SSM - Population Health 22 (2023) 101389

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Cumulative socioeconomic status and incident type 2 diabetes among African American adults from the Jackson heart study

LáShauntá M. Glover [a,*], Chantel L. Martin [a], Annie Green-Howard [b], Reuben Adatorwovor [c], Laura Loehr [d], Brooke Staley-Salil [a], Kari E. North [a], Mario Sims [e]

[a] Department of Population Health Sciences, Duke University School of Medicine, Durham, NC, USA
[b] Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
[c] Department of Biostatistics, College of Public Health, University of Kentucky, Lexington, KY, USA
[d] Division of General Medicine and Clinical Epidemiology, University of North Carolina School of Medicine, Chapel Hill, NC, USA
[e] Department of Social Medicine, Population, and Public Health, University of California, Riverside, Riverside, CA, USA

A B S T R A C T

Background: The cumulative socioeconomic status (SES) model posits that childhood and adult experiences accumulate to influence disease risk. While individual SES indicators such as education and income are independently associated with incident type 2 diabetes (T2D), the association of cumulative SES and incident T2D is unclear, especially in African American adults.

Methods: We utilized cohort data of African American participants (n = 3681, mean age 52.6 years) enrolled in the Jackson Heart Study from 2000 to 2013 free of T2D or cardiovascular disease at baseline (2000–2004). Cumulative SES scores at baseline were derived using six SES indicators (education, wealth, income, occupation, employment status, and mother's education) categorized as low, middle, and high. Incident T2D was defined at exam 2 (2005–2008) or exam 3 (2009–2013) based on fasting glucose ≥126 mg/dL, HbA1c ≥ 6.5, reported diabetic medication use, or self-reported physician diagnosis. Proportional hazards regression, allowing for interval censoring, was used to estimate the association between cumulative SES and incident T2D (hazard ratio(HR), 95% confidence interval (CI)) after adjustment for covariates. Sex and age differences were tested using interaction terms.

Results: There were 544 incident T2D cases. The association between low (versus high) cumulative SES and incident T2D was not significant (HR 1.04 [95% CI 0.85, 1.28]) and did not differ by sex (*p value for interaction*>0.05). However, there were differences by (age p value for interaction = 0.0052 for middle-aged adults and 0.0186 for older adults). Low (versus high) cumulative SES was associated a greater hazard of incident T2D among those 20–46 years (HR 1.12 [95% CI 1.03, 1.21]), 47–59 years (HR 1.25 [95% CI 1.06, 1.47]) and those 60–93 years (HR 1.39 [95% CI 1.09, 1.78]) after adjustment for sex and family history of diabetes. Associations attenuated after adding behavioral and lifestyle risk factors.

Conclusion: The association of low cumulative SES and incident T2D differed by age, which may suggest interventionist should consider impacts of SES on T2D by age.

1. Introduction

African American/Black adults have a greater burden of type 2 diabetes (T2D) in the United States (US) when compared with White adults (Virani et al., 2020). In 2020, the age-adjusted prevalence of T2D among Black adults was approximately 16.8%, while it was 10.0% for White adults (Control CfD and Prevention, 2020). Traditional risk factors such as physical inactivity, obesity, and unhealthy dietary intake are contributors to T2D (Kolb & Martin, 2017); however, upstream factors such as socioeconomic status (SES), which impacts downstream access to material resources and behavioral outcomes, may be a fundamental cause of T2D (Braveman & Gottlieb, 2014). SES is a dynamic social construct which influences the ability to create or consume goods in society, and is most commonly captured by education, income, and occupation. Historically, structural racism has contributed to higher concentrations of poverty in contemporary African American communities, which is a contributing factor of racial and social class disparities in cardiovascular morbidities such as T2D (Williams & Collins, 2016).

Social experiences, including experiences related to SES, throughout life contribute to adult health and disease risk (Krieger, 2005; Pollitt et al., 2005). Cumulative SES measures include multiple indicators at different time points, and thus, are more strongly associated with cardiovascular morbidities than utilizing adult SES or childhood SES alone (Pollitt et al., 2005). Because SES indicators are captured at more than

Abbreviations: SES, Socioeconomic Status; T2D, Type 2 Diabetes; CVD, Cardiovascular Disease; SD, Standard deviation; JHS, Jackson Heart Study; HR, Hazard Ratio; NHANES, National Health and Nutrition Examination Survey.

* Corresponding author.
E-mail address: lashaunta.glover@duke.edu (L.M. Glover).

https://doi.org/10.1016/j.ssmph.2023.101389
Received 18 October 2022; Received in revised form 25 February 2023; Accepted 27 March 2023
Available online 28 March 2023

one point in time, the combined effects of these indicators represents the accumulated 'health capital' (Guimarães, 2007). Previous studies have found inverse associations between individual SES indicators such as education and income and a greater risk of T2D (Beckles et al., 2019; Krishnan et al., 2010; Robbins et al., 2005). However, the socioeconomic experience of an individual is multi-dimensional, and the inclusion of multiple SES indicators is important for capturing the accumulation of SES. One cross-sectional study examined the cumulative effect of four indicators (education, income, minority race/ethnic group, and single living status) on prevalent T2D using data from NHANES (1999–2006) (Echouffo-Tcheugui et al., 2016). The results suggested that exposure to more than one social risk indicator (versus exposure to none) was associated with a greater odds of T2D. The authors were unable to perform incident analyses; therefore, our understanding of the effects of cumulative disadvantage on incident T2D is limited.

This study examined the association of cumulative SES, defined using six SES indicators (education, income, occupation, wealth, employment status, and mother's education) with incident T2D among African American adults from the Jackson Heart Study (JHS). We also examined whether sex and age differences exist in the association due to reported differences in SES and T2D by age and sex (Assari et al., 2017; Forouhi & Wareham, 2019; Huebschmann et al., 2019; Robert et al., 2009). Our guiding hypothesis was that there would be an inverse association between cumulative SES and incidence of T2D, and there would be differences by age and sex.

2. Methods

The JHS is a prospective cohort study of the burden and incidence of CVD among self-identified African American adults (3371 women, 1935 men; age 20–95 years old) (Fuqua et al., 2005). Non-institutionalized adults residing in the tri-county area (Hinds, Madison, and Rankin) of the Jackson, Mississippi Metropolitan Statistical Area were eligible for recruitment. Four recruitment methods were conducted during the baseline examination from 2000 to 2004. Participants were sampled from 1) a subset of participants from the Atherosclerosis Risk in Communities (ARIC) study, 2) random selection from the Mississippi Department of Transportation Driver's License and Identification List, 3) volunteers that signed up for the study, and 4) family members of participants who agreed to be a part of the study. The final percentages from the sampling frame included: 30% ARIC study, 17% random, 22% volunteer, and 31% secondary family members of those who agreed to be participants (n = 5306). Participants completed in-home interviews, self-administered questionnaires, and in-clinic examinations to obtain demographic, socioeconomic, psychosocial, behavioral, anthropometric, health history, and clinical data. The JHS includes 2 additional exams: exam 2 (2005–2008) and exam 3 (2009–2013) (Fuqua et al., 2005). The study was approved by the institutional review boards of the University of Mississippi Medical Center, Jackson State University, and Tougaloo College. All participants provided written informed consent.

2.1. Exposure

Cumulative SES was conceptualized as the combined effects of education, wealth, income, occupation, employment status, and mother's education from the baseline examination. All of the measures were categorical measures collected from questionnaires in the JHS. Education was defined as the highest degree or years of school completed. Thus, investigators were able to derive education as: <Less than High School diploma, High School Diploma, Some College/Technical/Vocational school, College degree or more. Wealth was defined by assets a participant had attained, measured by home ownership (yes or no), car ownership (yes or no), or monetary assets that could be utilized in cases of emergency. The options for monetary assets ranged from $0 to $200,000 or more, and the midpoint of each category bracket was summed to create a total score. The score was then dichotomized at the median to create a measure of monetary assets (<35K or ≥35K). Income was defined as the reported total combined family income, their family size, and poverty threshold from the year of examination. The JHS derived income categories (poor, lower-middle, upper-middle, and affluent). Occupation was defined as the participant's main job or most recent occupation. Categories were derived from Occupational Handbook and included managerial, sales, technical, farming, construction, and production positions. Employment status represented their current working situation (e.g. full-time/part-time/unemployed/retired-not working). Mother's education was defined as the mother or most important female caretaker's educational attainment when the participant was at least 16 years of age, with the same categories as the participant's education. All indicators were updated to have 3-levels. Table 1 shows the SES indicators, the description of each indicator, and values (0, 0.5, or 1) assigned to each indicator's 3-level categories.

The cumulative SES score was developed similarly to previous research (James et al., 2006). A score of 0 was assigned for the lowest relative SES level, thus < High School, poor income, homemaker

Table 1
Socioeconomic Status indicators used to create the cumulative socioeconomic status score in Jackson Heart Study participants at exam 1 (2000–2004), n = 5306.

SES indicators	Description	SES categories and values assigned	N (%)
Education	Highest degree or years of school completed	<HS = 0	1099 (20.7)
		HS-Some College = 0.5	2118 (39.9)
		College degree or more = 1	2076 (39.1)
Income	Total combined family income using census size destinations for family size and specific calendar year poverty level	Poor = 0	919 (17.4)
		Lower and Upper-middle = 0.5	2797 (52.9)
		Affluent = 1	1570 (29.7)
Occupation	Main job or most recent occupation using the Standard Occupational Classification Manual	Construction/ Production/Farming = 0	1120 (21.1)
		Service/Sales = 0.5	2254 (42.5)
		Managerial/ Professional = 1	1878 (35.4)
Employment	Current working situation	Unemployed/ Homemaker = 0	303 (5.7)
		Retired not working/ temporary lay off/on leave = 0.5	1674 (31.6)
		Employed = 1	3299 (62.2)
Wealth	Assets attained: car ownership, home ownership, and liquid assets valued <35K or ≥35K	Have 0 out of 3 = 0	378 (7.15)
		Have 1 out of 3 = 0.5	1613 (30.5)
		Have 2 or 3 = 1	3297 (62.4)
Mother's Education	Female caretaker educational attainment when the participant was at least 16 years	<HS = 0	2238 (42.2)
		HS-Some College = 0.5	1633 (30.8)
		College grad or more = 1	1435 (27.0)

*Values were imputed for this variable.
Notes: Abbreviations: SES - socioeconomic status; HS - high school.

occupations, unemployment, low wealth (e.g., no or only 1 asset), or < High School mother's education were assigned a 0. A score of 0.5 was assigned for the middle relative SES level, thus those who completed high school and/or some college/technical school, had "lower-middle" or "upper-middle" income, were most recently in service/sales occupations, retired and not working/temporarily laid off/on leave, had mid-level wealth (e.g., having at least 2 assets), or reported mother's education as "high school diploma to some college" were assigned a 0.5. A score of 1 was assigned to the highest relative SES level, thus those who were college graduates, had "affluent" income, had recently worked in managerial/professional occupations, were employed, had high wealth (e.g., all 3 assets), or had mothers who had college degrees received a score of 1.

A sum of their observed scores across the 6 indicators represented the cumulative SES score (range: 0–6), and a tertile distribution of the score created low, middle, and high (referent) cumulative SES. The cumulative SES score was also standardized using standard deviation (sd) units.

2.2. Outcome

At each exam, T2D was defined as having at least one of the following: a fasting glucose ≥126 mg/dL, or HbA1c ≥ 6.5, or diabetic medication use within 2 weeks prior to the examination center visit, or a self-reported physician diagnosis. To identify those with incident T2D, participants who had diabetes at baseline/first examination were excluded. Participants who had cardiovascular disease (CVD) at baseline, defined as self-reported physician diagnosis and/or confirmed heart disease from an electrocardiogram, were also excluded. Thereafter, participants who had T2D at exams 2 and/or 3 were considered incident T2D cases. The probability of misclassifying an incident T2D case as a type 1 diabetes (T1D) case was low because T1D has an earlier onset and longer duration than T2D cases, and T2D represents over 90% of all diabetes cases in the US. (Imayama et al., 2011; Lyssenko & Laakso, 2013)

2.3. Covariates

Demographic covariates included age (years) and sex (male/female). For testing age differences, we created age group categories using a tertile distribution (20–46 years, 47–59 years, and 60–93 years), due to the unique distribution of age. Specifically, the tertile distribution was used to make comparisons by age, considering sample size (e.g., there were only 140 participants who were at least 30 years of age, and 49 participants who were at least 80 years of age, therefore these participants were placed in the lowest and highest age category, respectively). Participants were asked about their family history of diabetes with the following questions: "Did your mother have diabetes?" and "Did your father have diabetes?" If participants indicated one or both parents had diabetes, they were coded as having a family history of diabetes. Behavioral variables such as physical activity, smoking, alcohol intake, and percent daily dietary fat in addition to risk factors such as adiposity were considered potential mediators according to previous research (Lee et al., 2011; Pampel et al., 2010; Robbins et al., 2005) but were also deemed important covariates for the current analyses due to their representation of baseline health status. The American Heart Association's Life's Simple 7 was used to define physical activity and smoking, where ideal physical activity (yes vs. no) was defined by having at least 150 min of self-reported moderate physical activity or 75 min of vigorous physical activity per week, and ideal smoking (yes vs. no) was classified as never smoking or had quit smoking at least 12 months ago. Participants were asked whether they had consumed alcohol in the last 12 months to measure alcohol intake. Waist circumference (cm) was used to capture adiposity. Percent of dietary fat per day was measured from a dietary survey at baseline, and greater values were used as proxies for high-fat diets. While many of the covariates were measured at multiple exams, we included data from the baseline/first exam visit, which aligns with the cumulative SES exposure measure.

2.4. Statistical analysis

At baseline (n = 5306), there were greater than 10% missing observations for income (n = 818), wealth (n = 863), and mother's education (n = 1435). Due to the possibility of inducing bias by only including those with complete SES indicators, values were imputed under the assumption that these variables were missing at random. Missing observations for income, wealth, and mother's education were imputed by inserting predicted values based on sex, age, education, and occupation (for income and wealth) characteristics from those with complete data (Van Buuren et al., 2006). Thus, for each missing observation, we examined the age, sex, education, and occupation and recoded their missing value to match participants who had the same age, sex, education and occupation. After conducting this approach, we also used multivariate imputation by chained equations with 5 data sets to verify if the distributions were similar (see Supplemental Table C). After removing participants who had prevalent T2D and CVD at baseline, the sample size in JHS was 3681.

Proportional hazards regression, that allowed for interval censoring, was used to estimate the association between cumulative SES scores (total, categorical, and standardized) and incident T2D with hazard ratios (HR, 95% confidence intervals (CI)). Because there was no date of incident T2D diagnosis, this type of regression was used to approximate time to event based on years between baseline and visit 2 and years between visit 2 and visit 3. We tested the proportional hazards assumptions using Kaplan-Meier curves. Confidence intervals excluding 1 and p-values based on two-tailed tests ($p < 0.05$) were considered statistically significant. The fully-adjusted model included age, sex, and family history of diabetes. We added health behaviors and risk factors (Model 2) to determine how much these factors accounted for the association between SES and incident T2D. Interaction terms were used to evaluate whether there were age and sex differences in the association of low vs. high and middle vs. high cumulative SES and incident T2D in Models 1 and 2. If interaction terms were statistically significant, we stratified the analyses. All analyses were conducted in SAS version 9.4 (SAS Institute, Cary, NC) and STATA 16 (College Station, TX).

3. Results

The mean age was 52.6 years (sd = 12.9). Most participants were female (63.3%) and had ideal smoking habits (85.6%). Twenty-one percent (21.4%) had ideal physical activity, and 49.9% reported they did not drink alcohol in the last 12 months. The average waist circumference was 98.4 cm (sd = 15.8) and the average daily dietary fat was 35%. Around 3% (3.4%) of participants had a family history of diabetes. The mean cumulative SES score was 3.75 (sd = 1.24) (Table 2). Supplemental Table A shows a comparison of these characteristics among those with and without T2D and/CVD at baseline.

There were 544 incident T2D cases (data not shown). Supplemental Table B shows the number of T2D cases by each SES indicator and the association of individual SES indicators with incident T2D after baseline exclusions. A greater hazard for incident T2D was found for lower education (<HS: HR 1.30, 95% CI 1.02, 1.65), employment status (Retired/temporary laid off: HR 1.39, 95% CI (1.15, 1.69)), and low mother's education (<HS: HR 1.57 95% CI 1.17, 2.11). Associations attenuated after adjustment for age, sex, and family history of diabetes, except for the association between HS-Some College (vs. College Degree or more) and incident T2D (HR 1.22, 95% CI (1.01, 1.46). The tertile distribution of the cumulative SES score was not significiantly associated with incident T2D (Supplemental Table B). Table 3 shows the association of cumulative SES and incident T2D after adjusting for age, sex, and family history of T2D in model 1 and in model 2. There were no detected violations of the proportional hazards assumptions for all variables in the models. There were no statistically significant associations between

Table 2
Baseline characteristics for participants without type 2 diabetes and cardiovascular disease, Jackson Heart Study (2000–2004).

Characteristics	Sample without Diabetes or CVD (n = 3861)
Demographics	
Age, years (Mean, SD)	52.6 ± 12.9
Sex (%)	
Female	63.3
Male	36.7
Health Behaviors (%)	
Ideal Smoking	
Yes	85.6
No	14.4
Ideal Physical Activity	
Yes	21.4
No	78.6
Alcohol	
Yes	50.1
No	49.9
Risk Factors	
Waist circumference (cm) (Mean, SD)	98.4 ± 15.8
Dietary fat (%)	35 ± 6.8
Family history of diabetes (%)	
Yes	3.4
No	76.6
Don't Know	20.0
Socioeconomic status (SES) (%)	
Low (mean score: 2.45)	36.3
Middle (mean score: 3.91)	32.1
High (mean score: 5.06)	31.6
Cumulative SES (Mean, SD)	3.75 ± 1.24

Note: Ideal smoking was defined as never smoking or had quit smoking at least 12 months ago prior to the baseline exam. Ideal physical activity was defined by having at least 150 min of self-reported moderate or 75 min of vigorous physical activity per week. Alcohol consumption was based on self reported drinking at least 12 months prior to the baseline exam. Family history of diabetes was defined by having at least one parent with diagnosed diabetes.

Table 3
Association of cumulative socioeconomic status and incident T2D (HR 95% CI), Jackson Heart Study (n = 3681, 2005–2013).

Cumulative SES	Model 1	Model 2
Low SES vs. High SES	1.04 (0.85, 1.28)	0.97 (0.78, 1.21)
Middle SES vs. High SES	1.00 (0.81,1.24)	1.00 (0.80, 1.25)
Total Score	0.97 (0.91, 1.04)	1.00 (0.93, 1.07)
Standardized Score	0.96 (0.88, 1.05)	1.00 (0.91, 1.09)

Note: Abbreviations: SES - socioeconomic status; T2D - Type 2 Diabetes; Model 1 adjusted for age, sex, and family history of diabetes. Model 2 added smoking, physical activity, alcohol, dietary fat (%), and waist circumference (cm).

the total score, low or middle (vs. high) cumulative SES scores and incident T2D, nor the standardized score, and incident T2D in model 1. The addition of covariates in model 2 did not change the statistical significance but did change the direction of the effect estimates for low vs. high cumulative SES, the total score, and the standardized score.

The interaction terms between low (vs. high) and middle (vs. high) cumulative SES and sex were not statistically associated with incident T2D (data not shown). However, the interaction terms for cumulative SES and age groups were statistically significant (p-value for interaction for middle-aged adults = 0.0052 and older adults = 0.0186) (data not shown) after adjustment of covariates in models 1 and 2. Models stratified by age showed a significant association between cumulative SES and incident T2D in models 1. As shown in Table 4, participants with low (vs. high) cumulative SES had a greater hazard of incident T2D when adjusting for sex and family history of diabetes in all age groups. The effect estimate was highest among participants 60–93 years with low (vs. high) cumulative SES (HR 1.39, 95% CI 1.09, 1.78). However, this association attenuated in model 2. Among all adults with low cumulative SES (n = 1336), those 47–59 years had a greater cumulative incidence of T2D than those 20–46 years and 60–93 years of age (Gray's test p-value = 0.0012; Supplemental Fig. 1).

Table 4
Association of cumulative SES and incident T2D by age group (HR 95% CI), Jackson Heart Study (n = 3861, 2005–2013).

Number of T2D cases	Model 1		Model 2	
	Low vs. High Cumulative SES	Middle vs. High Cumulative SES	Low vs. High Cumulative SES	Middle vs. High Cumulative SES
Age 20–46 years				
136	**1.12 (1.03, 1.21)**	1.09 (0.99, 1.19)	1.06 (0.97, 1.16)	1.07 (0.97, 1.18)
Age 47–59 years				
226	**1.25 (1.06, 1.47)**	1.18 (0.98, 1.42)	1.12 (0.94, 1.34)	1.14 (0.94, 1.39)
Age 60–93 years				
182	**1.39 (1.09, 1.78)**	1.28 (0.97, 1.69)	1.19 (0.91, 1.55)	1.22 (0.91, 1.64)

Note: Abbreviations: SES - socioeconomic status; T2D - Type 2 Diabetes. Model 1 adjusted for sex and family history. Model 2 added physical activity, smoking, waist circumference (cm), alcohol intake, and dietary fat (%).

4. Discussion

This study tested the association of cumulative SES and incident T2D in an African American longitudinal cohort. In this study, we found partial support for our hypotheses. Though cumulative SES was not associated with T2D risk nor were there significant differences by sex, there were some detectable differences by age. Low cumulative SES increased the risk of incident T2D in each age group, but adjusting for behavioral and lifestyle factors attenuated the association. The results highlight risk differences in T2D by age and cumulative SES levels and are partially consistent with previous reports of studies examining the associations between SES and risk of T2D.

SES factors in childhood and adulthood indeed act together to influence the development of chronic illness later in life, which supports the cumulative SES model (Pollitt et al., 2005). Previous studies have found significant associations between cumulative SES (as defined by both childhood and adulthood SES indicators) and markers of inflammation (Pollitt et al., 2008), allostatic load (Merkin et al., 2014), metabolic syndrome (Chichlowska et al., 2009), and subclinical atherosclerosis (Carson et al., 2007). In a study of 10,308 participants from the Whitehall II study (British Civil Servants 20–64 years), a cumulative score of father's occupation, participant education, and participant occupation was utilized to determine the association of SES with incident T2D (Stringhini et al., 2013). Their results showed an inverse association between cumulative SES and incident T2D. Additionally, smoking, low physical activity, BMI, CRP, and IL-6 mediated the association of low cumulative SES and incident T2D. Our study adds the association of cumulative SES and incident T2D among African American adults, but there were no associations except when stratifying by age. Age is also a strong risk factor for the development of T2D, and we are currently unaware of previous studies reporting an age interaction in the association of cumulative SES and diabetes risk. Differences by sex were expected, however, our results suggested no difference between men and women.

The cumulative SES score in this study includes SES indicators from both adulthood and childhood. Previous studies suggest an inverse association between SES indicators and incident T2D (Beckles et al., 2019; Krishnan et al., 2010; Robbins et al., 2005), however, this analyses showed unique patterns of SES and incident T2D, with greater T2D cases common among higher SES participants (see Supplemental Table B). As mentioned in other studies of JHS participants that have examined SES as an exposure (Glover et al., 2020; Beckles et al., 2019), most participants were also upwardly mobile (e.g., reported higher educational

attainment than their parents), which may have influenced T2D risk. A study by Assari et al. (Assari et al., 2020) has shown diminished returns in CVD outcomes for higher status Black persons compared to higher status White counterparts. The findings were attributed to possible poor health behaviors, greater stress, and navigating structural racism, including having a lower quality of education in Black communities. Low cumulative SES was associated with a greater cumulative incidence of T2D, especially among participants 47–59 years of age (Supplemental Figs. 1–3). It is possible that participants in this age group may experience more burden from socioeconomic stressors than participants in the other age groups, and this increased their risk of T2D.

Participants of the JHS are not representative of all African American adults. Other limitations should also be considered when interpreting these results, including the use of a cumulative SES score, which assumes that all SES indicators have equivalent social and economic impacts. Additionally, the cumulative SES score was limited to one early life SES factor (e.g., mother's education). Missing data for SES were imputed, and true values were unknown, but under the assumption of "missing at random," simulation studies have verified that imputing is a practical approach that can yield unbiased estimates (Little et al., 2014). However, missing data for diabetes, including those who were lost to follow-up or were excluded, could have biased the results. Additionally, some of the women participants could have had gestational diabetes during their childbearing years, which increases the risk of incident T2D later in life, but we could not account for this. With these limitations, there are notable strengths. This study captured more than one component of SES in the cumulative SES score and included measures rarely used in epidemiologic studies such as wealth, employment status, and parental education. This study also utilized data from a large, longitudinal study of underrepresented adults in research and demonstrated unique findings in the association of cumulative SES and incident T2D.

Age modified the association between low cumulative SES and incident T2D among African American adults enrolled in the JHS. Additional investigation is needed to verify whether these results occur in other cohorts, and determine biological or psychosocial mechanistic pathways involved in this association. Interventionists may want to consider childhood and adulthood SES, the cumulative effect of SES over the life course, and age when identifying vulnerable sub-populations at risk of T2D.

JHS disclaimer

The views expressed in this manuscript are those of the authors and do not necessarily represent the views of the National Heart, Lung, and Blood Institute; the National Institutes of Health; or the U.S. Department of Health and Human Services.

Ethical statement

No Declarations of Interest to disclose.

We certify the submitted manuscript is original research and the work performed to develop the manuscript product is accurate and objective.

The research data was obtained from the Jackson Heart Study and all authors are under a Data Use agreement which prevents sharing the data. Those who are interested in obtaining the data should contact the Jackson Heart Study (jhspub@umc.edu).

All references to other works have been appropriately cited.

All authors made significant contributions to the development of the manuscript.

There are no competing interest to disclose.

Should the authors discover significant errors during or after the publication process, we will notify the journal editor/publisher.

Author statement

Glover L: Conceptualization, methodology, formal analysis, writing-original draft preparation. **Martin C**: Conceptualization, methodology, writing-review & editing. **Green-Howard A**: formal analysis, data curation, supervision. **Adatorwovor R**: formal analysis, data curation, supervision. **Loehr L**: conceptualization, methodology, writing-review & editing. **Staley B**: writing-review & editing. **North K:** Conceptualization, methodology, writing-review & editing, supervision. **Sims M:** Conceptualization, methodology, writing-review & editing, supervision.

Declaration of competing interest

No conflicts of interest to disclose.

Data availability

The authors do not have permission to share data.

Acknowledgements

The Jackson Heart Study (JHS) is supported and conducted in collaboration with Jackson State University (HHSN268201800013I), Tougaloo College (HHSN268201800014I), the Mississippi State Department of Health (HHSN268201800015I) and the University of Mississippi Medical Center (HHSN268201800010I, HHSN268201800011I and HHSN268201800012I) contracts from the National Heart, Lung, and Blood Institute (NHLBI) and the National Institute for Minority Health and Health Disparities (NIMHD). The authors also wish to thank the staffs and participants of the JHS. Ms. Staley is supported by the Genetic Epidemiology of Heart, Lung, and Blood Traits Training Grant (GENHLB) T32HL129982. Dr. Sims was also supported by the NHLBI JHS contracts (HHSN268201800010I, HHSN268201800011I). Dr. Glover was supported by the NHLBI under award F31HL159910.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101389.

References

Assari, S., Cobb, S., Saqib, M., & Bazargan, M. (2020). Diminished returns of educational attainment on heart disease among Black Americans. *The Open Cardiovascular Medicine Journal, 14*, 5.

Assari, S., Moghani Lankarani, M., Piette, J. D., & Aikens, J. E. (2017). Socioeconomic status and glycemic control in type 2 diabetes; race by gender differences. *InHealthcare, 5*(4), 83 (MDPI).

Beckles, G. L., McKeever Bullard, K., Saydah, S., Imperatore, G., Loustalot, F., & Correa, A. (2019). Life course socioeconomic position, allostatic load, and incidence of type 2 diabetes among african American adults: The Jackson heart study, 2000-04 to 2012. *Ethnicity & Disease, 29*, 39–46.

Braveman, P., & Gottlieb, L. (2014). The social determinants of health: it's time to consider the causes of the causes. *Public Health Reports, 129*(Suppl 2), 19–31.

Carson, A. P., Rose, K. M., Catellier, D. J., Kaufman, J. S., Wyatt, S. B., Diez–Roux, A. V., & Heiss, G. (2007). Cumulative socioeconomic status across the life course and subclinical atherosclerosis. *Annals of Epidemiology, 17*, 296–303.

Chichlowska, K. L., Rose, K. M., Diez-Roux, A. V., Golden, S. H., McNeill, A. M., & Heiss, G. (2009). Life course socioeconomic conditions and metabolic syndrome in adults: The atherosclerosis risk in communities (ARIC) study. *Annals of Epidemiology, 19*, 875–883.

Control CfD and Prevention. (2020). *National diabetes statistics report*. Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services, 2020.

Echouffo-Tcheugui, J. B., Caleyachetty, R., Muennig, P. A., Narayan, K. M., & Golden, S. H. (2016). Cumulative social risk and type 2 diabetes in US adults: The national health and nutrition examination survey (NHANES) 1999-2006. *Eur J Prev Cardiol, 23*, 1282–1288.

Forouhi, N. G., & Wareham, N. J. (2019). Epidemiology of diabetes. *Medicine, 47*(1), 22–27.

Fuqua, S. R., Wyatt, S. B., Andrew, M. E., Sarpong, D. F., Henderson, F. R., Cunningham, M. F., & Taylor, H. A., Jr. (2005). Recruiting african-American

research participation in the Jackson heart study: Methods, response rates, and sample description. *Ethnicity & Disease, 15*(S6), 18–29.
Glover, L. M., Cain-Shields, L. R., Wyatt, S. B., Gebreab, S. Y., Diez-Roux, A. V., & Sims, M. (2020). Life course socioeconomic status and hypertension in african American adults: The Jackson heart study. *American Journal of Hypertension, 33*, 84–91.
Guimarães, R. M. (2007). Health capital, life course and ageing. *Gerontology, 53*, 96–101.
Huebschmann, A. G., Huxley, R. R., Kohrt, W. M., Zeitler, P., Regensteiner, J. G., & Reusch, J. E. (2019). Sex differences in the burden of type 2 diabetes and cardiovascular risk across the life course. *Diabetologia, 62*(10), 1761–1772.
Imayama, I., Plotnikoff, R. C., Courneya, K. S., & Johnson, J. A. (2011). Determinants of quality of life in adults with type 1 and type 2 diabetes. *Health and Quality of Life Outcomes, 9*, 1–9.
James, S. A., Fowler-Brown, A., Raghunathan, T. E., & Van Hoewyk, J. (2006). Life-course socioeconomic position and obesity in african American women: The pitt county study. *American Journal of Public Health, 96*, 554–560.
Kolb, H., & Martin, S. (2017). Environmental/lifestyle factors in the pathogenesis and prevention of type 2 diabetes. *BMC Medicine, 15*.
Krieger, N. (2005). Embodiment: A conceptual glossary for epidemiology. *Journal of Epidemiology & Community Health, 59*, 350–355.
Krishnan, S., Cozier, Y. C., Rosenberg, L., & Palmer, J. R. (2010). Socioeconomic status and incidence of type 2 diabetes: Results from the Black women's health study. *American Journal of Epidemiology, 171*, 564–570.
Lee, T. C., Glynn, R. J., Peña, J. M., Paynter, N. P., Conen, D., Ridker, P. M., Pradhan, A. D., Buring, J. E., & Albert, M. A. (2011). Socioeconomic status and incident type 2 diabetes mellitus: Data from the women's health study. *PLoS One, 6*, Article e27670.
Little, T. D., Jorgensen, T. D., Lang, K. M., & Moore, E. W. G. (2014). On the joys of missing data. *Journal of Pediatric Psychology, 39*, 151–162.
Lyssenko, V., & Laakso, M. (2013). Genetic screening for the risk of type 2 diabetes: Worthless or valuable? *Diabetes Care, 36*, S120–S126.
Merkin, S. S., Karlamangla, A., Diez Roux, A. V., Shrager, S., & Seeman, T. E. (2014). Life course socioeconomic status and longitudinal accumulation of allostatic load in adulthood: Multi-ethnic study of atherosclerosis. *American Journal of Public Health, 104*, e48–e55.
Pampel, F. C., Krueger, P. M., & Denney, J. T. (2010). Socioeconomic disparities in health behaviors. *Annual Review of Sociology, 36*, 349–370.
Pollitt, R. A., Kaufman, J., Rose, K. M., Diez-Roux, A. V., Zeng, D., & Heiss, G. (2008). Cumulative life course and adult socioeconomic status and markers of inflammation in adulthood. *Journal of Epidemiology & Community Health, 62*, 484–491.
Pollitt, R. A., Rose, K. M., & Kaufman, J. S. (2005). Evaluating the evidence for models of life course socioeconomic factors and cardiovascular outcomes: A systematic review. *BMC Public Health, 5*, 1–13.
Robbins, J. M., Vaccarino, V., Zhang, H., & Kasl, S. V. (2005). Socioeconomic status and diagnosed diabetes incidence. *Diabetes Research and Clinical Practice, 68*, 230–236.
Robert, S. A., Cherepanov, D., Palta, M., Dunham, N. C., Feeny, D., & Fryback, D. G. (2009). Socioeconomic status and age variations in health-related quality of life: Results from the national health measurement study. *The Journals of Gerontology: Serie Bibliographique, 64*(3), 378–389.
Stringhini, S., Batty, G. D., Bovet, P., Shipley, M. J., Marmot, M. G., Kumari, M., Tabak, A. G., & Kivimäki, M. (2013). Association of lifecourse socioeconomic status with chronic inflammation and type 2 diabetes risk: The Whitehall II prospective cohort study. *PLoS Medicine, 10*, Article e1001479.
Van Buuren, S., Brand, J. P., Groothuis-Oudshoorn, C. G., & Rubin, D. B. (2006). Fully conditional specification in multivariate imputation. *Journal of Statistical Computation and Simulation, 76*, 1049–1064.
Virani, S. S., Alonso, A., Benjamin, E. J., Bittencourt, M. S., Callaway, C. W., Carson, A. P., Chamberlain, A. M., Chang, A. R., Cheng, S., Delling, F. N., Djousse, L., Elkind, M. S. V., Ferguson, J. F., Fornage, M., Khan, S. S., Kissela, B. M., Knutson, K. L., Kwan, T. W., Lackland, D. T., … Tsao, C. W. (2020). Heart disease and stroke statistics-2020 update: A report from the American heart association. *Circulation, 141*, e139–e596.
Williams, D. R., & Collins, C. (2016). Racial residential segregation: A fundamental cause of racial disparities in health. *Public Health Reports, 116*(5), 404–416.