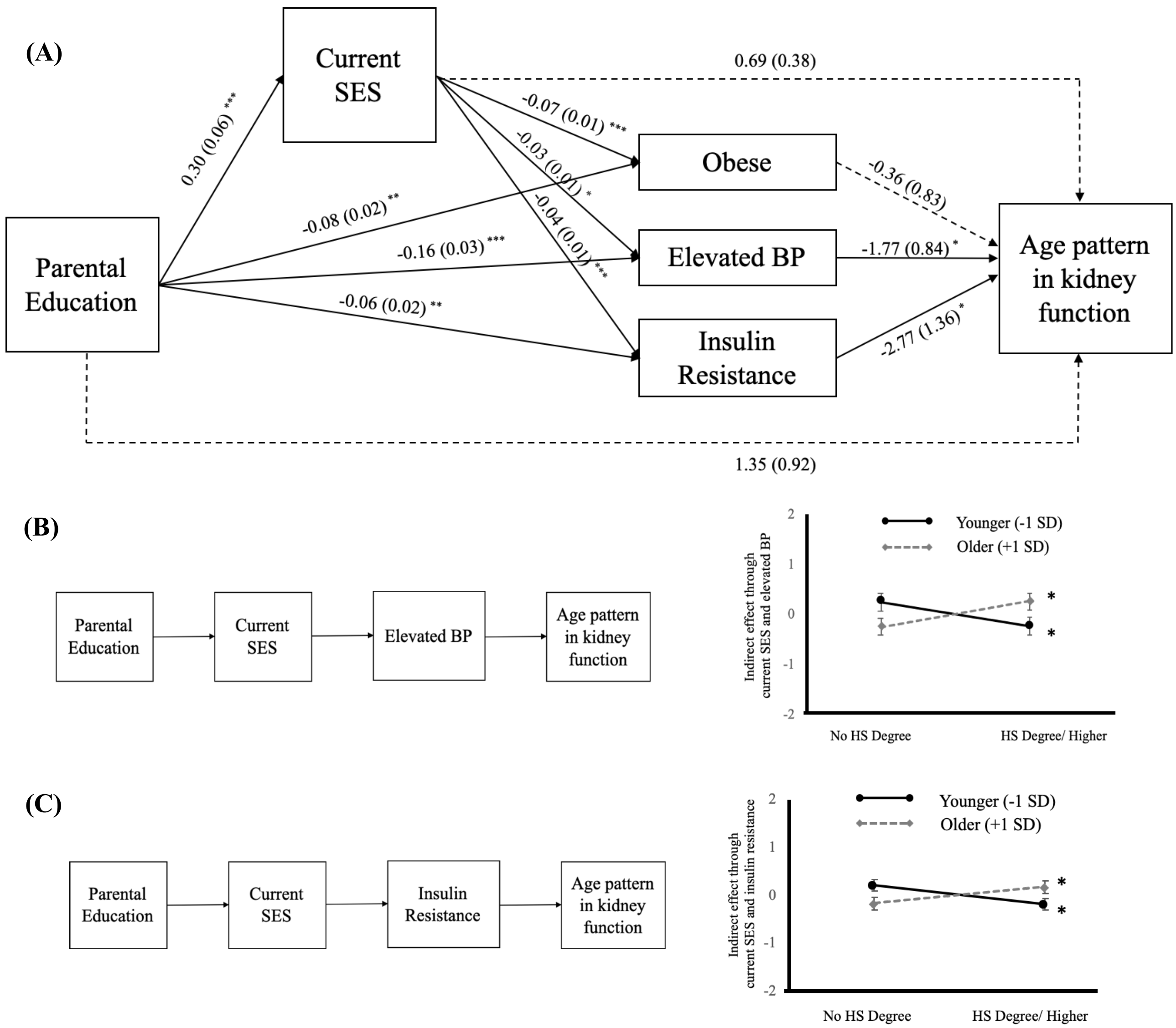


Figure **3.6**: (A) Moderated mediation analysis predicting age-related decrements in eGFR with solid lines indicating significant paths and dashed lines indicating non-significant paths. Path coefficients are the unstandardized estimates (standard error in parentheses). (B) Among White participants, there were significant indirect paths from parental education to age-related decrements in eGFR through current SES and elevated BP. The indirect effect was significant for both younger (-1 *SD*; lower parental education → elevated eGFR) and older (+1 *SD*; lower parental education → lower eGFR) participants. (C) There were also significant indirect paths from parental education to age-related decrements in eGFR through current SES and insulin resistance. The indirect effect was also significant for both younger (-1 *SD*; lower parental education → elevated eGFR) and older (+1 *SD*; lower parental education → lower eGFR) participants. Note: *$p < .05$; ** $p < .01$; ***$p < .001$

Discussion

Using cross-sectional information on eGFR values of middle-age and older Black and white Americans, this analysis has shown that parental educational attainment, a proxy of early life SES, is associated with age-related decrements in renal clearance. While it is was already known that early life conditions, especially prenatal events such as gestational age at delivery, are part of a critical period for kidney development (Kett & Denton, 2010), it appears that economic and social disadvantage may also contribute to kidney health in adulthood. Further, this analysis examined the life course pathways from parental education to age-related decrements in eGFR, which proved to be differentially manifest in Black and white Americans. Several notable racial differences in the life course pathways from parental education to the age-associated pattern of renal senescence were evident after considering current SES and relevant health-related risk factors, including obesity, hypertension and type 2 diabetes.

Age-Related Decrements in Kidney Function

Numerous clinical nephrology studies have characterized the process of renal senescence that occurs in most adults, including the age-related decrease in the size of the kidney, especially in the cortical region, the changes in the structure of the glomeruli which may become sclerotic, and the decrease in filtration rates, altering the concentrations of proteins and other soluble analytes in both urine and circulation (Hommos et al., 2017). Among the MIDUS participants, age-related decrement in eGFR averaged 0.84 mL/min/1.73 m^2 per year, consistent with the previous estimations of an annual decline fall of 0.40 and 1.07 ml/min/1.73 m^2 (Baba et al., 2015; Wetzels et al., 2007). However, there are also important differences in these age-associated renal profiles across racial groups, and the potential for social disparities in general health to affect the emergence and pace of kidney aging. Many of the younger Black participants had high eGFR values, which may be indicative of a renal hyperfiltration that can result in wear-and-tear on the glomeruli and increase the likelihood of a later progression to CKD. The high eGFR in the younger Black participants resulted in a larger difference when compared to the older Black participants, and the appearance of a steeper slope of decline. A similar pattern was evident in some of the younger white participants but more evident in the context of obesity, hypertension, and type 2 diabetes. The co-occurrence of poor renal health and elevated blood pressure, as well as the adverse effects of diabetes on the kidneys is well known to nephrologists.

Across both Black and white adults, the current analysis also replicated many previous reports of an age-related decline in renal clearance, which can be tracked by measuring the levels of creatinine in serum and urine, as well as by quantifying other proteins and analytes, including albumin and cystatin (Costello-White et al., 2015; Peralta et al., 2011; Peralta et al., 2013). Similar to the findings by Costello-White et al. (2015), we found there appeared to be a larger difference in the eGFR of younger and older Black adults suggested when compared to the age-related differences in the white participants. This racial difference was driven primarily by the higher eGFR in the younger Black adults, which can tax and damage sensitive aspects of the glomeruli. However, not all studies have confirmed that RHF can be used as a single indicator of risk. Using longitudinal data, RHF among Black adults was not found to be significantly associated with a higher likelihood of CKD (Chaiken et al., 1998). However, we did find that a higher percentage of the younger Black adults had a high eGFR that would meet the criteria for RHF when compared to the white adults. In younger adults, RHF was also more likely to be associated with obesity, high BP, and high HA1c levels indicative of type 2 diabetes (Low et al., 2018; Magee et al., 2009; Melsom et al., 2011; Oh et al., 2020; Palatini, 2012). Our modeling suggests that RHF is one of the indicators of risk in mid-adulthood, and consistent with the multifactorial etiology of renal senescence.

Parental Education and Age-Related Decrements in Kidney Function

The novelty of our findings is the demonstration that social factors, including familial context during childhood, can act through these pathways to impact kidney physiology in adulthood. Specifically, lower educational attainment of parents was associated with a larger age-related difference in eGFR, due to the higher eGFR values among younger participants and the lower clearance of the older participants. The conclusion that social and economic disadvantage can have a long-term impact on adult health is not new, but it has been more common to focus on other physiological systems, especially related to cardiovascular disease. In addition, the research has emphasized the importance of adult SES to a greater degree (Vart, Gansevoort, Joosten, et al., 2015). Our findings indicate that parental education level can serve as a proxy for social advantage and disadvantage during childhood, and it appeared to affect the eGFR in both Black and white adults. Furthermore, this analysis corroborates previous studies showing that SES and race linked to health can act in an additive way rather than an interactive one (Kawachi et al., 2005). We showed that there were distinct pathways from parental education to age-related decrements in kidney function among Black and white adults.

Our analysis also conveys the value of considering a life course perspective. Societal constraints on upper mobility can result in there being a connection between childhood SES and the economic and social success of adulthood. In our analyses, we also observed a correlation between the participants' reporting of the education level of their parents and their own current SES, albeit more evident among the white participants. Our statistical modeling was able to discern independent and additive contributions of both childhood SES and current standing to the measures of kidney health in the MIDUS participants. It should also be mentioned that at the time when the older MIDUS participants were children, there would been even more prominent social constraints on the opportunities available to most Black participants due to discrimination and institutional racial barriers that would limit access to educational and occupational advancement. Thus, it may not be surprising that the dual influence of childhood SES and adult SES was evinced differently among the Black and white participants.

It should also be acknowledged that there may have been an additional influence of prenatal factors, including delivery-related outcomes, that were not assessed in the MIDUS project. A number of studies have shown that prematurity and low birth weight can have a pervasive influence on the early life programming of the kidney, with effects on the nephron endowment (Brophy et al., 2018; Kett & Denton, 2010; Singh & Denton, 2015; Tiniakos et al., 2004; Wintour et al., 2003). Unfortunately, the occurrence of premature birth is still significantly more common among Black women, and provides another example of the early etiology of health disparities. The inter-generational continuity of these relationships is also evident in the fact that both gestational diabetes and gestational hypertension continue to be among the primary causes of premature birth. Our analyses confirmed the important associations between kidney health, hypertension and diabetes. It is important to better understand the factors that mediate the health effects of social and economic disadvantage.

One unanticipated finding was the absence of a significant association between parental education and current SES among Black participants, while it was strongly evident among white adults. This difference suggests that for Black participants, having parents with higher education did not guarantee a path to higher levels of adult SES. The finding is consistent with a previous analysis by Davis (1994) on the lack of intergenerational transmission of educational attainment among Black American men. Some possible contributors include the common incarceration of American Black men (Hagan & Foster, 2012) and the changes in family structures over time

(Song, 2016). A more recent study, however, found that intergenerational educational mobility among younger cohort of Black adults was increasing (Bloome & Western, 2011). Despite the evidence for increasing educational mobility, however, income mobility among Black adults was declining (Bloome & Western, 2011). There is a well-documented evidence that educational attainment is not always perfectly correlated with income, wealth, and other indicators of SES among Black adults. For example, Black adults tend to earn a lower income and are more likely to be unemployed when compared to their white adult counterparts who have the same level of education (Williams & Sternthal, 2010). It is also possible that that some aspects of our findings are unique to the Black participants in our study given that our Black sample was recruited mostly from Milwaukee County, WI. In addition, in contrast to white participants, current SES was not associated with any of the measured health-related risk factors. Other studies have found what seem to be similar discrapency, when considering race (Surachman et al., 2021; Surachman, Rice, et al., 2020), providing further support for the *diminishing return hypothesis* (Williams et al., 2010). Achieving a higher level of SES does not necessarily ensure better health among Black adults in the same way that it is manifest among white adults. In contrast, parental education during childhood was directly associated with health-related risk factors among Black adults, especially with elevated BP and insulin resistance. In turn, insulin resistance was associated with the age-related patterns in kidney function. Taken together, these findings provide a novel perspective on of the importance of early life SES in the context of kidney functioning and the mediation of good and poor health in adulthood.

The current study has multiple strengths. First, this study included participants from a wide age range enabling us to generate to provide robust estimates of age-related differences in kidney function. Second, the extensive biological and clinical information from MIDUS Biomarker Projects allowed us to include multiple health-related risk factors in the analysis. Thus, our findings on the association among parental education, race, and age-related differences in kidney function across adulthood were generated from a substantive dataset. Finally, the MIDUS study also included detailed information on current SES, incorporating both objective (e.g., income and education) and subjective measures (e.g., subjective social status and financial strain). However, it should also be acknowledged that this analysis does have some limitations. First, the unavailability of longitudinal biological information in the MIDUS study precluded a prospective analysis. However, the cross-sectional examination of age-related differences still provided a unique opportunity to examine the link between social factors across the life course and kidney function. With the availability of the longitudinal biological information in the MIDUS study in the future, it will be possible to prospectively address these questions. It should also be acknowledged that parental education was based on retrospective reports and this could introduce some bias, even though a previous analysis indicated a high level of accuracy in terms of retrospective reports of parental education from a small subset of sibling participants in MIDUS (Ward, 2011). Finally, the indicator of kidney function was based on serum creatinine, which is sensitive to both diet and muscle mass. In addition, we utilized the CKD-EPI formula to calculate eGFR, which is currently under scrutiny because it incorporates a race adjustment into the formula (Diao et al., 2021). However, we conducted sensitivity analysis by excluding the race adjustment from the formula and still had similar findings. Lastly, the majority of the Black participants was recruited from Milwaukee County, which could limit the generalizability of the findings to other regions. Despite this limitation, our additional analyses indicated that Black adults in Wisconsin are comparable to the larger US Black population in terms the key sociodemographic variables (see Appendix C). Future studies should prioritize replicating the current findings by utilizing representative Black adult from different regions of the US, including the Southern states, which often have poorer health overall.

Conclusion

These analyses demonstrated that familial SES can have a long-lasting influence on the preclinical renal senescence that is associated with the normal biology of aging. Lower parental education and race were independently associated with unhealthy kidney functioning in adulthood, a risk factor for the development of CKD. Furthermore, there were distinct life course pathways from parental education to kidney functioning in adulthood among Black and white adults. Among younger Black adults, lower parental education was associated with elevated kidney function, an indication of renal hyperfiltration, through insulin resistance. Among white adults, lower parental education, through current SES, elevated BP, and insulin resistance, was associated with elevated kidney function among younger adults and lower kidney function among older adults. A better understanding of the effect of parental educational attainment on adult filtration rates may help us to achieve more insights into the etiology of health disparities and the inter-generational perpetuation of risk.

Chapter 4

Intergenerational Educational Mobility and Age-Related Decrements in Kidney Function among Black and white American Adults

Introduction

In health disparities research, education level is favored over other indicators of SES (e.g., income or wealth) as the information is easier to collect, it tends to be consistent across adulthood, and there is lower concern over reverse causation as it is less affected by illness (Krieger et al., 1997). Furthermore, education level is also a robust predictor of multiple health outcomes, including multiple kidney outcomes in adulthood such as low eGFR and albuminuria (Vart, Gansevoort, Crews, et al., 2015; Vart, Gansevoort, Joosten, et al., 2015). In a systematic review and meta-analysis focusing on the association between SES and the risk of chronic kidney disease (CKD), the majority of the articles included in the analysis (29 out of 35 articles; 83%) utilized education as an indicator of SES (Vart, Gansevoort, Joosten, et al., 2015).

From the life course perspective, a focus on education level does not fully capture the socioeconomic context of exposure to risk and protective factors that matters on the development of health and disease in adulthood. Given that early life is a critical period for the development of adult kidney disease (Kett & Denton, 2010), focusing solely on education level in adulthood fails to capture the socioeconomic context during that period. As demonstrated in Chapter 3, parental education can be utilized as a proxy of early life social context and it is a robust predictor of kidney functioning during adulthood. Furthermore, a better approach to capturing socioeconomic context across the life course and how it creates disparities in adult kidney disease is by examining the life course pathways from parental education to kidney outcome in adulthood through one's education level, as evidence in Chapter 3. Examination of the life course pathways is useful for discerning the general pattern of socioeconomic accumulation across the life course, across the general population, and across different key stratification criteria (i.e., race, sex, or other). However, focus on life course pathways ignore the heterogeneity of intergenerational educational mobility (Surachman, Rice, et al., 2020). Different patterns of intergenerational educational mobility (e.g., lower parental education-lower participant's education vs. higher parental education-higher participant's education) may link differently to kidney outcomes during adulthood. As highlighted in the systematic review (Chapter 3), no analysis has been done to address this specific question. This analysis aimed to fill this gap in the literature by identifying intergenerational educational mobility patterns and examining the association between these different patterns and kidney functioning in adulthood.

The Non-Universal Meaning of Education

The major concern regarding the use of education level in health disparities research is that it does not have a universal meaning across different cohorts (Krieger et al., 1997) and across different racial groups (Williams et al., 2010). In the past century, the norm of education level among adults in the United States has dramatically increased across the successive birth cohorts (Schofer & Meyer, 2005; Snyder, 1993). At the same time, there have been increases in occupational complexity, specialization, and educational credentials required for better financial and social compensation (Case & Deaton, 2020). Thus, there has been a changing meaning to what is perceived to be the "minimum" educational credential associated with sufficient material and social resources to provide health benefits. There is robust evidence that educational credentials do not have universal meaning and its implication on health and well-being differs based on birth cohort/period (Sasson & Hayward, 2019). Demographic trends in health and mortality based on educational credentials have documented that educational inequality in the U.S. is consistently increasing, as indicated by the changing minimum educational credential needed to achieve health benefits across different periods. Having a high school (HS) diploma used to be a social marker to achieve health benefits relative to those without a high school degree. For example, data from a 1964-66 survey showed that having HS degree decreased the probability of infant mortality compared to those without a HS degree (MacMahon et al., 1972). However, there was no significant difference in infant mortality for a HS versus college degree (MacMahon et al., 1972). A more recent analysis using census data (2010 and 2017) indicated that only those with a bachelor's degree or higher received a health benefit of increased life expectancy, which was not present among those with lower levels of education (Sasson & Hayward, 2019). Furthermore, another recent analysis found that, unlike those who earned a bachelor's degree, individuals who achieved only some college education did not receive a similar health advantage, measured using cardiovascular and metabolic biomarkers (Zajacova & Johnson-Lawrence, 2016). This changing meaning of educational attainment across successive birth cohort should be considered when analyzing the association between educational mobility and disparities in health.

In addition to changing meaning across successive cohorts, education has also been shown to have different meanings across different racial groups in the United States. The most robust evidence is the comparison of the association between education level and occupation status, income, and wealth between white and Black adults in the United States. Compared to white adults with similar levels of education, Black adults are more likely to be unemployed, earn lower income, and accumulate less wealth (Williams & Mohammed, 2009).

These racial disparities on the meaning of education on socioeconomic return and accumulation may be the mechanisms that lead to the *diminishing return* of health benefits in achieving higher SES among Black adults. For example, unlike their white counterparts, the most affluent Black adults with the highest SES across their life course in two different adult cohorts did not show signs of lower inflammatory biomarkers relative to the Black adults with the lowest levels of SES across their life course (Surachman et al., 2021; Surachman, Rice, et al., 2020). The support for the diminishing return hypothesis between Black and white adults in the U.S. also evident across different health outcomes, including blood pressure (Assari, 2019) and self-rated health (Farmer & Ferraro, 2005). Other studies found racial disparities regarding the detrimental effects of upward mobility on physical health between Black and white adults (Brody et al., 2020; Miller et al., 2016). For Black adults, achieving upward mobility comes with maintaining a high-levels of self-control that may be detrimental to their biological functioning and lead to worse health outcomes. This hypothesis is known as the skin-deep resilience hypothesis (Brody et al., 2020).

Empirical Evidence of Educational Mobility and Health

Based on the systematic review in Chapter 2, there is no previous study that examine the association between intergenerational educational mobility, race, and kidney outcomes in adulthood. However, few studies have examined the association between educational mobility and risk factors for kidney disease. Loucks et al. (2010) examined SES mobility by comparing parental education and participant’s occupational status (laborer or professional) and found that stable low SES across the life course was associated with elevated c-reactive protein (CRP), while downward mobility was associated higher levels of interleukin-6 (IL-6) relative to those with stable high SES. Findings from an analysis of the skin-deep resilience hypothesis showed that upward mobility among young Black adults with higher self-control and longer childhood poverty duration was associated with higher susceptibility to metabolic syndrome and insulin resistance (Brody et al., 2020). In a different analysis, Miller et al. (2016) also found that young

Black adults who experienced upward educational mobility and showed higher levels of conscientiousness tended to have lower immune system. Finally, an analysis by Albrecht and Gordon-Larsen (2014) showed that the benefits of upward educational mobility differ based on immigration status, in which upward mobility was associated with lower BMI but only among first-generation immigrants. Taken together, it is not clear how intergenerational educational mobility may be associated with kidney functioning in adulthood. However, there is well-documented evidence on the racial differences in the benefit of upward mobility on risk factors for kidney disease. Findings from studies examining the skin-deep resilience hypothesis indicated the importance of exploring the psychosocial factors linked to educational mobility.

Current Study

This analysis aimed to identify intergenerational educational mobility among Black and white American adults by comparing parental education levels to participants' education. The meaning of educational credentials has changed across the past century (Schofer & Meyer, 2005; Snyder, 1993). For example, graduated from high school used to be a marker of achieving higher level of education in which there were health benefits associated with it (MacMahon et al., 1972). Nowadays, bachelor's degree is the educational credential associated with higher level of education with the most health benefits associated with it (Case & Deaton, 2020; Sasson & Hayward, 2019). These changing meanings in educational credential were the basis of the conceptualization of intergenerational educational mobility in this analysis (e.g., higher parental education = HS diploma or higher, otherwise considered as lower; higher participant's education = bachelor's degree or higher, moderate = some college, otherwise considered as lower). This analysis also aimed to examine racial differences in intergenerational educational mobility. Given the well-documented evidence of racial inequality in educational attainment in the United States, the intergenerational educational mobility among white adults would be characterized by overwhelmingly higher proportion of the stable high pattern (higher parental education-higher participant's education), while the mobility among Black adults would be characterized by higher proportion of the stable low pattern (lower parental education-lower participant's education). Furthermore, the upward mobility pattern (lower parental education-higher participant's education) would be observed more commonly among white rather than Black adults.

Finally, this analysis examined the association between intergenerational educational mobility and age-related decrements in eGFR and whether there were racial differences between Black and white adults on the association between intergenerational educational mobility and age-related decrements in kidney function. Studies have shown that upward mobility among Black individuals is associated with higher self-control that in turn associated with worse physiological functioning (Brody et al., 2020; Miller et al., 2016). Thus, the associations between intergenerational educational mobility and multiple psychosocial (e.g., self-control) and socioeconomic indicators were explored. Taken together, these exploratory analyses sought to fill the gap in the nephrology literature regarding the influence of SES mobility on the development of kidney disease in adulthood.

Methods

Data and Participants

Data for this particular analysis were from the Midlife in the United States (MIDUS) wave 2 Refresher (MIDUS R) study. Details important to the current study and additional information about MIDUS and biomarker data collection in the MIDUS study have been presented in the Methods section of Chapter 3.

Analytic Sample

The analytic sample included participants who completed the Biomarker Projects of MIDUS 2 and MIDUS R. Out of a potential pool of 2,118 participants (MIDUS 2 = 1,255, MIDUS R = 863), 1,930 were selected who self-identified as non-Hispanic Black (*n* = 369) and non-Hispanic white (*n* = 1,561). Participants with missing information for either serum creatinine (*n* = 20) or parental education (*n* = 49) were excluded. The final sample included 1,861 adults (non-Hispanic Black adults = 326, non-Hispanic white adults = 1,535).

Measures

Parental Education

During the baseline interview, participants reported the highest level of formal education for both their father or male household head and their mother or female household head on a 12-point scale (1 = no school/some grade school [1 to 6 years]; 6 = 1 to 2 years of college, no degree yet; 12 = Ph.D., Ed.D., MD etc.). Following Ferraro et al. (2016), parental education was based on the education level of the father or male household head. In the case where information was not available, the mother's or female household head's highest level of education was substituted. When both the father's and mother's education levels were available, only the father's education level was used. Parental education was dichotomized into no high school/GED degree (lower) and graduated from high school/GED or higher (higher).

Participant's Education

Similarly, participants reported their highest level of formal education on a 12-point scale (1 = no school/some grade school [1 to 6 years]; 6 = 1 to 2 years of college, no degree yet; 12 = Ph.D., Ed.D., MD etc.). Participant's education was transformed into three categories: high school/GED or lower (lower), some college (moderate), and bachelor's degree or higher (higher).

Intergenerational Educational Mobility

The classification of intergenerational educational mobility is presented in Figure 4.1. The two categories of parental education were compared to the three categories of participant's education, resulting in six categories of educational mobility. The six categories are: 1) Stable Low (parental education = lower, participant's education = lower), 2) Moderate Upward Mobility (parental education = lower, participant's education = moderate), 3) High Upward Mobility (parental education = lower, participant's education = higher), 4) Severe Downward Mobility (parental education = higher, participant's education = lower), 5) Moderate Downward Mobility (parental education = lower, participant's education = moderate, and 6) Stable High (parental education = higher, participant's education = higher).

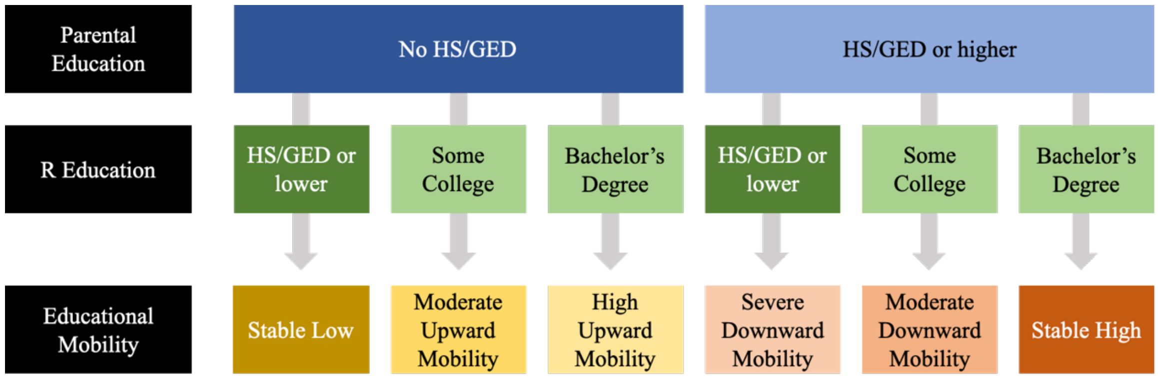


Figure **4.1**: Operationalization of intergenerational educational mobility in the current analysis (R Education = participant's education)

Age

Participants reported their birth dates during the Biomarker Project. Thus, each participant's age (years) was based on their age at the time of blood sample collection.

Kidney Function

Estimated glomerular filtration rate (eGFR) was calculated from serum creatinine using the CKD-EPI formula (Levey & Stevens, 2010). The CKD-EPI formula takes age, sex, and race into consideration when calculating eGFR. Serum creatinine was assayed from overnight fasted blood collected during the Biomarker Project using Roche Cobas Analyzer (Unity Meriter Lab, Madison, WI). The assay range was 0.06-30.5 mg/dL, with an inter-assay CV of 2.08%. across the 2 phases of MIDUS.

Covariates

Sex and Study Cohort. Throughout the whole analysis, sex (0 = female, 1 = male) and study cohort (0 = MIDUS Refresher, 1 = MIDUS 2) were included as covariates.

Household Income. Household income was included as an additional indicator of objective SES. Household income was be based on participant reports of total household income (including personal income, spousal income, and the income of other members) from wages, pension, Social Security, and other sources. The total household income in the MIDUS study was top-coded at $300,000. For the current analysis, household income will be compared to the US federal poverty line (adjusted for the total number of household members and the year of data collection) to create an income-to-poverty ratio. The raw value of the income-to-poverty ratio was converted into a binary variable: less than or equal to 150% and higher than 150%.

Discrimination. Two types of discrimination were included: lifetime discrimination and daily discrimination, developed by Williams et al. (1997). Lifetime discrimination was based on 11 items in which participants responded to the frequency of instances where they were discriminated against (e.g., denied a scholarship and hassled by the police) due to their race, gender, age, religion, physical appearance, sexual orientation, and other characteristics throughout their lifetime. A summary score was calculated based on the number of items in which participant reported at least one occasion in their lifetime where they experienced those items (min = 0, max = 11). Daily discrimination was based on participants' response regarding the frequency (1 = never, 2 = rarely, 3 = sometime, 4 = often) of experiencing the nine items of daily instances of discrimination (e.g., receive poorer service than other people at restaurants or stores and called names or insulted). A summary score was calculated based on the cumulative score from the nine items (min = 9, max = 36).

Psychosocial Factors. Two indicators known to mediate or moderate the association between SES, race, and health disparities were included: stressor exposure (Matthews & Gallo, 2011) and self-control (Brody et al., 2020). Perceived stress was based on participants' response to the Perceived Stress Scale (Cohen et al., 1983). Self-control was measured using a scale developed by Wrosch et al. (2000). The scale covered three dimensions of self-control, including persistence in goal striving, positive reappraisals, and lowering aspirations.

Health-Related Risk Factors. There were four indicators of health-related risk factors included in the analysis: current smoking status (0 = currently not smoking, 1 = currently smoking), obesity (BMI≥30 kg/m^2 = 1, otherwise coded as 0), elevated BP (systolic and diastolic BP ≥ 140/90 or self-report of hypertension diagnosis by a physician = 1, otherwise coded as 0), and insulin resistance (HbA1c ≥ 6.5% or fasting blood glucose ≥ 126 mg/dL or self-reported diagnosis of type 2 diabetes by a physician = 1, otherwise coded as 0).

Statistical Analysis

The current analysis examined the association between intergenerational educational mobility and age-related decrements in eGFR among Black and white American adults. Specifically, the goals of the first part of the analysis were (Figure 4.2): a) to identify intergenerational educational mobility among Black and white adults; b) to examine the association between intergenerational educational mobility and age-related decrements in eGFR; and c) to examine racial differences between Black and white adults on the association between intergenerational mobility and age-related decrements in eGFR.

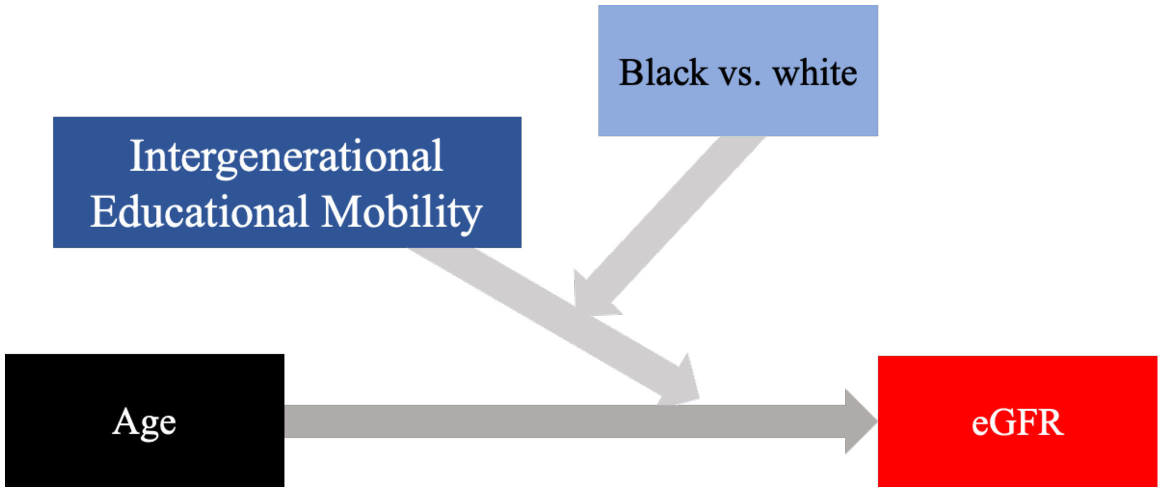


Figure **4.2**: Graphic representation of the goal of the second empirical analysis

The association between intergenerational educational mobility and age-related decrements in eGFR was examined using a multiple linear regression analysis. In the first model (Model 1.1), educational mobility, age, and the interaction between the two were included in the model predicting eGFR, controlling for sex and study cohort. The association between educational mobility and age-related decrements in eGFR was examined through the interaction between age (mean centered) and educational mobility (using the Stable High as the reference group) on eGFR. In the second model (Model 1.2), race (Black coded as 0 and white coded as 1) and the interaction terms among age, race, and parental education were added into the model. Racial differences in the association between educational mobility and age-related decrements in eGFR were tested through the three-way interaction among age, race, and educational mobility. Finally, the rest of the covariates, including household income, lifetime and daily discrimination, psychosocial factors, and health-related factors were added into the model.

Sensitivity analyses were conducted to test the robustness of the findings. First, the association between participant's education and age-related decrements in eGFR was examined.

The goal was to assess whether the findings pertaining to the association with intergenerational educational ability was driven by a participant's education. Second, the association between educational mobility and multiple variables that are known to mediate and moderate the association between SES, race, and health disparities including lifetime and daily discrimination, psychosocial factors (stressor exposure and self-control), and health-related factors (smoking status, obesity, hypertension, and insulin resistance) were examined.

Results

Descriptive Characteristics of the Participants

The detailed information regarding characteristics of the participants in the analysis is presented in the Results section of Chapter 3 (see Table 3.1).

Intergenerational Educational Mobility

The breakdown of parental education and participant's education for each racial group is presented in Table 4.1. Slightly more than half of the Black participants reported that their parents attained higher levels of education (HS/GED diploma or higher). Among white participants, more than two-third reported that their parents achieved higher levels of education. Over half of the white participants earned a bachelor's degree or higher, while the proportion of Black participants in that category was around 25%.

Table **4.1**: Parental education and participant's education for each racial group (*N* = 1,861)

Education Level	Black (n = 326)		White (n = 1,535)		χ^2
	n	%	n	%	
Parental Education					
No HS/ GED	153	46.9	467	30.4	32.99***
HS/GED or higher	173	53.1	1,068	69.6	
Participant's Education					
HS/ GED or lower	123	37.7	300	19.5	50.64***
Some college	120	36.8	437	28.5	
Bachelor's degree or higher	83	25.5	798	52.0	

The distribution of intergenerational educational mobility for Black and white groups is presented in Table 4.2. Among Black participants, the largest proportion of educational mobility group was in the Stable Low group (19.3%), while slightly less than one-tenth of white participants were categorized in the same group. The largest proportion of educational mobility group among white participants was in the Stable High group (42.1%). The proportion of Black participants in the same educational mobility group was 15.6%.

Table **4.2**: Distribution of intergenerational educational mobility for each racial group (N = 1,861)

Intergenerational Educational Mobility	Black (n = 326)		White (n = 1,535)		χ^2
	n	%	n	%	
Stable Low	**63**	**19.3**	162	10.6	104.26***
Severe Downward Mobility	60	18.4	138	9.0	
Moderate Upward Mobility	58	17.8	153	10.0	
Moderate Downward Mobility	62	19.0	284	18.5	
High Upward Mobility	32	9.8	152	9.9	
Stable High	51	15.6	**646**	**42.1**	

Intergenerational Educational Mobility and eGFR

Black participants, in general, showed a higher mean of eGFR relative to white participants (Table 4.3). A breakdown of mean eGFR across educational mobility did not provide meaningful information other than that across all educational mobility groups, Black adults showed higher mean eGFR compared to white adults. Figure 4.3 provides descriptive information on the association between intergenerational educational mobility and eGFR across different age groups among Black (A) and white (B) participants. There are clear patterns of differences in the level of age-related decrements in eGFR across age groups, especially among Black participants. Black participants in the Stable Low, Severe Downward, and Moderate Upward groups showed steeper declines in eGFR as age increased, driven by the elevated eGFR among younger participants and lower eGFR among older participants.

Intergenerational Educational Mobility and Age-Related Decrements in eGFR

The summary from the multiple linear regression analysis is presented in Table 4.4. The first regression model (Model 1) examined the prediction of age-related decrements by educational mobility groups (using Stable High as the reference group), controlling for sex and study cohort. Participants in the Stable Low (B = -0.40, SE = 0.10, $p < .001$), Severe Downward (B = -0.25, SE = 0.10, $p < .05$), and Moderate Upward (B = -0.38, SE = 0.10, $p < .001$) groups showed steeper age-related decrements in eGFR compared to participants in the Stable High group. However, the slopes of age-related decrements in eGFR for the Moderate Downward (B = -0.11, SE = 0.08, p = .17) and High Upward (B = -0.13, SE = 0.11, p = .24) groups were not significantly different from the slope of the Stable High group.

Table **4.3**: Mean eGFR based on educational mobility among Black and white groups (N = 1,861)

Intergenerational Educational Mobility	Black (n = 326)		White (n = 1,535)	
	M	*SD*	*M*	*SD*
Stable Low	102.83	23.99	87.32	18.67
Severe Downward Mobility	106.69	21.75	91.66	16.99
Moderate Upward Mobility	94.88	27.54	85.57	18.71
Moderate Downward Mobility	104.24	21.15	91.02	16.99
High Upward Mobility	96.06	23.30	83.41	17.02
Stable High	103.37	20.20	89.35	15.89
Group mean	101.81	23.35	88.69	18.98

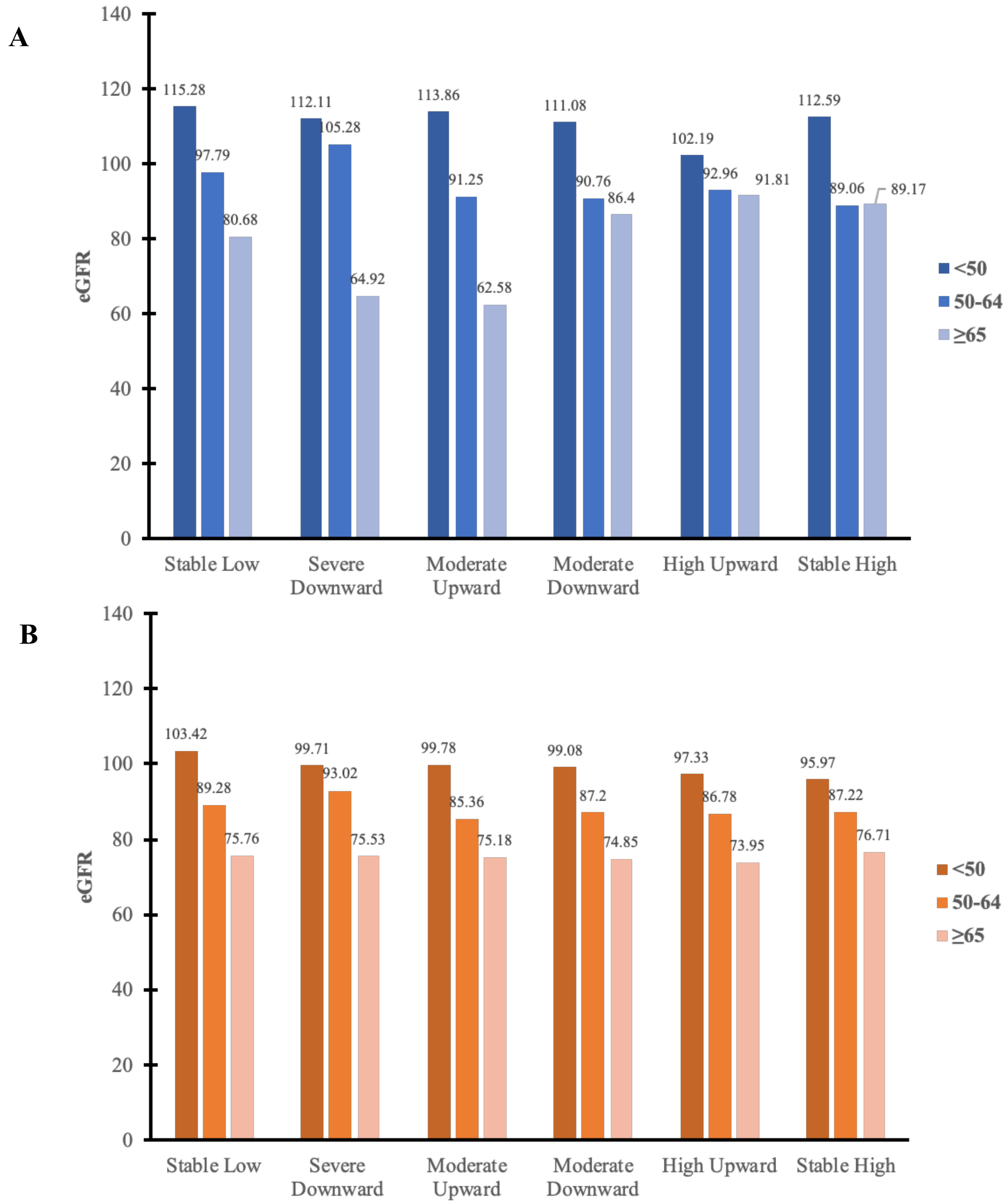


Figure **4.3**: Breakdown of mean eGFR based on intergenerational educational mobility and age groups among Black (A) and white (B) participants.

In Model 2, race and the three-way interaction between age, educational mobility, and race were included in the model to examine whether there were racial differences in the association between educational mobility and age-related decrements in eGFR between Black and white groups. There were racial differences between Black and white participants when comparing the slopes of age-related decrements in eGFR between the Moderate Upward and the Stable High groups (B = 0.55, SE = 0.29, p < .05). The significant three-way interaction remained and the regression coefficient increased (B = 0.65, SE = 0.29, p < .05) after adding multiple covariates into the model (see Model 3), including current SES, daily and lifetime discrimination, psychosocial covariates, and health-related risk factors. Simple slope analysis indicated that the slopes of age-related decrements in eGFR for the Moderate Upward and the Stable High groups among Black and white participants were (Figure 4.4.A): 1) Moderate Upward-Black = -1.61, 2) Stable High-Black = -0.85, 3) Moderate Upward-white = -0.78, and 4) Stable High-white = -0.67. The slope of age-related decrement in eGFR for the Moderate Upward group among Black participants was significantly steeper relative to the slope for the Moderate Upward group among white participants (slope difference = 0.83, t = 3.95, p < .001), the slope for the Stable High group among Black participants (slope difference = 0.76, t = 2.81, p < .01), and the slope for the Stable High group among white participants (slope difference = 0.94, t = 5.02, p < .001).

Additional Analysis

Participant's Education and Age-Related Decrements in eGFR

A set of multiple linear regression analyses was conducted to examine whether racial differences in the steeper age-related decrement in eGFR among the Moderate Upward group (relative to the Stable High group) was mainly driven by participant's education level. Moderate

Upward mobility was characterized by having parents with lower education level (i.e., no HS/GED degree) and some college for the participant's education level. This additional analysis examined whether there were racial differences between Black and white participants regarding the association between having some college education (relative to having bachelor's degree) on age-related decrements in eGFR. The summary from the analysis is presented in Table 4.5. In general, while having some college education relative to a bachelor's degree was associated with steeper age-related decrements in eGFR even after controlling for covariates (Model 3; $B = -0.42$, $SE = 0.20$, $p < .05$), racial differences on the association (i.e., three-way interaction between age, some college vs. bachelor's degree, and race) were not significant (Model 3; $B = 0.38$, $SE = 0.21$, $p = .08$). Figure 4.4.B provides graphic representation of the association between some college education (vs. a bachelor's degree) and age-related decrements in eGFR across different racial groups.

Characterizing the Moderate Upward Mobility Group among Black Participants

Another additional analysis was conducted by linking intergenerational educational mobility to multiple variables that are known to mediate or moderate the association between education, race, and disparities in health. The goal was specifically to characterize the Moderate Upward Mobility group among Black participants and to have better speculation of why they showed steeper age-related decrements in eGFR. In terms of demographic characteristics, the Moderate Upward group among Black participants showed the highest mean of age, and the majority of participants in that group were female. Compared to white adults, Black adults showed higher levels of lifetime (t [$df = 270.61$] $= 11.64$, $p < .001$) and daily (t [$df = 280.93$] $= 6.52$, $p < .001$) discrimination. Within Black group, lifetime discrimination (F [$df = 322$] $= 3.73$, $p < .01$), but not daily discrimination (F [$df = 322$] $= 1.81$, $p = .11$), was significantly differentiated by intergenerational educational mobility. Lifetime discrimination was higher among the Moderate Upward (*M* = 3.22, *SD* = 2.81) and High Upward (*M* = 3.28, *SD* = 2.34) groups. Furthermore, Black relative to white group also showed higher levels of stressor exposure (t [df = 1853] = 7.06, $p < .001$), persist in goal striving (t [df = 1839] = 4.07, $p < .001$), and positive reappraisal (t [df = 1839] = 5.08, $p < .001$). Within Black group, only positive reappraisal was significantly differentiated by educational mobility (F [df = 309] = 3.72, $p < .01$). The High Upward group showed the highest mean score of positive reappraisal (*M* = 3.50, *SD* = 0.45). The mean score of positive appraisals among the Moderate Upward group (*M* = 3.29, *SD* = 0.64) was not significantly different from the mean score of the High Upward group. Furthermore, compared to white participants, Black participants showed a significantly higher proportion of those with lower income, lower financial well-being, and higher financial strain. Within the Black group, the Moderate Upward group showed a significantly higher proportion of those with lower income, lower financial well-being, and higher financial strain compared to those in the High Upward and Stable High groups.

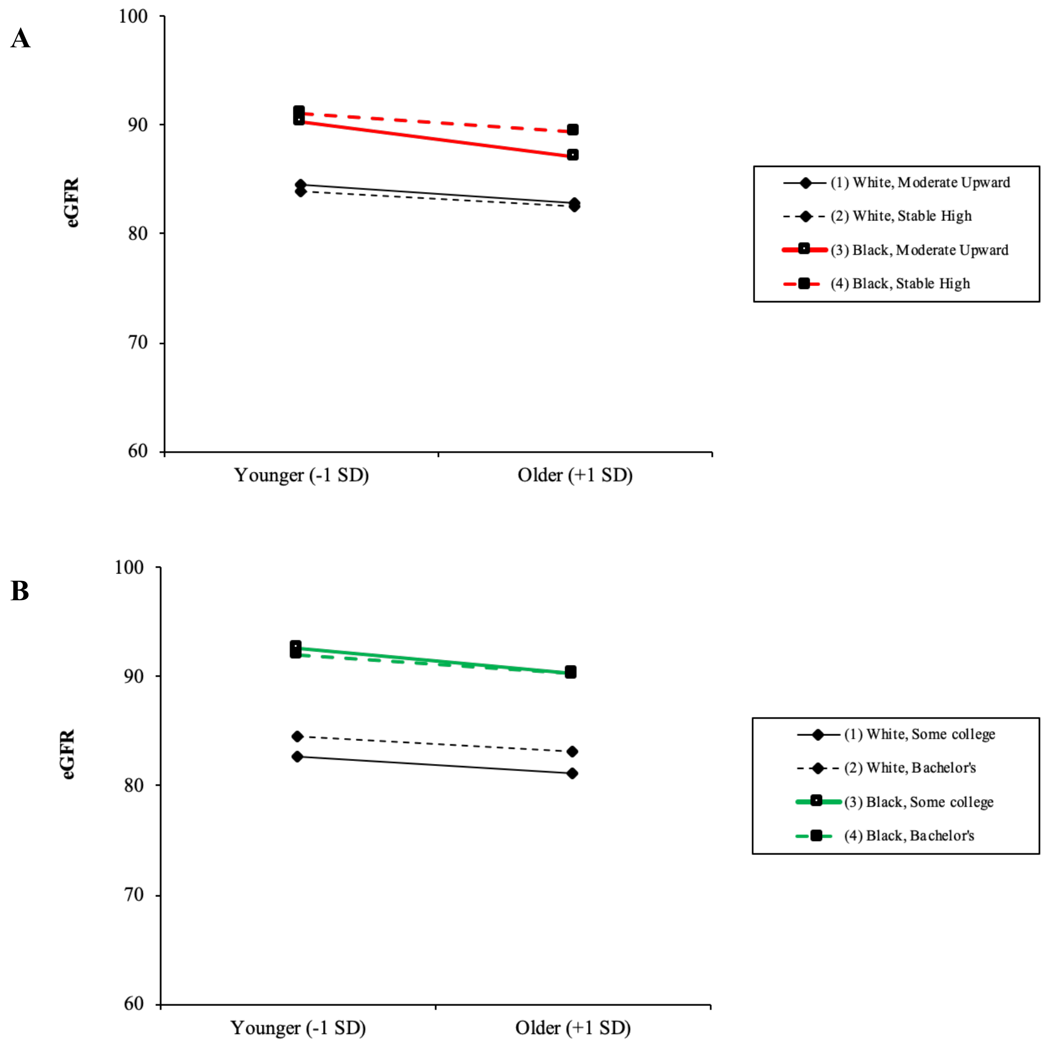


Figure **4.4**: Simple slopes based on the significant three-way interaction between age, Moderate Upward mobility status (vs. Stable High), and race on predicting eGFR (A). Simple slopes based on the non-significant three-way interaction between age, some college status (vs. bachelor's degree), and race on predicting eGFR (B)

Table **4.4**: Intergenerational educational mobility and age-related decrements in kidney function (*N* = 1,861)

	Model 1[a]		Model 2[a]		Model 3[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Intercept	**89.13 (0.81)*****	87.54, 90.72	**96.79 (2.62)*****	91.65, 101.93	**98.20 (4.75)*****	88.89, 107.51
Age (centered)	**-0.71 (0.05)*****	-0.81, -0.61	**-0.85 (0.20)*****	-1.25, -0.45	**-0.85 (0.20)*****	-1.25, -0.45
Educational mobility						
Stable Low vs. Stable High	**6.67 (1.26)*****	4.21, 9.16	3.19 (3.26)	-3.20, 9.57	3.99 (3.40)	-2.67, 10.65
Severe Downward vs. Stable High	**5.55 (1.27)****	3.06, 8.04	2.05 (3.49)	-4.80, 8.91	0.39 (3.62)	-6.72, 7.50
Moderate Upward vs. Stable High	**2.78 (1.28)***	2.28, 5.28	-2.00 (3.28)	-8.44, 4.43	-2.02 (3.38)	-8.64, 4.60
Moderate Downward vs. Stable High	1.39 (1.05)	-0.67, 3.46	0.47 (3.50)	-6.39, 7.33	1.49 (3.68)	-5.73, 8.70
High Upward vs. Stable High	0.99 (1.40)	-1.76, 3.74	-2.02 (3.28)	-9.40, 5.36	-1.28 (3.81)	-8.76, 6.20
Participant's education*Age						
Stable Low vs. Stable High*Age	**-0.40 (0.10)*****	-0.60, -0.20	-0.32 (0.27)	-0.85, 0.21	-0.16 (0.28)	-0.70, 0.39
Severe Downward vs. Stable High*Age	**-0.25 (0.10)***	-0.45, -0.20	-0.13 (0.27)	-0.65, 0.39	0.08 (0.27)	-0.60, 0.45
Moderate Upward vs. Stable High*Age	**-0.38 (0.10)*****	-0.58, -0.18	**-0.72 (0.26)****	-1.23, -0.21	**-0.75 (0.27)****	-1.27, -0.22
Moderate Downward vs. Stable High*Age	-0.11 (0.08)	-0.28, 0.05	-0.01 (0.27)	-0.54, 0.52	0.05 (0.28)	-0.50, 0.60
High Upward vs. Stable High*Age	-0.13 (0.11)	-0.34, 0.08	0.23 (0.35)	-0.45, 0.92	0.22 (0.35)	-0.47, 0.90
Race (0 = Black, 1 = white)			**-8.97 (2.68)****	-14.22, -3.72	**-7.60 (2.79)***	-13.08, -2.12
Age*Race			0.18 (0.21)	-0.23, 0.59	0.17 (0.21)	-0.23, 0.59
Participant's education*Race						
Stable Low vs. Stable High*Race			1.36 (3.58)	-5.66, 8.38	-0.14 (3.70)	-7.40, 7.12
Severe Downward vs. Stable High*Race			1.83 (3.78)	-5.58, 9.24	3.00 (3.90)	-4.64, 10.65
Moderate Upward vs. Stable High*Race			3.02 (3.60)	-4.04, 10.08	2.62 (3.69)	-4.62, 9.85
Moderate Downward vs. Stable High*Race			0.05 (3.67)	-7.15, 7.25	-1.30 (3.85)	-8.85, 6.24
High Upward vs. Stable High*Race			2.32 (4.06)	-5.65, 10.29	1.39 (4.13)	-6.70, 9.48
Participant's education*Age*Race						
Stable Low vs. Stable High*Age*Race			0.02 (0.30)	-0.56, 0.59	-0.12 (0.30)	-0.72, 0.47
Severe Downward vs. Stable High*Age*Race			-0.01 (0.29)	-0.58, 0.57	-0.01 (0.30)	-0.59, 0.57
Moderate Upward vs. Stable High*Age*Race			**0.55 (0.29)***	0.01, 1.11	**0.65 (0.29)***	0.08, 1.23
Moderate Downward vs. Stable High*Age*Race			-0.08 (0.28)	-0.64, 0.47	-0.12 (0.29)	-0.69, 0.46
High Upward vs. Stable High*Age*Race			-0.37 (0.37)	-1.09, 0.35	-0.30 (0.37)	-1.02, 0.42
F	69.99***		41.18***		28.15***	
Adj. *R*-squared	.33		.35		.35	

Note: a = sex and study cohort were included as covariates; b = sex, study cohort, adult SES, lifetime and daily discrimination, psychosocial factors, and health-related factors were included as covariates; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table **4.5**: Participant's education and age-related decrements in kidney function (*N* = 1,861)

	Model 1[a]		Model 2[a]		Model 3[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Intercept	**89.21 (0.78)*****	87.69, 90.73	**96.22 (1.90)*****	92.49, 99.94	**97.66 (4.34)*****	89.15, 106.18
Age (centered)	**-0.73 (0.04)*****	-0.82, -0.65	**-0.81 (0.16)*****	-1.12, -0.50	**-0.81 (0.16)*****	-1.12, -0.50
R Education						
HS/GED vs Bachelor's	**5.86 (0.94)*****	4.02, 7.70	**4.15 (1.09)****	2.02, 6.28	**3.42 (1.12)****	1.21, 5.62
Some college vs Bachelor's	1.43 (0.85)	-0.23, 3.09	0.68 (0.91)	-1.11, 2.47	0.33 (0.94)	-1.52, 2.17
R education*Age						
HS/GED vs Bachelor's*Age	**-0.29 (0.08)*****	-0.44, -0.15	-0.24 (0.20)	-0.63, 0.15	-0.12 (0.20)	-0.52, 0.27
Some college vs Bachelor's*Age	**-0.17 (0.07)****	-0.31, -0.04	**-0.43 (0.20)***	-0.81, -0.05	**-0.42 (0.20)***	-0.82, -0.03
Race (0 = Black, 1 = white)			**-8.42 (1.93)*****	-12.19, -4.64	**-7.30 (2.05)*****	-11.32, -3.28
Age*Race			0.10 (0.16)	-0.22, 0.43	0.11 (0.16)	-0.22, 0.43
R education*Race						
HS/GED vs Bachelor's*Race			-0.98 (2.60)	-6.07, 4.12	-0.84 (2.70)	-6.13, 4.45
Some college vs Bachelor's*Race			-2.25 (2.52)	-7.19, 2.70	-2.14 (2.60)	-7.23, 2.96
R education*Age*Race						
HS/GED vs Bachelor's*Age			0.05 (0.22)	-0.38, 0.47	-0.05 (0.22)	-0.48, 0.38
Some college vs Bachelor's*Age			0.34 (0.21)	-0.07, 0.75	0.38 (0.21)	-0.04, 0.79
F	128.39***		78.05***		42.16***	
Adj. *R*-squared	.32		.35		.35	

Note: a = sex and study cohort were included as covariates; b = sex, study cohort, adult SES, lifetime and daily discrimination, psychosocial factors, and health-related factors were included as covariates; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table **4.6**: The association between intergenerational educational mobility and discrimination, psychosocial factors, social and financial status, and health-related risk factors (*N* = 1,861)

	Black						White					
	Stable Low	Severe Downward	Moderate Downward	Moderate Upward	High Upward	Stable high	Stable Low	Severe Downward	Moderate Downward	Moderate Upward	High Upward	Stable high
Demographic												
Age	51.6 (10.9)	46.0 (11.7)	45.9 (11.2)	53.7 (12.3)	52.5 (9.6)	46.2 (10.7)	59.4 (11.3)	54.4 (11.6)	50.8 (12.6)	58.2 (11.5)	60.2 (12.2)	52.1 (12.2)
Female	66.7	70.0	59.7	74.1	59.4	78.4	58.6	56.5	49.3	58.2	42.8	50.2
Discrimination												
Lifetime	1.75 (2.26)	2.02 (2.29)	2.97 (2.73)	3.22 (2.81)	3.28 (2.35)	2.94 (2.49)	0.82 (1.48)	0.80 (1.41)	1.10 (1.83)	1.07 (1.61)	0.92 (1.57)	0.84 (1.29)
Daily	13.2 (5.79)	15.3 (6.62)	14.3 (5.55)	15.6 (6.25)	15.6 (6.89)	16.2 (6.44)	13.1 (4.48)	13.1 (4.39)	13.2 (4.70)	13.7 (4.68)	12.2 (4.14)	11.9 (3.84)
Psychosocial Factors												
Perceived stress	25.3 (6.4)	25.6 (6.66)	24.1 (6.40)	25.1 (6.58)	22.5 (6.73)	23.2 (6.44)	25.3 (6.40)	25.6 (6.66)	24.1 (6.40)	25.1 (6.58)	22.5 (6.73)	23.21 (6.44)
Persist in goal striving	3.20 (0.55)	3.24 (0.61)	3.43 (0.50)	3.32 (0.55)	3.43 (0.45)	3.37 (0.44)	3.14 (0.56)	3.23 (0.55)	3.11 (0.58)	3.21 (0.56)	3.19 (0.54)	3.21 (0.52)
Positive Reappraisal	3.06 (0.56)	3.15 (0.64)	3.39 (0.60)	3.29 (0.64)	3.50 (0.45)	3.36 (0.50)	3.03 (0.61)	3.11 (0.64)	3.07 (0.63)	3.09 (0.56)	3.06 (0.62)	3.10 (0.60)
Lower Aspiration	2.37 (0.66)	2.33 (0.72)	2.18 (0.58)	2.25 (0.68)	2.07 (0.53)	2.11 (0.53)	2.30 (0.53)	2.25 (0.59)	2.18 (0.53)	2.27 (0.53)	2.20 (0.53)	2.16 (0.51)
Social and Financial Status												
Income (%, <150% poverty line)	41.0	53.4	35.5	32.8	25.0	5.9	19.9	17.6	10.7	14.8	6.1	5.5
Current financial status	3.73 (2.30)	4.43 (2.52)	4.45 (2.68)	4.77 (2.34)	5.94 (2.38)	5.94 (2.35)	5.82 (2.53)	5.88 (2.39)	6.09 (2.11)	6.18 (2.32)	6.92 (2.06)	6.78 (1.99)
Not enough money (%)	74.6	54.2	58.1	55.2	37.5	31.4	24.7	27.0	23.6	21.1	13.2	14.5
Struggling to pay bills (%)	69.8	71.7	64.5	58.6	37.5	49.0	32.7	35.5	34.5	28.9	19.7	22.9
Health-Related Risk Factors												
Currently smoking (%)	39.7	40.0	25.8	22.4	15.6	3.9	16.0	16.7	13.7	15.0	4.6	5.6
Obese (%)	55.6	61.7	58.1	63.8	56.3	66.7	50.0	41.3	42.6	49.0	38.8	31.4
Elevated BP (%)	77.8	51.7	51.6	74.1	62.5	47.1	61.7	50.0	50.0	58.2	60.5	40.2
Insulin resistance (%)	46.0	23.3	21.0	43.1	31.3	31.4	25.9	17.4	16.5	19.0	13.2	10.4

Discussion

This analysis characterized intergenerational educational mobility patterns among Black and white adults in the MIDUS study by comparing their parental education (lower = no HS; higher = HS and higher) to their own education level (lower = HS/lower; moderate = some college; higher = bachelor's degree). Furthermore, this analysis examined the association between intergenerational educational mobility and age-related decrements in eGFR. Black participants were spread out across the six categories of intergenerational educational mobility. Almost 20% of Black participants experienced the Stable Low pattern (lower parental education and lower participant's education) and the proportion of the Stable High pattern (higher parental education and higher participant's education) was around 15%. Among white participants, intergenerational educational mobility was dominated by the Stable High pattern (~ 42%) while around 10% experienced the Stable Low pattern.

Controlling for sex and study cohort, those in the Stable Low, Severe Downward (higher parental education and lower participant's education), and Moderate Upward (lower parental education and moderate participant's education) groups showed steeper age-related decrements in eGFR relative to those in the Stable High group. However, the slopes for age-related decrements in eGFR for the Moderate Downward (higher parental education and moderate participant's education) and the High Upward (lower parental education and higher participant's education) groups were not significantly different from the Stable High group's slope. Further analysis showed that the association between the Moderate Upward group (vs. Stable High) and steeper age-related decrements in eGFR was conditional on race. Black adults who experienced Moderate Upward mobility especially showed steeper age-related decrements in eGFR. The three-way interaction remained significant even after controlling for discrimination, psychosocial variables, and multiple health-related risk factors. Additional analyses showed that Black adults in the Moderate Upward group showed higher levels of daily and lifetime discrimination, lower financial status, higher financial strain, and worse health-related risk factors.

Racial Differences in Intergenerational Educational Mobility

The striking difference between Black and white participants in terms of the distribution of intergenerational educational mobility patterns corroborated previous findings on Black-white disparities in educational attainment and educational mobility. The higher proportion of white adults with the Stable High pattern indicated the higher likelihood to pass socioeconomic advantage on to the next generation. Among Black adults, the level of uncertainty was higher, supported by the spread of the proportions of educational mobility across the six categories. Others have noticed similar pattern of educational mobility among Black adults. In an analysis among American Black men, Davis (1994) noted that Black fathers' educational attainment did not guarantee that their sons would attain similar or higher education level. In Chapter 3, the lack of correlation between parental education and participant’s current SES among Black adults may also be driven by this lack of association between parental education and participant’s education. Multiple factors may explain the lack of guarantee of an intergenerational transfer of educational advantage among Black adults, including mass incarceration (Hagan & Foster, 2012) and the changing family structure (i.e., increased number of single-parent families; Song, 2016).

Another study examining a different cohort (1940s and 1960s birth cohort) during a different period (1990s), however, found that intergenerational educational upward mobility among a younger cohort of Black adults was increasing (Bloome & Western, 2011). This rising pattern of upward educational mobility was attributed to the changing educational policy in the United States (Bloome & Western, 2011). Thus, the patterns of educational mobility may change across different cohorts and periods. Given that the majority of Black participants in this analysis were recruited from Milwaukee County, the current finding regarding educational mobility may be unique to the current Black sample.

Intergenerational Educational Mobility and Age-Related Decrements in eGFR

The findings regarding the steeper age-related decrements in eGFR among the Stable Low and Severe Downward groups were expected. A previous study examining the link between educational mobility and inflammation also found similar results, in which the stable low pattern was associated with higher CRP while downward mobility was associated with higher IL-6 (Loucks et al., 2010). However, the significant association between Moderate Upward (vs. Stable High) mobility and age-related decrements in eGFR was unanticipated. This group was characterized by lower parental education and moderate participant's education (i.e., some college). An analysis by Zajacova and Johnson-Lawrence (2016) has documented the anomaly of the lack of health benefits from attaining some college relative to those who achieved a college degree. It is possible that attaining some college did not compensate for the detrimental impact of disadvantages associated with lower parental education.

Further analysis on racial differences in the association between educational mobility and age-related decrements in eGFR indicated that the association between Moderate Upward (vs. Stable High) and age-related decrements in eGFR was conditional on race. Upon closer examination, Black adults in the Moderate Upward group particularly showed the steepest slope of age-related decrements in eGFR. In order to make a better conjecture as to of why Black adults with Moderate Upward mobility were the most disadvantaged in terms of their kidney functioning, the association between educational mobility and multiple covariates were explored. Black adults in the Moderate Upward mobility showed higher levels of lifetime discrimination, comparable to the High Upward group. Among Black adults, discrimination is higher among individuals who experienced upward socioeconomic mobility (Surachman et al., 2021). Furthermore, upward mobility among Black adults is also associated with higher self-control (Brody et al., 2020). In this analysis, we showed that the Moderate and Upward Mobile groups showed higher self-control, especially regarding the positive reappraisal domain. However, there was no evidence that the Moderate Upward mobility group receive similar financial returns as evident among the High Upward group did. This combination of high discrimination and low financial returns may be the reason that the experience of Moderate Upward mobility was detrimental on health, including kidney functioning in adulthood. Using the COVID-19 vaccination metaphor, those who earned bachelor's degree is the equivalent of receiving two doses of the vaccines and gaining the immunity needed to protect them from the harmful experience of discrimination. However, the educational credential of some college is the equivalent of only receiving one shot of vaccine and thus being unable to gain the immunity necessary to be shielded from the harm of early life disease programming and life course factors associated with upward mobility, such as higher levels of discrimination. Further systematic analysis to examine this hypothesis is needed. It is also important to mention that the Moderate Upward group showed the highest mean of age compared to other mobility patterns. The steeper slope may be due to the fact that there were more older individuals in this group.

The current study has multiple strengths. First, the extensive biological, clinical, and psychological information from the MIDUS study allowed us to include multiple psychosocial factors and health-related risk factors in the analysis. Second, this study included participants from a wide age range that enabled robust estimates of age-related decrements in eGFR. However, it should also be acknowledged that this analysis does have some limitations. First, the unavailability of longitudinal biological information in the MIDUS study prohibited a prospective analysis. Second, it should also be acknowledged that parental education was based on retrospective reports and this could introduce some bias, even though a previous analysis indicated a high level of accuracy in terms of retrospective reports of parental education from a small subset of sibling participants in MIDUS (Ward, 2011). Third, the indicator of kidney function was based on serum creatinine, which is sensitive to both diet and muscle mass. In addition, we utilized the CKD-EPI formula to calculate eGFR, which is currently under scrutiny because it incorporates a race adjustment into the formula (Diao et al., 2021). Finally, the majority of the Black participants were recruited from Milwaukee County, WI, which could limit the generalizability of the findings to other regions.

Conclusion

This findings from the current analysis add to the knowledge of how different patterns of intergenerational educational mobility linked differently to age-related decrements in eGFR. This analysis indicated that Moderate Upward pattern (lower parental education [i.e., no HS degree] and moderate participant's education [i.e., some college]) was associated with significantly steeper age-related decrements in eGFR when compared to those who experienced Stable High pattern (higher parental education [i.e., HS degree or higher] and higher participant's education [i.e., bachelor's degree or higher]). The steeper age-related decrements in eGFR among the Moderate Upward group was especially more pronounced among Black participants. Further analysis indicated that Black adults in the Upwardly Mobile group reported higher levels of lifetime discrimination and higher self-control. However, they showed higher proportion of lower income, lower financial well-being, and higher financial strain. For Black adults, maintaining higher self-control is required to make it to college. At the same time, making it to higher education opens the possibility of higher exposures to discrimination. However, for those without bachelor's degrees, all these challenges come without the financial/material and social status benefits. Future studies should try to replicate these findings and further formally examine whether discrimination, self-control, and financial status and strain mediate or moderate the association between intergenerational educational mobility and age-related decrements in eGFR among Black and white adults.

Chapter 5

Subjective Socioeconomic Status across the Life Course and Age-Related Decrements in Kidney Function among Black and white American Adults

Introduction

In Chapters 3 and 4, the life course analyses focused solely on education, one of the objective indicators of SES. In the last two decades, there have been growing interests in understanding the role of subjective SES in the context of health disparities (Adler et al., 2000; Arber et al., 2014). Despite these growing interests, the systematic review in Chapter 2 showed that no empirical paper has examined the association between subjective SES and disparities in kidney disease. In this chapter, the associations between multiple indicators of subjective SES across the life course and kidney functioning in adulthood among Black and white American adults were explored.

Subjective SES

One of the persistent debates in the study of health disparities is regarding the mechanism of how inequality leads to differences in health outcomes, whether it is due to a lack of material resources or whether it is caused by a perceptual relative hierarchy (Carpiano et al., 2008). Focus on the lack of material resources has been dominating the field of health disparities research and it was only recently that perceptual relative hierarchy, or subjective SES, become a major topic on the study of disparities in health (Adler et al., 2000). Subjective SES is formally defined as one's perception of their position in social hierarchy (Davis, 1956; Singh-Manoux et al., 2003).

Increased interests in understanding the association between subjective SES and health disparities are influenced by two programs of research (Operario et al., 2004; Singh-Manoux et al., 2003; Singh-Manoux et al., 2005): 1) the study of gradients on the association between SES and health, indicating that it is not only the deprivation of material resources (i.e., poverty) that matters for health disparities, but the perception of the hierarchy of social status as well; 2) research involving animals on the association between hierarchy and health through the stress physiological pathways.

Research on social status stemmed from the Weberian tradition of stratification and inequality, in which access to valuable resources is determined by status, wealth, and power (Breen, 2005; Ridgeway & Nakagawa, 2014). Status is formally defined as the relative hierarchy of individuals, groups, or objects based on a mutual standard of social values (Ridgeway & Nakagawa, 2014). We care about status in the study of inequality and health disparities because social status influences an individual's feelings, attitudes, and behaviors by shaping the proximal conditions of one's life (McLeod & Lively, 2006). Social status is especially associated with the probability of exposure to chronic stressors and the availability of resources to cope with them (Pearlin et al., 2005; Thoits, 2010). In addition to dealing with chronic stressors related to social status, individuals from minority background also have to deal with discrimination-related stressors (Thoits, 2010). Thus, differential exposure to chronic stressors is a possible mechanism through which subjective SES is linked to disparities in health (Pearlin et al., 2005; Thoits, 2010).

Subjective SES and Health

Research in subjective SES and its association with health stemmed from different scientific traditions across multiple fields including sociology and psychology. The sociological research on stress and health shed light on the importance of financial strain, as a major type of stressors, on affecting health and well-being (Kahn & Pearlin, 2006). Research on the psychological mechanisms that link SES and health led to the development of subjective social status (SSS), a single measure of an individual's perception of the social hierarchy (Adler et al., 2000). Finally, research in the area of family resource management and consumer science directed their focus on financial well-being, a person's assessment of their current financial situation (Brüggen et al., 2017). As described below, each of these constructs is a robust predictor of health and well-being. However, there is a lack of empirical studies examining the association between these multiple indicators of subjective SES and kidney functioning across adulthood. Furthermore, there is a lack of focus to examining racial differences, especially between Black and white adults, on the association between subjective SES and kidney functioning across adulthood.

Subjective Social Status (SSS)

Studies on SSS usually utilized the single measure of the MacArthur ladder of social status (Adler et al., 2000). Multiple studies have shown the predictive validity of the ladder on predicting health outcomes including self-rated health, psychopathology, and major physical health outcomes including cardiovascular risk and mortality (Adler & Stewart, 2007). Furthermore, studies have shown that the ladder captures a different construct when compared to traditional SES measures such as income and education (Adler & Stewart, 2007; Adler et al., 2000; Singh-Manoux et al., 2005). An analysis by Wolff et al. (2010) examined racial differences in SSS between Black and white adults and found that Black adults rated their SSS higher than white adults, especially when proximal referent group (i.e., comparing one social status to other people in the same community) was used. Furthermore, a meta-analysis by Cundiff and Matthews (2017) showed that the association between SSS and physical health was stronger for Black relative to white adults. However, there is no study that has examined the association between SSS and kidney function in adulthood and racial differences in the association.

Financial Strain

Financial strain is defined as one's perception regarding financial inadequacy or financial concerns and worries (Hibbert et al., 2004; Voydanoff, 1990). This concept is also referred to as economic distress (Voydanoff, 1990) or economic pressure (Conger et al., 1992). Higher financial strain is a robust predictor for multiple health outcomes, including obesity (Conklin et al., 2013), insulin resistance (Puterman et al., 2012), and mortality (Szanton et al., 2008). Furthermore, there is well-documented evidence that in general, Black adults reported higher financial strain compared to white adults (Hall et al., 2009; Lincoln et al., 2003). Financial strain is hypothesized to be one of the psychosocial factors that contribute to racial disparities in CKD (Bruce et al., 2009; Bruce et al., 2015). However, there is a lack of empirical analysis examining the association between financial strain and kidney function in adulthood and racial disparities on the association.

Financial Well-Being

Financial well-being, assessment of one's current financial situation, has been shown to be associated with multiple health outcomes, including overall well-being (Netemeyer et al., 2018), self-reported health status (Arber et al., 2014), and depression (Hale, 1982). There is a lack of knowledge regarding racial differences in financial well-being, especially between Black and white adults. A study by Clark et al. (2020) showed that Black women reported lower levels of financial well-being compared to white women, partly due to higher reports of financial strain.

There is a lack of knowledge on the association between financial well-being and kidney function across adulthood or regarding Black-white differences in the association.

Subjective SES across the Life Course

While each indicator of subjective SES is a robust predictor of health, above and beyond objective indicators of SES, little is known regarding the interconnectedness among these indicators and how they link to health. Furthermore, some have also suggested incorporating the life course framework into the study of subjective SES and its association with health and well-being (Kahn & Pearlin, 2006; Szanton et al., 2010). One way to examine the association between life course subjective SES and health is by examining the heterogeneity of trajectories or mobility patterns based on multiple indicators of subjective SES across the life course (Surachman et al., 2021; Surachman, Rice, et al., 2020). Different patterns of subjective SES mobility across the life course may link differently to health, including kidney functioning in adulthood.

Current Study

Despite the well-documented evidence regarding the association between subjective SES and multiple health outcomes, little is known about whether it is associated with kidney outcomes. This analysis examined the association between multiple indicators of subjective SES across the life course, including SSS, financial strain, and financial well-being, and age-related decrements in eGFR. In addition, this analysis examined whether the association between each indicator of subjective SES and kidney function was conditional on age. Furthermore, this analysis identified the heterogeneity of subjective SES mobility across the life course and examined whether different types of subjective SES mobility link differently to age-related decrements in eGFR. Finally, racial differences on the association between subjective SES mobility and age-related decrements in eGFR were examined. Taken together, this analysis contributed to the gap in the literature of how subjective SES across the life course may contribute to faster aging kidney and the development of CKD.

Methods

Data and Participants

Data for this particular analysis were from the Midlife in the United States (MIDUS) wave 2 Refresher (MIDUS R) study. Details important to the current study and additional information about MIDUS and biomarker data collection in the MIDUS study have been presented in the Methods section of Chapter 3.

Analytic Sample

The analytic sample included participants who completed the Biomarker Projects of MIDUS 2 and MIDUS R. Out of a potential pool of 2118 participants (MIDUS 2 = 1255, MIDUS R = 863), 1930 were selected who self-identified as non-Hispanic Black (*n* = 369) and non-Hispanic white (*n* = 1561). Participants with missing information for either serum creatinine (*n* = 20) or parental education (*n* = 49) were excluded. The final sample included 1861 adults (non-Hispanic Black adults = 326, non-Hispanic white adults = 1535).

Measures

Childhood Financial Well-Being

Participants responded to the question "Thinking back to your family's financial situation when you were growing up, was your family better off or worse off financially than the average family was at that time?" on a 7-point scale (1 = a lot better off, 2 = somewhat better off, 3 = a little better off, 4 = same as average family, 5 = a little worse off, 6 = somewhat worse off, 7 = a lot worse off). The original response was reverse coded (1 = a lot worse off to 7 = a lot better off) and recoded into a binary variable (0 = a lot worse off/somewhat worse off/a little worse off, 1 = same as average family/a little better off/somewhat better off/a lot better off).

Current Subjective Social Status

Participants' perception regarding their current social standing was measured using the McArthur Scale of Subjective Social Status Community Ladder (Adler & Stewart, 2007). Participants were asked to place themselves on a 10-point ladder that represented the community social standing, where the top of the ladder represented the highest standing and the bottom represented the lowest standing. The original coding indicated that 1 represented the top rung and 10 represented the bottom rung. The score from the original coding was reverse coded (1 = the bottom to 10 = the top).

Current Financial Well-Being

There were two questions regarding current financial status, current financial situation, and current control over financial situation. Participants were asked to rate their current financial situation on an 11-point scale where 0 represented the worst possible financial situation and 10 represented the best possible financial situation. In addition, participants also responded to the question regarding their perception of their control over their current financial situation on an 11-point scale where 0 represented no control at all and 10 represented very much control.

Current Financial Strain

Current financial strain was based on participants' response to two questions. First, participants responded to the question, "In general, would you say you (and your family living with you) have more money than you need, just enough for your needs, or not enough to meet your needs?", on a 3-point scale (1 = more money than you need, 2 = just enough money, 3 = not enough money). The original response was reverse coded (1 = not enough money to 3 = more money than you need) and recoded as a binary variable (0 = not enough money, 1 = just enough money/more money than you need). Second, participants responded to the question, "How difficult is it for you (and your family) to pay your monthly bills?", on a 4-point scale (1 = very difficult, 2 = somewhat difficult, 3 = not very difficult, 4 = not at all difficult). The original response was recoded into a binary variable (0 = very difficult/ somewhat difficult, 1 = not very difficult/ not at all difficult).

Age

Participants reported their birth dates during the Biomarker Project. Thus, each participant's age (years) was based on their age at the time of blood sample collection.

Kidney Function

Estimated glomerular filtration rate (eGFR) was calculated from serum creatinine using the CKD-EPI formula (Levey & Stevens, 2010). The CKD-EPI formula takes age, sex, and race into consideration when calculating eGFR. Serum creatinine was assayed from overnight fasted blood collected during the Biomarker Project using Roche Cobas Analyzer (Unity Meriter Lab, Madison, WI). The assay range was 0.06-30.5 mg/dL, with an inter-assay CV of 2.08%. across the 2 phases of MIDUS.

Covariates

Covariates included in the analysis were sex (0 = female, 1 = male), study cohort (0 = MIDUS Refresher, 1 = MIDUS 2), education level (0 = no bachelor's degree, 1 = bachelor's degree or higher), and multiple indicators of health-related risk factors. Health-related risk factors were: current smoking status (0 = currently not smoking, 1 = currently smoking), obesity (BMI≥30 kg/m^2 = 1, otherwise coded as 0), elevated BP (systolic and diastolic BP ≥ 140/90 or self-report of hypertension diagnosis by a physician = 1, otherwise coded as 0), and insulin resistance (HbA1c ≥ 6.5% or fasting blood glucose ≥ 126 mg/dL or self-reported diagnosis of type 2 diabetes by a physician = 1, otherwise coded as 0).

Statistical Analysis

The analytic plan was divided into two different parts. The first part of the analysis examined the association between multiple indicators of subjective SES across the life course and age-related decrements in eGFR among Black and white adults. The second part of the analysis identified the heterogeneity of subjective SES mobility across the life course and examined the association between subjective SES mobility and age-related decrements in eGFR among Black and white adults. The specific goals of the second part of the analysis were (Figure 5.1): a) to identify the heterogeneity of subjective SES mobility based on multiple indicators of subjective SES across the life course; b) to examine the association between subjective SES mobility and age-related decrements in eGFR; and c) to examine racial differences between Black and white adults on the association between subjective SES mobility and age-related decrements in eGFR. Identification of latent classes of subjective SES mobility was accomplished via latent class analysis (LCA). LCA is a person-centered analysis that fits the goal to model heterogeneity of subjective SES mobility based on multiple categorical indicators by providing intuitive parsimonious solutions (Fosco & Bray, 2016; Surachman, Rice, et al., 2020).

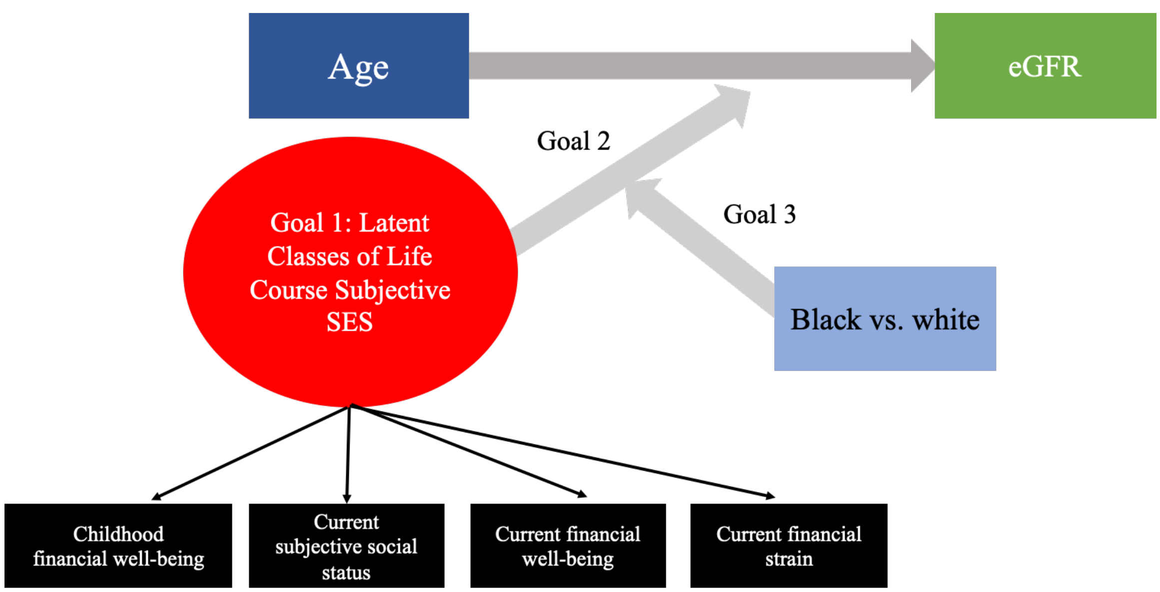


Figure **5.1**: A graphic representation of the latent class analysis of subjective SES mobility and their association with age-related decrements in eGFR among Black and white participants

Subjective SES and Age-Related Decrements in eGFR

A multiple linear regression analysis was utilized to examine the association between each indicator of subjective SES and age-related decrements in eGFR. Analysis was conducted separately for each indicator of subjective SES. Prior to the regression analysis, subjective social status (SSS) and both indicators of financial well-being were centered. For each indicator of subjective SES, analysis adhered to the following model building procedure. In the first model (Model 1), when testing the association between SSS and kidney functioning for example, age, SSS, and the interaction between age and SSS were included in the model. Sex and study cohort were also included as covariates. In the second model (Model 2), race, and the three-way interaction between age, SSS, and race were added to the model to test whether there were racial differences on the association between SSS and kidney functioning. In the final model (Model 3), the covariates were entered into the model, including education, income, and health-related risk factors.

Latent Classes of Subjective SES Mobility and Age-Related Decrements in eGFR

The second part of the analysis was divided into three steps: 1) model selection and identification, 2) measurement invariance test based on race, and 3) testing the association between latent classes with age-related decrements in kidney function. Prior to LCA, SSS and both indicators of financial well-being were converted to binary variables, in which values lower than the median for each variable were categorized as lower and the rest was grouped as higher. Thus, all the indicators of subjective SES were binary variables when included in the latent class analysis. Selection of the optimally fitting model was based on model fit statistics and selection criteria, parsimony principle, and theoretical interpretability (Lanza et al., 2007). Model fit statistics and selection criteria included the Akaike information criterion (AIC), Bayesian information criterion (BIC), sample-size adjusted BIC (a-BIC), entropy, Bozdogan's consistent AIC (CAIC), and bootstrapped likelihood ratio test (BLRT). A better fit model was indicated by lower values of AIC, BIC, a-BIC and CAIC. Furthermore, higher values for entropy indicated higher classification utility, hence a better fit model. Finally, a significant *p*-value of BLRT indicated an improvement in model fit compared to a model with one fewer class. To select the best fitting model, latent class models based on six indicators of subjective SES across the life course with 1- to 5-class solutions were tested. Model identification was conducted by utilizing 1,000 sets of random starting values. After the best fitting model was selected, focus was directed toward two sets of parameters. The first set was the latent class membership probabilities, which indicate the distribution of the classes in the sample or the size of each latent class. The second parameter was the item-response probabilities, which indicate the probabilities of providing certain responses to the observed variables, conditional on class membership. The item-response probabilities were used to label the latent classes. Identification of the best fitting model was conducted using PROC LCA on SAS (Lanza et al., 2007).

The next step of the analysis examined measurement invariance on the selected best fitting model based on race. When the measurement invariance assumption holds, the best fitting model selected in the previous step of the analysis implies the same meaning for both racial groups. Measurement invariance was conducted by comparing two nested models. In the first model, item-response probabilities were freely estimated, while in the second model, item-response probabilities were restricted to being equal across racial groups. Given that the two models were nested, model fit of the two models were then compared using the likelihood-ratio difference test. A non-significant *p*-value would indicate support for measurement invariance, implying that the meaning of the latent classes was similar across the two racial groups. On the other hand, a significant *p*-value would indicate that the assumption of measurement invariance across racial groups did not hold. In the case of severe differences in measurement, separate analyses of latent classes for each racial group is recommended (Lanza et al., 2007).

The final step of the analysis was to examine the association between latent classes of subjective SES mobility and age-related decrements in kidney function. The latent class moderation analysis (Rhoades Cooper & Lanza, 2014) was utilized to examine the hypothesis. Each participant was classified to a latent class in the best-fitting LCA model by utilizing an improved inclusive classify-analyze approach (Bray et al., 2015). This approach is known for reducing any attenuation in the association between latent class membership and the outcome (Bray et al., 2015). Finally, *n*-1 dummy-coded variables indicating membership in one of the latent classes of SES mobility were created. The most affluent latent class was treated as the reference group. A multiple linear regression analysis was utilized to examine the association between subjective SES mobility and age-related decrements in kidney function and to test whether there were racial differences between Black and white adults in that association. Sex, study ccohort, education level, household income, and health-related risk factors were included as covariates.

Results

Descriptive Characteristics of the Participants

The detailed information regarding characteristics of the participants in the analysis is presented in the Results section of Chapter 3 (see Table 3.1).

Subjective SES Among Black and White Adults

Table 5.1 provides comparisons between Black and white participants for each indicator of subjective SES across the life course. Black and white participants rated their childhood financial status similarly. Close to one-third of Black and white participants perceived that their childhood financial status was lower than the general family around them (χ^2 [*df* = 1] = 0.14, $p > .05$). Black participants rated their current standing in the community (*M* = 6.22, *SD* = 2.08) significantly lower than their white counterpart (*M* = 6.60, *SD* = 1.74), *t* [*df* = 376.1] = 2.88, $p < .01$. Similarly, Black participants also rated their current financial status (*M* Black = 4.74 [*SD* = 2.54], *M* white = 6.42 [*SD* = 2.19]; t [*df* = 432.5] = 11.07, $p < .001$) and control over financial status (*M* Black = 6.17 [*SD* = 3.14], *M* white = 6.84 [*SD* = 2.47]; t [*df* = 413.5] = 3.59, $p < .001$) significantly lower than white participants. Finally, significantly more Black participants than white participants that perceived they did not have enough money to meet basic needs (% Black = 53.8, % white = 18.9; χ^2 [*df* = 1] = 174.64, $p < .001$) and struggling to pay monthly bills (% Black = 60.7, % white = 27.5; χ^2 [*df* = 1] = 133.62, $p < .001$), indicating higher levels of current financial strain.

Table **5.1**: Comparison of subjective SES indicators among Black and white participants (*N* = 1,861)

Subjective SES	Black (*n* = 326)	White (*n* = 1,535)	All (*N* = 1,861)	t/ χ^2
Childhood financial well-being				
Lower childhood financial status (%)	28.4	29.5	29.3	0.14
Current subjective social status				
Subjective social status (*M* [SD])	6.22 (2.08)	6.60 (1.74)	6.54 (1.80)	2.88^{**}
Current financial well-being				
Current financial status (*M* [SD])	4.74 (2.54)	6.42 (2.19)	6.13 (2.34)	11.07^{***}
Control over financial status (*M* [SD])	6.17 (3.14)	6.84 (2.47)	6.72 (2.61)	3.59^{***}
Current financial strain				
Not enough money to meet needs (%)	53.8	18.9	25.0	174.64^{***}
Struggling to pay bills (%)	60.7	27.5	33.3	133.62^{***}

Note: t/ χ^2 = *t* value or chi-square value from comparison across racial groups. * = $p < .05$, ** = $p < .01$, and *** = $p < .001$

Subjective SES and Age-Related Decrements in eGFR

The summary from the multiple linear regression analysis on the association between each indicator of subjective SES across the life course and age-related decrements in eGFR is presented in Table 5.2. Among the indicators of subjective SES, financial well-being and financial strain, but not childhood financial status and subjective social status, were associated with age-related decrements in eGFR. Lower financial status (Model 1; $B = 0.05$, $SE = 0.01$, $p < .01$), but not lower control over financial status (Model 1; $B = 0.02$, $SE = 0.01$, $p > .05$), was associated with steeper age-related decrements in eGFR, controlling for sex and study cohort. As indicated in Figure 5.2.A, participants who reported lower financial status (-1 *SD*), showed slightly higher eGFR across different age groups, but steeper age-related decrements in eGFR compared to those who perceived higher financial status (+1 *SD*). Furthermore, participants who reported that they did not have enough money to meet basic needs (Model 1; $B = 0.27$, $SE = 0.07$,

$p < .001$) and were struggling to pay monthly bills (Model 1; $B = 0.16$, $SE = 0.07$, $p > .05$) also showed steeper age-related decrements in eGFR, controlling for sex and study cohort. Figure 5.2.B and C provide graphic representation of the association between financial strain and age-related decrements in eGFR. The significant association between current financial status (Model 2; $B = 0.05$, $SE = 0.01$, $p < .01$), availability of money (Model 2; $B = 0.27$, $SE = 0.07$, $p < .01$), and hardship to pay bills (Model 2; $B = 0.17$, $SE = 0.07$, $p < .05$) remained after education, income, and health-related risk factors were added into the model.

Racial Differences on the Association Between Subjective SES and Age-Related Decrements in eGFR

The association between each indicator of subjective SES and age-related decrements in eGFR was not conditional on race (Model 3 and Model 4 in Table 5.2).

Table **5.2**: Summary from the multiple linear regression analysis on the association between each indicator of subjective SES across the life course and age-related decrements in eGFR (*N* = 1,861)

	Model 1[a]		Model 2[b]		Model 3[a]		Model 4[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Childhood Financial Status								
Intercept	**91.39 (0.89)*****	89.65, 93.14	**92.95 (1.51)*****	89.97, 95.93	**98.02 (1.68)*****	94.72, 101.32	**97.93 (2.05)*****	93.92, 101.95
Age (mean centered)	**-0.78 (0.06)*****	-0.89, -0.67	**-0.77 (0.06)*****	-0.89, -0.66	**-0.91 (0.14)*****	-1.19, -0.63	**-0.86 (0.14)*****	-1.14, -0.58
Childhood financial status	-0.90 (0.81)	-2.50, 0.70	-0.53 (0.82)	-2.13, 1.08	-2.17 (1.98)	-6.04, 1.71	-2.29 (1.98)	-6.19, 1.60
Childhood financial status*Age	-0.08 (0.07)	-0.21, 0.05	-0.07 (0.07)	-0.20, 0.06	-0.23 (0.17)	-0.55, 0.10	-0.26 (0.17)	-0.58, 0.07
Race (0 = Black, 1 = white)					**-8.80 (1.79)*****	-12.31, -5.30	**-8.23 (1.83)*****	-11.82, -4.65
Age*Race					0.18 (0.15)	-0.12, 0.48	0.13 (0.15)	-0.18, 0.43
Childhood financial status*Race					1.12 (2.16)	-3.11, 5.36	1.71 (2.17)	-2.54, 5.97
Childhood financial status*Age*Race					0.21 (0.18)	-0.14, 0.57	0.25 (0.18)	-0.10, 0.61
F	159.5***		78.2***		105.9***		64.88***	
Adj. R^2	.30		.32		.34		.35	
Subjective Social Status								
Intercept	**90.43 (0.70)*****	89.06, 91.80	**92.64 (1.43)*****	89.83, 95.45	**96.62 (1.09)*****	94.48, 98.77	**97.01 (1.62)*****	93.84, 100.19
Age (centered)	**-0.82 (0.03)*****	-0.88, -0.76	**-0.81 (0.03)*****	-0.87, -0.75	**-1.02 (0.08)*****	-1.18, -0.86	**-0.98 (0.08)*****	-1.14, -0.82
Subjective social status (centered)	0.11 (0.21)	-0.30, 0.53	0.37 (0.22)	-0.06, 0.79	0.51 (0.49)	-0.44, 1.46	0.76 (0.49)	-0.20, 1.72
Subjective social status*Age	0.02 (0.02)	-0.01, 0.05	0.02 (0.02)	-0.01, 0.05	0.01 (0.04)	-0.07, 0.08	0.02 (0.04)	-0.05, 0.10
Race (0 = Black, 1 = white)					**-8.22 (1.06)*****	-10.3, -6.14	**-7.30 (1.12)*****	-9.50, -5.09
Age*Race					**0.27 (0.09)****	0.10, 0.44	**0.25 (0.09)****	0.08, 0.42
Subjective social status*Race					-0.42 (0.54)	-1.47, 0.64	-0.53 (0.54)	-1.59, 0.53
Subjective social status*Age*Race					0.01 (0.04)	-0.08, 0.09	-0.01 (0.04)	-0.09, 0.08
F	154.30***		74.48***		100.22***		60.99***	
Adj. R^2	.30		.31		.33		.34	
Current Financial Status								
Intercept	**90.34 (0.70)*****	88.97, 91.71	**91.94 (1.44)*****	88.11, 94.76	**96.55 (1.14)*****	94.32, 98.77	**96.63 (1.69)*****	93.32, 99.94
Age (centered)	**-0.84 (0.03)*****	-0.90, -0.78	**-0.83 (0.03)*****	-0.90, -0.77	**-1.04 (0.08)*****	-1.20, -0.89	**-1.00 (0.08)*****	-1.16, -0.84
Current financial status (centered)	**-0.37 (0.16)***	-0.68, -0.05	-0.05 (0.17)	-0.39, 0.29	0.17 (0.35)	-0.52, 0.87	0.31 (0.36)	-0.40, 1.02
Current financial status*Age	**0.05 (0.01)****	0.02, 0.07	**0.05 (0.01)****	0.02, 0.07	0.04 (0.03)	-0.02, 0.10	0.04 (0.03)	-0.02, 0.09
Race (0 = Black, 1 = white)					**-8.20 (1.10)*****	-10.35, -6.05	**-7.52 (1.15)*****	-9.77, -5.28

	Model 1[a]		Model 2[b]		Model 3[a]		Model 4[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Age*Race					**0.28 (0.09)****	0.12, 0.45	**0.25 (0.09)****	0.08, 0.42
Current financial status*Race					-0.27 (0.40)	-1.05, 0.51	-0.29 (0.40)	-1.08, 0.50
Current financial status*Age*Race					-0.01 (0.03)	-0.08, 0.05	-0.01 (0.03)	-0.07, 0.05
F	166.57***		80.66***		107.57***		65.95***	
Adj. R^2	.31		.33		.34		.35	
Control Over Financial Status								
Intercept	**90.59 (0.70)*****	89.22, 91.96	**92.43 (1.42)*****	89.62, 95.23	**96.46 (1.06)*****	94.37, 98.53	**96.56 (1.60)*****	93.41, 99.70
Age (centered)	**-0.84 (0.03)*****	-0.90, -0.78	**-0.83 (0.03)*****	-0.90, -0.76	**-1.05 (0.07)*****	-1.20, -0.91	**-1.01 (0.08)*****	-1.16, -0.86
Control over financial status	-0.21 (0.14)	-0.49, 0.07	-0.05 (0.15)	-0.34, 0.23	-0.11 (0.28)	-0.67, 0.44	-0.02 (0.29)	-0.58, 0.55
Control over financial status*Age	0.02 (0.01)	-0.01, 0.04	0.02 (0.01)	-0.01, 0.04	0.04 (0.02)	-0.01, 0.09	0.04 (0.02)	-0.01, 0.08
Race (0 = Black, 1 = white)					**-8.01 (1.01)*****	-9.99, -6.02	**-7.27 (1.08)*****	-9.38, -5.16
Age*Race					**0.30 (0.08)*****	0.15, 0.46	**0.27 (0.08)****	0.11, 0.43
Control over financial status*Race					0.01 (0.33)	-0.62, 0.65	-0.06 (0.33)	-0.70, 0.59
Control over financial status*Age*Race					-0.03 (0.03)	-0.08, 0.02	-0.03 (0.03)	-0.08, 0.02
F	163.60***		79.83***		107.76***		65.92***	
Adj. R^2	.31		.32		.34		.35	
Availability of Money to Meet Needs								
Intercept	**91.86 (0.93)*****	90.05, 93.68	**92.52 (1.49)*****	89.60, 95.44	**96.81 (1.35)*****	94.16, 99.46	**96.82 (1.76)*****	93.37, 100.27
Age (centered)	**-1.04 (0.07)*****	-1.17, -0.91	**-1.03 (0.07)*****	-1.17, -0.90	**-1.25 (0.11)*****	-1.46, -1.05	**-1.19 (0.11)*****	-1.40, -0.98
Money to meet needs (0 = not enough, 1 = enough or more)	**-1.98 (0.88)***	-3.70, -0.25	-0.50 (0.93)	-2.31, 1.32	-0.52 (1.82)	-4.10, 3.06	-0.12 (1.85)	-3.75, 3.51
Money to meet needs*Age	**0.27 (0.07)*****	0.12, 0.41	**0.27 (0.07)*****	0.12, 0.42	**0.38 (0.15)***	0.09, 0.67	**0.34 (0.15)***	0.05, 0.63
Race (0 = Black, 1 = white)					**-8.56 (1.57)*****	-11.64, -5.48	**-8.05 (1.62)*****	-11.23, -4.88
Age*Race					**0.39 (0.13)****	0.15, 0.46	**0.32 (0.14)***	0.05, 0.58
Money to meet needs*Race					0.80 (2.10)	-3.31, 4.91	0.99 (2.11)	-3.14, 5.12
Money to meet needs*Age*Race					-0.25 (0.17)	-0.59, 0.09	-0.18 (0.17)	-0.52, 0.16
F	168.92***		81.62***		109.01***		66.72***	
Adj. R^2	.31		.33		.34		.35	
Struggle Paying Bills								
Intercept	**92.11 (0.85)*****	90.45, 93.77	**92.78 (1.46)*****	89.92, 95.64	**97.52 (1.31)*****	94.95, 100.09	**96.98 (1.73)*****	93.59, 100.38

	Model 1[a]		Model 2[b]		Model 3[a]		Model 4[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Age (centered)	**-0.93 (0.06)*****	-1.04, -0.82	**-0.93 (0.06)*****	-1.04, -0.82	**-1.14 (0.10)*****	-1.33, -0.95	**-1.11 (0.10)*****	-1.30, -0.91
Struggling paying bills (0 = yes, 1 = no)	**-2.82 (0.81)*****	-4.41, -1.24	**-1.66 (0.84)***	-3.32, -0.01	-3.21 (1.85)	-6.83, 0.41	-2.49 (1.87)	-6.16, 1.19
Struggling paying bills*Age	**0.16 (0.07)***	0.03, 0.29	**0.17 (0.07)***	0.04, 0.30	0.18 (0.15)	-0.12, 0.47	0.21 (0.15)	-0.08, 0.51
Race (0 = Black, 1 = white)					**-8.59 (1.44)*****	-11.42, -5.76	**-7.79 (1.50)*****	-10.72, -4.86
Age*Race					**0.37 (0.12)****	0.14, 0.60	**0.34 (0.12)****	0.11, 0.57
Struggling paying bills*Race					2.36 (2.05)	-1.67, 6.38	1.91 (2.07)	-2.14, 5.96
Struggling paying bills*Age*Race					-0.15 (0.17)	-0.48, 0.18	-0.16 (0.17)	-0.49, 0.17
F	169.26		81.69		108.86***		66.65***	
Adj. R^2	.31		.33		.34		.35	

Note: a = sex and study cohort were included as covariates; b = sex, study cohort, education level, household income to poverty ratio, and health-related factors were included as covariates; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

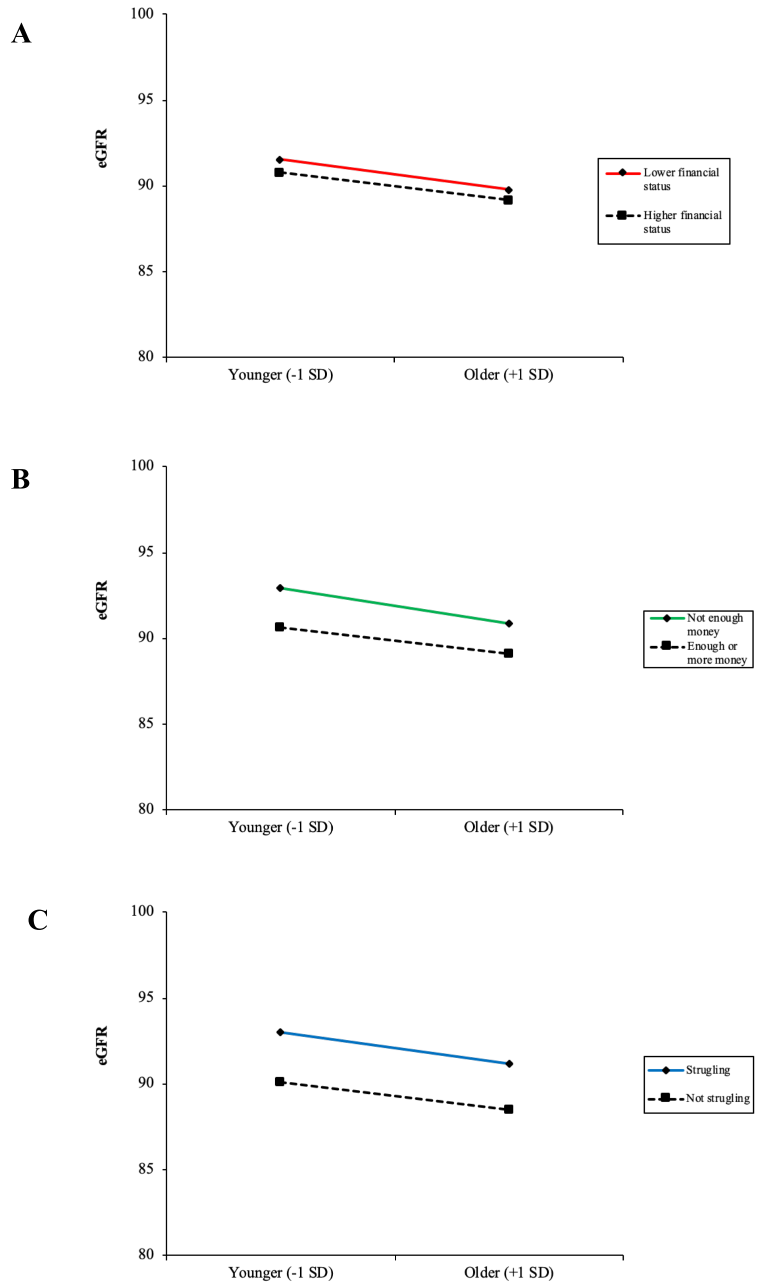


Figure **5.2**: The simple slopes from the significant two-way interactions between financial status (A), availability of money to meet needs (B), and hardship to pay bills (C) with age on predicting eGFR.

Results from Latent Class Analysis

Model Identification

Models with 1- to 5-class solution were identified. The summary of model fit criteria and results from the bootstrapped likelihood ratio test for each model is presented in Table 5.3. The 4-class model showed the lowest values for all model fit criteria. In addition, the 4-class model was also the last class with a significant bootstrapped likelihood ratio test. This indicates that moving from a 4-class to 5-class solution did not significantly increase the model fit. Thus, the 4-class model was selected as the best fitting solution.

Table **5.3**: Model fit information for the 1- to 5-class solution from the latent class analysis

No. of classes	Log-likelihood	Degrees of freedom	AIC	BIC	a-BIC	Entropy	BLRT
1	-6176.54	57	1994.58	2027.75	2008.69	—	—
2	-5272.11	50	199.73	271.61	230.31	.86	$p < .01$
3	-5230.47	43	130.45	241.02	177.48	.86	$p < .01$
4	**-5201.47**	**36**	**86.44**	**235.72**	**149.94**	**.74**	$\boldsymbol{p < .01}$
5	-5197.30	29	92.10	280.08	172.06	.78	$p = .74$

Note: Dashes indicate criterion was not applicable; boldface type indicates selected model. AIC = Akaike information criterion; BIC = Bayesian information criterion; a-BIC = sample size adjusted BIC; BLRT = bootstrapped likelihood ratio test.

Table 5.4 provides a summary of latent class membership probabilities and item-response probabilities for the 4-class model. Class 1 was labeled as Downward Mobility (latent class membership probability = 17.56%). This class was characterized by a higher probability of reporting higher childhood financial status but low probabilities of reporting high current social status, high financial well-being, and low financial strain. Class 2 was labeled as Low Strain

(5.74%). The most striking characteristic of this class was the high probability of reporting that they had enough money to meet basic needs and did not struggle to pay bills. However, the probabilities of responding to high childhood SES, current SES, and financial well-being were low. The characteristics of class 3 were the exact opposite of class 2. Hence, it was labeled as High Strain (19.53%). Class 3 showed higher probabilities of confirming high levels of childhood financial status, current social status, and financial well-being, but lower probabilities of reporting lower current financial strain. Finally, class 4, the largest in size (57.18%), was labeled Stable High. This class was characterized by higher probabilities of reporting high subjective SES across the life course.

Table **5.4**: Latent class membership probabilities and item-response probabilities

Indicator	Class 1: Downward Mobility (17.56%)	Class 2: Low Strain (5.74%)	Class 3: High Strain (19.53%)	Class 4: Stable High (57.18%)
Childhood Financial Well-Being				
Higher childhood financial status	**.66**	.51	**.67**	**.75**
Current Social Status				
Higher community standing	.52	.49	**.75**	**.86**
Current Financial Well-Being				
Higher current financial status	.10	.53	**.82**	**1.00**
Higher control over financial status	.35	.51	**.89**	**.97**
Current Financial Strain				
Enough money to meet needs	.12	**1.00**	.57	**.98**
Not difficult to pay monthly bills	.04	**1.00**	.29	**.95**

Measurement Invariance Test Based on Race

The likelihood-ratio difference test was not significant ($p > .05$). Thus, the measurement invariance assumption holds that the meaning of the latent classes from the 4-class solution was consistent across the two racial groups. The 4-class model was utilized to predict age-related decrements in eGFR.

Subjective SES Mobility and Age-Related Decrements in eGFR

Each participant was assigned to best class in the four-latent class solution based on posterior probability (i.e., maximum-probability assignment). A series of multiple linear regression analyses was conducted after each participant was assigned to their “best” latent class that represented their subjective SES mobility. The Stable High class was treated as the reference group. The summary from the regression analysis is presented in Table 5.5. Controlling for sex and study cohort (Model 1), the Downward class (B = -0.25, SE = 0.09, $p < .01$), the Low Strain class (B = -0.34, SE = 0.14, $p < .05$), and the High Strain class (B = -0.22, SE = 0.08, $p < .01$) showed steeper age-related decrements in eGFR compared to the Stable High class. Adding education, income, and health-related factors to the model (Model 2), the Downward class (B = -0.26, SE = 0.09, $p < .01$), the Low Strain class (B = -0.32, SE = 0.14, $p < .05$), and the High Strain class (B = -0.20, SE = 0.08, $p < .01$) showed significantly steeper age-related decrements in eGFR compared to the Stable High class, even though the associations were slightly attenuated.

Racial Differences on the Association Between Subjective SES Mobility and Age-Related Decrements in eGFR

Furthermore, the difference in age-related decrements in eGFR between the Downward class relative to the Stable High class was conditional on race (Model 2; B = 0.44, SE = 0.21, $p < .05$). However, after adding the rest of the covariates (education, income, and health-related risk factors) to the model (Model 3), the three-way interaction between Downward class (vs. Stable High class), age, and race became marginally significant (B = 0.38, SE = 0.21, $p = .07$).

Table **5.5**: Latent classes of subjective SES mobility and age-related decrements in eGFR (*N* = 1,861)

	Model 1[a]		Model 2[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Intercept	**91.25 (1.18)*****	88.94, 93.56	**91.71 (1.73)*****	88.32, 95.10
Age (centered)	**-0.73 (0.04)*****	-0.80, -0.66	**-0.72 (0.04)*****	-0.80, -0.65
Subjective SES Mobility				
Downward vs Stable High	**2.81 (1.02)****	2.81, 4.82	1.23 (1.09)	-0.91, 3.37
Low Strain vs Stable High	0.40 (1.71)	-2.95, 3.74	-0.71 (1.71)	-4.07, 2.65
High Strain vs Stable High	**2.32 (1.00)***	0.37, 4.27	1.21 (1.03)	-0.80, 3.22
Subjective SES Mobility*Age				
Downward vs Stable High *Age	**-0.25 (0.09)****	-0.41, -0.08	**-0.26 (0.09)****	-0.42, -0.09
Low Strain vs Stable High *Age	**-0.34 (0.14)***	-0.61, -0.06	**-0.32 (0.14)***	-0.59, -0.05
High Strain vs Stable High *Age	**-0.22 (0.08)****	-0.38, -0.06	**-0.20 (0.08)***	-0.37, -0.04
F	95.93***		60.71***	
Adj. *R*-squared	.32		.33	

Note: a = sex and study cohort were included as covariates; b = sex, study cohort, education level, household income to poverty ratio, and health-related factors were included as covariates; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table **5.6**: Racial differences in the association between subjective SES mobility and age-related decrements in eGFR (N = 1,861)

	Model 1[a]		Model 2[b]	
	B (*SE*)	95% *CI*	*B* (*SE*)	95% *CI*
Intercept	**96.33 (1.96)*****	92.49, 100.17	**95.21 (2.36)*****	90.59, 99.83
Age (centered)	**-0.81 (0.14)*****	-1.08, -0.55	**-0.80 (0.14)*****	-1.07, -0.53
Subjective SES Mobility				
Downward vs Stable High	2.62 (2.25)	-1.79, 7.03	1.82 (2.31)	-2.73, 6.35
Low Strain vs Stable High	10.78 (5.61)	-0.22, 21.79	9.90 (5.60)	-1.08, 20.88
High Strain vs Stable High	2.94 (2.36)	-1.69, 7.57	2.64 (2.39)	-2.04, 7.33
Subjective SES Mobility*Age				
Downward vs Stable High *Age	**-0.47 (0.19)***	-0.83, -0.10	**-0.45 (0.19)***	-0.81, -0.09
Low Strain vs Stable High *Age	-0.30 (0.40)	-1.08, 0.48	-0.26 (0.40)	-1.03, 0.52
High Strain vs Stable High *Age	-0.24 (0.19)	-0.61, 0.13	-0.18 (0.19)	-0.55 0.20
Race (0 = Black, 1 = white)	**-5.69 (1.73)****	-9.09, -2.30	**-5.28 (0.17)****	-8.69, -1.86
Age*Race	0.10 (0.14)	-0.18, 0.37	0.10 (0.14)	-0.17, 0.38
Subjective SES Mobility*Race				
Downward vs Stable High*Race	-2.20 (2.54)	-7.18, 2.79	-1.70 (2.56)	-6.72, 3.32
Low Strain vs Stable High*Race	-11.49 (5.88)	-23.02, 0.03	-11.07 (5.85)	-22.54, 0.41
High Strain vs Stable High*Race	-2.53 (2.61)	-7.64, 2.59	-2.74 (2.63)	-7.90, 2.42
Subjective SES Mobility*Age*Race				
Downward vs Stable High*Age*Race	**0.44 (0.21)***	0.02, 0.85	0.38 (0.21)	-0.03, 0.79
Low Strain vs Stable High*Age*Race	0.01 (0.42)	-0.81, 0.84	-0.02 (0.42)	-0.85, 0.80
High Strain vs Stable High*Age*Race	0.13 (0.21)	-0.29, 0.54	0.05 (0.21)	-0.37, 0.46
F	58.72***		44.10***	
Adj. *R*-squared	.35		.35	

Note: a = sex and study cohort were included as covariates; b = sex, study cohort, education level, household income to poverty ratio, and health-related factors were included as covariates; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Discussion

In the current analysis, subjective SES was used as an umbrella term for various constructs that tapped into the perception of hierarchy and socioeconomic conditions. Each of these indicators came from a different scientific tradition across different field related to social, behavioral, and health sciences (Adler et al., 2000; Brüggen et al., 2017; Kahn & Pearlin, 2006). This indicates that there are huge interests across multiple fields to understanding how one's subjective perception of social status may influence health and well-being. Despite the long-standing interests on this topic, there is a lack of efforts to understanding the role of subjective SES on disparities in kidney functioning across adulthood and disparities in development of CKD. This analysis compiled six indicators of subjective SES across the life course, including childhood financial well-being, subjective social status, current financial well-being (financial status and control over financial status), and two variables associated with financial strain. In this analysis, the association between each measure of subjective SES and age-related decrements in kidney function was examined and racial differences in the associations were tested. In separate analyses, current financial status and the two indicators of financial strain (i.e., perceived availability of money to meet basic needs and perceived hardship level to pay bills) were significantly associated with age-related decrements in kidney function. Lower financial status and higher strain were associated with faster age-related decrements in eGFR, even after controlling for education, income, and health-related risk factors. However, there is no support for racial differences in the association between each indicator of subjective SES and age-related decrements in eGFR.

Furthermore, this analysis explored the heterogeneity of subjective SES mobility across the life course by utilizing latent class analysis. The 4-class model was deemed as the best fitting model. The four latent classes of subjective SES mobility were Downward (higher childhood financial status but low all current subjective SES indicators), Low Strain (lower current financial strain and lower in all other indicators), High Strain (higher current financial strain and higher other subjective SES indicators), and Stable High (higher subjective SES across the life course). Compared to the Stable High class, the rest of the latent classes showed significantly steeper slopes of age-related decrements in eGFR, even after objective SES and health-related covariates were included in the analysis. Furthermore, the association between the Downward (vs. Stable High) class and age-related decrements in eGFR was conditional on race. Black participants in the Downward class showed significantly steeper decrements in eGFR across adulthood. However, the three-way interaction became non-significant after education, income, and health related covariates were included in the analysis.

Subjective SES Across the Life Course

Among the six indicators of subjective SES included in the analysis, childhood financial status was the only indicator in which there were no racial differences in the rating between Black and white participants. Previous studies have examined racial differences in current subjective social status (Wolff et al., 2010) and financial strain (Hall et al., 2009; Kahn & Pearlin, 2006), but none has examined racial differences in the retrospective self-report of childhood financial status. The higher levels of financial strain among Black compared to white adults corroborated previous findings on the topics (Hall et al., 2009; Kahn & Pearlin, 2006). However, Wolff et al. (2010) found that Black adults tend to report a higher subjective social status, but only when a proximal referent was used as a comparison group (i.e., compared to their own community). Unfortunately, the MIDUS survey did not differentiate reference groups when inquiring subjective social status. It is possible that the similarity in reports of financial status during childhood between Black and white adults was due to the unclear reference group. However, it is also possible that Black adults tend to perceived their childhood financial status higher regardless of their objective report of childhood SES (in Chapter 3, it was clear that the parental education of Black adults was lower than white adults). It is important to explore factors that are associated with this discrepancy. One possible explanation is racial differences in perception about the growing socioeconomic inequality in the United States (Kraus et al., 2017). Black adults compared to white adults may objectively experience and subjectively perceive that the increasing inequality in the United State have bigger impacts on their current socioeconomic conditions, that lead to a higher appreciation of their past financial status.

The current analysis provided new knowledge regarding how different indicators of subjective SES predicted kidney functioning in adulthood. The significant association between financial status and strain on kidney functioning above and beyond income and education provided support that these constructs are unique and differ from objective indictors of SES (Operario et al., 2004; Singh-Manoux et al., 2005). Financial strain has been an integral part of the sociological study of stress and health (Kahn & Pearlin, 2006; Pearlin et al., 2005). There is well-established knowledge on the underlying mechanisms that link social status, financial strain, and health. For that reason, financial strain is well-integrated to multiple research areas concerning health disparities, including disparities in cancer (Advani et al., 2014; Lathan et al., 2016) and cardiovascular disease (Thurston et al., 2014). However, the role of financial strain in the disparities and progression of kidney disease is not yet well-understood.

Heterogeneity of Subjective SES Mobility Across the Life Course

The novelty of the current analysis was the examination of heterogeneity of subjective SES mobility across the life course. Using latent class analysis, this study showed the different patterns of mobility based on six indicators of subjective SES. Others have utilized a similar method to examine SES trajectories based on both objective and subjective indicators of SES (Surachman et al., 2021; Surachman, Rice, et al., 2020). Unlike the findings from the current analysis, latent classes of SES trajectories based on objective and subjective SES were differed between Black and white adults (Surachman et al., 2021; Surachman, Rice, et al., 2020). In the current analysis, latent classes of subjective SES mobility were not differed for Black and white participants. The racial differences in objective SES between Black and white adults were larger compared to differences in subjective SES.

Furthermore, this analysis showed the predictive utility of these latent classes of subjective SES on kidney functioning. The findings showed that compared to the most prominent class (i.e., the Stable High class), the other classes showed steeper age-related decrements in eGFR. These indicate that any type of disadvantages associated with subjective SES may impact kidney function and lead to less healthy functioning. While the findings showed no racial differences when examining each individual indicator and its association with kidney functioning, the association between the Downward class and steeper age-related decrements in eGFR was conditional on race. Black adults in the Downward class are perhaps at the most disadvantage position when it comes to the link between subjective SES across the life course and kidney functioning in adulthood. However, the racial differences in the association between subjective SES mobility and age-related decrements in eGFR were fully explained by the covariates, including income and health related risk factors.

There are multiple strengths to the current analysis. This analysis included participants from a wide age range enabling us to generate robust estimates of age-related differences in kidney function. Furthermore, the extensive biological and clinical information from MIDUS Biomarker Projects allowed us to include multiple health-related risk factors in the analysis. Thus, our findings on the association among educational mobility, race, and age-related decrements in kidney function across adulthood were generated from a substantive dataset. Finally, the MIDUS study also included detailed information on both objective (e.g., income and education) and subjective measures (e.g., subjective social status and financial strain). In the current analysis, findings associated with subjective SES and age-related decrements in eGFR were robust as they were controlled for objective indicators of SES (i.e., education and household income).

It should also be acknowledged that this analysis does have some limitations. First, the unavailability of longitudinal biological information in the MIDUS study precluded a prospective analysis. However, the cross-sectional examination of age-related differences still provided a unique opportunity to examine the link between social factors across the life course and kidney function. With the availability of the longitudinal biological information in the MIDUS study in the future, it will be possible to prospectively address these questions. It should also be acknowledged that parental education was based on retrospective reports and this could introduce some bias, even though a previous analysis indicated a high level of accuracy in terms of retrospective reports of parental education from a small subset of sibling participants in MIDUS (Ward, 2011). Finally, the indicator of kidney function was based on serum creatinine, which is sensitive to both diet and muscle mass. In addition, we utilized the CKD-EPI formula to calculate eGFR, which is currently under scrutiny because it incorporates a race adjustment into the formula (Diao et al., 2021). However, we conducted sensitivity analysis by excluding the race adjustment from the formula and still had similar findings. Lastly, the majority of the Black participants was recruited from Milwaukee County, which could limit the generalizability of the findings to other regions. Despite this limitation, our additional analyses indicated that Black adults in Wisconsin are comparable to the larger US Black population in terms the key sociodemographic variables (see Appendix C). Future studies should prioritize replicating the current findings by utilizing representative Black adult from different regions of the US, including the Southern states, which often have poorer health overall.

Conclusion

Despite the long-standing interests in understanding the role of subjective SES in health disparities, little is known whether different indicators of subjective SES are associated with kidney functioning across adulthood. The findings from the current analysis showed that current financial status and financial strains were robust predictor of age-related decrements in eGFR, above and beyond the influence of education and household income. However, there were no evidence of racial differences between Black and white adults on the association between current financial status and financial strains and age-related decrements in eGFR. Furthermore, this analysis demonstrated the utilization of latent class analysis to examine the heterogeneity of subjective SES mobility based on multiple indicators of subjective SES across the life course. The findings indicated that compared to a pattern of stable high subjective SES across the life course, any types of subjective SES disadvantage across the life course were associated with steeper age-related decrements in eGFR. Taken together, these findings fill the gap on the lack of knowledge of the association between subjective SES and kidney functioning in adulthood.

Chapter 6

Overall Discussion

CKD is a major public health problem in the United States. As indicated by Healthy People 2030, reducing the burden of CKD in the U.S. is a public health priority. The major challenge to addressing this problem is the persistent SES and racial disparities in CKD. Actions are needed to eliminate these persistent SES and racial disparities in CKD. At the same time, more efforts are necessary to better understand the role of SES and race in creating disparities in CKD. Based on the systematic review of the current literature on the intersectionality between SES, race, and kidney disease in the United States (Chapter 2), it was clear that there is a lack of empirical studies that incorporate the life course framework to examine racial and socioeconomic disparities in kidney disease. The overarching goal of this dissertation was to integrate the life course framework into the study of socioeconomic and racial disparities in kidney functioning across the adult life span.

This dissertation included three empirical analyses that examined the three frameworks of how life course SES creates health disparities in adulthood (Figure 1.1). The first empirical analysis (Chapter 3) focused on the critical period framework by examining the association between parental education, a proxy for early life socioeconomic context, and age-related decrements in eGFR. In addition, the first empirical analysis also focused on the accumulation framework by testing the life course pathways that link parental education to age-related decrements in eGFR through current SES and health-related risk factors. The second and third empirical analyses focused on the mobility framework, focusing on the heterogeneity of SES trajectories across the life course. In the second empirical analysis (Chapter 4), SES mobility was examined through the lens of intergenerational educational mobility, an objective marker of SES mobility. This analysis also examined the association between different patterns of intergenerational educational mobility and age-related decrements in eGFR and racial differences on the association between educational mobility and kidney functioning in adulthood. Finally, the third empirical analysis explored the heterogeneity of SES mobility patterns based on multiple indicators of subjective SES across the life course and how different profiles of mobility may be associated with age-related decrements in eGFR. Taken together, these analyses demonstrated the importance and the application of the lice course framework in the context of kidney functioning among Black and white American adults.

Early Life as a Critical Period for Kidney Functioning in Adulthood

There is well-documented evidence that early life is a critical period for kidney development and maturation, in which suboptimal development and maturation are associated with a higher susceptibility to kidney disease in adulthood (Kett & Denton, 2010; Luyckx & Brenner, 2010). This dissertation furthered our understanding of this topic by demonstrating that parental education was a robust indicator of social context in early life. The first empirical analysis showed that lower parental education was associated with an unhealthy pattern of kidney functioning in adulthood, characterized by steeper age-related decrements in eGFR across adulthood. A faster decline in eGFR among relatively healthy adults is a robust indicator of the progression to CKD and the detrimental complications (e.g., cardiovascular disease and mortality) associated with the disease (Peralta et al., 2011; Rifkin et al., 2008; Shlipak et al., 2005). As predicted, the association between parental education and age-related decrements in eGFR was not conditional on race. Race and parental education were both independently associated with kidney functioning in adulthood. They follow the additive instead of the interactive pattern of creating disparities in kidney functioning across adulthood.

Furthermore, the first empirical analysis furthered our understanding regarding the life course pathways from parental education to age-related decrements in eGFR. Black and white adults showed different patterns of life course pathways from parental education to age-related decrements in eGFR. Among white participants, parental education was associated with kidney functioning across adulthood through current SES (education and income) and health-related risk factors, especially elevated blood pressure and insulin resistance. Among Black adults, parental education was associated with age-related decrements in kidney function via diabetes. Specifically, the indirect effect through diabetes was significant only among younger adults. Lower parental education was associated with the risk of renal hyperfiltration among younger Black adults. Renal hyperfiltration is a robust marker of progressive declines in kidney function and faster progression of CKD (Low et al., 2018). Taken together, the first analysis provided a novel understanding of the long arm of early socioeconomic context on kidney functioning across adulthood.

Educational Mobility and Kidney Functioning in Adulthood

The second empirical analysis (Chapter 4) was built upon the findings from the first empirical paper. While examination of life course pathways from parental education to kidney functioning through current SES and health-related risk factors was useful to capture the general patterns of how early life factors create disparities in adulthood, it ignored the heterogeneity of different patterns of socioeconomic mobility across the life course. Understanding this knowledge is critical in order to examine groups of individuals that are especially at risk for worse kidney functioning and at a higher probability of developing CKD. In the second empirical analysis, SES mobility was conceptualized by comparing parental education to participant's education to create profiles of intergenerational educational mobility. Black participants were spread out among the six possible educational mobility patterns, with the Stable Low group (lower parental and participant's education) showing the highest proportion (~20%). On the other hand, close to half of the white participants showed the Stable High pattern (higher parental and participant's education).

The most noticeable finding from the second empirical paper was that the Moderate Upward group (parental education = lower [no HS degree], participant's education = moderate [some college]) showed steeper age-related decrements in eGFR compared to the Stable High group. Furthermore, the results showed that the association between Moderate Upward mobility (vs. the Stable High group) and steeper age-related decrements in eGFR (compared to the Stable High group) was conditional on race. Closer examination showed that Black adults in the Moderate Upward group were at the most disadvantaged position, indicated by the steeper age-related decrements in eGFR. An exploratory analysis showed that Black adults in the Moderate Upward group experienced higher levels of lifetime discrimination, self-control, and lower levels of social and financial status (especially compared to those who had earned bachelor's degrees). This combination of high discrimination, high self-control, and low financial return may be a potential explanation for the less healthy pattern of kidney functioning among Black adults in the Moderate Upward group.

Previous studies on the detrimental impact of upward mobility for Black adults (i.e., the skin-deep resilient hypothesis) focused mostly on the higher levels of planful self-control, characterized by planning, persistence, and future goal orientation (Brody et al., 2020). In addition to individual's characteristics of self-regulation, this analysis highlights that structural and external factors, including stressors related to discrimination and the lack of financial returns, may also play important roles in why upward mobility among Black, especially among those who do not attain bachelor's degree, can be detrimental for their physical health, including their kidney functioning. However, participants in this group also showed the highest mean of age, which may explain the steeper age-related decrements in eGFR. Future studies should systematically examine whether discrimination and the lack of financial return mediate the association between educational mobility and steeper age-related decrements in eGFR.

The Importance of Subjective SES Across the Life Course

Despite the increasing focus on the role of subjective SES on health disparities, there is a lack of understanding and empirical works that examine the association between subjective SES and kidney functioning across adulthood. The last empirical paper examined the individual association between six indicators of subjective SES and age-related decrements in eGFR. The six indicators of subjective SES were: 1) childhood financial status, 2) current social status, 3) current financial status, 4) control over financial status, 5) availability of money to meet needs, and 6) hardship of paying bills. The findings showed that current financial status and the two indicators of financial strain were the most robust predictors of age-related decrements in eGFR, above and beyond objective SES indicators (i.e., income and education). Despite the higher levels of subjective SES among white relative to Black adults (except for childhood financial status), there was no evidence of racial differences in the association between each indicator of subjective SES and age-related decrements in eGFR.

Furthermore, the third empirical paper utilized a novel approach to examine the heterogeneity of subjective SES mobility across the life course based on the six aforementioned indicators. Using latent class analysis, four different patterns of subjective SES mobility were identified. This analysis showed that latent classes of subjective SES mobility were robust predictors of age-related decrements in eGFR. The findings indicated that any sort of hardship associated with subjective SES across the life course was associated with compromised kidney functioning, indicated by steeper age-related decrements in eGFR. One of the major hypotheses on the important roles of subjective SES in affecting health is through the stress process (Operario et al., 2004; Singh-Manoux et al., 2003). Future analyses should prioritize systematically testing whether the different patterns of subjective SES across the life course are associated with differential exposure to stressors and differences in stress physiology. Furthermore, formal examination on whether differences in stressor exposure and stress physiology mediate the association between subjective SES mobility and differences in kidney functioning in adulthood. Previous studies, mostly focusing on mobility based on objective indicators of SES, have shown the detrimental impact of downward mobility (relative to the stable high pattern) on inflammatory biomarkers (Loucks et al., 2010), even though the association was conditional on race (Surachman, Rice, et al., 2020). Inflammatory physiology has is an important factor that influences aging kidney functioning in adulthood, especially among Black adults (Costello-White et al., 2015). In addition to replicating these findings by using subjective SES mobility, future studies should also consider testing the role of subjective mobility and stressor exposure on other important physiological systems as part of the stress networks (McEwen, 1998). In summary, this analysis expands our focus on understanding the complex social contexts linked to SES and racial disparities in kidney functioning by exploring the important roles of subjective SES.

Life Course SES is Important in Understanding Disparities in Kidney Functioning

These analyses represent a first small step toward understanding the complex roles of life course SES and race in kidney disease disparities. There are limitations associated with the current analyses that need to be addressed in future empirical studies. These analyses are cross-sectional. SES indicators across the life course in these analyses were based on retrospective reports. Replications based on prospective information of SES are necessary. Similarly, kidney function in these analyses was based on a single measure of serum creatinine. Longitudinal changes of kidney function based on multiple markers (i.e., serum cystatin and urine proteinuria) would provide better glimpses of the accelerated renal senescent processes that are critical for the development and progression of CKD. Furthermore, there is concern regarding the limited generalization of these findings because the majority of the Black participants in the MIDUS study were recruited from Milwaukee County, WI. While an additional analysis (see Appendix C) showed that the Black adult population in Wisconsin are similar to the national U.S., Black adult population in some key demographic characteristics, future studies should replicate these findings by using data from representative Black adult sample or data from Black adults from other regions in the US (e.g., Black adults from the southern U.S.). Finally,

Despite the limitations, this dissertation demonstrates multiple ways to incorporate the life course framework into the study of disparities in kidney functioning in adulthood. Taken together, this dissertation provides novel understandings of how social factors contribute to the development of unhealthy patterns of age-related decrements in eGFR across adulthood. This dissertation demonstrated the utilization of the three frameworks of life course SES, the critical period framework, the accumulation framework, and the mobility framework, in the study of disparities in kidney functioning across the adult life span. This dissertation also showed the importance of incorporating the intersectionality between life course SES and race on creating disparities in kidney functioning in adulthood. Together, the analyses in this dissertation provide an important contribution to our understanding that kidney development and functioning across the life span are embedded within the social contexts across the life course. The first empirical analysis is among the first that formally examined the association between parental education and kidney functioning in adulthood and testing the life course pathways from parental education to kidney functioning in education through current SES and health-related risk factors. Furthermore, the second and third empirical analyses are also among the first that examines the association between SES mobility patterns, either using objective (i.e., education) or subjective (i.e., financial strain, financial well-being, and social status) SES indicators, and kidney functioning in adulthood.

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Appendices

Appendix A. Standardized Form to Record Relevant Information from Each Articles

Article #
Article title
First author
Year
Journal
Component
Introduction
Goal of the paper
Explicit hypotheses
Data source
Study name
Study goal
Study year
Recruitment procedure
Geographic location
Participants characteristics
Overall size
Analytic sample
Exclusion/ inclusion
Longitudinal/ CS
Birth year/ age
Setting (clinic, population, etc.)
Measures
Socioeconomic status
Racial composition
Outcome
Others
Covariates
Statistical Analysis
Missing data
Analytic method
Results
Summary
Subgroup analysis
Discussion
Summary

Appendix B. Bivariate correlations between study variables

B.1 Bivariate correlations between study variables based on data from all participants (N = 1861)

No		2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Parental education (0 = no HS, 1 = HS or higher)	.09***	-.24***	.28***	.11***	.06*	.08**	.04	.16***	-.09***	-.17***	.13***	-.13***	.04	.15***
2	eGFR	1	-.55***	-.09***	-.02	-.16***	-.17***	-.18***	-.18***	.07**	-.17***	-.002	-.26***	-.05*	.05*
3	Age		1	-.04	-.03	.20***	.16***	.20***	.14***	-.03	.31***	.14***	.16***	.07**	-.13***
4	Education (0 = HS, 1 = some college, 2 = bachelor's degree or higher)			1	.29***	.22***	.26***	.20***	.56***	-.13***	-.12***	-.14***	-.21***	.08**	.13***
5	Household income				1	.28***	.33***	.28***	.61***	-.06*	-.09***	-.12***	.29***	.14***	-.05*
6	Current financial status					1	.60***	.63***	.78***	-.12***	-.04	-.09***	.25***	.09***	-.04
7	Availability of money to meet need						1	.65***	.80***	-.14***	-.06*	-.11***	.31***	.12***	-.09***
8	Difficulty levels paying bills							1	.79***	-.14***	-.05*	-.09***	.24***	.10***	-.09***
9	Current SES score								1	-.17***	-.10***	-.16***	.36***	.14***	-.03
10	Obese									1	.22***	.19***	-.17***	-.02	.05*
11	Elevated BP										1	.19***	-.09***	.06*	-.04
12	Insulin resistance											1	-.18***	-.02	-.04
13	Race												1	.13***	-.05*
14	Sex													1	.05*
15	Study wave														1

Note: *$p < .05$; ** $p < .01$; ***$p < .001$.

B.2 Bivariate correlations between study variables among Black participants (*n* = 326)

No		2	3	4	5	6	7	8	9	10	11	12	13	14
1	Parental education (0 = no HS, 1 = HS or higher)	.14*	-.28***	.10	-.01	.06	.09	-.00	.07	.03	-.23***	.18**	-.01	.19**
2	eGFR	1	-.53***	-.08	-.04	-.09	-.08	-.14*	-.10	.09	-.21***	-.05	-.09	.03
3	Age		1	-.01	.04	.14*	.05	.10	.10	-.08	.36***	.23***	.03	.19**
4	Education (0 = HS, 1 = some college, 2 = bachelor's degree or higher)			1	.36***	.29***	.27***	.22***	.62***	.03	-.09	-.03	-.02	.12*
5	Household income				1	.28***	.34***	.31***	.69***	.02	-.01	-.01	.19**	-.12*
6	Current financial status					1	.46***	.50***	.71***	.05	.01	-.00	-.04	-.01
7	Availability of money to meet need						1	.52***	.71***	-.03	-.05	-.08	.04	.02
8	Difficulty levels paying bills							1	.73***	.02	-.13*	-.04	.07	-.08
9	Current SES score								1	.02	-.07	-.04	.09	-.01
10	Obese									1	.11*	.10	-.25***	.02
11	Elevated BP										1	.22***	-.01	.05
12	Insulin resistance											1	-.10	-.10
13	Sex												1	.01
14	Study wave													1

Note: *$p < .05$; ** $p < .01$; ***$p < .001$.

B.3. Bivariate correlations between study variables among white participants (*n* = 1535)

No		2	3	4	5	6	7	8	9	10	11	12	13	14
1	Parental education (0 = no HS, 1 = HS or higher)	.13***	-.26***	.29***	.11***	.02	.03	.01	.14***	-.10***	-.15***	-.09**	.02	.15***
2	eGFR	1	-.55***	-.03	-.06*	-.10***	-.10***	-.12***	-.09**	.01	-.21***	-.05*	-.00	.05
3	Age		1	-.09**	-.11***	.17***	.13***	.19***	.09**	.01	.32***	.16***	.06*	-.12***
4	Education (0 = HS, 1 = some college, 2 = bachelor’s degree or higher)			1	.22***	.16***	.20***	.14***	.52***	-.12***	-.10***	-.12***	.07*	.15***
5	Household income				1	.22***	.24***	.21***	.53***	-.01	-.08**	-.11***	.08**	-.02
6	Current financial status					1	.59***	.63***	.78***	-.10***	-.02	-.06*	.08**	-.03
7	Availability of money to meet need						1	.65***	.79***	-.11***	-.03	-.06*	.09**	-.10***
8	Difficulty levels paying bills							1	.79***	-.13***	-.01*	-.05***	.07***	-.08***
9	Current SES score								1	-.15***	-.07**	-.12***	.11***	-.02
10	Obese									1	.23***	.18***	-.05*	.05
11	Elevated BP										1	.17***	.09**	-.04
12	Insulin resistance											1	.03	-.03
13	Sex												1	.07*
14	Study wave													1

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Appendix C. Additional analysis comparing the Black adult population in Wisconsin and the United States in 2004-2006

According to the 2000 US Census, 90% of Black individuals in Wisconsin resided in Milwaukee County (WDHS, 2008). The MIDUS sample includes an oversampling of the Black adult population using Milwaukee County, Wisconsin (WI) as the sampling unit. Concerns regarding the correspondence of this sample of US Blacks in comparison to the rest of the United States consistently emerge when researchers try to evaluate the nature and extent of white-Black differences. Using data from the Current Population Survey for 2004-2006, we compare demographic and socioeconomic characteristics, health status, and metro/non-metro residence of the Black adult population living in WI with Black adults living in other states. We limited our analysis to adults over 18 years and adjusted for the complex survey design by applying survey weights.

In Supplementary Table C.1, we compare the characteristics of Black adults in WI with those living in the rest of the US for the years in which the MIDUS incorporated a second group of Black respondents (i.e, Refresher phase, MR). During those years, the average age for Black adults in WI was slightly lower (40.6 years) than that of the rest of the country (42.7 years). Both samples had comparable proportions of Male respondents (WI=.40, non-WI=.45). The proportion of Black adults who were Single/Never married was higher for those living in WI than for the rest of the nation. Regarding socioeconomic differences, we found that Black adults in WI had lower rates of High School completion (WI=0.74, non-WI=0.80), similar proportions of the population who had worked in the last year (WI and non-WI=0.66), and a higher proportion living below the poverty threshold (WI=0.28, non-WI=0.20). When Health status was considered, we found that 24% of the WI Black adults reported poor/fair self-reported health in comparison to the rest of the US (20%). Finally, Black adults lived in a central city at higher rates in WI (82%) than in the rest of the country (45%).

Our findings indicate that Black adults in WI are comparable to the rest of the US in terms of age-sex distribution, work and health status. Limiting the sampling to WI would yield an overrepresentation of Black adults living in metropolitan areas, higher poverty rates, and lower educational attainment.

Supplementary Table **C.1**: Demographic and socioeconomic characteristics of the Black population in Wisconsin and the rest of the United States (Current Population Survey, 2004-2006)[1]

	Wisconsin (n=357)		Rest of U.S. (n=46,857)	
	Proportion	S.E.	Proportion	S.E.
Demographic Characteristics				
Age (continuous)[2]	40.6	0.82	42.7	0.08
% Male	0.40	0.03	0.45	0.00
Single/Never Married	0.52	0.03	0.40	0.00
Socioeconomic Characteristics				
Completed a High School Diploma or more	0.74	0.02	0.80	0.00
Worked during the last year	0.66	0.03	0.66	0.00
Below the poverty line	0.28	0.02	0.20	0.00
Health Status				
Poor/Fair Self-Reported Health	0.24	0.02	0.20	0.00
Metro/Non-Metro status				
Living in Central city in a Metropolitan Area	0.82	0.02	0.45	0.00

Note: 1. Adjusted for complex survey design. 2. For the continuous variable we show the average

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Wardecker, B. M., **Surachman, A.**, Matsick, J. L., & Almeida, D. M. (in press). Daily stressor reactivity and daily well-being among sexual minority and heterosexual adults in the United States: Results from the National Study of Daily Experiences (NSDE). *Annals of Behavioral Medicine*.

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