ABSTRACT

Title of dissertation: SOCIAL DETERMINANTS OF CARDIOVASCULAR DISEASE ACROSS THE LIFE COURSE

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According to data from the National Center for Health Statistics, cardiovascular disease is one of the leading causes of death in the United States, contributing to about 697,000 (or 1 in 5) deaths in 2020 alone.[1] Given the public health burden of this disease, it is imperative that research identifies and continues to investigate population factors that may contribute to or alleviate this burden in the United States. The proposed study aimed to analyze such factors across the life course. Study 1 examined associations between an expanded set of Adverse Childhood Experiences (ACEs) and childhood obesity among 10-17 year olds using the National Survey of Children's Health, as well as sex and age differences within these associations. Study 2 investigated high optimism as a modifier and mediator of the association between childhood socioeconomic disadvantage and CVD in midlife, using the Midlife in the United States Study, a U.S. prospective cohort. Study 3 examined temporal trends in the associations between adult socioeconomic status and CVD mortality using nationally-representative data from the 1997-2018 National Health Interview Survey.

SOCIAL DETERMINANTS OF CARDIOVASCULAR DISEASE ACROSS THE LIFE COURSE

by

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Chapter 1: Introduction

Heart disease is the leading cause of death in the United States,[2,3] with 11.3% of the United States population reporting some type of cardiovascular disease (CVD) as of 2018.[4] The Centers for Disease Control and Prevention (CDC) estimate that a CVD death occurs approximately every 34 seconds.[1] Although the prevalence of CVD mortality has decreased in the last two decades,[5] the prevalence of heart disease has remained relatively stable,[6] emphasizing a need for further research focusing on improving cardiovascular health at the population level.

Decades of research have identified a plethora of biological (e.g. genetic predisposition, comorbid conditions) and social (e.g. socioeconomic status, childhood adversity) contributors of CVD.[7–11] However, additional research is necessary to understand factors that may mediate or moderate associations between the social determinants of CVD, to inform future interventions or policies focused on decreasing population vulnerability to CVD.

This dissertation aimed to examine such factors across the life course. Study 1 examined associations between Adverse Childhood Experiences (ACEs) and childhood obesity among 10–17-year-olds using the National Survey of Children's Health, as well as sex and age differences within these associations. Study 2 investigated high optimism as both a modifier and a mediator of the association between childhood socioeconomic disadvantage and cardiovascular disease in midlife, using the Midlife in the United States Study, a U.S. prospective cohort. Study 3 examined temporal trends in the association between adult socioeconomic status and cardiovascular mortality using nationally-representative data from the 1997-2018 National Health Interview Survey.

Chapter 2: Nationally-Representative Associations Between Adverse Childhood Experiences and Childhood Obesity (Manuscript 1)

1. Background

i. Significance

Childhood obesity is a significant public health problem in the United States. In 2018, 1 in 5 children or adolescents were obese,[12] and the prevalence of childhood obesity has steadily increased over the last few decades. Nationally-representative data from the National Health and Nutrition Examination Survey (NHANES) show that among children aged 2-19 years, the obesity rate has increased from 5.2% in 1971-1974, to 19.3% in 2017-18.[13,14] Previous research has established associations between childhood obesity and several conditions that increase cardiovascular disease (CVD) risk in adulthood, including high blood pressure and high cholesterol.[15–17] For example, prospective data from the International Childhood Cardiovascular Cohort Consortium shows childhood obesity, measured by body-mass index, is associated with 3.4 times the hazard of adult CVD events after a mean follow-up time of 35 years.[18,19] Given these findings, it is essential to identify early risk factors of childhood obesity at the population level.

Data from the 2017-18 National Survey of Children's Health (NSCH) showed that one in three children aged 0-17 (33.3%) have experienced at least one parent-reported Adverse Childhood Experience (ACE) in their lifetime, and 14.1% of children 0-17 have experienced two or more.[20] Decades of research have consistently documented associations between ACEs and negative health outcomes in both childhood, including obesity,[21] and adulthood, including mortality, depression, and cardiovascular disease.[22–25] However, a recent systematic review noted that there are still outstanding questions related to sex differences and how the relationship between ACEs and childhood obesity may change through different developmental stages. [21]

ii. Existing Knowledge

Adverse Childhood Experiences and Childhood Obesity

Adverse Childhood Experiences (ACEs) encompass a range of negative early life events that can occur at both the family-level (e.g., parental mental illness, parental divorce) and community-level (e.g. exposure to violence in the neighborhood). There is a well-established relationship between ACEs and negative health outcomes in both childhood and adulthood, with research dating back to the 1990s.[22–25]

Using data from low-income families enrolled in Early Head Start (N=1,335), researchers observed that at age 11, children with four or more ACEs reported in infancy or toddlerhood had 2.65 times the odds of childhood obesity compared to children without ACEs.[26] Similarly, research including 48,856 10 to 17-year-olds from the 2016-2018 National Survey of Children's Health (NSCH) showed associations between each individual ACE and obesity (e.g. parental divorce: OR: 1.61, 95% CI: 1.41-1.84). Having two or more ACEs, compared to no ACEs, was also associated with 1.78 times the odds of having obesity, adjusted for sociodemographic characteristics (age, sex, race and Hispanic origin, parents' highest level of education), and health behaviors (physical activity, screen time, and sleep).[27] However, this study did not investigate sex or age as effect modifiers of this relationship. A recent systematic review summarized the findings of 24 studies examining associations between ACEs and childhood obesity, including cross-sectional and longitudinal studies of children aged 0-17, had similar conclusions.[21]

Potential Sex Differences in the Associations Between ACEs and Obesity

Although research has consistently shown associations between ACEs and childhood obesity, a recent systematic review[21] noted that there is still a debate in the literature as to whether the association may be stronger among girls or boys. Previous work has documented that girls are more likely to experience ACEs than boys,[24,28] and often use internalizing behaviors to cope with these experiences, while boys are more likely to engage in externalizing behaviors.[29,30] Given that disordered eating (e.g., overeating) has been associated with mental health disorders (e.g., anxiety, depression),[31] researchers theorize that associations between ACEs and childhood obesity may be stronger among girls compared to boys. While the extant literature in this area has shown sex as a significant modifier in the association between early adversity and childhood obesity, the studies focused on smaller, non-representative samples, only examined a limited set of adversities, and produced conflicting results in regard to whether the association is stronger among girls or boys.[21] Therefore, additional work is needed in larger, nationally-representative samples to help understand these associations.

In a Finnish sample of 449 adolescents aged 12 to 17, experiencing sexual abuse was associated with an increased likelihood of obesity (OR: 3.5; 95% CI: 1.2-9.6) among girls only, adjusting for age, place of residence, regular smoking, and psychiatric disorders.[32] Data from the Human Development Study of Early Child Care also showed that associations between long-term exposure to maternal depressive symptoms from one month to Grade 6, and BMI at age 15 were more pronounced among girls compared to boys.[33] In contrast, findings from a cohort of 10,977 adolescents showed that boys raised in violent homes were more likely to be obese (OR:2.0; 95% CI: 1.2-3.5) or overweight (OR: 1.4; 95% CI: 1.1-1.9) compared to boys not exposed to violence in the home. Associations were not statistically significant for girls.[34]

Potential Age Interactions in the Associations Between ACEs and Obesity

Although previous research has established associations between ACEs and obesity, there are limited studies that examine age interactions within these associations or include children of all ages (e.g. from birth to adulthood), according to a recent review.[21] It is well established that the detrimental impact is observed in adulthood, but the time point at which it affects child or adolescent health is less clear. Studies following children into young adulthood suggest that the effect of ACEs exposure may not be immediate although this has not yet been studied for childhood obesity; for example, results from the Georgia Stress and Heart study (with 23 years of follow-up from age 5 to 38, N=394) show that associations between exposure to four or more ACEs and elevated blood pressure are not observed until young adulthood.[35] Findings from the UK Millennium Cohort Study (N=8823), which followed children from age 3 to 14, also showed that symptoms of internalizing behaviors continually increased following ACEs exposure at age 3.[36] Determining whether the association between ACEs and obesity varies by age group is essential for informing optimal time points for intervention programs and policies.

In a longitudinal study that followed girls with a history of maltreatment (N=303) and a comparison group without a history of maltreatment (N=151) from age 9 to 22, BMI was not significantly higher among the maltreated group until the girls were 16-17 years of age.[37] In contrast, data from the Avon Longitudinal Study of Parents and Children did not find any significant associations between child abuse and adolescent obesity when following children from 4 weeks to 18 years of age.[38] Other work has established associations between childhood adversity and obesity at age 5,[39] 6^{th}-8^{th} grades,[40] and 8^{th}, 9^{th}, and 11^{th} grades,[41] but did not have a diverse age (e.g. inclusive of children from birth to adulthood) sample to investigate age group differences.

Child development research has also highlighted important milestones throughout childhood that may influence the impact that ACEs has on their health. For example, work from the Fragile Families and Child Wellbeing Study shows associations between ACEs and increased odds of internalizing behaviors, externalizing behaviors, and ADHD diagnosis,[42] which growing research suggests may increase the likelihood of childhood obesity.[43,44] As children move into adolescence, they may be more vulnerable to engage in risky behaviors (e.g. substance use, alcohol consumption)[45,46] which may also increase their likelihood of obesity; given that these behaviors are more prevalent among children with ACEs, this population may be especially at risk.[47] Therefore, it is important to examine relationships between ACEs and obesity in these developmental age groups.

iii. Gaps In Knowledge

Although previous work has shown associations between the standard set of ACEs and childhood obesity, additional research is needed to investigate (1) sex and (2) age as potential modifiers of these associations in a nationally-representative sample. Given that obesity is an early marker of CVD,[9,18,19] it is important to identify risk factors for early biological pathways that may contribute to this condition.

2. Specific Aims

i. Broad Objective of The Project

This study will expand on existing work by testing associations between ACEs and childhood obesity, as well as examine whether sex and/or age are modifiers of these associations.

ii. Research Question and Hypotheses

This study aims to answer the following questions: are associations between ACEs and childhood obesity modified by (1) age and/or (2) sex?

HYPOTHESIS 1: Sex will modify all associations between ACEs and childhood obesity, such that associations will be stronger among girls compared to boys.

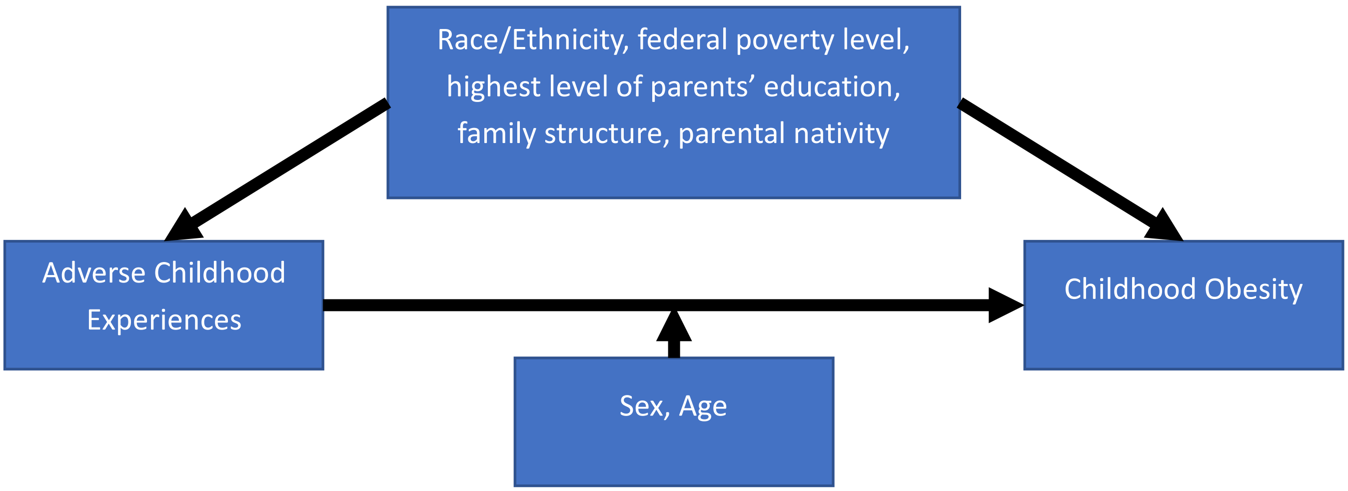
HYPOTHESIS 2: Age will modify all associations between ACEs and childhood obesity, such that the associations will be stronger among older children (aged 16-17 years) compared to younger children (aged 10-12 years, and 13-15 years) for both boys and girls.

3. Theoretical Framework

This study draws on the social production of disease as the theoretical basis for analyzing sex and age differences in the association between ACEs and childhood obesity. In contrast to other theories that focus on individual choices and traits as contributors to disease, social production of disease theory states that population-level patterns of health and disease are products of an established societal hierarchy built on social and economic differences. Research guided by this theory focuses on comparing health and disease status between disadvantaged and advantaged groups, given that disease risk for these individuals is related to their group membership.

The present study examined associations between ACEs and childhood obesity, as well as whether this association may vary by sex and/or age. Children with exposure to ACEs are less likely to have access to certain available resources, including household stability, instrumental support, and food security, and thus may be less likely to engage in health promoting behaviors including having regular well visits and nutritious meals. A child's access is dependent on their group membership rather than individual traits or choices; thus, this theory is well fit to guide the current study. Given that girls and older children are more likely to report ACEs compared to boys, the potential health consequences associated with this group membership are also supported by this theory. Below is a directed acyclic graph (DAG) to illustrate the exposure, outcome, and potential confounders and modifier considered within this study.

FIGURE 1: DIRECTED ACYCLIC GRAPH ILLUSTRATING MANUSCRIPT 1, AIM 1



Methods

i. Overall Study Design
This is a cross-sectional study.

ii. Data Sources
This study used data from the 2020-2021 National Survey of Children's Health.[48]

National Survey of Children's Health (NSCH)

The National Survey of Children's Health (NSCH) is a nationally representative, annual, mail-based and web-based survey of parents/guardians of children aged 0-17 years. Households selected to participate in the NSCH were sent an invitation encouraging them to complete a web questionnaire, followed by a paper questionnaire for non-responders. Survey topics on the NSCH include health, health behaviors, health care utilization, and demographics of a child in their household. Parents/guardians also provide information about themselves and their household.

iii. Participants and Criteria for Selection

The study sample comprised of all children aged 10-17 in the 2020-2021 NSCH with complete data on the exposure, ACEs, and outcome, childhood obesity, of interest. The NSCH collects childhood obesity data (operationalized as BMI) only on children 10 years and older, based on previous research showing this measure is only reliable for this age group.[49] After data cleaning, the study sample included 38,193 children.

iv. Outcome Variable: Potential Measurement Issues

The outcome of interest, childhood obesity, was ascertained from an NSCH recode that uses parent-reported height and weight measurements to calculate BMI for children aged 10-17. Children will be categorized as overweight or if their BMI is in the 85th to 94th percentile, or obese if their BMI is greater than the 95th percentile for their age and sex, as per previous research and clinical guidelines,[50–52] and being underweight or having a healthy weight if their BMI falls between the 5th and 85th percentiles.

Given that the outcome of interest was ascertained via parent-report, there is potential for reporting bias. Previous work has compared data from the 1994-2004 National Health Interview Survey and 2003-2004 National Survey of Children's Health to the 1999-2004 National Health and Nutrition Examination Survey (NHANES), which uses measured data rather than parent-report. The results of this study suggest that parents overestimate overweight among younger children, but underestimate among older children, suggesting that parent-reported height and weight may be inaccurate. A recent meta-analysis comparing parent-reported data to measured data at both the population and individual-level also found that parents overestimated height and weight measurements at the population-level (prevalence ratio: 1.118 (1.027, 1.216) and were also inaccurate at the individual-level (sensitivity: 0.713 (0.700, 0.726); specificity: 0.918 (0.915, 0.922).[53] However, it is also important to note that in the absence of physical examinations, parent-report is the most feasible way to obtain this data on a national survey.

v. Exposure Variables: Potential Measurement Issues

The exposure of interest, Adverse Childhood Experiences, was parent-reported in a series of dichotomous (yes/no) questions asking whether the child had ever (1) had a parent/guardian divorce or separate, (2) had a parent/guardian die, (3) had a parent/guardian serve time in jail or prison, (4) witnessed domestic violence in the home, (5) lived with anyone with a mental illness, (6) lived with anyone with a substance use problem, (7) been treated or judged unfairly because of their race or ethnic group, (8) been treated or judged unfairly because of their sexual orientation and gender identity. Each ACE was considered individually and cumulatively (continuous summed score) in analyses.

The measurement of the exposure in this study may be vulnerable to recall bias, given that parents of older children may be recalling up to 17 years in the past when reporting their child's ACEs status. Considering that children with high exposure to ACEs are more likely than others to spend time in the foster care system or experience placement instability,[54] parents or guardians surveyed as part of the NSCH may also not be fully aware of what their children have experienced in the past, especially for ACEs that occur outside the home (e.g. discrimination due to race and Hispanic origin). Parents/guardians may also underreport ACEs due to social desirability bias, given out of fear of child protection authorities. However, in comparison to other methods of assessing ACEs (e.g. caseworker reports, medical records), previous work has shown that the NSCH measure show similar results.[55] Given that the ACEs questions included in the NSCH ask about lifetime prevalence (i.e. whether a child had "ever" had this experience), these questions cannot guarantee that ACEs exposure occurred prior to the outcome, thus not allowing for temporality assessment.

vi. Potential Confounders and Effect Modifiers

This study considered a series of potential confounders as identified from previous research:[56–59] race and Hispanic origin, family income, highest level of parents' education, family structure, and parental nativity. Age group and sex were tested as effect modifiers. All variables were parent-reported at the time of the NSCH interview.

Sex was considered dichotomously (male vs. female). *Age* was considered in three categories (10-11 years, 12-14 years, and 15-17 years), following important developmental milestones as indicated by the CDC.[45,46,60] *Race and Hispanic origin* was operationalized into five categories following other articles using the NSCH:[61] Hispanic, Non-Hispanic White, Non-Hispanic Black, and Non-Hispanic Asian. *Family income as a percentage of the federal poverty level (FPL)* was based on the reported household income level and imputed when missing, resulting in four categories: <100% FPL, 100-199% FPL, 200-399% FPL, and 400%+ FPL. *Highest level of parents' education* was operationalized as (1) less than high school/GED, (2) high school diploma/GED, (3) some college, and (4) Bachelor's degree or higher. *Family structure* was operationalized as (1) two parents, currently married, (2) two parents, not currently married, (3) single mother, and (4) other family type, no parent reported). *Parental nativity* was operationalized as (1) parent born in the U.S., (2) any parent born outside U.S., and (3) other (child born in the U.S., parents are not listed).

vii. Mediators

This study did not consider any mediators.

viii. Power Analyses

Based on previous research,[21,26,27] a small to medium effect size was expected. Given that this is a secondary data analysis, with a predetermined sample size of approximately N=20,000 children, GPower was used to determine whether this sample size was sufficient to achieve a power of 0.80, with α=0.05 and a two-sided test. Based on McKelvey et al., which suggests a small or medium effect size, and given that moderate correlation between the exposure and covariates is expected, the proportion of variance in the dependent variable that can be explained by the independent variable was estimated at 0.25. For a small effect size (Cohen's d, $f^2 = 0.02$), the expected odds ratio was estimated at 1.1, requiring a sample size of 4,660 to be sufficiently powered to detect differences. For a medium effect size (Cohen's d, $f^2 = 0.15$), the expected odds ratio was estimated at 1.3, requiring a sample size of 634 to be sufficiently powered to detect differences.[62] Given the study sample size included 38,193 children, the proposed analyses were sufficiently powered to detect a small or medium effect size.[63]

ix. Statistical Analyses

Descriptive Analyses and Quality Assurance

Descriptive statistics of all variables were calculated, using survey weights to present nationally-representative estimates. Percentages of binary and categorical variables were presented; mean values and standard deviations were presented for the continuous variables.

Missing Data

All observations with complete data on the outcome, childhood obesity, exposure, ACEs, and potential effect modifiers, age and sex, were included, with intent to impute missing data for all other covariates with greater than 10% missing through multiple imputation.

Model Building/Assessment of Model Fit

A series of multinomial models examining the associations between ACEs (both individually and cumulatively) and childhood BMI (underweight/normal weight, overweight, obese) were constructed, with potential confounders added sequentially in blocks. Survey weights were used in all analyses to present nationally-representative estimates. The proportional odds assumption was tested via the PREDPROBS command in PROC LOGISTIC, showing this assumption was violated ($p<0.0001$). Conceptually, the impact of ACEs on childhood BMI is not theorized to be the same at every level of BMI, thus also conceptually violating the proportional odds assumption. Therefore, a multinomial model rather than an ordinal logistic was appropriate.

Bivariate models with and without each confounder were compared to determine whether each was related to a greater than 10% change in estimate when included. Of all the potential confounders, only family structure, family income, and highest level of parents' education were consistently related to a greater than 10% change in estimate; however, all considered potential confounders selected *a priori* were included in analyses to allow comparability with previous research.

Thus, a series of multinomial models were constructed with each ACE or the cumulative ACE score in its own model: Model 1, the unadjusted model, included only the exposure of interest, Model 2 added sociodemographic variables (race and Hispanic origin, family structure, parental nativity) and Model 3 added family income. Interaction terms between ACEs*sex and ACEs*age were tested to determine whether age and sex were significant effect modifiers for each exposure in separate models. Sex- or age-stratified models were constructed for exposures with significant interaction terms.

Akaike information criterion (AIC), a measure of relative goodness of fit, were used to compare models. The variance inflation factor (VIF) was used to ensure that the multicollinearity of interaction terms and their original variables did not interfere with the independence of the model.

4. Results

Table 1 presents weighted descriptive statistics of the study sample. In general, most participants were Non-Hispanic White (51.00%), in their mid-teens (M=13.46 years) and had parents that attended at least some college (70.80%). Most children in the study sample lived with two married parents (64.32%), had families with family incomes greater than or equal to 400% of the federal poverty level (31.87%), and had both parents born in the U.S. (68.00%). On average, study participants experienced less than one Adverse Childhood Experience on average (Range, 0-10; M=0.93). Compared to children included in the study sample, those excluded due to missing data experienced a higher number of ACEs on average (Range, 0-10; M = 1.25), a greater proportion of Non-Hispanic Black children (21.77% vs. 12.54%) and had parents with lower levels of education and family income (Table 2).

Several, but not all, ACEs were related to childhood BMI. In unadjusted models, all ACEs except household mental illness were related to higher odds of being overweight or obese (e.g. household substance abuse, obese, AOR: 1.23, 95% CI: 1.02, 1.47; Table 3). When adjusted for age, sex, and race and Hispanic origin, all significant associations remained except for discrimination due to race or ethnicity (obese, AOR: 1.01, 95% CI: 0.78, 1.30). Additional adjustment for family structure and parental nativity only showed associations for difficulty with basic needs being met, having a parent/guardian incarcerated, discrimination due to sexual orientation or gender identity, and overall number of ACEs (e.g. overall number of ACEs, obese, AOR: 1.10, 95% CI: 1.05, 1.15).

Significant associations generally attenuated in fully adjusted models but remained significant. Difficulty with basic needs being met had 26% higher odds (AOR: 1.26, 95% CI: 1.02, 1.57; Table 3) of being classified as overweight, and 34% higher odds (AOR: 1.34, 95% CI: 1.11, 1.63) of being classified as obese, compared to children without that experience. Having a parent or guardian incarcerated was related to 47% higher odds of being obese (AOR: 1.47, 95% CI: 1.18, 1.81) compared to children that did not have a parent or guardian incarcerated. Children that experienced discrimination to their sexual orientation or gender identity had almost twice the odds of being overweight compared to children without this experience (AOR: 1.92, 95% CI: 1.25, 2.93). Each additional ACE reported was related to 7% higher odds of being overweight (AOR: 1.07, 95% CI: 1.01, 1.13) and 8% higher odds of being obese (AOR: 1.08, 95% CI: 1.03, 1.13).

Interaction tests for age and sex were completed for all exposure variables in fully adjusted models. Only the interaction term between witnessing domestic violence and sex reached significance ($p < .05$). As a result, sex-stratified models examining associations between witnessing domestic violence and childhood BMI were constructed. Among males, witnessing domestic violence was related to 48% higher odds of being overweight (AOR: 1.48, 95% CI: 1.003, 2.19; Table 4) in the fully adjusted model, but was unrelated to obesity in all models. Among females, witnessing domestic violence was related to 43% higher odds of being obese (AOR: 1.43, 95% CI: 1.03, 1.99) when adjusted for age, race and Hispanic origin, family structure, and parental nativity; this association was non-significant when additionally adjusting for parents' education and family income. Witnessing domestic violence was unrelated to being overweight among females in all models.

5. Discussion

Using a nationally representative sample of children in the United States, the present study examined whether associations between Adverse Childhood Experiences and childhood BMI varied by age and sex. In the full sample, difficulty with basic needs being met, having a parent/guardian incarcerated, discrimination due to sexual orientation or gender identity, and overall number of ACEs experienced were related to being overweight or obese in fully adjusted models. However, interaction tests revealed that only sex was an effect modifier of the relationship between witnessing domestic violence and childhood BMI; all other interaction terms were null.

This analysis aligns with previous work showing relationships between ACEs and childhood BMI, when examined both individually and cumulatively.[26,27] For Aim 1, which hypothesized sex differences in all associations between ACEs and childhood BMI, our hypothesis was largely not supported. The present study also supports past work showing sex differences in the association between violence in the home and childhood obesity; however, while previous work found associations for boys only,[34] the current analysis found witnessing domestic violence was related to being overweight for boys, and related to being obese for girls. While the present study used a cross-sectional sample of children aged 10-17 years from 2020-2021, the previous study used data from the 2001 Nurses Study to assess domestic violence exposure before five years of age with a follow-up between the ages of 12-20; deviations in results may have stemmed from these differences in study design. The present study did not find that the relationship between household mental illness and childhood obesity varied by sex, thus deviating from other work that found associations were more pronounced in girls compared to boys.[33] This study also focused on an overall younger age group than the current one with a smaller sample size, which may partially explain this discrepancy.

Similarly, Aim 2 was also not supported by our findings. Limited studies examine age interactions in the associations between ACEs and childhood obesity, and most focus on early childhood;[21] this limited work supports that the impact of ACEs on childhood obesity may not be observed until late adolescence.[37] Although the current results suggest that associations between ACEs and childhood obesity do not vary with age, it is possible that cross-sectional data may be limited in its ability to assess this. Future research should explore longitudinal data to continue to build work in this area.

Strengths and Limitations

This study has several strengths. This study uses the NSCH, a large, nationally-representative data source, meaning the results will be generalizable to the United States population of children. This analysis will also make important contributions to the literature by investigating sex and age as effect modifiers of the associations between ACEs and childhood obesity.

However, it is also important to acknowledge that the results of this study may be limited. Given the cross-sectional nature of the NSCH, it is impossible to determine temporality between ACEs and childhood obesity, or the duration and timing of the exposure. However, as the NSCH includes items around discrimination due to race, sexual orientation, and gender identity which are not included in other longitudinal surveys (e.g., Add Health), this data source still has the ability to make a unique and important contribution to the literature. As discussed previously, there may be potential misclassification error for both ACEs and BMI. It is particularly important to note the limitations of parent-reported ACEs, which may be underreported due to parents' fears of involvement with child protective services, or lack of knowledge about ACEs that occur outside the home (e.g, treated or judged unfairly due to race, sexual orientation, or gender identity). However, as the majority of previous work has relied on this method,[39,59,61] the impact is expected to be minimal. Although potential confounders were identified a priori, unmeasured confounders may exist and cannot be accounted for within the analysis.

Public Health Significance

Examining the association between discrimination based on sexual orientation and gender identity and childhood BMI is important for continued work identifying health risks for the LGBTQ+ population. The identification of sex as an effect modifier in the association between witnessing domestic violence and childhood BMI is also important for understanding the different levels of risk that girls and boys may experience, although their household experience may appear similar at first glance. Future work should focus on replicating these analyses with longitudinal data to further understand the roles of sex and age within these relationships.

6. Human Subjects/Ethical Considerations

This study was approved by the University of Maryland Institutional Review Board.

TABLE 1. SAMPLE CHARACTERISTICS, NATIONAL SURVEY OF CHILDREN'S HEALTH 2020-2021, N=38,193

Variable	% or M(SD)
Number of Adverse Childhood Experiences, M (SD)	0.99 (0.02)
Body Mass Index, %	
Underweight	6.74
Healthy Weight	59.67
Overweight	16.28
Obese	17.3
Sex, %	
Male	51.26
Female	48.74
Child Age, M (SD)	13.46 (0.03)
Race and Hispanic Origin, %	
Hispanic	26.32
White, non-Hispanic	51.00
Black, non-Hispanic	12.54
Asian, non-Hispanic	4.5
Other/Multi-racial, non-Hispanic	5.63
Parents' Highest Level of Education	
Less Than High School	9.91
High School Diploma/GED	19.3
Some College or Higher	70.8
Family Structure	
Two parents, married	64.32
Two parents, unmarried	6.02
Single Parent	25.06
Other	4.6
Family Income	
<100% FPL	17.12
100%-199% FPL	20.97
200%-399% FPL	30.05
≥400% FPL	31.87
Parent Nativity	
All parents born in the U.S.	68.00
At least one parent not born in the U.S.	27.62
Child born in the U.S., parent nativity unknown	4.38

Notes: GED, General Education Development, SD, standard deviation. All estimates use survey weights to present nationally-representative estimates.

TABLE 2. INCLUDED VS. EXCLUDED PARTICIPANTS SAMPLE CHARACTERISTICS, NATIONAL SURVEY OF CHILDREN'S HEALTH 2020-2021, N=42,968

	Included Participants (N=38,193)	Excluded Participants (N=4,212)
Variable	**% or M(SD)**	
Number of Adverse Childhood Experiences, M (SD)	0.99 (0.02)	1.25 (0.11)
Body Mass Index, %		
Underweight	6.74	5.90
Healthy Weight	59.67	61.42
Overweight	16.28	17.96
Obese	17.3	14.72
Sex, %		
Male	51.26	49.83
Female	48.74	50.17
Child Age, M (SD)	13.46 (0.03)	13.45 (0.08)
Race and Hispanic Origin, %		
Hispanic	26.32	31.43
White, non-Hispanic	51.00	37.00
Black, non-Hispanic	12.54	21.77
Asian, non-Hispanic	4.50	4.62
Other/Multi-racial, non-Hispanic	5.63	5.17
Parents' Highest Level of Education		
Less Than High School	9.91	19.68
High School Diploma/GED	19.30	27.32
Some College or Higher	70.80	53.01
Family Structure		
Two parents, married	64.32	43.42
Two parents, unmarried	6.02	7.99
Single Parent	25.06	37.41
Other	4.60	11.19
Family Income		
<100% FPL	17.12	29.18
100%-199% FPL	20.97	25.61
200%-399% FPL	30.05	23.84
≥400% FPL	31.87	21.37
Parent Nativity		
All parents born in the U.S.	68.00	46.65
At least one parent not born in the U.S.	27.62	28.34
Child born in the U.S., parent nativity unknown	4.38	25.01

Notes: GED, General Education Development, SD, standard deviation. All estimates use survey weights to present nationally-representative estimates.

TABLE 3. MULTINOMIAL LOGISTIC REGRESSIONS ESTIMATING THE ODDS OF BMI CATEGORIZATION BY ADVERSE CHILDHOOD EXPERIENCES (N=38,193) WITH ALL EXPOSURES IN SEPARATE MODELS.

	Model 1		Model 2		Model 3		Model 4	
Adverse Childhood Experiences	OR	95% CI	AOR	95% CI	AOR	95% CI	AOR	95% CI
Difficulty with Basic Needs Being Met								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	**1.47**	**(1.20, 1.81)**	**1.40**	**(1.13, 1.73)**	**1.36**	**(1.10, 1.69)**	**1.26**	**(1.02, 1.57)**
Obese	**1.98**	**(1.66, 2.36)**	**1.80**	**(1.50, 2.16)**	**1.64**	**(1.36, 1.98)**	**1.34**	**(1.11, 1.63)**
Parental Divorce								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.15	(0.99, 1.33)	1.14	(0.99, 1.33)	1.11	(0.93, 1.32)	1.09	(0.92, 1.31)
Obese	**1.37**	**(1.20, 1.57)**	**1.34**	**(1.16, 1.53)**	1.05	(0.88, 1.26)	1.04	(0.87, 1.24)
Death of a Parent/Guardian								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.08	(0.79, 1.46)	1.09	(0.80, 1.47)	1.03	(0.76, 1.41)	1.01	(0.74, 1.38)
Obese	**1.39**	**(1.05, 1.84)**	**1.34**	**(1.01, 1.77)**	1.03	(0.77, 1.38)	0.99	(0.73, 1.33)
Parent/Guardian Incarcerated								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.11	(0.88, 1.40)	1.12	(0.89, 1.40)	1.09	(0.85, 1.39)	1.03	(0.80, 1.32)
Obese	**2.09**	**(1.71, 2.55)**	**2.00**	**(1.64, 2.45)**	**1.68**	**(1.36, 2.09)**	**1.47**	**(1.18, 1.81)**
Domestic Violence								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.21	(0.93, 1.59)	1.24	(0.94, 1.63)	1.21	(0.91, 1.62)	1.20	(0.90, 1.60)
Obese	**1.43**	**(1.15, 1.78)**	**1.42**	**(1.14, 1.78)**	1.17	(0.92, 1.47)	1.13	(0.90, 1.43)
Violence in the Neighborhood								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.02	(0.74, 1.41)	0.99	(0.72, 1.38)	0.97	(0.69, 1.35)	0.94	(0.67, 1.32)
Obese	**1.48**	**(1.12, 1.94)**	**1.37**	**(1.04, 1.81)**	1.19	(0.90, 1.58)	1.13	(0.85, 1.50)

Household Mental Illness								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.05	(0.85, 1.30)	1.14	(0.93, 1.42)	1.15	(0.92, 1.43)	1.15	(0.92, 1.44)
Obese	1.15	(0.96, 1.37)	**1.26**	**(1.05, 1.51)**	1.16	(0.97, 1.40)	1.18	(0.98, 1.42)
Household Substance Abuse								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.19	(0.96, 1.48)	**1.25**	**(1.003, 1.55)**	1.24	(0.98, 1.57)	1.23	(0.98, 1.55)
Obese	**1.23**	**(1.02, 1.47)**	**1.32**	**(1.09, 1.587)**	1.12	(0.93, 1.36)	1.13	(0.93, 1.37)
Discrimination due to Race/Ethnicity								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.27	(0.99, 1.65)	1.16	(0.89, 1.53)	1.18	(0.90, 1.54)	1.21	(0.93, 1.59)
Obese	**1.29**	**(1.01, 1.64)**	1.01	(0.78, 1.30)	1.01	(0.79, 1.30)	1.12	(0.87, 1.44)
Discrimination due to SOGI								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	**1.71**	**(1.08, 2.72)**	**1.95**	**(1.25, 3.04)**	**1.93**	**(1.25, 2.97)**	**1.92**	**(1.25, 2.93)**
Obese	1.30	(0.93, 1.82)	**1.53**	**(1.07, 2.20)**	1.41	(0.97, 2.06)	1.43	(0.98, 2.09)
Number of ACEs								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	**1.08**	**(1.03, 1.12)**	**1.08**	**(1.03, 1.13)**	**1.08**	**(1.02, 1.14)**	**1.07**	**(1.01, 1.13)**
Obese	**1.16**	**(1.12, 1.21)**	**1.15**	**(1.11, 1.20)**	**1.10**	**(1.05, 1.15)**	**1.08**	**(1.03, 1.13)**

AOR=adjusted odds ratio; GED=General Education Development or High School Equivalency Diploma; ACEs=Adverse Childhood Experiences

NOTE: All analyses employ survey weights to produce nationally-representative estimates. Interaction terms between each ACE and age, and each ACE and sex, were non-significant at p<0.05, except for domestic violence (p = 0.0466).

Model 1 displays the unadjusted association between parents' highest level of education and heart disease.

Model 2 adds age, sex, and race/ethnicity.

Model 3 adds family structure and parental nativity

Model 4 adds highest level of parents' education (Bachelor's Degree+, Some College, High School Diploma/GED, Less Than High School) and household income as a percentage of the federal poverty level.

TABLE 4. MULTINOMIAL LOGISTIC REGRESSIONS ESTIMATING THE ODDS OF BMI CATEGORIZATION BY WITNESSING DOMESTIC VIOLENCE STRATIFIED BY SEX (N=38,193).

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	OR	95% CI	AOR	95% CI	AOR	95% CI	AOR	95% CI
Males (N= 19,886)								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	**1.49**	**(1.01, 2.21)**	**1.53**	**(1.04, 2.24)**	1.49	(0.998, 2.23)	**1.48**	**(1.003, 2.19)**
Obese	1.24	(0.88, 1.73)	1.22	(0.88, 1.70)	0.97	(0.69, 1.36)	0.95	(0.68, 1.33)
Females (N=18,475)								
Underweight/Healthy Weight	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Overweight	1.00	(0.73, 1.38)	1.00	(0.71, 1.41)	1.01	(0.70, 1.45)	0.98	(0.68, 1.41)
Obese	**1.74**	**(1.31, 2.31)**	**1.65**	**(1.21, 2.24)**	**1.43**	**(1.03, 1.99)**	1.37	(0.98, 1.91)

AOR=adjusted odds ratio; GED=General Education Development or High School Equivalency Diploma; ACEs=Adverse Childhood Experiences

NOTE: All analyses employ survey weights to produce nationally-representative estimates.

Model 1 displays the unadjusted association between parents' highest level of education and heart disease.

Model 2 adds age, sex, and race and Hispanic origin.

Model 3 adds family structure and parental nativity

Model 4 adds highest level of parents' education (Bachelor's Degree+, Some College, High School Diploma/GED, Less Than High School) and family income as a percentage of the federal poverty level.

Chapter 3: The Role of High Optimism in the Association Between Childhood Socioeconomic Disadvantage and Heart Disease (Manuscript 2)

1. Background

i. Significance

In the U.S., 38% of children live in families classified as low-income by the U.S. Census Bureau.[64] Population-based research in the United States has consistently shown the detrimental impacts of socioeconomic disadvantage in childhood on long-term health,[65] including heart disease and its comorbid conditions (e.g. hypertension and diabetes);[66–70] however, more work is needed to understand downstream factors that may influence the development of cardiovascular disease (CVD), including psychological mediators and/or heterogeneity in associations based on psychological traits.

Heart disease is one of the leading causes of death in the United States.[2] Many risk factors for heart disease include non-modifiable characteristics such as age or family history,[71,72] or behavioral factors that may be difficult to alter, like physical activity and smoking.[73] Thus, the identification of other modifiable risk factors, such as psychological characteristics, is essential for improving population health. A 2021 scientific statement by the American Heart Association highlights a growing body of research that shows relationships between an individual's psychological state and cardiovascular health,[74] suggesting that psychological factors may be important for developing evidence-based intervention programs for vulnerable populations. Given that prior studies suggest that health behaviors account for less than half of the association between socioeconomic status (SES) and CVD,[75] researchers theorize that psychological processes may partially account for the remainder of this relationship.

ii. Existing Knowledge

Childhood Socioeconomic Disadvantage and Heart Disease

Associations between childhood socioeconomic disadvantage and heart disease are well-established. A recent 2021 systematic review concluded that there are consistent associations between low socioeconomic status (SES) in childhood and cardiovascular disease (CVD), even when different methods of measuring SES are used (e.g. highest level of parents' education, perceived childhood financial status, family income).[76] These results were also robust to variable adjustment for childhood and adulthood risk factors for CVD, including smoking, adult SES, and family history of disease. Previous findings from the Midlife in the United States Study (MIDUS) using ten years of follow-up data showed that childhood disadvantage was associated with a 13% increase in odds of developing heart disease in adulthood.[77] A prospective cohort study in the Netherlands followed participants from 1991-2007 (i.e., 17 years of follow-up) and found that poorer childhood socioeconomic conditions were associated with CVD mortality, but only among men with the poorest childhood circumstances.[78] Furthermore, results from the Health and Retirement Study (1992-2012) show that respondents with low childhood SES and high adult SES were 1.60 times as likely to report coronary heart disease relative to people with high childhood SES and high adult SES, suggesting that childhood socioeconomic disadvantage impacts health independent of adult SES.[79]

Optimism and Heart Disease

Optimism is a dispositional trait that reflects the extent to which people hold positive expectations for the future.[80] A growing body of literature suggests that optimism may be a protective factor against CVD. A study using data from the Women's Health Initiative found that optimists had a 9% lower hazard of coronary heart disease (CHD) and a 20% lower hazard of coronary heart disease-related mortality compared to pessimists, over 8 years of follow-up.[81] Similarly, research from the Nurses' Health Study showed that respondents in the highest quartile of optimism have a 38% lower hazard of heart disease-related death compared to those in the lowest quartile, over 8 years of follow-up.[82] A study using four years of follow-up from the Health and Retirement Study found that even when adjusting for sociodemographic characteristics, health behaviors, and health conditions, individuals with the highest level of dispositional optimism had 48% lower odds of heart failure compared to those with the lowest level of dispositional optimism.[83] Recent work with MIDUS found associations between psychological resources, including optimism, and an index of 30 chronic conditions, including diabetes, hypertension, joint/bone diseases, anxiety/depression, and stroke.[84] A 2021 review summarized the existing literature, concluding that optimism is consistently associated with a lower risk of CVD and lower rates of CVD mortality, independent of sociodemographic factors and depression.[85]

The Role of Psychological Factors for Early Adversity and CVD development

A large set of studies have explored mechanisms that may explain the relationship between childhood socioeconomic disadvantage and CVD. In general, researchers theorize that individuals with disadvantaged backgrounds encounter higher levels of stress than individuals with advantaged backgrounds, and additionally possess fewer resources to address these stressors than their advantaged counterparts.[86] Prior studies find health behaviors and accelerated disease processes (e.g. allostatic load) contribute to the relationship between childhood SES and CVD, but do not entirely explain the existing gradient.[75] Thus, researchers theorize that psychological processes may partially account for the remainder of this association.

There is increasing evidence that psychological factors may modify or mediate relationships between early adversity and health, although few studies have focused on CVD, in particular. In a cross-sectional analysis of 5,313 participants included in the Hispanic

Community Health Study, researchers found that lower SES, measured by a combination of self-reported educational attainment and household income, was related to metabolic syndrome, measured by a series of biomarkers (e.g. blood pressure, fasting glucose), indirectly through psychosocial resources, including purpose in life, self-esteem, and optimism.[87] Using data from a community sample of 246 men, researchers also found that psychological resources, including optimism, self-esteem, positive and negative affect, personal mastery, and sense of control, modified the association between low childhood SES and cardiovascular reactivity, such that lower childhood SES predicted systolic blood pressure recovery only among men with fewer psychological resources [88] Also within MIDUS, research supports that positive reappraisal, or reframing stressors as positive, may moderate the association between low subjective social status and morbidity, evaluated as a longitudinal change in self-reported chronic conditions, somatic symptoms, and self-rated health, such that this association is stronger among individuals with low reappraisal compared to high. The authors suggest future work should further explore the role of reappraisal within this association, while using more direct measurements of economic inequality.[89]

iii. Gaps in Knowledge

Although the associations between childhood socioeconomic disadvantage and CVD are well-established, additional research is needed to identify the role of optimism within this relationship.[7,76,90] While prior studies have explored general psychological resources as mediators between early life adversity and adult health,[87–89] few, if any, prior studies have investigated high optimism as a mediator between childhood socioeconomic disadvantage and CVD. Additionally, although previous work supports optimism as an effect modifier between early adversity and CVD-related outcomes, this work has focused on smaller, non-representative samples[88] or has not yet investigated childhood socioeconomic disadvantage specifically.[84,91]

Given that heart disease is among one of the leading causes of death in the United States,[2] it is essential to identify potential mechanisms and opportunities for intervention among those most vulnerable.

2. Specific Aims

i. Broad Objective of the Project

This study expands on existing work by examining high optimism as (1) a modifier and (2) a mediator of the association between childhood socioeconomic disadvantage and heart disease.

ii. Research Question and Hypothesis

This study aimed to examine whether high optimism (1) modifies or (2) mediates the association between childhood socioeconomic disadvantage and heart disease.

HYPOTHESIS 1: High optimism will modify the association between childhood socioeconomic disadvantage, indicated by the highest level of parents' education, and heart disease, such that the association between childhood socioeconomic disadvantage and heart disease will be weaker among individuals with high optimism compared to individuals with low optimism.

HYPOTHESIS 2: High optimism will mediate the association between childhood socioeconomic disadvantage, indicated by the highest level of parents' education, and heart disease.

3. Theoretical Framework

This study draws on the social production of disease[92] and the Shift-and-Persist Model[93] as the theoretical bases for analyzing high optimism as a mediator of the association between childhood socioeconomic disadvantage and heart disease. In contrast to other theories that focus on individual choices and traits as contributors to disease, social production of disease theory states that population-level patterns of health and disease are products of an established societal hierarchy built on social and economic differences. Research guided by this theory focuses on comparing health and disease status between disadvantaged and advantaged groups, given that disease risk for these individuals is related to their group membership. The Shift-and-Persist Model describes the tendency of some individuals to positively reframe or reappraise stressors to move forward. This can be beneficial for individuals living in adverse environments, as they are able to control the self and adjust to the world around them, which can be more advantageous than attempting to control or change the world itself.[93]

The present study will examine whether high optimism serves as a modifier or mediator of childhood socioeconomic disadvantage and heart disease. In the face of adverse situations, such as a socioeconomically disadvantaged childhood, optimism may help individuals reframe their current situation to benefit their health, leading to a lower risk of heart disease. Below is a directed acyclic graph (DAG) to illustrate the exposure, outcome, and potential confounders and mediator considered within this study.

FIGURE 2. DIRECTED ACYCLIC GRAPH ILLUSTRATING MANUSCRIPT 2, AIM 1

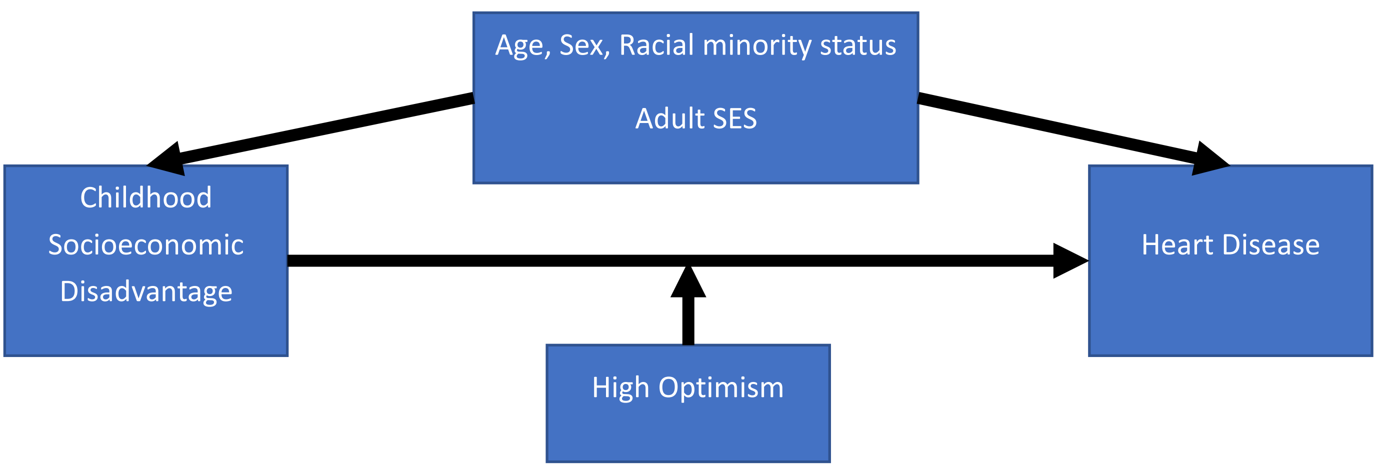
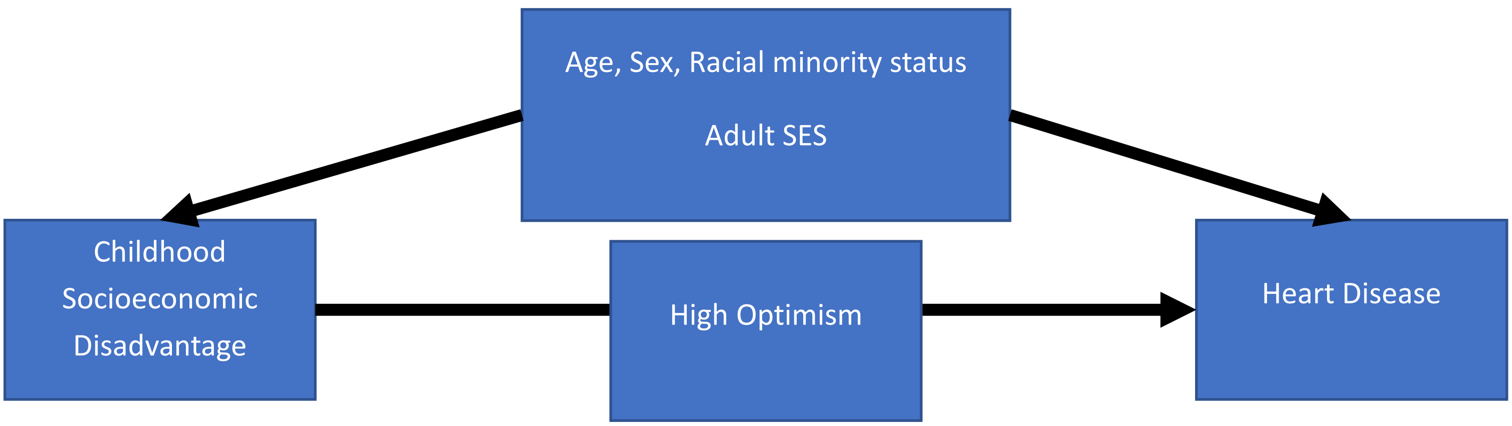


Figure 3. Directed Acyclic Graph illustrating Manuscript 2, Aim 2



4. Methods

i. Overall Study Design

This is a prospective cohort study, with individuals followed from MIDUS 1 (1995-1996) to MIDUS III (2013-2015).

ii. Data Source

This project used data from the Midlife in the United States Study (MIDUS), a national cohort study of noninstitutionalized English-speaking adults between the ages of 25-74 at baseline, recruited through random-digit-dialing.[94] Once selected, MIDUS participants were interviewed at three separate time points: MIDUS I (N=7,108; 1995-1996), MIDUS II (N=4,963; 2004-2005; 70% response rate from MIDUS I), and MIDUS III (N=3,294; 2013-2015; 66% response rate from MIDUS II). For each time assessment, data was collected via a phone interview and self-administered questionnaire (SAQ). The SAQs were mailed to the participant's residence. Linked data from the National Death Index (NDI) was also used to identify participants who died from acute myocardial infarction or stroke.

iii. Participants and Criteria for Selection

All participants with complete data on childhood socioeconomic disadvantage, optimism, and heart disease at MIDUS I were included in analyses; covariates with greater than 10% missing data were imputed using multiple imputation.

iv. Outcome Variable: Potential Measurement Issues

Heart disease was self-reported at MIDUS I, II, and III. Participants were classified as having heart disease if they indicated they (1) had ever had a heart attack, coronary heart disease, ischemia, heart failure, or stroke, or (2) had taken prescription medicine for a heart condition in the past 30 days. Participants were also categorized as having heart disease if myocardial infarction or stroke was listed as their cause of death via the NDI.

Given that the outcome is primarily self-reported, it may be vulnerable to recall bias; Participants may incorrectly recall whether they have been diagnosed with heart disease or not. Additionally, considering research suggests that 30-50% of U.S. adults are non-adherent to long-term medications,[95] it is possible that participants may report not taking a prescription medication for a condition in the past 30 days even though the medication may have been prescribed. There may also be inaccuracies in the death certificate data used by the NDI, as established by previous studies.[96,97] A 2010 analysis found that 48% of the studied death certificates had at least one data issue, including providing a mechanism of death (e.g. cardiopulmonary arrest) or disease process (e.g. urosepsis) rather than an underlying cause of death.[96] However, since the NDI is not the primary source of outcome data, this vulnerability likely had minimal impact on the study.

v. Exposure Variable: Potential Measurement Issues

Childhood socioeconomic disadvantage, the exposure of interest, was self-reported at MIDUS I, and proxied through parents' highest level of education. MIDUS collects two items that asked participants to report the highest level of education that their mother and father had each completed with 12 response options from (1) no school/grade school to (12) graduate/professional degree. These variables were operationalized as a single categorical variable to reflect the highest education attained between the two parents, and then categorized into a four level variable to represent important cut-offs in earning ability (less than high school, high school diploma/GED, some college, and Bachelor's degree or higher).[68,98,99]

The measurement of the exposure in this study may be vulnerable to recall bias, given that MIDUS participants are aged 25-74 years when they are asked to report their childhood SES: as many as 70 years in the past. However, previous research suggests that using parents' highest level of education is more accurate than other retrospective proxies of childhood socioeconomic disadvantage (e.g. perceived childhood financial status);[93,100,101] Previous work with MIDUS specifically shows that twins have the greatest concordance when reporting the highest level of their parents' education, compared to childhood welfare status and perceived childhood financial status (perceived relative childhood financial status, $\kappa = 0.30$; highest level of mothers' education, $\kappa = 0.66$; highest level of fathers' education, $\kappa = 0.64$; childhood welfare status, $\kappa = 0.61$).[101] Despite this, it is also important to note that there may be misclassification of the exposure, considering that the level of education reported may not have been the level of education the parent had during the respondent's childhood (e.g. if a parent had attained additional education levels after the respondent had already grown up).

vi. Potential Confounders and Effect Modifiers

This study considered a series of potential confounders as identified from previous research. Confounders included age, sex, racial minority status, and adult socioeconomic status.[67,93,102] All potential confounders were reported at MIDUS I.

Age was considered as a continuous variable. *Sex* was considered dichotomously (male vs. female). *Racial minority status* was operationalized into a binary variable (White vs. Non-White) based on a low number of participants in more detailed racial and ethnic groups. *Adult socioeconomic status* was measured by the participant's highest level of education (less than high school, high school diploma/GED, some college, and Bachelor's degree or higher).

Dispositional *optimism* was reported at MIDUS II in 2004-2006 through the validated six-item Life Orientation Test, which asks participants to respond to six items (e.g. "In uncertain times, I usually expect the best") on a five point Likert scale from (1) A lot agree to (5) A lot disagree. An optimism score was constructed by calculating the sum of the values of the items in the scale, reverse-coding items as necessary so high scores reflect higher optimism. Valid scores were computed for all participants that responded to at least three of the six items. For missing items, the mean value of completed items was imputed as in previous studies.[103–105] When testing effect modification, a median-split of the high optimism score was used following previous research.

vii. Mediators

Dispositional *optimism* was reported at MIDUS II in 2004-2006, as described above. For mediation analyses, a continuous optimism score with higher scores reflecting higher optimism, was used.[106,107]

viii. Power Analyses

Based on previous research,[68,84,88] a medium effect size was expected. Given that this is a secondary data analysis, with a predetermined sample size of approximately N=5,289 adults, PROC POWER in SAS 9.4 was used to determine the level of power that can be achieved with the present sample size. Based on preliminary analyses with the current sample, the probability of event was estimated at 0.28, with standard deviation=0.32, and a moderate correlation between the exposure and included covariates (R^2=0.25). Using a one-sided test and an estimated hazard ratio of 1.3, this sample size achieved a power of 0.80, with α=0.05.

ix. Statistical Analyses

Descriptive Analyses and Quality Assurance

Descriptive statistics of all variables were calculated. Percentages of binary and categorical variables were presented; mean values and standard deviations were presented for continuous variables. A comparison of included and excluded participants was also completed.

Missing Data

All observations with complete data on the exposure (childhood socioeconomic disadvantage), outcome (heart disease at MIDUS III), and the modifier/mediator (optimism) will be included in the analysis. Missing values for all covariates were imputed using PROC MIANALYZE.

Aim 1: Model Building/Assessment of Model Fit

A series of Cox regression models were fit to examine the association between childhood socioeconomic disadvantage and heart disease, with potential confounders added sequentially in blocks. Given that the study required a time-to-event analysis, the Cox model is appropriate. A model building approach was used for analyses, following prior research:[76] Model 1, the unadjusted model, included only childhood socioeconomic disadvantage. Model 2 added sociodemographic variables (age, sex, and racial minority status). Model 3 will additionally include adult socioeconomic status.

Akaike information criterion (AIC), a measure of relative goodness of fit, was used to compare models. The variance inflation factor (VIF) was used to ensure that the multicollinearity of interaction terms and their original variables would not interfere with the independence of the model.

Models with and without each confounder were compared, to assess whether the inclusion of each confounder was related to a 10% change in estimate. High optimism was tested as an effect modifier, using an interaction term between childhood socioeconomic disadvantage and optimism as a categorical variable. Optimism-stratified models were constructed for models with significant interaction terms; potential confounders were also tested, as described as above, in stratified models.

Aim 2: Mediation Analysis

Indirect associations for the potential mediator were estimated using VanderWeele's difference method[108] to calculate the change in the association beta estimate when including each potential mediator, using our fully adjusted Cox model (Model 3). Beta estimates were directly used to calculate percentages mediated; the percentage mediated was calculated as the indirect effect beta estimate divided by the total effect beta estimate. Bootstrapping with 1000 repetitions were used to generate 95% confidence intervals (CIs) for each indirect association.

5. Results

Table 5 presents descriptive statistics of the study sample (N=5,289). In general, the majority of participants were White (79.88%), middle-aged (46.64±12.43 years), and had parents that attended at least some college (37.23%). Optimism-stratified descriptive statistics showed adults with higher optimism were more likely to be older and more educated and were less likely to be a racial minority. Compared to excluded participants, which had missing data on the exposure, outcome, or modifier/mediator, included participants were less likely to report heart disease throughout the follow-up period, had higher levels of optimism, were younger, were less likely to be a racial/ethnic minority, and were more likely to have parents with higher education (Table 6).

Based on a significant interaction term between childhood socioeconomic disadvantage and optimism in the demographic-adjusted model ($p < .0001$), separate Cox models stratified by optimism (using a median-split) were fit to estimate the hazard of heart disease for low and high optimism groups separately. Among adults with low optimism, adults whose parents obtained less than a high school diploma/GED had a 42% higher hazard of heart disease compared to adults whose parents obtained a Bachelor's degree or higher (AHR: 1.42, 95% CI: 1.07, 1.87), adjusted for age, sex, and racial/ethnic minority status (Table 2). Also in the low optimism group, adults whose parents obtained a high school diploma/GED had a 37% higher hazard of heart disease compared to adults whose parents obtained a Bachelor's degree or higher, adjusted for age, sex, and racial/ethnic minority status (AHR: 1.37, 95% CI: 1.04, 1.80). When further adjusted for respondent's highest level of education, these associations were attenuated. No significant associations between childhood socioeconomic status and heart disease were observed in the high optimism group.

To address Aim 2, I conducted mediation analyses to examine indirect effects via respondent's highest level of education and optimism (Table 7). Mediation analyses did not reveal significant indirect effects for education alone (Indirect Effect Estimate: 0.05; 95% CI: -

0.33, 0.27), optimism alone (Indirect Effect Estimate: 0.01; 95% CI: -0.31, 0.31), or education and optimism combined (Indirect Effect Estimate: 0.04; 95% CI: -0.31, 0.26).

6. Discussion

Using a national cohort of middle-aged adults, the present study examined optimism as a modifier and mediator of the association between childhood socioeconomic disadvantage and heart disease. Childhood socioeconomic disadvantage, represented by parents' highest level of education, was related to heart disease among adults with lower optimism only. Associations in the higher optimism group were null. Mediation analyses showed that education and optimism were not significant mediators between childhood socioeconomic disadvantage and heart disease. These results suggest that higher levels of optimism may provide a buffering effect against childhood socioeconomic disadvantage for heart disease but does not explain the association between childhood socioeconomic disadvantage and heart disease.

The present study aligns with previous work suggesting that optimists have a lower risk of heart-related diseases including coronary heart disease, heart-related mortality, and heart failure compared to adults without high optimism; and extends existing research by providing evidence for optimism as a significant effect modifier of the association between childhood socioeconomic disadvantage and heart disease, using 23 years of follow-up.[81–83] However, our findings deviate from previous work that suggests optimism and other psychosocial resources may explain the relationship between early adversity and metabolic syndrome using data from the Hispanic Community Health Study.[87] Given that study examined metabolic syndrome rather than heart disease, it is possible that the mediation effect observed in this study does not extend to heart disease. Additionally, as previous work used a composite variable of psychosocial resources rather than focusing on optimism alone, other variables included in the composite (e.g. purpose in life) may be responsible for the observed effect. It is also important to note that the previous work used cross-sectional data rather than longitudinal, which may have hindered the ability of prior work to accurately identify a mediation effect.

Study Strengths and Limitations

This study has several strengths. This study uses MIDUS, a large national cohort to examine high optimism as a mediator between childhood socioeconomic disadvantage and incident heart disease. This analysis will allow researchers to identify potential opportunities for intervention along the pathway between childhood socioeconomic disadvantage and incident heart disease. Second, this study assesses dispositional optimism through a validated scale, and is the first to my knowledge to examine high optimism as a mediator in the association between childhood socioeconomic disadvantage and incident heart disease.

However, it is also important to note that the results of this study may be limited. First, although MIDUS is a national cohort, the study sample is disproportionately comprised of White, highly educated adults, even when including the Milwaukee sample, an oversample of African-American adults to increase diversity; thus, the generalizability of results is also limited. Second, although potential confounders were identified a priori, unmeasured confounders may exist and cannot be accounted for within the analysis. Third, the retrospective report of childhood socioeconomic disadvantage may be vulnerable to recall bias, especially given that MIDUS participants are asked to recall up to 70 years in the past. However, previous research suggests that using parents' highest level of education is more accurate than other retrospective proxies of childhood socioeconomic disadvantage (e.g. perceived childhood financial status),[93,100,101] and previous work with MIDUS specifically shows that twins have the greatest concordance when reporting the highest level of their parents' education, compared to childhood welfare status and perceived childhood financial status.[101] Fourth, the reliance on self-reported outcomes may also introduce bias and differential misclassification. Participants may have poor recall of their disease status or current medication, and participants with fewer financial resources and/or lower education may be less likely to access health care[109] and thus will be less likely to receive and report a heart disease diagnosis. This may decrease the prevalence of heart disease among those with a history of childhood socioeconomic disadvantage and thus bias results toward the null. However, recent work has shown a high level of agreement between self-report of ischemic heart disease and patient medical records ($\kappa = 0.87$), so the impact of recall bias on outcome classification may be minimal.[110]

Public Health Significance

The identification of high optimism as a modifier of the association between childhood socioeconomic disadvantage and heart disease may support the uptake of easily accessible psychological interventions (e.g. positive psychology, mindfulness) for heart disease prevention. Future work should focus on replicating these analyses with more diverse samples, to determine whether this effect may extend to other populations.

7. Human Subjects and Ethical Considerations

This study was approved by the University of Maryland Institutional Review Board.

Table 5. Sample Characteristics, Midlife in the United States Study (N=5,289)

Variable	Full Sample (N=5,289) % or Mean (SD)	High Optimism (N=2,914) % or Mean (SD)	Low Optimism (N=2,375) % or Mean (SD)	p-value
Highest Level of Parents' Education				<.0001
Less Than High School	26.87	24.7	29.53	
High School Diploma/GED	35.90	34.22	37.97	
Some College	15.58	16.9	13.94	
Bachelor's Degree or Higher	21.65	24.2	18.56	
Heart Disease (M1, M2, M3), %	19.51	19.3	19.82	0.0001
Optimism	22.95 (4.75)	--	--	
Age at Baseline (M1)	46.64 (12.43)	47.69 (12.24)	45.34 (12.55)	<.0001
Male, %	45.85	46.2	45.46	0.1192
Racial/Ethnic Minority Status	20.12	16.9	24.1	<.0001
Highest Level of Education				<.0001
Less Than High School	7.02	4.1	10.6	
High School Diploma/GED	28.44	24.0	33.9	
Some College	30.9	30.8	31.0	
Bachelor's Degree or Higher	33.64	41.1	24.55	

Notes: GED, General Education Development, SD, standard deviation

TABLE 6. INCLUDED (N=5,289) VS. EXCLUDED (N=266) PARTICIPANTS, MIDLIFE IN THE UNITED STATES STUDY (1996-2018).

	Included Participants (N=5,289)	**Excluded Participants (N=266)**	
Variable	**% or Mean (SD)**	**% or Mean (SD)**	p-value
Highest Level of Parents' Education			0.35
Less Than High School	26.87	11.11	
High School Diploma/GED	35.90	44.44	
Some College	15.58	33.33	
Bachelor's Degree or Higher	21.65	11.11	
Any Heart Disease	19.51	25.88	0.01
Optimism	23.11 (4.75)	21.38 (4.61)	<.0001
Age at Baseline	46.6 (12.44)	54.54 (12.85)	<.0001
Male, %	45.85	42.11	0.23
Racial/Ethnic Minority Status	20.34	57.65	<.0001
Highest Level of Education			<.0001
Less Than High School	6.99	37.59	
High School Diploma/GED	28.41	35.34	
Some College	30.91	19.92	
Bachelor's Degree or Higher	33.69	7.14	

Notes: Descriptive analyses were conducted on participants with available data. Any heart disease includes respondents that reported heart disease at any time point during the follow-up period. GED, General Education Development, SD, standard deviation

TABLE 7. COX REGRESSIONS ESTIMATING THE HAZARD OF HEART DISEASE, STRATIFIED BY OPTIMISM (MIDLIFE IN THE UNITED STATES STUDY, 1995-2018), N=5,289

	Model 1		**Model 2**		**Model 3**		**Model 4**	
High Optimism (N=2,914)	AHR	95% CI	AHR	95% CI	**AHR**	95% CI	AHR	95% CI
Highest Level of Parents' Education								
Bachelor's Degree or Higher	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Some College	1.11	(0.85, 1.45)	1.15	(0.87, 1.50)	1.15	(0.88, 1.51)	1.05	(0.80, 1.37)
High School Diploma/GED	1.21	(0.96, 1.54)	1.20	(0.94, 1.52)	1.19	(0.93, 1.51)	0.97	(0.75, 1.24)
Less Than High School Diploma/GED	1.10	(0.85, 1.41)	1.13	(0.89, 1.47)	1.10	(0.85, 1.42)	0.87	(0.66, 1.13)

	Model 1		**Model 2**		**Model 3**		**Model 4**	
Low Optimism (N=2,375)	AHR	95% CI	AHR	95% CI	AHR	95% CI	AHR	95% CI
Highest Level of Parents' Education								
Bachelor's Degree or Higher	ref	1.00	ref	1.00	ref	1.00	ref	1.00
Some College	0.92	(0.65, 1.30)	0.93	(0.66, 1.32)	0.90	(0.63, 1.28)	0.83	(0.58, 1.17)
High School Diploma/GED	**1.35**	**(1.03, 1.78)**	**1.35**	**(1.03, 1.77)**	**1.37**	**(1.04, 1.80)**	1.18	(0.89, 1.57)
Less Than High School Diploma/GED	**1.43**	**(1.09, 1.89)**	**1.48**	**(1.12, 1.95)**	**1.42**	**(1.07, 1.87)**	1.12	(0.83, 1.50)

Note: Results were stratified by a median-split optimism variable based on an interaction term between childhood socioeconomic disadvantage and optimism was significant (p<.0001).

AHR=adjusted hazard ratio; GED=General Education Development or High School Equivalency Diploma

Model 1 displays the age-adjusted association between parents' highest level of education and heart disease.

Model 2 adds sex.

Model 3 adds racial minority status.

Model 4 adds respondent’s educational attainment (Bachelor's Degree+, Some College, High School Diploma/GED, Less Than High School).

TABLE 8. MEDIATION ANALYSES DESCRIBING THE ASSOCIATIONS BETWEEN CHILDHOOD SOCIOECONOMIC DISADVANTAGE AND HAZARD OF INCIDENT HEART DISEASE (N = 5,289).

	Total Effect Estimate	Indirect Effect Estimate	95% CI	Percent Mediated
+education	0.05	0.05	(-0.33, 0.27)	88.63%
+optimism	0.19	0.01	(-0.31, 0.31)	6.47%
+education and optimism	0.05	0.04	(-0.31, 0.26)	91.55%

Note: Childhood socioeconomic disadvantage is operationalized as Parents' Education: High School Diploma/GED or Lower vs. Some College or Higher. Confounders include age, sex, and minority status. All models include age, sex, and racial minority status as potential confounders. Percent mediated was calculated by dividing the indirect effect estimate by the total effect estimate, to determine what proportion of the total estimate may be attributed to the examined mediator. Given that education may also be theorized as a mediator in addition to a confounder, it was examined here in addition in optimism. Bootstrapping with 1000 repetitions were used to generate 95% confidence intervals for each indirect association.

Chapter 4: Temporal Trends in The Association Between Socioeconomic Status and Cardiovascular Mortality (Manuscript 3)

1. Background

i. Significance

According to 2018 data from the National Health Interview Survey, 12.1% of the U.S. population report having some type of cardiovascular disease (CVD), including coronary heart disease, hypertension, and stroke.[4] Heart disease is the leading cause of death in the United States, with 161.5 deaths per 100,000 reported in 2019.[2] Although the prevalence of CVD mortality has decreased in the last two decades, the rate of decline has slowed in recent years,[5] suggesting the need to identify additional factors that may be targeted for improve cardiovascular health on the population level.

In 2020, the U.S. poverty rate increased to 11.4% from 10.5% in 2019: the first year that the poverty rate increased following five years of decline.[111] Although researchers anticipate the 2021 U.S. poverty rate will be lower than in past years (between 7.7 and 8.5% percent),[112,113] this decrease is likely a temporary result of increased aid available during the COVID-19 pandemic. Thus, it is likely that poverty rates will rise again in the years following the pandemic, which resulted in the loss of employment for over 9.6 million workers in the United States.[114] Given that the associations between socioeconomic disadvantage and cardiovascular health are well-established,[7,115] it is essential that researchers continue to examine the relationships between socioeconomic disadvantage and CVD outcomes in order to appropriately target timely interventions and public health policies.

ii. Existing Knowledge

Socioeconomic Factors and CVD Mortality

Prior work has established associations between SES and CVD mortality.[116–119] Results from the English Longitudinal Study of Ageing, a large prospective study, show that among individuals aged 50-64 years, those in the lowest wealth tertile had 3.73 times the hazard of cardiovascular mortality compared to those in the highest wealth tertile with a mean follow-up of 9.4 years.[116] In a prospective cohort of 59,000 black women followed from 1995-2011, researchers found that women in the lowest quartile of neighborhood SES had 1.40 times the hazard of CVD mortality compared to those in the highest quartile, adjusted for sociodemographic characteristics and health behaviors.[117] Similarly, in an analysis of adults aged 35-72 in Finland, researchers found that participants with higher education and non-manual occupations had a lower hazard of CVD mortality compared to those with lower education or manual occupations (mean follow-up = 28.5 years for censored individuals; 19.5 years for deceased individuals),[118] and in a socially representative cohort of 3,924 British men followed over 12 years, researchers found a graded increase in CVD mortality risk through quintiles of deprivation score.[119]

Measurement of Socioeconomic Status

Previous research suggests that different methods of measuring SES have their own advantages and disadvantages when it comes to associations with health. For example, while income may demonstrate an individual's access to material goods and services that benefit health, it is also age-dependent and often suffers from a higher nonresponse rate than other SES measures.[120] Related, research focused on childhood socioeconomic disadvantage suggests that reliance on a single metric of socioeconomic status (SES) may not allow researchers to investigate how specific aspects of socioeconomic status impact health.[100] Studies examining SES and CVD mortality use a wide range of socioeconomic indicators, including highest level of education, occupation, income, deprivation score, and wealth.[116–119] Given that the field lacks consensus on the optimal way to measure SES, it is important to evaluate which socioeconomic indicators are more strongly associated with health outcomes; this information is essential for identifying (1) opportunities for intervention among the socioeconomically disadvantaged.

Temporal Trends in Associations Between SES and CVD Mortality

Temporal trend analyses in this area suggest that associations between SES and CVD in the United States may be strengthening over time.[115,121] For example, a 2002 study examining county-level SES and CVD mortality revealed that SES disparities in CVD mortality have widened from 1969-1970 to 1997-1998.[115] Notably, analyses examining associations between individual-level SES and CVD risk factors using the National Health and Nutrition Examination Survey (NHANES) from 1971-2002 showed that socioeconomic disparities in smoking and high blood pressure prevalence have widened, which may contribute to differences in CVD mortality.[14] Outside of the United States, results from the Turin Longitudinal Study in Italy (1971-2011) show that educational inequalities in CVD mortality have declined.[122]

iii. Gaps in Knowledge

A 2017 systematic review showed that few studies have examined temporal trends in SES and CVD mortality.[7] Specifically, no studies to date have examined income disparities in CVD mortality, and only one has examined educational disparities in CVD mortality using data from Italy (1971-2011).[122] To our knowledge, the most recent studies in this area studying temporal trends in the United States have only used data up until the early 2000's, thus limiting their ability to draw conclusions about the present-day U.S. population.[115,123] Considering that CVD mortality is one of the leading causes of death in the U.S. and income inequality has increased in the last half-century,[124] it is essential to understand the relationships between SES and CVD mortality using recent data.

2. Specific Aims

i. Broad Objective of the Project

This study expands on existing work by (1) testing associations between adult SES and CVD mortality, and (2) examining temporal trends of these associations.

ii. Research Question and Hypothesis

This study aimed to answer the following questions: (1) what are the associations between SES and CVD mortality? And (2) have associations between SES and CVD mortality changed over time?

HYPOTHESIS 1: Socioeconomically disadvantaged individuals will have a higher likelihood of CVD mortality compared to socioeconomically advantaged individuals as indicated by highest level of education and federal poverty level.

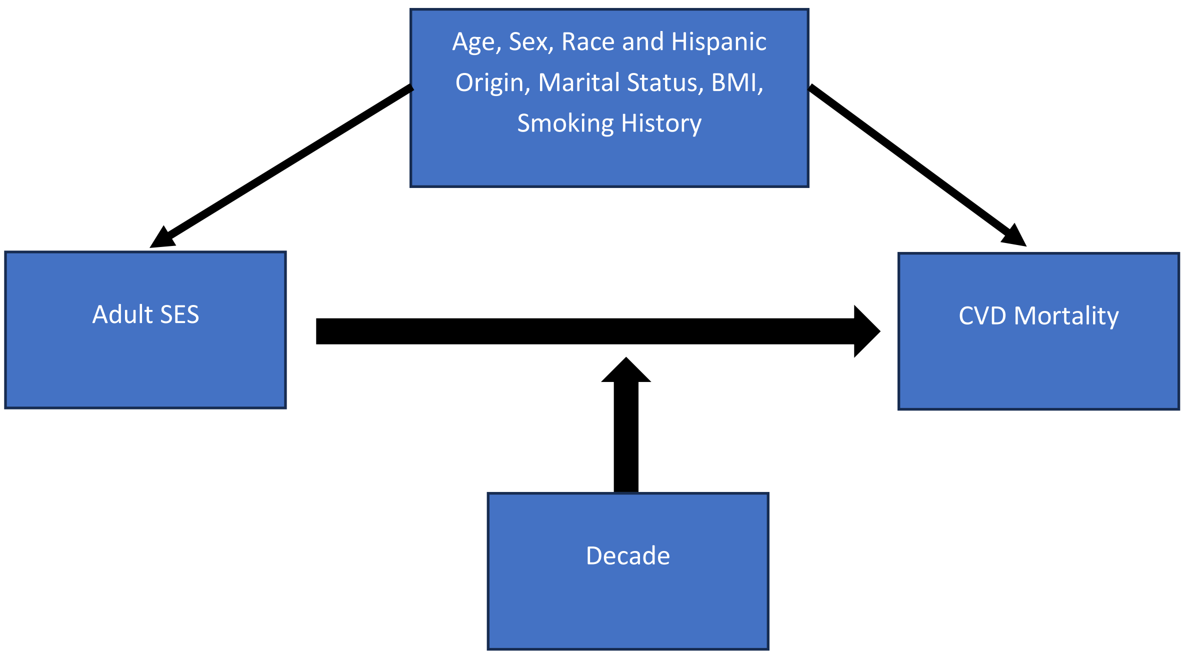
HYPOTHESIS 2: Socioeconomic disparities in CVD mortality will be wider in more recent decades (2010-2018) compared to previous decades (1990-1999, 2000-2009) as indicated by both highest level of education and federal poverty level.

3. Theoretical Framework

This study draws on the social production of disease[92] as a theoretical basis for analyzing temporal trends in associations between adult socioeconomic status and CVD mortality. In contrast to other theories that focus on individual choices and traits as contributors to disease, social production of disease theory states that population-level patterns of health and disease are products of an established societal hierarchy built on social and economic differences. Research guided by this theory focuses on comparing health and disease status between disadvantaged and advantaged groups, given that disease risk for these individuals is related to their group membership.

The present study examined the association between adult SES and CVD mortality, thus directly examining health as a result of socioeconomic differences. Below is a directed acyclic graph (DAG) to illustrate the exposure, outcome, and potential confounders considered within this study.

FIGURE 4. DIRECTED ACYCLIC GRAPH ILLUSTRATING MANUSCRIPT 3, AIMS 1 AND 2.



4. Methods

i. Overall Study Design

This is a prospective cohort study, with individuals followed via the National Death Index (NDI) from 1997-2019.

ii. Data Sources

This study used the National Health Interview Survey (NHIS) linked to the NDI. The NHIS is a nationally-representative survey of the civilian noninstitutionalized U.S. population, conducted annually by the National Center for Health Statistics (NCHS). Items on the NHIS cover a wide range of topics, including sociodemographic characteristics, healthcare utilization, health behaviors, and health conditions. The NDI is a national registry of deaths in the United States, which includes the date and cause of death.

The National Health Interview Survey (1997 – 2018)

For NHIS data collection, households are sampled and selected for in-person interviews conducted by trained staff from the United States Census Bureau with some follow-up interviews completed via telephone. For the study period, the NHIS was comprised of three interview components: (1) family core, (2) Sample Adult, and (3) Sample Child. The family core consisted of items related to basic sociodemographic characteristics and health information. From 1997 to 2018, one adult was randomly selected from the household and was the sole subject of the Sample Adult portion of the survey. Similarly, one child from the household was selected to be the sole subject of the Sample Child portion; information was collected from a knowledgeable adult present at the time of the interview.[125] Data was downloaded from the Integrated Public Use Microdata Series (IPUMS) website, which harmonizes NHIS data across all years.

National Death Index (2019)

Public-use linked mortality files were available for the 1997-2018 NHIS. The linked file includes survey data from the Sample Adult NHIS and mortality data from the 2019 National Death Index.[126] On this basis, the follow-up time across participants in our study ranged from 1 to 28 years.

iii. Participants and Criteria for Selection

The study sample was comprised of all participants with complete data on the exposure and outcome of interest via the Sample Adult interview. Covariates with greater than 10% missing were imputed using multiple imputation.

iv. Outcome Variable: Potential Measurement Issues

The outcome of interest, cardiovascular mortality, was obtained via the NDI. The NDI categorizes the underlying leading cause of death as (1) disease of heart, (2) malignant neoplasms, (3) chronic lower respiratory diseases, (4) accidents (unintentional injuries), (5) cerebrovascular diseases, (6) Alzheimer's disease, (7) diabetes mellitus, (8) influenza and pneumonia, (9) nephritis, nephrotic syndrome and nephrosis, or (10) all other causes. Participants recorded in the NDI as dying of diseases of the heart were categorized as having cardiovascular mortality. Participants that were still alive at follow-up (2018) were censored, and participants that died of non-cardiovascular causes were censored at their time of death, following previous literature.[127,128]

The primary measurement issue with this variable lies in the established inaccuracy of death certificates,[96,97] where the NDI obtains its information. A 2010 analysis found that 48% of the studied death certificates had at least one data issue, including providing a mechanism of death (e.g. cardiopulmonary arrest) or disease process (e.g. urosepsis) rather than an underlying cause of death.[96]

v. Exposure Variable: Potential Measurement Issues

The exposure of interest, individual-level SES, was ascertained via two measures on the NHIS: (1) household income and (2) highest level of education completed.

Respondents reported individual-level income, which was subsequently aggregated and recoded on the household level. The resulting variable was comprised of 11 income categories in increments of $5,000 from (1) 0 - $4,999 to (11) $75,000 and over. Following previous research,[127,129] family income was measured as a percentage of the federal poverty level ratio (<100%, 100-199%, 200-299%, 300-399%, 400% or greater). In cases where income data was missing, the NCHS-imputed income variable was used.[130] The highest level of education completed (1997-2018) was ascertained by a 21-level variable, ranging from (1) Never attended/kindergarten only to (21) Doctoral degree (PhD, EdD). Following previous research,[100,131] education was operationalized as a five-level variable: (1) less than high school diploma/GED (less than 12 years of school), (2) high school diploma/GED (12 years of school), (3) some college (13-15 years of school), and (4) college degree (15 years of school), and (5) graduate degree or more (16 years of school).

The primary measurement issues include (1) cross-sectional nature of SES measurement, (2) nonresponse on exposure variables, and (3) social desirability bias. As SES was measured via the NHIS, an annual cross-sectional data source, our study will only ascertain an individual's SES at one point in time: this may misrepresent the respondent's socioeconomic situation. For example, household income may change from year to year due to loss of employment or disability. Our study will also be unable to capture SES earlier in the life course, which previous work has shown is also influential for health outcomes.[118,132,133] Previous research also shows that income nonresponse typically ranges from 20-40%, depending on the specificity of the item (e.g. whether asking respondents for categorical income vs. the specific amount);[134–136] If a complete case analysis is used, this may lead to selection bias. However, given that imputed income data is available for the NHIS and education has a very low percent missing (NHIS 2018: <1% missing on education),[34] minimal impact is expected.

vi. Potential Confounders and Effect Modifiers

This study considered a series of potential confounders (age, sex, race and Hispanic origin, marital status, BMI, smoking) and one effect modifier (decade) as identified from previous research.[127,138] All variables were reported by proxy or self-reported at the time of the NHIS interview.

Age will be coded as a continuous variable. *Sex* will be coded dichotomously (male, female). *Race and Hispanic origin* will be operationalized into five categories following other NCHS data products: Hispanic, Non-Hispanic White, Non-Hispanic Black, and Non-Hispanic Asian, and Non-Hispanic Other.[139–141] *Marital status* will be operationalized as (1) Married, (2) Separated, (3) Divorced, (4) Widowed, and (5) Never Married. *BMI* will be calculated using self-reported height and weight measures and then operationalized following standard BMI cut-offs (underweight: BMI <18.5 kg/m^2; normal weight: 18.5 kg/m$^2 \leq$ BMI ≤ 24.9 kg/m^2; overweight: 25 kg/m$^2 \leq$ BMI ≤ 29.9 kg/m^2; obese: BMI ≥ 30 kg/m^2).[142] Lifetime prevalence of *smoking* will be ascertained via a binary item that asks whether the respondent has smoked at least 100 cigarettes in their entire life. *Decade* will be defined by the date of the interview (1997-2007 vs. 2008-2018).

vii. Mediators

No mediators will be assessed in this study.

viii. Power Analyses

Based on previous research,[115,116,143] a medium effect size was expected. Given that this is a secondary data analysis, with a predetermined sample size of approximately N=500,000 adults, PROC POWER in SAS 9.4 was used to determine the level of power that can be achieved with the present sample size. Based on preliminary analyses with the National Health Interview Survey, the probability of event was estimated at 0.11, and a moderate correlation between the exposure and included covariates (R2=0.25). Using a one-sided test and an estimated hazard ratio of 1.3, this sample size is expected to achieve a power greater than 99%, with $\alpha=0.05$.

ix. Statistical Analyses

Descriptive Analyses and Quality Assurance

Descriptive analyses of all variables were presented, overall and stratified by decade. Percentages of binary and categorical variables were presented; mean values and standard deviations were presented for the continuous variables.

Missing Data

All participants with complete data on the exposure and outcome were included in analyses. In cases where covariates were missing more than 10% of data, values were imputed using multiple imputation. Significant differences between those included and excluded in the sample were compared.

Model Building/Assessment of Model Fit

Separate Cox proportional hazards regression models were fit for each SES indicator, with potential confounders added sequentially in blocks. Mortality-adjusted sampling weights were used for analyses. Given that the study outcome is CVD mortality, a time-to-event analysis was appropriate, with the time between the NHIS interview and mortality via the National Death Index as the length of follow-up variable. The time-to-event A series of four models were constructed: Model 1, the unadjusted model, included only the exposure variable, SES, Model 2 added sociodemographic variables (age, race or Hispanic origin, sex), Model 3 added marital status, and Model 4 added BMI and smoking.

Akaike information criterion (AIC), a measure of relative goodness of fit, was used to compare models. The variance inflation factor (VIF) will be used to ensure that the multicollinearity of interaction terms and their original variables will not interfere with the independence of the model.

Analysis of Potential Confounders and Effect Modifiers

Age, sex, race/ethnicity, marital status, BMI, and smoking were assessed as potential confounders. To assess confounders, two models were run: first, a basic model with only the exposure (SES) and the outcome (CVD mortality), and second a model with the exposure, outcome, and the potential confounder. The associations between the exposure and outcome variables were compared between models, and variables with a 10% or greater change in the hazard ratio were conceptualized as confounders.

Decade was tested as an effect modifier, using interaction terms between education*decade and family income*decade. For significant interaction terms (p <.05), models stratified by decade were constructed; potential confounders were also tested as previously described within stratified models.

5. Results

Table 9 presents descriptive statistics of the study sample, weighted to the national population. In general, most participants were White, non-Hispanic (73.27%), female (54.00%), in midlife (M (SD) = 48.08 (18.14)), were married (46.98%), and were overweight or obese (60.49%). In respect to socioeconomic indicators, 57.18% of participants had attended at least some college, and most had a family income that was 200% of the federal poverty level or greater (72.33%). Only 4.29% of the sample had a cardiovascular-related death. When stratified by decade, descriptive statistics were overall similar with a few exceptions: the percentage of cardiovascular deaths was higher from 1997-2007 compared to 2008-2018 (5.5% vs. 2.6%), and participants had a higher percentage of having family incomes less than 100% FPL in 2008-2018 compared to 1997-2007 (14.29% vs. 10.5%). There were higher percentages of Hispanic (14.90% vs. 10.63; Table 10) and Non-Hispanic Asian (7.80% vs. 3.42%) among excluded participants compared to included participants; body mass index was also higher among excluded participants, while the percentage of participants that had ever smoked 100 cigarettes in their lifetime was lower (36.40% vs. 44.59%).

In main analyses, highest level of education was related to a higher hazard of cardiovascular-related mortality adjusted for all covariates. Compared to adults with a graduate degree or higher, adults with less than a high school diploma/GED had over twice the hazard (AHR: 2.22, 95% CI: 2.05, 2.40), adults with a high school diploma/GED had a 76% higher hazard (AHR: 1.76, 95% CI: 1.63, 1.90), and adults with some college had a 62% higher hazard (AHR: 1.62, 95% CI: 1.50, 1.76), and adults with a Bachelor's degree had a 17% higher hazard (AHR: 1.17, 95% CI: 1.08, 1.28) of cardiovascular-related mortality. The interaction term between highest level of education and decade was significant ($p < .0001$), so stratified models were constructed. When stratified by decade, associations were significant for both decades adjusted for all covariates, with slightly stronger associations between 1997-2007 (less than high school/GED, AHR: 2.21, 95% CI: 2.02, 2.42) compared to 2008-2018 (less than high school/GED, AHR: 2.17, 95% CI: 1.87, 2.52) (Table 11).

In parallel, family income as a percentage of the federal poverty level (FPL) was also related to a higher hazard of cardiovascular-related mortality adjusted for all covariates. Compared to adults with a family income of 400% FPL or greater, adults with family incomes of less than 100% FPL had more than twice the hazard (AHR: 2.25, 95% CI: 2.10, 2.41), adults with family incomes of 100-199% FPL had nearly twice the hazard (AHR: 1.96, 95% CI: 1.85, 2.08), adults with family incomes 200-299% FPL had a 50% higher hazard (AHR: 1.50, 1.43-1.62), and adults with family incomes 300-399% FPL had a 34% higher hazard (AHR: 1.34, 95% CI: 1.25-1.43) of cardiovascular-related mortality. The interaction term between family income and decade was significant ($p < .0001$), so stratified models were constructed. When stratified by decade, associations were significant for both decades adjusted for all covariates, with slightly stronger associations between 2008-2018 (less than 100% FPL, AHR: 2.28, 95% CI: 1.99, 2.63) compared to 1997-2007 (less than 100% FPL, AHR: 2.23, 95% CI: 2.06, 2.41) (Table 12).

6. Discussion

Using a nationally representative sample of adults in the United States, the present study examined associations between different socioeconomic indicators and cardiovascular-related mortality, as well as if these associations varied by decade. In the full sample and in stratified analyses, associations were significant for both indicators adjusted for all potential confounders. For education, associations between lower education levels and cardiovascular-related mortality were slightly stronger in 1997-2007 compared to 2008-2018. In contrast, associations between lower levels of family income and cardiovascular-related mortality were slightly stronger in 2008-2018 compared to 1997-2007. However, given that these differences were relatively small, the associations observed suggest that education and income have similar associations with health.

These findings are consistent with previous work that show associations between socioeconomic disadvantage and cardiovascular-related mortality, supporting our hypothesis for Aim 1.[4–7] For Aim 2, we hypothesized that associations between both socioeconomic indicators and cardiovascular-related mortality widened over time. These hypotheses were partially supported by our results. Decade-stratified analyses between education and cardiovascular-related mortality aligned with previous work in Italy using data from 1971-2011 to show that educational inequalities in CVD mortality have declined.[12] Similarly, decade-stratified analyses for family income and cardiovascular-related mortality were consistent to previous work using

NHANES (1969-1970; 1997-1998) showing that SES disparities in CVD mortality had widened over time.[13] These findings may be explained by the fact that although educational attainment is increasing, with more individuals increasing their highest level of education, the income gap is widening, with much of the nation's wealth concentrated in a small proportion of the population.[20]

Although both education and family income are commonly used measures of socioeconomic status, associations between these indicators and cardiovascular-related mortality showed slightly different patterns when stratified by decade. For both overall and stratified models, education was more strongly associated with cardiovascular-related mortality compared to income. This finding aligns with previous work suggesting that education has a stronger association with health than income.[21] Theorized reasons for this difference include the presence of resources that are associated with education that may not necessarily be associated with income. The ability to obtain an education may reflect the possession of both financial and psychosocial support early in life, which may also impact the development of beneficial health behaviors (smoking and drinking habits). Furthermore, educational attainment may represent an individual's consistent ability to obtain a certain level of employment or income, while income alone may not be representative of an individual's earning potential over time, and thus only provides a snapshot of an individual's socioeconomic situation. Thus, both education and income may contribute differently to overall health and should both be considered in public health research.

Study Strengths and Limitations

This study has several strengths. First, this study uses the NHIS, a large, nationally-representative data source, meaning the results will be generalizable to the United States population of adults. Second, this study is the first to our knowledge to examine temporal trends within associations between SES and CVD-related outcomes using multiple decades of U.S. data (1990-2018) since 2002.[121] This analysis allows researchers to understand whether the relationships between these variables are changing over time. Third, the use of multiple SES indicators allows researchers to understand whether associations between SES and CVD mortality are similar when using different measures.[120]

However, it is also important to note that the results of this study may be limited. First, as SES has the potential to change quickly and often throughout the life course[144] due to various factors that are unable to be measured in a cross-sectional data collection (e.g. loss of employment, unexpected medical expenses, loss of income due to a household member leaving), the major limitation to this study is that SES is only measured at one time-point: the period of exposure to the reported SES level is unknown. Second, although potential confounders were identified a priori, unmeasured confounders may exist and are unable to be accounted for within the analysis. As previously described, there may also be differential reporting bias for the exposure, due to income nonresponse or overreporting of income due to social desirability bias.

Public Health Significance

Examining associations between socioeconomic indicators and cardiovascular-related mortality using recent data is essential to providing an accurate picture of current population health. Understanding the unique relationships that different socioeconomic indicators may have with health outcomes can help further the development of robust measurement of socioeconomic status, and improve public health research in this area as a whole. Future work may focus on understanding how these associations may differ by subgroup, including race and Hispanic origin, or gender.

7. Human Subjects and Ethical Considerations

This study was approved by the University of Maryland Institutional Review Board.

TABLE 9. SAMPLE CHARACTERISTICS, NATIONAL HEALTH INTERVIEW SURVEY, 1997-2018, N=548,397

		1997-2007 (N=253,658)	2008-2018 (N=294,739)
Variable	**% or M(SD)**	**% or M(SD)**	**% or M(SD)**
Highest Level of Education,%			
Less Than High School	13.05	14.20	11.43
High School Diploma/GED	29.78	31.05	28.00
Some College	30.09	29.33	31.14
Bachelor's Degree (4 Years of College)	17.67	16.72	19.00
Graduate Degree or Higher	9.42	8.70	10.40
Family Income			
Less than 100% FPL	12.06	10.47	14.29
100-199% FPL	15.61	14.89	16.62
200-299% FPL	20.11	18.17	22.48
300-399% FPL	12.96	13.88	11.84
400% FPL or greater	34.73	36.70	32.30
Cardiovascular-Related Mortality, %	4.29	5.49	2.60
Age at Baseline, M (SD)	48.08 (18.14)	46.80 (17.86)	49.17 (18.31)
Male, %	46.00	45.73	46.37
Race and Hispanic Origin, %			
Hispanic	10.63	9.74	11.89
Non-Hispanic White	73.27	74.99	70.86
Non-Hispanic Black	11.86	11.60	12.24
Non-Hispanic Asian	3.42	2.86	4.20
Non-Hispanic Other	0.82	0.82	0.82
Marital Status, %			
Married	46.98	48.54	44.80
Separated	3.10	3.11	3.07
Divorced	14.75	14.26	15.44
Widowed	9.88	10.12	9.55
Never Married	25.29	23.97	27.15
Body Mass Index, %			
Underweight	1.34	1.43	1.22
Healthy Weight	38.17	39.93	35.71
Overweight	36.07	36.27	35.78
Obese	24.42	22.37	27.29
Ever smoked 100 cigarettes, %	44.59	45.89	42.78

Notes: P-values show chi-square and t-tests determining significant differences between decades. GED, General Education Development, SD, standard deviation

TABLE 10. INCLUDED VS. EXCLUDED PARTICIPANTS, NATIONAL HEALTH INTERVIEW SURVEY 1997-2018, N= 611,505

	Included Participants (N=548,397)	Excluded Participants (N=63,108)
Variable	**% or M(SD)**	**% or M(SD)**
Highest Level of Education,%		
Less Than High School	13.05	17.56
High School Diploma/GED	29.78	32.31
Some College	30.09	28.50
Bachelor's Degree (4 Years of College)	17.67	14.28
Graduate Degree or Higher	9.42	7.35
Family Income		
Less than 100% FPL	12.06	19.41
100-199% FPL	15.61	21.67
200-299% FPL	20.11	21.46
300-399% FPL	12.96	11.54
400% FPL or greater	34.73	25.92
Cardiovascular-Related Mortality, %	4.29	5.04
Age at Baseline, M (SD)	48.08 (18.14)	48.88 (18.37)
Male, %	46.00	37.15
Race and Hispanic Origin, %		
Hispanic	10.63	12.89
Non-Hispanic White	73.27	66.94
Non-Hispanic Black	11.86	14.46
Non-Hispanic Asian	3.42	4.72
Non-Hispanic Other	0.82	0.99
Marital Status, %		
Married	46.98	42.96
Separated	3.10	3.51
Divorced	14.75	14.27
Widowed	9.88	12.14
Never Married	25.29	27.13
Body Mass Index, %		
Underweight	1.34	1.40
Healthy Weight	38.17	39.09
Overweight	36.07	37.19
Obese	24.42	22.32
Ever smoked 100 cigarettes, %	44.59	41.04

Notes: P-values show chi-square and t-tests determining significant differences between decades. GED, General Education Development, SD, standard deviation

TABLE 11. COX REGRESSIONS ESTIMATING ASSOCIATIONS BETWEEN HIGHEST LEVEL OF EDUCATION AND CARDIOVASCULAR-RELATED MORTALITY, STRATIFIED BY DECADE (NATIONAL HEALTH INTERVIEW SURVEY 1997-2018), N=548,397.

	Model 1		Model 2		Model 3		Model 4	
	AHR	95% CI	AHR	95% CI	AHR	95% CI	AHR	95% CI
NHIS, 1997-2018								
Highest Level of Parents' Education								
Less Than High School Diploma/GED	**2.18**	**(2.02, 2.35)**	**2.45**	**(2.27, 2.65)**	**2.36**	**(2.18, 2.55)**	**2.22**	**(2.05, 2.40)**
High School Diploma/GED	**1.67**	**(1.55, 1.79)**	**1.85**	**(1.72, 2.00)**	**1.84**	**(1.71, 1.99)**	**1.76**	**(1.63, 1.90)**
Some College	**1.57**	**(1.45, 1.70)**	**1.73**	**(1.60, 1.87)**	**1.70**	**(1.57, 1.84)**	**1.62**	**(1.50, 1.76)**
Bachelor's Degree	**1.14**	**(1.05, 1.24)**	**1.19**	**(1.09, 1.29)**	**1.19**	**(1.10, 1.30)**	**1.17**	**(1.08, 1.28)**
Graduate Degree	ref	1.000	ref	1.000	ref	1.000	ref	1.000
NHIS, 1997-2007 (N=253,658)								
Highest Level of Parents' Education								
Less Than High School Diploma/GED	**2.16**	**(1.98, 2.35)**	**2.42**	**(2.22, 2.64)**	**2.35**	**(2.15, 2.57)**	**2.21**	**(2.02, 2.42)**
High School Diploma/GED	**1.67**	**(1.54, 1.82)**	**1.87**	**(1.71, 2.03)**	**1.86**	**(1.71, 2.03)**	**1.78**	**(1.63, 1.94)**
Some College	**1.59**	**(1.46, 1.74)**	**2.75**	**(1.60, 1.91)**	**1.74**	**(1.59, 1.90)**	**1.65**	**(1.51, 1.81)**
Bachelor's Degree	**1.11**	**(1.01, 1.21)**	**1.15**	**(1.05, 1.26)**	**1.16**	**(1.06, 1.27)**	**1.14**	**(1.04, 1.25)**
Graduate Degree	ref	1.00	ref	1.00	ref	1.00	ref	1.00
NHIS, 2008-2018 (N=294,739)								
Highest Level of Parents' Education								
Less Than High School Diploma/GED	**2.17**	**(1.87, 2.52)**	**2.45**	**(2.11, 2.85)**	**2.31**	**(1.99, 2.69)**	**2.17**	**(1.87, 2.52)**
High School Diploma/GED	**1.61**	**(1.39, 1.88)**	**1.80**	**(1.54, 2.09)**	**1.76**	**(1.51, 2.04)**	**1.67**	**(1.44, 1.94)**
Some College	**1.51**	**(1.29, 1.77)**	**1.66**	**(1.42, 1.95)**	**1.61**	**(1.38, 1.89)**	**1.53**	**(1.31, 1.79)**
Bachelor's Degree	**1.21**	**(1.02, 1.45)**	**1.28**	**(1.07, 1.53)**	**1.27**	**(1.06, 1.51)**	**1.25**	**(1.05, 1.49)**
Graduate Degree	ref	1.00	ref	1.00	ref	1.00	ref	1.00

Note: Results were stratified by decade based on a significant interaction term between highest level of education and decade (p<.0001).

AHR=adjusted hazard ratio; GED=General Education Development or High School Equivalency Diploma

Model 1 displays the age-adjusted association between highest level of education and hazard of cardiovascular-related mortality.

Model 2 adds sex and race and Hispanic origin.

Model 3 adds marital status.

Model 4 adds body mass index and history of smoking.

TABLE 12. COX REGRESSIONS ESTIMATING ASSOCIATIONS BETWEEN FAMILY INCOME AND CARDIOVASCULAR-RELATED MORTALITY, STRATIFIED BY DECADE (NATIONAL HEALTH INTERVIEW SURVEY 1997-2018), N=548,397.

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	AHR	95% CI	AHR	95% CI	AHR	95% CI	AHR	95% CI
NHIS, 1997-2018								
Family Income								
Less than 100% FPL	**2.17**	**(2.03, 2.31)**	**2.61**	**(2.44, 2.79)**	**2.31**	**(2.15, 2.47)**	**2.25**	**(2.10, 2.41)**
100-199% FPL	**1.93**	**(1.82, 2.03)**	**2.18**	**(2.06, 2.31)**	**2.01**	**(1.89, 2.13)**	**1.96**	**(1.85, 2.08)**
200-299% FPL	**1.51**	**(1.42, 1.61)**	**1.61**	**(1.51, 1.71)**	**1.55**	**(1.46, 1.65)**	**1.5**	**(1.43, 1.62)**
300-399% FPL	**1.36**	**(1.27, 1.46)**	**1.41**	**(1.31, 1.51)**	**1.37**	**(1.28, 1.47)**	**1.34**	**(1.25, 1.43)**
400% FPL or greater	ref	1.00	ref	1.00	ref	1.00	ref	1.00
NHIS, 1997-2007 (N=253,658)								
Family Income								
Less than 100% FPL	**2.15**	**(2.00, 2.31)**	**2.57**	**(2.39, 2.77)**	**2.28**	**(2.11, 2.47)**	**2.23**	**(2.06, 2.41)**
100-199% FPL	**1.85**	**(1.73, 1.97)**	**2.10**	**(1.96, 2.24)**	**1.93**	**(1.81, 2.07)**	**1.90**	**(1.77, 2.03)**
200% FPL and greater	**1.57**	**(1.46, 1.68)**	**1.66**	**(1.55, 1.77)**	**1.59**	**(1.49, 1.71)**	**1.56**	**(1.45, 1.67)**
300-399% FPL	**1.36**	**(1.25, 1.47)**	**1.40**	**(1.30, 1.52)**	**1.36**	**(1.26, 1.47)**	**1.33**	**(1.23, 1.44)**
400% FPL or greater	ref	1.00	ref	1.00	ref	1.00	ref	1.00
NHIS, 2008-2018 (N=294,739)								
Family Income								
Less than 100% FPL	**2.22**	**(1.94, 2.53)**	**2.69**	**(2.35, 3.09)**	**2.35**	**(2.04, 2.70)**	**2.28**	**(1.99, 2.63)**
100-199% FPL	**2.11**	**(1.88, 2.37)**	**2.38**	**(2.12, 2.68)**	**2.17**	**(1.93, 2.45)**	**2.11**	**(1.87, 2.38)**
200% FPL and greater	**1.45**	**(1.28, 1.63)**	**1.54**	**(1.37, 1.74)**	**1.50**	**(1.33, 1.69)**	**1.48**	**(1.31, 1.66)**
300-399% FPL	**1.38**	**(1.19, 1.61)**	**1.41**	**(1.22, 1.65)**	**1.39**	**(1.19, 1.61)**	**1.35**	**(1.16, 1.57)**
400% FPL or greater	ref	1.00	ref	1.00	ref	1.00	ref	1.00

Note: Results were stratified by decade based on a significant interaction term between family income and decade (p<.0001).

AHR=adjusted hazard ratio; GED=General Education Development or High School Equivalency Diploma

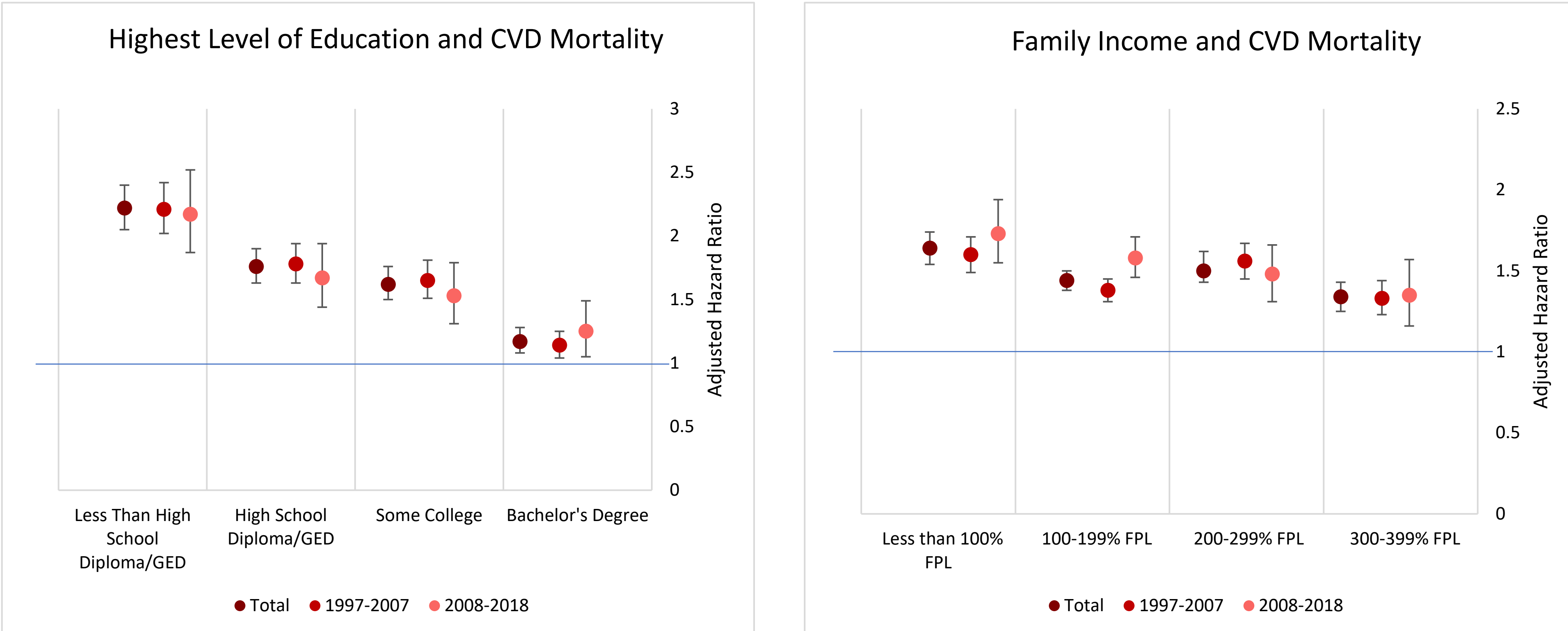
Model 1 displays the age-adjusted association between family income and hazard of cardiovascular-related mortality.

Model 2 adds sex and race and Hispanic origin.

Model 3 adds marital status.

Model 4 adds body mass index and history of smoking.

FIGURE 5: COMPARISON OF SOCIOECONOMIC INDICATORS AND CVD MORTALITY, MANUSCRIPT 3 AIM 1



Chapter 5: Conclusions & Public Health Significance

This research provides insight into the social determinants of CVD, as well as factors that may modify or mediate these associations. Although previous research has identified biological and social risk factors of CVD, there is limited research investigating secondary research questions related to these associations, including whether there may be demographic or social differences within these relationships. By determining that sex differences exist in the association between witnessing domestic violence and childhood BMI, this research contributes toward identifying vulnerable populations for interventions. Study 1 also contributes new information on the association between sexual orientation and gender identity discrimination and BMI among children, which further emphasizes existing work highlighting the vulnerability of this demographic group and may encourage additional work in this area.

The identification of high optimism as a modifier or mediator in the association between childhood socioeconomic disadvantage and incident heart disease (Study 2) provides support the use of easily accessible psychological interventions (e.g. positive psychology, mindfulness) for heart disease prevention. Given that many interventions that encourage optimism are low-cost compared to more traditional methods of therapy, this work illuminates a manageable path for alleviating health burden among vulnerable individuals.

Study 3 presents new information about temporal trends within the associations between family income and CVD mortality, which had not been previously investigated to my knowledge. This work also updates previous literature examining how the associations between education and CVD mortality may have changed over time with more recent data.

By identifying temporal trends within the association between SES and CVD mortality, this work may help demonstrate a continued need for policies or programs targeted at decreasing CVD mortality risk at the population level. By examining two different SES indicators by the same outcome, this research furthers existing work exploring how these two commonly used indicators differ in their associations with health. This work contributes to ongoing conversations within research as to how best select a measure of SES in survey research.

References

1. *About Multiple Causes of Death, 1999-2020*. Centers for Disease Control and Prevention, National Center for Health Statistics https://wonder.cdc.gov/mcd-icd10.html

2. Kochanek KD. Mortality in the United States, 2019. 2020;(395):8.

3. Ritchey MD, Wall HK, George MG, Wright JS. US trends in premature heart disease mortality over the past 50 years: Where do we go from here? *Trends Cardiovasc Med*. 2020;30(6):364-374. doi:10.1016/j.tcm.2019.09.005

4. Summary Health Statistics, 2018. https://ftp.cdc.gov/pub/Health_Statistics/NCHS/NHIS/SHS/2018_SHS_Table_A-1.pdf

5. Sidney S, Quesenberry CP, Jaffe MG, et al. Recent Trends in Cardiovascular Mortality in the United States and Public Health Goals. *JAMA Cardiol*. 2016;1(5):594. doi:10.1001/jamacardio.2016.1326

6. Respondent-reported prevalence of heart disease in adults aged 18 and over, by selected characteristics: United States, selected years 1997–2019. *Health, United States*. Published online 2021 2020:2.

7. de Mestral C, Stringhini S. Socioeconomic Status and Cardiovascular Disease: an Update. *Curr Cardiol Rep*. 2017;19(11):115. doi:10.1007/s11886-017-0917-z

8. Piché ME, Tchernof A, Després JP. Obesity Phenotypes, Diabetes, and Cardiovascular Diseases. *Circ Res*. 2020;126(11):1477-1500. doi:10.1161/CIRCRESAHA.120.316101

9. Powell-Wiley TM, Poirier P, Burke LE, et al. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation*. 2021;143(21). doi:10.1161/CIR.0000000000000973

10. Suglia SF, Koenen KC, Boynton-Jarrett R, et al. Childhood and Adolescent Adversity and Cardiometabolic Outcomes: A Scientific Statement From the American Heart Association. *Circulation*. 2018;137(5). doi:10.1161/CIR.0000000000000536

11. Silander K, Alanne M, Kristiansson K, et al. Gender Differences in Genetic Risk Profiles for Cardiovascular Disease. Janssens ACJW, ed. *PLoS ONE*. 2008;3(10):e3615. doi:10.1371/journal.pone.0003615

12. Childhood Overweight & Obesity | Overweight & Obesity | CDC. Published September 17, 2021. Accessed February 14, 2022. https://www.cdc.gov/obesity/childhood/index.html

13. Hales CM. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. 2017;(288):8.

14. Health-E Stats, December 2020. Published online 2020:7.

15. Cote AT, Harris KC, Panagiotopoulos C, Sandor GGS, Devlin AM. Childhood obesity and cardiovascular dysfunction. *J Am Coll Cardiol*. 2013;62(15):1309-1319. doi:10.1016/j.jacc.2013.07.042

16. Umer A, Kelley GA, Cottrell LE, Giacobbi P, Innes KE, Lilly CL. Childhood obesity and adult cardiovascular disease risk factors: a systematic review with meta-analysis. *BMC Public Health*. 2017;17(1):683. doi:10.1186/s12889-017-4691-z

17. Lloyd LJ, Langley-Evans SC, McMullen S. Childhood obesity and risk of the adult metabolic syndrome: a systematic review. *Int J Obes (Lond)*. 2012;36(1):1-11. doi:10.1038/ijo.2011.186

18. Jacobs DR, Woo JG, Sinaiko AR, et al. Childhood Cardiovascular Risk Factors and Adult Cardiovascular Events. *N Engl J Med*. 2022;386(20):1877-1888. doi:10.1056/NEJMoa2109191

19. Ingelfinger JR. Childhood Risk Factors and Prediction of Adult Cardiovascular End Points. *N Engl J Med*. 2022;386(20):1948-1949. doi:10.1056/NEJMe2203743

20. Adverse Childhood Experiences: NSCH Data Brief, June 2020. :2.

21. Schroeder K, Schuler BR, Kobulsky JM, Sarwer DB. The association between adverse childhood experiences and childhood obesity: A systematic review. *Obesity Reviews*. 2021;22(7). doi:10.1111/obr.13204

22. Crandall A, Miller JR, Cheung A, et al. ACEs and counter-ACEs: How positive and negative childhood experiences influence adult health. *Child Abuse & Neglect*. 2019;96:104089. doi:10.1016/j.chiabu.2019.104089

23. Su S, Jimenez MP, Roberts CTF, Loucks EB. The Role of Adverse Childhood Experiences in Cardiovascular Disease Risk: a Review with Emphasis on Plausible Mechanisms. *Curr Cardiol Rep*. 2015;17(10):88. doi:10.1007/s11886-015-0645-1

24. Felitti VJ, Anda RF, Nordenberg D, et al. Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: The Adverse Childhood Experiences (ACE) Study. *American journal of preventive medicine*. 1998;14(4):245-258.

25. Salas J, van den Berk-Clark C, Skiöld-Hanlin S, Schneider FD, Scherrer JF. Adverse childhood experiences, depression, and cardiometabolic disease in a nationally representative sample. *Journal of Psychosomatic Research*. 2019;127:109842. doi:10.1016/j.jpsychores.2019.109842

26. McKelvey LM, Saccente JE, Swindle TM. Adverse Childhood Experiences in Infancy and Toddlerhood Predict Obesity and Health Outcomes in Middle Childhood. *Childhood Obesity*. 2019;15(3):206-215. doi:10.1089/chi.2018.0225

27. Santos M, Burton ET, Cadieux A, et al. Adverse childhood experiences, health behaviors, and associations with obesity among youth in the United States. *Behavioral Medicine*. Published online July 6, 2022:1-11. doi:10.1080/08964289.2022.2077294

28. Baglivio MT, Epps N, Swartz K, Huq MS, Sheer A, Hardt NS. The prevalence of adverse childhood experiences (ACE) in the lives of juvenile offenders. *Journal of juvenile justice*. 2014;3(2).

29. Leban L. The effects of adverse childhood experiences and gender on developmental trajectories of internalizing and externalizing outcomes. *Crime & Delinquency*. 2021;67(5):631-661.

30. Leban L, Gibson CL. The role of gender in the relationship between adverse childhood experiences and delinquency and substance use in adolescence. *Journal of criminal justice*. 2020;66:101637.

31. Mitchell KS, Wolf EJ, Reardon AF, Miller MW. Association of eating disorder symptoms with internalizing and externalizing dimensions of psychopathology among men and women. *International Journal of Eating Disorders*. 2014;47(8):860-869.

32. Isohookana R, Marttunen M, Hakko H, Riipinen P, Riala K. The impact of adverse childhood experiences on obesity and unhealthy weight control behaviors among adolescents. *Comprehensive Psychiatry*. 2016;71:17-24. doi:10.1016/j.comppsych.2016.08.002

33. Cordola Hsu AR, Niu Z, Lei X, et al. Adolescents' Depressive Symptom Experience Mediates the Impact of Long-Term Exposure to Maternal Depression Symptoms on Adolescents' Body Mass Index. *Annals of Behavioral Medicine*. 2020;54(7):510-517. doi:10.1093/abm/kaz069

34. Jun HJ, Corliss HL, Boynton-Jarrett R, Spiegelman D, Austin SB, Wright RJ. Growing up in a domestic violence environment: relationship with developmental trajectories of body mass index during adolescence into young adulthood. *J Epidemiol Community Health*. 2012;66(7):629-635. doi:10.1136/jech.2010.110932

35. Su S, Wang X, Pollock JS, et al. Adverse childhood experiences and blood pressure trajectories from childhood to young adulthood: the Georgia stress and Heart study. *Circulation*. 2015;131(19):1674-1681.

36. Bevilacqua L, Kelly Y, Heilmann A, Priest N, Lacey RE. Adverse childhood experiences and trajectories of internalizing, externalizing, and prosocial behaviors from childhood to adolescence. *Child Abuse & Neglect*. 2021;112:104890.

37. Schneiderman JU, Negriff S, Peckins M, Mennen FE, Trickett PK. Body mass index trajectory throughout adolescence: a comparison of maltreated adolescents by maltreatment type to a community sample: BMI trajectory. *Pediatric Obesity*. 2015;10(4):296-304. doi:10.1111/ijpo.258

38. Hawton K, Norris T, Crawley E, Shield JPH. Is Child Abuse Associated with Adolescent Obesity? A Population Cohort Study. *Childhood Obesity*. 2018;14(2):106-113. doi:10.1089/chi.2017.0141

39. Boynton-Jarrett R, Fargnoli J, Suglia SF, Zuckerman B, Wright RJ. Association Between Maternal Intimate Partner Violence and Incident Obesity in Preschool-Aged Children: Results From the Fragile Families and Child Well-being Study. *Arch Pediatr Adolesc Med*. 2010;164(6). doi:10.1001/archpediatrics.2010.94

40. Pretty C. Adverse childhood experiences and the cardiovascular health of children: a cross-sectional study. Published online 2013:8.

41. Davis L, Barnes AJ, Gross AC, Ryder JR, Shlafer RJ. Adverse Childhood Experiences and Weight Status among Adolescents. *The Journal of Pediatrics*. 2019;204:71-76.e1. doi:10.1016/j.jpeds.2018.08.071

42. Hunt TKA, Berger LM, Slack KS. Adverse Childhood Experiences and Behavioral Problems in Middle Childhood. *Child Abuse Negl*. 2017;67:391-402. doi:10.1016/j.chiabu.2016.11.005

43. Cortese S. The Association between ADHD and Obesity: Intriguing, Progressively More Investigated, but Still Puzzling. *Brain Sci*. 2019;9(10):256. doi:10.3390/brainsci9100256

44. Datar A, Sturm R. Childhood Overweight and Parent- and Teacher-Reported Behavior Problems: Evidence From a Prospective Study of Kindergartners. *Archives of Pediatrics & Adolescent Medicine*. 2004;158(8):804-810. doi:10.1001/archpedi.158.8.804

45. CDC. Child Development: Young Teens (12-14 years old) | CDC. Centers for Disease Control and Prevention. Published September 23, 2021. Accessed December 23, 2022. https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/adolescence.html

46. CDC. Child Development: Adolescence (15-17 years old) | CDC. Centers for Disease Control and Prevention. Published November 7, 2019. Accessed December 23, 2022. https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/adolescence2.html

47. Garrido EF, Weiler LM, Taussig HN. Adverse Childhood Experiences and Health-Risk Behaviors in Vulnerable Early Adolescents. *The Journal of Early Adolescence*. 2018;38(5):661-680. doi:10.1177/0272431616687671

48. *National Survey of Children's Health Guide to Multi-Year Estimates*. U.S. Census Bureau; 2022. https://www2.census.gov/programs-surveys/nsch/technical-documentation/methodology/NSCH-Guide-to-Multi-Year-Estimates.pdf

49. Vanderwall C, Randall Clark R, Eickhoff J, Carrel AL. BMI is a poor predictor of adiposity in young overweight and obese children. *BMC Pediatr*. 2017;17(1):135. doi:10.1186/s12887-017-0891-z

50. Burke NJ, Hellman JL, Scott BG, Weems CF, Carrion VG. The impact of adverse childhood experiences on an urban pediatric population. *Child Abuse Negl*. 2011;35(6):408-413. doi:10.1016/j.chiabu.2011.02.006

51. Akinbami LJ, Ogden CL. Childhood Overweight Prevalence in the United States: The Impact of Parent-reported Height and Weight. *Obesity*. 2009;17(8):1574-1580. doi:10.1038/oby.2009.1

52. CDC. BMI for Children and Teens. Centers for Disease Control and Prevention. Published December 3, 2021. Accessed February 13, 2022. https://www.cdc.gov/obesity/childhood/defining.html

53. He J, Fan X. How Accurate Is Using Parent-Reported Height and Weight for Screening Children and Adolescents for Overweight and Obesity? Meta-Analyses at Both Population and Individual Levels. *Childhood Obesity*. 2018;14(5):302-315. doi:10.1089/chi.2018.0062

54. Liming KW, Akin B, Brook J. Adverse Childhood Experiences and Foster Care Placement Stability. *Pediatrics*. 2021;148(6):e2021052700. doi:10.1542/peds.2021-052700

55. Bethell CD, Carle A, Hudziak J, et al. Methods to Assess Adverse Childhood Experiences of Children and Families: Toward Approaches to Promote Child Well-being in Policy and Practice. *Academic Pediatrics*. 2017;17(7):S51-S69. doi:10.1016/j.acap.2017.04.161

56. Aris IM, Rifas-Shiman SL, Jimenez MP, et al. Neighborhood Child Opportunity Index and Adolescent Cardiometabolic Risk. *Pediatrics*. 2021;147(2):e2020018903. doi:10.1542/peds.2020-018903

57. Jackson D, Chilton M, Johnson K, Vaughn M. Adverse Childhood Experiences and Household Food Insecurity: Findings From the 2016 National Survey of Children's Health. *American Journal of Preventive Medicine*. Published online November 9, 2019. doi:10.1016/j.amepre.2019.06.004

58. Bethell C, Gombojav N, Solloway M, Wissow L. Adverse Childhood Experiences, Resilience and Mindfulness-Based Approaches: Common Denominator Issues for Children with Emotional, Mental, or Behavioral Problems. *Child Adolesc Psychiatr Clin N Am*. 2016;25(2):139-156. doi:10.1016/j.chc.2015.12.001

59. Bethell CD, Newacheck P, Hawes E, Halfon N. Adverse Childhood Experiences: Assessing The Impact On Health And School Engagement And The Mitigating Role Of Resilience. *Health Affairs*. 2014;33(12):2106-2115. doi:10.1377/hlthaff.2014.0914

60. CDC. Child Development: Middle Childhood (9-11 years old) | CDC. Centers for Disease Control and Prevention. Published September 23, 2021. Accessed December 23, 2022. https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/middle2.html

61. Alcalá HE, Ng AE, Tkach N, Salam Z. Adverse Childhood Experiences and Utilization and forgoing of Health Care among Children: A Nationally Representative Study in the United States. *Children's Health Care*. Published online 2022:1-16.

62. Cohen J. Statistical power analysis for the behavioral sciences. Lawrence Erlbaum Associates. *Hillsdale, NJ*. Published online 1988:20-26.

63. Erdfelder E, Faul F, Buchner A. GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers*. 1996;28(1):1-11. doi:10.3758/BF03203630

64. United States Demographics of Low-Income Children. National Center for Children in Poverty. Accessed February 17, 2022. https://www.nccp.org/demographic/

65. Cohen S, Janicki-Deverts D, Chen E, Matthews KA. Childhood socioeconomic status and adult health: Childhood socioeconomic status and adult health. *Annals of the New York Academy of Sciences*. 2010;1186(1):37-55. doi:10.1111/j.1749-6632.2009.05334.x

66. Tsenkova V, Pudrovska T, Karlamangla A. Childhood Socioeconomic Disadvantage and Prediabetes and Diabetes in Later Life: A Study of Biopsychosocial Pathways. *Psychosomatic Medicine*. 2014;76(8):622-628. doi:10.1097/PSY.0000000000000106

67. Non AL, Rewak M, Kawachi I, et al. Childhood Social Disadvantage, Cardiometabolic Risk, and Chronic Disease in Adulthood. *American Journal of Epidemiology*. 2014;180(3):263-271. doi:10.1093/aje/kwu127

68. Boylan JM, Cundiff JM, Fuller-Rowell TE, Ryff CD. Childhood socioeconomic status and inflammation: Psychological moderators among Black and White Americans. *Health Psychology*. 2020;39(6):497-508. doi:10.1037/hea0000866

69. Slopen N, Goodman E, Koenen KC, Kubzansky LD. Socioeconomic and Other Social Stressors and Biomarkers of Cardiometabolic Risk in Youth: A Systematic Review of Less Studied Risk Factors. Janda M, ed. *PLoS ONE*. 2013;8(5):e64418. doi:10.1371/journal.pone.0064418

70. Glover LM, Cain-Shields LR, Wyatt SB, Gebreab SY, Diez-Roux AV, Sims M. Life Course Socioeconomic Status and Hypertension in African American Adults: The Jackson Heart Study. *Am J Hypertens*. 2020;33(1):84-91. doi:10.1093/ajh/hpz133

71. North BJ, Sinclair DA. The Intersection Between Aging and Cardiovascular Disease. *Circ Res*. 2012;110(8):1097-1108. doi:10.1161/CIRCRESAHA.111.246876

72. Lloyd-Jones DM, Nam BH, D'Agostino, Sr RB, et al. Parental Cardiovascular Disease as a Risk Factor for Cardiovascular Disease in Middle-aged Adults: A Prospective Study of Parents and Offspring. *JAMA*. 2004;291(18):2204. doi:10.1001/jama.291.18.2204

73. Heart Disease and Stroke | CDC. Published February 3, 2022. Accessed February 25, 2022. https://www.cdc.gov/chronicdisease/resources/publications/factsheets/heart-disease-stroke.htm

74. Levine GN, Cohen BE, Commodore-Mensah Y, et al. Psychological Health, Well-Being, and the Mind-Heart-Body Connection: A Scientific Statement From the American Heart Association. *Circulation*. 2021;143(10). doi:10.1161/CIR.0000000000000947

75. Lantz PM, Lynch JW, House JS, et al. Socioeconomic disparities in health change in a longitudinal study of US adults: the role of health-risk behaviors. *Social Science & Medicine*. 2001;53(1):29-40. doi:10.1016/S0277-9536(00)00319-1

76. Pool LR, Aguayo L, Brzezinski M, et al. Childhood Risk Factors and Adulthood Cardiovascular Disease: A Systematic Review. *The Journal of Pediatrics*. 2021;232:118-126.e23. doi:10.1016/j.jpeds.2021.01.053

77. Ferraro KF, Schafer MH, Wilkinson LR. Childhood Disadvantage and Health Problems in Middle and Later Life: Early Imprints on Physical Health? *Am Sociol Rev*. 2016;81(1):107-133. doi:10.1177/0003122415619617

78. Kamphuis CB, Turrell G, Giskes K, Mackenbach JP, van Lenthe FJ. Socioeconomic inequalities in cardiovascular mortality and the role of childhood socioeconomic conditions and adulthood risk factors: a prospective cohort study with 17-years of follow up. *BMC Public Health*. 2012;12(1):1045. doi:10.1186/1471-2458-12-1045

79. Lee M, Khan MM, Wright B. Is Childhood Socioeconomic Status Related to Coronary Heart Disease? Evidence From the Health and Retirement Study (1992-2012). *Gerontology and Geriatric Medicine*. 2017;3:2333721417696673. doi:10.1177/2333721417696673

80. Carver CS, Scheier MF, Segerstrom SC. Optimism. *Clin Psychol Rev*. 2010;30(7):879-889. doi:10.1016/j.cpr.2010.01.006

81. Tindle HA, Chang YF, Kuller LH, et al. Optimism, Cynical Hostility, and Incident Coronary Heart Disease and Mortality in the Women's Health Initiative. *Circulation*. 2009;120(8):656-662. doi:10.1161/CIRCULATIONAHA.108.827642

82. Kim ES, Hagan KA, Grodstein F, DeMeo DL, De Vivo I, Kubzansky LD. Optimism and Cause-Specific Mortality: A Prospective Cohort Study. *Am J Epidemiol*. 2017;185(1):21-29. doi:10.1093/aje/kww182

83. Kim ES, Smith J, Kubzansky LD. Prospective Study of the Association Between Dispositional Optimism and Incident Heart Failure. *Circulation: Heart Failure*. 2014;7(3):394-400. doi:10.1161/CIRCHEARTFAILURE.113.000644

84. Woo J, Lehrer HM, Whyne E, Steinhardt M. The longitudinal association of psychological resources with chronic conditions and the mediating roles of health behaviours and allostatic load. *Psychology & Health*. 2020;35(5):629-643. doi:10.1080/08870446.2019.1656205

85. Amonoo HL, Celano CM, Sadlonova M, Huffman JC. Is Optimism a Protective Factor for Cardiovascular Disease? *Curr Cardiol Rep*. 2021;23(11):158. doi:10.1007/s11886-021-01590-4

86. Gallo LC, Matthews KA. Understanding the association between socioeconomic status and physical health: do negative emotions play a role? *Psychol Bull*. 2003;129(1):10-51. doi:10.1037/0033-2909.129.1.10

87. McCurley JL, Penedo F, Roesch SC, et al. Psychosocial Factors in the Relationship between Socioeconomic Status and Cardiometabolic Risk: the HCHS/SOL Sociocultural Ancillary Study. *ann behav med*. 2017;51(4):477-488. doi:10.1007/s12160-016-9871-z

88. Boylan JM, Jennings JR, Matthews KA. Childhood Socioeconomic Status and Cardiovascular Reactivity and Recovery among Black and White Men: Mitigating effects of Psychological Resources. *Health Psychol*. 2016;35(9):957-966. doi:10.1037/hea0000355

89. O'Leary D, Uysal A, Rehkopf DH, Gross JJ. Subjective social status and physical health: The role of negative affect and reappraisal. *Social Science & Medicine*. 2021;291:114272. doi:10.1016/j.socscimed.2021.114272

90. Taylor SE, Seeman TE. Psychosocial resources and the SES–health relationship. In: *Socioeconomic Status and Health in Industrial Nations: Social, Psychological, and Biological Pathways.* Annals of the New York Academy of Sciences. New York Academy of Sciences; 1999:210-225.

91. Pitzer LM, Fingerman KL. Psychosocial Resources and Associations Between Childhood Physical Abuse and Adult Well-being. :9.

92. Krieger N. Epidemiology and the web of causation: Has anyone seen the spider? *Social Science & Medicine*. 1994;39(7):887-903. doi:10.1016/0277-9536(94)90202-X

93. Chen E, Miller GE, Lachman ME, Gruenewald TL, Seeman TE. Protective Factors for Adults From Low-Childhood Socioeconomic Circumstances: The Benefits of Shift-and-Persist for Allostatic Load. *Psychosomatic Medicine*. 2012;74(2):178-186. doi:10.1097/PSY.0b013e31824206fd

94. *How Healthy Are We?: A National Study of Well-Being at Midlife*. The University of Chicago Press; 2004:ix, 687.

95. Osterberg L, Blaschke T. Adherence to Medication. *New England Journal of Medicine*. 2005;353(5):487-497. doi:10.1056/NEJMra050100

96. Cambridge B, Cina SJ. The Accuracy of Death Certificate Completion in a Suburban Community. *The American Journal of Forensic Medicine and Pathology*. 2010;31(3):232-235. doi:10.1097/PAF.0b013e3181e5e0e2

97. Maudsley G, Williams EMI. 'Inaccuracy' in death certification – where are we now? *Journal of Public Health*. 1996;18(1):59-66. doi:10.1093/oxfordjournals.pubmed.a024463

98. Gruenewald TL, Karlamangla AS, Hu P, et al. History of socioeconomic disadvantage and allostatic load in later life. *Social Science & Medicine*. 2012;74(1):75-83. doi:10.1016/j.socscimed.2011.09.037

99. Liu Y, Lachman ME. Socioeconomic Status and Parenting Style From Childhood: Long-Term Effects on Cognitive Function in Middle and Later Adulthood. Suitor JJ, ed. *The Journals of Gerontology: Series B*. 2019;74(6):e13-e24. doi:10.1093/geronb/gbz034

100. Braveman PA, Cubbin C, Egerter S, et al. Socioeconomic Status in Health Research: One Size Does Not Fit All. *JAMA*. 2005;294(22):2879. doi:10.1001/jama.294.22.2879

101. Ng AE, Turpin R, Connor EM, Slopen N. Retrospective reports of socioeconomic disadvantage in childhood and mortality risk: are associations consistent across measures and sex? *Geroscience*. Published online May 30, 2022. doi:10.1007/s11357-022-00594-4

102. Tsenkova VK, Carr D, Coe CL, Ryff CD. Anger, adiposity, and glucose control in nondiabetic adults: findings from MIDUS II. *J Behav Med*. 2014;37(1):37-46. doi:10.1007/s10865-012-9460-y

103. Boehm JK, Chen Y, Williams DR, Ryff C, Kubzansky LD. Unequally Distributed Psychological Assets: Are There Social Disparities in Optimism, Life Satisfaction, and Positive Affect? Wallander JL, ed. *PLoS ONE*. 2015;10(2):e0118066. doi:10.1371/journal.pone.0118066

104. Segerstrom SC, Evans DR, Eisenlohr-Moul TA. Optimism and pessimism dimensions in the Life Orientation Test-Revised: Method and meaning. *Journal of Research in Personality*. 2011;45(1):126-129. doi:10.1016/j.jrp.2010.11.007

105. Ryff CD Burton. What to Do about Positive and Negative Items in Studies of Psychological Well-Being and Ill-Being? *Psychotherapy and Psychosomatics*. 2006;76(1):61.

106. Boehm JK, Williams DR, Rimm EB, Ryff C, Kubzansky LD. Relation between Optimism and Lipids in Midlife. *Am J Cardiol*. 2013;111(10):1425-1431. doi:10.1016/j.amjcard.2013.01.292

107. Boehm JK, Williams DR, Rimm EB, Ryff C, Kubzansky LD. Association Between Optimism and Serum Antioxidants in the Midlife in the United States Study. *Psychosomatic Medicine*. Published online 2013:9.

108. VanderWeele TJ. Mediation Analysis: A Practitioner's Guide. *Annu Rev Public Health*. 2016;37:17-32. doi:10.1146/annurev-publhealth-032315-021402

109. McMaughan DJ, Oloruntoba O, Smith ML. Socioeconomic Status and Access to Healthcare: Interrelated Drivers for Healthy Aging. *Front Public Health*. 2020;8:231. doi:10.3389/fpubh.2020.00231

110. NAJAFI F, MORADINAZAR M, HAMZEH B, REZAEIAN S. The reliability of self-reporting chronic diseases: how reliable is the result of population-based cohort studies. *J Prev Med Hyg*. 2019;60(4):E349-E353. doi:10.15167/2421-4248/jpmh2019.60.4.1118

111. Shrider EA, Kollar M, Chen F, Semega J. Income and Poverty in the United States: 2020. *Current Population Reports US Census Bureau*. Published online 2021.

112. Parolin Z, Collyer S, Curran MA, Wimer C. The Potential Poverty Reduction Effect of the American Rescue Plan. :3.

113. Wheaton L, Giannarelli L, Dehry I. Assessing the Impact of Benefits and Stimulus Measures. :46.

114. Bennett J. Fewer jobs have been lost in the EU than in the U.S. during the COVID-19 downturn. Pew Research Center. Accessed November 8, 2021. https://www.pewresearch.org/fact-tank/2021/04/15/fewer-jobs-have-been-lost-in-the-eu-than-in-the-u-s-during-the-covid-19-downturn/

115. Singh GK, Siahpush M. Increasing inequalities in all-cause and cardiovascular mortality among US adults aged 25–64 years by area socioeconomic status, 1969–1998. *International Journal of Epidemiology*. 2002;31(3):600-613. doi:10.1093/ije/31.3.600

116. Demakakos P, Biddulph JP, Bobak M, Marmot MG. Wealth and mortality at older ages: a prospective cohort study. *J Epidemiol Community Health*. 2016;70(4):346-353. doi:10.1136/jech-2015-206173

117. Bethea TN, Palmer JR, Rosenberg L, Cozier YC. Neighborhood Socioeconomic Status in Relation to All-cause, Cancer, and Cardiovascular Mortality in the Black Women's Health Study. *Ethn Dis*. 2016;26(2):157. doi:10.18865/ed.26.2.157

118. Elo IT, Martikainen P, Myrskylä M. Socioeconomic status across the life course and all-cause and cause-specific mortality in Finland. *Social Science & Medicine*. 2014;119:198-206. doi:10.1016/j.socscimed.2013.11.037

119. Ramsay SE, Morris RW, Whincup PH, et al. The influence of neighbourhood-level socioeconomic deprivation on cardiovascular disease mortality in older age: longitudinal multilevel analyses from a cohort of older British men. *J Epidemiol Community Health*. 2015;69(12):1224-1231. doi:10.1136/jech-2015-205542

120. Shavers VL. Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc*. 2007;99(9):1013-1023.

121. Kanjilal S. Socioeconomic Status and Trends in Disparities in 4 Major Risk Factors for Cardiovascular Disease Among US Adults, 1971-2002. *Arch Intern Med*. 2006;166(21):2348. doi:10.1001/archinte.166.21.2348

122. Stringhini S, Spadea T, Stroscia M, et al. Decreasing educational differences in mortality over 40 years: evidence from the Turin Longitudinal Study (Italy). *J Epidemiol Community Health*. 2015;69(12):1208-1216. doi:10.1136/jech-2015-205673

123. Kallan J. Effects of sociodemographic variables on adult mortality in the United States: Comparisons by sex, age, and cause of death. *Biodemography and Social Biology*. 1997;44(1-2):136-147. doi:10.1080/19485565.1997.9988940

124. Attanasio O, Pistaferri L. Consumption Inequality over the Last Half Century: Some Evidence Using the New PSID Consumption Measure. *American Economic Review*. 2014;104(5):122-126. doi:10.1257/aer.104.5.122

125. Fowler FJ. The redesign of the National Health Interview Survey. *Public Health Rep*. 1996;111(6):508-511.

126. NCHS Data Linkage - Mortality Data - Public-Use Files. Published September 1, 2021. Accessed November 11, 2021. https://www.cdc.gov/nchs/data-linkage/mortality-public.htm

127. Saydah S, Lochner K. Socioeconomic Status and Risk of Diabetes-Related Mortality in the U.S. *Public Health Rep*. 2010;125(3):377-388. doi:10.1177/003335491012500306

128. Lee H, Singh GK. Psychological distress, life expectancy, and all-cause mortality in the United States: results from the 1997–2014 NHIS-NDI record linkage study. *Annals of Epidemiology*. 2021;56:9-17. doi:10.1016/j.annepidem.2021.01.002

129. Connor EM, Zablotsky B. The association between air pollution and childhood asthma: United States, 2010-2015. *Journal of Asthma*. Published online September 29, 2021:1-16. doi:10.1080/02770903.2021.1988105

130. Schenker N, Raghunathan TE, Chiu PL, Makuc DM, Zhang G, Cohen AJ. Multiple Imputation of Missing Income Data in the National Health Interview Survey. *Journal of the American Statistical Association*. 2006;101(475):924-933.

131. Lynch J, Kaplan G. *Socioeconomic Position*. Vol 2000. Social epidemiology. New York: Oxford University Press; 2000.

132. Turrell G, Lynch JW, Leite C, Raghunathan T, Kaplan GA. Socioeconomic disadvantage in childhood and across the life course and all-cause mortality and physical function in adulthood: evidence from the Alameda County Study. *Journal of Epidemiology & Community Health*. 2007;61(8):723-730.

133. Crandall CJ, Merkin SS, Seeman TE, Greendale GA, Binkley N, Karlamangla AS. Socioeconomic status over the life-course and adult bone mineral density: The Midlife in the U.S. Study. *Bone*. 2012;51(1):107-113. doi:10.1016/j.bone.2012.04.009

134. Juster FT, Smith JP. Improving the Quality of Economic Data: Lessons from the HRS and AHEAD. *Journal of the American Statistical Association*. 1997;92(440):1268-1278. doi:10.2307/2965397

135. Moore JC, Stinson LL, Welniak E. Income reporting in surveys: Cognitive issues and measurement error. *Cognition and survey research*. Published online 1999:155-174.

136. Yan T, Curtin R, Jans M. Trends in Income Nonresponse Over Two Decades. *Journal of Official Statistics*.:20.

137. NHIS 2018 Family Frequency Report. https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2018/familyxx_freq.pdf

138. Liao Y, Cooper RS, Cao G, Kaufman JS, Long AE, McGee DL. Mortality From Coronary Heart Disease and Cardiovascular Disease Among Adult U.S. Hispanics: Findings From the National Health Interview Survey (1986 to 1994). *Journal of the American College of Cardiology*. 1997;30(5):1200-1205. doi:10.1016/S0735-1097(97)00278-7

139. Black LI, Ng AE, Zablotsky B. Stressful Life Events and Healthcare Utilization Among US Children Aged 2–17 Years. Published online 2023.

140. Ng AE, Adjaye-Gbewonyo D, Vahratian A. Health Conditions and Health Care Use Among American Indian and Alaska Native Adults by Tribal Land Residential Status: United States, 2019–2021. Published online 2023.

141. Black LI. Influenza Vaccination in the Past 12 Months Among Children Aged 6 Months–17 Years: United States, 2019. 2021;(407):8.

142. Weir CB, Jan A. *BMI Classification Percentile And Cut Off Points*. StatPearls Publishing, Treasure Island (FL); 2020. http://europepmc.org/abstract/MED/31082114

143. Lee H, Singh GK. Social Isolation and All-Cause and Heart Disease Mortality Among Working-Age Adults in the United States: The 1998–2014 NHIS–NDI Record Linkage Study. *Health Equity*. 2021;5(1):750-761. doi:10.1089/heq.2021.0003

144. Gottschalk P, Moffitt R. The Rising Instability of U.S. Earnings. *Journal of Economic Perspectives*. 2009;23(4):3-24. doi:10.1257/jep.23.4.3