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Childhood SES gradients in adult functional limitations: Does state-level macro-economic context matter?☆

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ABSTRACT

Numerous studies document associations between childhood socioeconomic status (SES) and adult health, but less is understood about how macroeconomic context shapes these links. The current study examined whether income and income inequality measured at the state level moderated the association between parent education and functional limitations in a national sample of adults. Time-series economic data, derived from tax records (1917–2014), were merged with Midlife in the United States Study (MIDUS) data ($N = 10{,}685$; Mean age = 47.7, $SD = 13.6$; 51 % female) by state/year to assess economic conditions during four life stages: childhood (0–15), emerging adulthood (20–25), early adulthood (ages 30–35), and midlife (ages 40–45). Results showed that higher state mean income (at all four ages of exposure) was associated with fewer adult functional limitations. Childhood exposure to higher state-level income inequality (but not later periods) predicted more adult functional limitations. Childhood SES–adult health associations weakened with higher state income during childhood ($B = 0.023$, $p = .018$) and emerging adulthood ($B = 0.036$, $p = .026$), but not in later stages. Income inequality did not moderate SES–health links. Findings suggest that the impact of childhood SES on adult health varies by state economic context, particularly mean income, with effects dependent on exposure timing. Notably, childhood income inequality also independently predicted worse health outcomes, irrespective of state income. Future directions and policy implications are discussed.

1. Introduction

Extensive prior research has documented links between childhood socioeconomic status (SES) and adult health. Children growing up in families with lower levels of education, income, or occupation status have shorter life expectancies, experience more disability, and have higher rates of disease across the life span than those growing up in more affluent families (Clarke et al., 2022; Guralnik et al., 2006; Kivimäki et al., 2020; Sommer et al., 2015). The link between childhood SES and health has been documented using data collected at various levels of geography, including within countries, states, or local areas (Case et al., 2002; Chen and Miller, 2013).

In addition to these within-place SES gradients, between-place differences in health are also evident such that those living in more affluent places (irrespective of the family SES) tend to have longer life expectancies, higher self-rated health, and lower rates of disability (Deaton, 2013; Dwyer-Lindgren et al., 2017; Mackenbach, 2019; Subramanian et al., 2002). In the United States, higher state-level mean income and state GDP per capita have been associated with lower mortality rates (Couillard et al., 2021), fewer functional limitations (Montez et al., 2017), and higher self-rated health (Subramanian et al., 2001). Importantly, the magnitude of associations between state-level average

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income and state-level mortality has also increased in recent decades, suggesting the growing importance of state context (Couillard et al., 2021; Vierboom et al., 2019).

However, relatively little attention has been given to whether individual-level SES gradients in health are modified by between-place difference in affluence, particularly with respect to associations between childhood SES and adult health. Place-related contextual factors might amplify or attenuate health inequalities, but results remain inconsistent. On the one hand, studies have indicated that the health of low SES groups may be most impacted by contextual variation. For example, in more affluent places within the US, adults with lower income have been found to have better health outcomes, compared to those with similar incomes in less affluent places, leading to a flatter SES-health gradient (Chetty et al., 2016). Similar results have been reported at the state and country levels, such that areas with higher average income have been reported to have flatter SES-health gradients (Linden and Ray, 2017; Rosengren et al., 2019). Other cross-national evidence also underscores that beyond mean income, institutional architectures (e.g., welfare and health-care systems) can condition these gradients (Andersson et al., 2023; Sieber et al., 2020).

However, other studies have found that area level affluence has no impact on the magnitude of the SES-health gradient (Präg et al., 2016; Semyonov et al., 2013) or is associated with larger SES inequalities (Mackenbach et al., 2018). One key consideration that may help to resolve these inconsistencies is that most studies examining adult SES-health gradients across different socioeconomic contexts have not adjusted for area-level income inequality when considering the role of area level average income. Higher income inequality has been associated with poorer health outcomes in US states, particularly for less advantaged socioeconomic groups (Kahn et al., 2000; Kennedy et al., 1998; Lochner et al., 2001) and thus is an important consideration when addressing the role of area level affluence. Notably, all studies cited here focus on adult SES gradients. Childhood SES offers a near-exogenous starting point, largely set by parents and policy, that limits the confounding and reverse causation that complicate studies of adult SES. Additionally, prior research points to long lag times between economic conditions and health outcomes, suggesting that early-life exposures may be especially consequential. Yet little is known about whether the strength of the childhood-SES gradient in adult health varies across macro-economic contexts. Early clues come from international comparisons show large cross-country differences in childhood-SES effects (Clarke et al., 2022; Mazzonna, 2014) and a recent U.S. study links higher state cost of living to steeper childhood-SES gradients in adolescent hippocampal volume (Weissman et al., 2023). However, systematic tests of state-level affluence as a moderator are virtually absent.

Life-course theory distinguishes sensitive-period mechanisms from cumulative-disadvantage processes. Sensitive-period models posit that exposures in childhood—when biological, cognitive, and social systems are highly malleable—can establish long-lasting "set points" for health (Hertzman and Boyce, 2010; Shonkoff and Garner, 2012). For example, living in an affluent state typically affords better-funded public schools, safer neighborhoods, and higher-quality parks and recreation facilities. These resources encourage physical activity, healthy peer networks, and stress-buffering contact with nature in childhood; the skills, habits, and physiological advantages gained during this window tend to track into adulthood, partly explaining why early disadvantage remains evident decades later (DeWeese et al., 2022; Fuller-Rowell and Leonard, 2024; Jones et al., 2019). In contrast, cumulative-disadvantage theory argues that initial shortfalls in resources do not merely persist—they compound. Early under-investment in schooling, for instance, dampens academic achievement, narrows college access, and sets in motion lower-wage employment trajectories; each subsequent transition can widen the health gap through repeated exposure to economic strain, hazardous work, and limited health resources (Dannefer, 2003, 2020; Ferraro and Shippee, 2009). Whether affluence in one's childhood state can interrupt these pathways remains largely untested.

Another strand of theory further emphasizes labor-market mechanisms. Although children are not themselves in the labor force, childhood SES powerfully sorts individuals into later labor-market positions by shaping educational attainment, cognitive and non-cognitive skills, and social capital into adulthood (Clougherty et al., 2010; Fujishiro et al., 2010, 2020). These characteristics determine the kinds of jobs people obtain—and thus their exposure to physical hazards, job strain, income volatility, and employer-provided benefits that directly affect functional health in adulthood (Beltrán-Sánchez et al., 2017; Hoven and Siegrist, 2013). Because job opportunities, wage structures, and employment protections differ sharply between richer and poorer states (Blundell et al., 2018), state-level affluence across the life course could either buffer or magnify the health impact of a low-SES childhood. Our study therefore asks whether state affluence during childhood and/or adulthood moderates the childhood-SES gradient in adult functional health.

A significant methodological challenge in research examining these questions relates to the need for time-series data at the area level. Most prior studies of context have focused on a single point in time, usually during adulthood, assessed at the time of person-level data collection (Wheaton and Clarke, 2003). This undermines being able to determine how characteristics of economic contexts at different periods of the life span shape how socioeconomic disadvantage influences health. To address this need, the current study used time-series economic data combined with person-level data to estimate exposure at various points in a person's life span (e.g., childhood, late adolescence, early adulthood, adulthood). This allows for consideration of when specific economic characteristics may have the largest impact on associations between socioeconomic status in childhood and subsequent health outcomes.

Functional limitations—the reduced capacity to perform fundamental physical tasks—was the health outcome of interest for five key reasons. First, functional decline is central to conceptualizations of physical aging (Colón-Emeric et al., 2013; Ferrucci et al., 2018), with established differences across socioeconomic groups (Davies et al., 2025; Lima-Costa et al., 2016). Second, it is a widely used measure with documented reliability and construct validity (Guralnik and Ferrucci, 2003). Third, it is well validated as a predictor of subsequent morbidity and mortality (Gao et al., 2023). Fourth, national data suggest one in four adults aged 18–44 report some level of functional limitation (Zajacova and Margolis, 2025), with prevalence rising to over half among adults aged 45–64 (Zajacova and Montez, 2017). Moreover, increasing rates of pain and disability in mid-life highlight the growing public-health relevance of functional health well before old age (Case and Deaton, 2017). And lastly, a measure of functional limitations is assessed on all MIDUS (Midlife in the United States) cohorts. Our overarching hypothesis was that state level socioeconomic disadvantage would exacerbate effects of childhood socioeconomic disadvantage on adult functional limitations at all ages of exposure, but with early exposure to area level disadvantage being more consequential than later exposure due to both sensitive period and cumulative effects.

2. Methods

2.1. Participants

Data were drawn from the Midlife in the United States (MIDUS) study and an economic time series database based on U.S. tax records from 1917 to 2015. Analyses focused on a combined sample of the original MIDUS 1 (1995–1996) cohort and the MIDUS Refresher (2011–2014). The total combined analytic sample included 10,685 participants (mean age = 47.7, SD = 13.6, 51 % female, 86 % White; 6 % Black). The core sample was recruited in 1995–1996, consisted of a national sample of 7108 non-institutionalized adults ages 25–74 from the 48 contiguous United States (Radler and Ryff, 2010). The Refresher

sample, an independent national probability sample, ages 25–74, was recruited primarily in 2012, and included 3577 adults.

2.2. Measures

2.2.1. Childhood socioeconomic status

Participants reported on the highest level of formal education obtained by each of their parents on a 12-point scale: 1: no school/some grade school (grades 1–6); 2: eight grade/junior high school (grades 7–8); 3: some high school (grades 9–12 no diploma/no GED); 4: GED; 5: graduated from high school; 6: 1–2 years of college, no degree yet; 7: 3 or more years of college, no degree yet; 8: Graduated from 2-year college, vocational school, or associates degree; 9: graduated from a 4 or 5 year college, or bachelor's degree; 10: some graduate school; 11: master's degree; 12: professional degree (e.g., PhD, MD). The highest parental education level reported was used as an indicator of childhood SES (Fuller-Rowell et al., 2013; Willroth et al., 2021). Empirical validation studies linking survey reports of parent education to administrative records or to sibling/parent proxies show high concordance ($\kappa \approx$ 0.75–0.85) and only modest attenuation of coefficients (Havari and Mazzonna, 2015; Warren et al., 2022). As shown in these studies and in Krieger et al. (1998), recall errors appear largely random with respect to adult SES and health, implying that measurement error would tend to attenuate rather than inflate associations with subsequent health.

2.2.2. Functional limitations

Functional limitations were assessed using an established 7-item physical limitations scale (Friedman et al., 2015; Piazza et al., 2018). Participants rated the extent to which their health limits them in: carrying groceries; climbing several flights of stairs; bending, kneeling, or stooping; walking beyond a mile; walking several blocks; engaging in vigorous activities (such as running or lifting heavy objects); and doing moderate activities (like bowling or vacuuming). Responses were scaled from 1 (not at all) to 4 (a lot). A mean score was calculated across these seven items for each participant.

2.2.3. Demographic characteristics

Demographic controls included age (25–39, 40–49, 50–64, 65+), gender (female coded as 1; male coded as 0), cohabitation status (married or cohabiting as 1; otherwise coded as 0), and race (non-Hispanic Black, non-Hispanic White, other race). Sample sizes in the current study allowed for separate consideration of non-Hispanic Black and non-Hispanic White race categories (hereafter referred to as Black and White). However, very low sample sizes for other groups (Hispanic, Native American, Asian, multiracial, and other) precluded meaningful separate analyses. These groups were therefore combined into an "other race" category.

2.2.4. State economic characteristics

State-level economic characteristics (mean income and income inequality) were obtained from an established time series database (Frank, 2009, 2014; Sommeiller and Price, 2018). This data source is based on income tax (IRS) data that includes income from realized capital gains, and has been validated against independently derived estimates (Piketty et al., 2018; Piketty and Saez, 2003). Estimates used in our analyses draw on data from 1917 to 2014. *State-level mean income* represents the average income per tax unit, inflation adjusted using the Consumer Price Index and expressed in 2015 dollars. To leverage the strengths of these data sources, and to facilitate interpretability, we focused on the top 10 % income share as our primary measure of income inequality (Piketty and Saez, 2003). The Gini coefficient was also considered and yielded similar results (see additional analyses below).

State level time series data were merged with person-level MIDUS data by state of residence and calendar year to estimate exposure to state economic characteristics during four periods of the life span: childhood (ages 0–15), emerging adulthood (20–25), early adulthood (30–35), and midlife (40–45). Variations of a variable for calendar year of birth were used for the data merge (e.g., the year in which a participant turned 20 was used to assign state economic data for age 20). A mean score across calendar years within each age range was calculated to estimate exposure during each period. MIDUS does not include full residential histories, so we were unable to track movement across state lines at each life stage. As a result, we assigned geographic exposures based on respondents' state of residence in adulthood, assuming stability across the life course. The potential implications of this assumption are addressed in the Discussion.

2.3. Analysis plan

Our data are cross-classified: every participant belongs to both a state and a birth-year cohort, two groupings that are not nested within one another. To model this structure, we formed unique state by birth-year "state-cohort" cells and then estimated a two-level multilevel model, with individuals at level 1 and state-cohort cells at level 2. Collapsing the cross-classification in this way is an established strategy in multilevel modeling (Raudenbush and Bryk, 2002, p. 376) and has been applied in select policy and cohort studies (Bailey et al., 2021; O'Malley and Johnston, 2013). Though seldom used in life-course health research, this design links macroeconomic conditions to the exact life-stage window each cohort experienced, delivering temporal precision with simple estimation. Wider adoption of this robust framework could greatly advance understanding of how place- and time-specific contexts shape health and well-being across the life span (Wheaton and Clarke, 2003).

Random effects were estimated, allowing both the intercept (level of functional limitations) and slope (association between childhood SES and functional limitations) to vary across clusters. Separate models were run for each of the four age ranges (0–15, 20–25, 30–35, 40–45) to examine the effects of state-level economic exposures at each life stage. For each age range, two models were estimated. Model 1 tested the main effects of childhood SES and state economic characteristics on functional limitations. Model 2 tested whether state income and inequality moderated the childhood SES gradient. To aid interpretation, childhood SES, state economic characteristics, and functional limitations were all standardized (z-scored) to have a mean of 0 and a standard deviation of 1. Model parameter estimates are unstandardized.

Models for the 30–35 and 45-45 age ranges excluded participants who had not yet reached those ages, resulting in sample sizes of 8405 and 5855 respectively. All other models included the full sample (n = 10,685). Regarding other missing data, 17 % of the sample total sample had missing data on functional limitations due to incomplete self-administered questionnaires (Radler and Ryff, 2010). State-level variables had up to 7 % missingness, race had 6 %, and parent education had 4 %. All other study variables had less than 3 % missingness. Models were estimated using full information maximum likelihood (FIML) to handle missing data (Enders, 2022). Inclusion of socioeconomic status and other demographic controls in our models helps mitigate bias from potential non-random missingness (Enders, 2013; Radler and Ryff, 2010).

Additional analyses tested: (1) specific sub-periods of childhood exposure (ages 0–5 and 10–15); (2) whether contemporaneous or lagged contextual exposures (merged by survey year or with a 10-year lag) could account for the observed age-specific effects; (3) differences by race and gender; (4) higher-order interactions (i.e., whether moderation by state income varied by income inequality); (5) an alternative inequality measure (Gini coefficient); (6) whether moderation results changed when state mean income and income inequality were modeled separately rather than jointly; (7) the robustness of the findings after adjustment for adult educational attainment; (8) the robustness of the findings after adjustment for childhood health and family structure (single parent status); (9) whether the results held when additionally adjusting for parent occupational prestige as an alternative measure of childhood SES; (10) whether the results held when restricting the

sample to respondents with complete data on functional limitations; and (11) whether analogous patterns emerged for other health outcomes (chronic conditions, self-rated health, depressive symptoms). The Online Supplement provides summary descriptions and full tables of these additional results (Tables S1–S20), which aid in interpretation of the primary findings.

3. Results

Descriptive statistics for each study variable are shown in Table 1. In the combined core and refresher samples, 85.7 % of participants identified as White, 6.4 % as Black, and 7.9 % as other races. The other race category included Hispanic (3.4 %), Asian (1.1 %), Native American (0.8 %), multiracial (0.5 %) and other (2.1 %). The proportion of females was 51.8 %, and a majority of the sample were in a cohabiting relationship (70.2 %). Ages ranged from 25 to 74 years ($M = 47.8$, $SD = 13.6$). The mean level of parental education was 5.90 ($SD = 2.90$), and participants reported an average of 1.62 ($SD = 0.81$) functional limitations. State mean income, inflation-adjusted to 2015 U.S. dollars (in thousands), varied across the ages of exposure/periods of the life span, starting from a mean of 7.32 ($SD = 6.73$) for the 0–15 age group to a mean of 33.57 ($SD = 16.26$) for the 40–45 age group. The top 10 % income share also increased with age, from 34.67 ($SD = 3.56$) for ages 0–15 to 40.67 ($SD = 6.06$) for ages 40–45. Correlations between state-level mean income and income inequality were smaller during the childhood period (online supplement, Table S21). This is consistent with prior work documenting an increase in the magnitude of this correlation in recent decades (Frank, 2009; Sommeiller and Price, 2018).

3.1. State characteristics (ages 0–15) as moderators of the SES gradient

Model results showing state-level predictors (ages 0–15) and individual-level predictors of functional limitations are shown in Table 2. In Model 1, higher childhood SES, represented by the highest educational attainment of either parent, was associated with fewer functional limitations ($B = -0.089$, $SE = 0.01$, $p < .001$). Higher state income was associated with fewer functional limitations ($B = -0.093$, $SE = 0.013$, $p < .001$), and higher state income inequality (top 10 % income share) was associated with more functional limitations ($B = 0.04$, $SE = 0.012$, $p = .001$). In unstandardized units of state income, a $10,000 increase was associated with a 0.138 *SD* decrease in functional limitations. And a 5-percentage point increase in the top 10 % income share (ages 0–15) was associated with a 0.056 *SD* increase in functional limitations.

Demographic control measures were also significantly associated with functional limitations. Compared to non-Hispanic Whites, Black adults ($B = 0.136$, $SE = 0.051$, $p = .008$) and those of other races ($B = 0.122$, $SE = 0.041$, $p < .003$) had higher functional limitations. Females reported higher functional limitations than males ($B = 0.233$, $SE = 0.02$, $p < .001$), and cohabitation was associated with fewer functional limitations ($B = -0.218$, $SE = 0.024$, $p < .001$). Older age groups also had higher functional limitations than younger groups ($ps < 0.001$).

Model 2 showed that the association between childhood SES and functional limitations varied as a function of state mean income ($B = 0.023$, $SE = 0.01$, $p = .018$). These results, shown in Fig. 1, show that people from states with a lower mean income (−1 SD) had a stronger

Table 1
Descriptive statistics.

Variables	M ± SD	%
Race (White)		85.7
Race (Black)		6.4
Race (Other)		7.9
Gender (Female)		51.8
Cohabitation		70.2
Age (years)	47.77 ± 13.62	
Age (25–39.99)		32.0
Age (40–49.99)		24.0
Age (50–64.99)		28.6
Age (65+)		14.7
Highest Parent Education	5.90 ± 2.90	
Functional limitations	1.62 ± 0.81	
State mean income (ages 0–15)	7.32 ± 6.73	
State mean income (ages 20–25)	15.98 ± 12.65	
State mean income (ages 30–35)	24.77 ± 15.68	
State mean income (ages 40–45)	33.57 ± 16.26	
Top 10 % income share (ages 0–15)	34.67 ± 3.56	
Top 10 % income share (ages 20–25)	35.55 ± 4.43	
Top 10 % income share (ages 30–35)	38.00 ± 5.71	
Top 10 % income share (ages 40–45)	40.67 ± 6.06	

Note. State income is inflation-adjusted with values shown in 2015 U.S. dollars (coded in thousands).

Table 2
Results for models examining state mean income and income inequality (top 10 % income share) at ages 0–15 as a moderator of the association between parent education and functional limitations.

	MODEL 1		MODEL 2	
	B	*SE*	*B*	SE
Intercept	−0.217***	0.029	−0.208***	0.029
Race (White = reference category)	–	–	–	–
Race (Black = 1)	0.136**	0.051	0.128*	0.051
Race (Other Race = 1)	0.122**	0.041	0.122**	0.021
Age (25–39 = reference category)	–	–	–	–
Age (40–49 = 1)	0.163***	0.027	0.155***	0.027
Age (50–64 = 1)	0.347***	0.031	0.334***	0.032
Age (65–75 = 1)	0.583***	0.042	0.568***	0.042
Gender (Female = 1)	0.233***	0.020	0.229***	0.02
Cohabitation Status	−0.218***	0.024	−0.224***	0.024
Parent education	−0.089***	0.01	−0.087***	0.01
State-Level Variables:				
State mean income	−0.093***	0.013	−0.107***	0.015
Income inequality	0.04***	0.012	0.038**	0.012
Cross-Level Interactions:				
Parent education*state mean income			0.023*	0.01
Parent education*income inequality			0.002	0.011

Note. Unstandardized estimates are shown. All continuous predictor variables are grand mean centered and z-scored to have a mean of zero and a standard deviation of 1. *p < 0.05. **p < 0.01. ***p < 0.001.

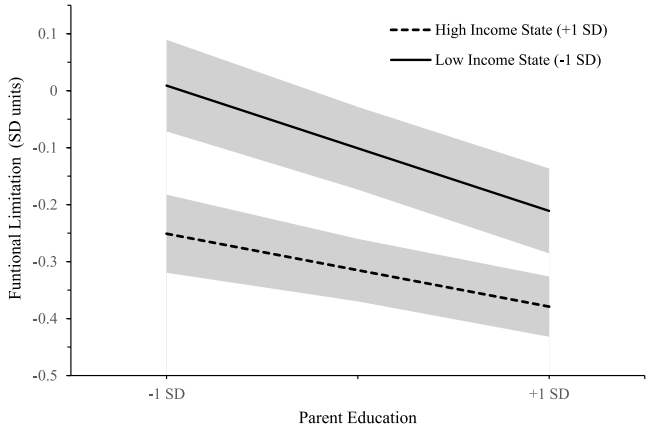

Fig. 1. Interaction between parent education and childhood state income (ages 0–15) predicting adult functional limitations. *Note*. Parent education: −1 SD = <high school (3.0), 0 = some college (5.9), +1 SD = college degree (8.8). Lines shown for low (−1 SD = $590) and high (+1 SD = $14,050) state income. Shaded areas are 95 % CIs. Y-axis is in SD units from Model 2; negative values reflect coding of the reference group (young, male, white; see Table 2).

negative association between childhood SES and functional limitations ($B = -0.110$, $SE = 0.015$, $p < .001$) than those from higher income (+1SD) states ($B = -0.064$, $SE = 0.013$, $p < .001$). Compared to those exposed to average state income levels during childhood, those exposed to higher levels (by $10,000) showed a 0.034 reduction in the absolute magnitude of the childhood SES gradient in functional limitations (e.g., from −0.087 at average income to −0.053 at high income—a 39 % decrease in the steepness of the gradient). State income inequality was not a significant predictor of the slope of childhood SES on functional limitations ($B = 0.002$, $SE = 0.011$, $p = .864$).

3.2. State characteristics (ages 20–25) as moderators of the SES gradient

Models examining state-level predictors (ages 20–25) and individual-level predictors of functional limitations are shown in Table 3. Model 1 showed that higher childhood SES was associated with fewer function limitations ($B = -0.09$, $SE = 0.011$, $p < .001$). At the state level, higher state mean income was also associated with fewer functional limitations ($B = -0.106$, $SE = 0.021$, $p < .001$). In unstandardized units of the predictor, each $10,000 increase in state income (ages 20–25) was associated with a −0.084 SD decrease in functional limitations. However, higher state income inequality (top 10 % income share) was not a significant predictor of functional limitations ($B = 0.02$, $SE = 0.017$, $p = .261$).

Model 2 showed that the association between childhood SES and functional limitations again varied as a function of state mean income ($B = 0.036$, $SE = 0.016$, $p = .026$). This interaction is illustrated in Fig. 2, which shows that those from states with a lower mean income had a stronger negative association between childhood SES and functional limitations ($B = -0.124$, $SE = 0.02$, $p < .001$) than those from higher income states ($B = -0.052$, $SE = 0.018$, $p = .004$). Compared to those exposed to average state income levels during emerging adulthood, those exposed to higher levels (by $10,000) showed a 0.028 reduction in the absolute magnitude of the childhood SES gradient in functional limitations (e.g., from −0.088 at average income to −0.060 at high income—a 32 % decrease in the steepness of the gradient). State income inequality was not a significant predictor of the slope of childhood SES on functional limitations ($B = -0.016$, $SE = 0.017$, $p = .287$).

Table 3
Results for models examining state mean income and income inequality (top 10 % income share) at ages 20–25 as a moderator of the association between parent education and functional limitations.

	MODEL 1		MODEL 2	
	B	*SE*	*B*	*SE*
Intercept	−0.211***	0.03	−0.201***	0.03
Race (White = reference category)	–	–	–	–
Race (Black = 1)	0.141**	0.051	0.134**	0.05
Race (Other Race = 1)	0.123**	0.041	0.124**	0.041
Age (25–39 = reference category)	–	–	–	–
Age (40–49 = 1)	0.141***	0.028	0.135***	0.028
Age (50–64 = 1)	0.337***	0.033	0.321***	0.034
Age (65–75 = 1)	0.59***	0.043	0.568***	0.043
Gender (Female = 1)	0.233***	0.02	0.229***	0.02
Cohabitation Status	−0.218***	0.024	−0.224***	0.024
Parent education	−0.09***	0.011	−0.088***	0.01
State-Level Variables:				
State mean income	−0.106***	0.021	−0.119***	0.021
Income inequality	0.02	0.017	0.018	0.017
Cross-Level Interactions:				
Parent education*state mean income			0.036*	0.016
Parent education*income inequality			−0.016	0.017

Note. Unstandardized estimates are shown. All continuous predictor variables are grand mean centered and z-scored to have a mean of zero and a standard deviation of 1. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

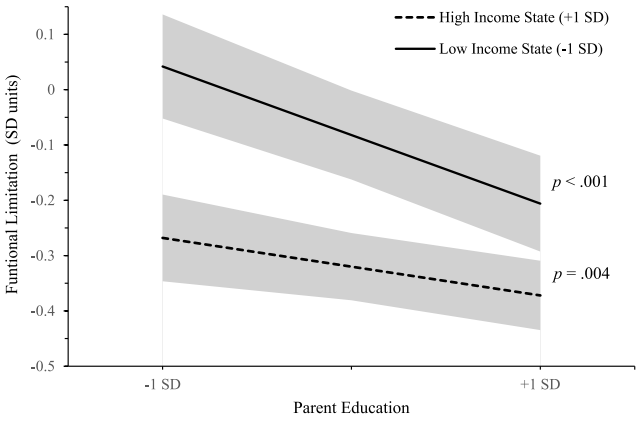

Fig. 2. Interaction between parent education and state income in emerging adulthood (ages 20–25) predicting adult functional limitations. *Note*. Parent education: −1 SD = <high school (3.0), 0 = some college (5.9), +1 SD = college degree (8.8). Lines shown for low (−1 SD = $3320) and high (+1 SD = $28,637) state income. Shaded areas are 95 % CIs. Y-axis is in SD units from Model 2; negative values reflect coding of the reference group (young, male, white; see Table 3).

3.3. State exposures at later ages (30–35, 40–45)

Full results of models examining effects of state characteristics at 30–35 and 40–45 are provided in supplemental materials (Tables S22–S23). For Model 1 results examining state exposures at ages 30–35, higher childhood SES was associated with fewer functional limitations ($B = -0.097$, $SE = 0.012$, $p < .001$), and higher state mean was associated with fewer subsequent functional limitations ($B = -0.13$, $SE = 0.028$, $p < .001$). Higher state income inequality was not a significant predictor of functional limitations ($B = 0.015$, $SE = 0.024$, $p = .541$). Model 2 showed that neither state mean income ($B = 0.017$, $SE = 0.024$, $p = .314$) nor state income inequality ($B = -0.007$, $SE = 0.024$, $p = .556$) were significant moderators of the association between childhood SES and functional limitations.

Results for state exposures at ages 40–45 were similar. Higher childhood SES was associated with fewer functional limitations in Model 1 ($B = -0.108$, $SE = 0.015$, $p < .001$), and higher state mean income was associated with fewer subsequent functional limitations ($B = -0.093$, $SE = 0.033$, $p = .005$). Higher state income inequality was not a significant predictor of functional limitations ($B = -0.02$, $SE = 0.03$, $p = .510$). Model 2 showed that neither state mean income ($B = -0.034$, $SE = 0.033$, $p = .293$) nor state income inequality ($B = 0.021$, $SE = 0.032$, $p = .506$) were significant moderators of the association between childhood SES and functional limitations.

4. Discussion

State-level mean income has become a stronger predictor of health outcomes in recent decades (Couillard et al., 2021; Vierboom et al., 2019), yet its role in socioeconomic health inequalities remains understudied. We examined how childhood SES–adult health gradients vary across state economic contexts, focusing on state income and inequality. While prior research has examined place-based economic moderators of the adult SES-health gradient (Linden and Ray, 2017; Zheng and George, 2012), our study is among the first to examine state-level macroeconomic factors as moderators of the association between childhood SES and adult health. Results indicated that lower state income during childhood/emerging adulthood amplified SES disparities in functional limitations (i.e., steeper childhood SES gradients in low-income states). While state inequality did not moderate SES gradients, childhood exposure to inequality independently predicted more adult functional

limitations.

Our findings build on literature linking childhood SES to subsequent health and extend this work by showing that the childhood SES-health gradient is steeper in states with lower average SES. Our results indicate that the amplifying effect of area-level socioeconomic disadvantage on the adult SES gradient, as reported in prior work (Howell and Howell, 2008; Linden and Ray, 2017), also appears to be evident for the childhood SES gradient. Our results also add to and align with more general evidence showing that characteristics of area level contexts may have a more pronounced impact on subsequent health outcomes for low SES groups than for high SES groups (Chetty et al., 2016). These results are congruent with a dual risk theoretical perspective, which proposes that the presence of two or more risk factors (in this case family-SES and areas-level SES) can have multiplicative rather than merely additive effects on health or well-being outcomes (Fuller-Rowell et al., 2024; Zeringue et al., 2023). These results also align with social stress theory, which proposes that disadvantaged (low SES) groups may be more vulnerable to adverse contextual exposures (Diderichsen et al., 2019). However, the divergence in findings between functional limitations and self-reported mental health outcomes (reported in the online supplement) underscores the importance of considering domain-specific pathways when evaluating contextual influences on health. Given that most prior research focused on adult SES gradients in health and well-being, more work is also needed to replicate and extend our findings, particularly by examining policy-relevant contextual moderators of childhood SES gradients (discussed further below).

Income inequality may harm health through structural pathways, such as via residential income segregation that reduces access to resources for less advantaged groups (Chetty et al., 2022; Watson, 2009), as well as psychological pathways, such as via chronic stress, which appears to be higher in more unequal societies due to status competition (Wilkinson and Pickett, 2009). For children, these pathways may in part operate indirectly—through parental stress and investment, neighborhood safety, and institutional quality—and can initiate behavioral and biological embedding that endures (Hertzman and Boyce, 2010; Shonkoff and Garner, 2012). Children grow up within families, schools, and neighborhoods that reflect status-oriented norms intensified under high inequality (Pickett and Wilkinson, 2015; Wilkinson and Pickett, 2009). In high-inequality contexts, parents experience greater financial strain and mental health burden, public goods (e.g., schools, parks) receive less investment, and neighborhood violence is more prevalent—conditions that shape children's development long before labor-market entry (Kawachi et al., 1999; Kosec, 2014; Rakesh et al., 2025). Concurrently, chronic exposure to these stress-laden environments during sensitive periods can "get under the skin" via dysregulated physiological activity, accelerated allostatic load, and stress-related epigenetic modifications, with effects that track into adulthood and manifest in functional health (Hertzman and Boyce, 2010; McEwen and Gianaros, 2011; Shonkoff and Garner, 2012).

While prior studies link state-level inequality to population health (Lochner et al., 2001; Subramanian and Kawachi, 2004), our focus on childhood exposure reveals enduring effects: inequality during childhood predicts functional limitations decades later, independent of individual SES. This aligns with evidence that inequality erodes communal trust and safety nets, exacerbating health risks across socioeconomic strata (Kawachi and Kennedy, 1999; Pickett and Wilkinson, 2015).

Our findings align with prior studies linking childhood inequality exposure to self-rated health and physiological dysregulation (Lillard et al., 2015; Zheng et al., 2022), but extend this work in key ways. Prior work relied on national-level inequality trends, masking critical state-level heterogeneity in both baseline inequality and its trajectory over time. Further, these studies did not account for time-varying state characteristics. By leveraging a state-level time series database, we demonstrate that childhood exposure to inequality predicts functional limitations in adulthood, even after adjusting for state mean income. Notably, this association persists even after controlling for state mean income, underscoring inequality's unique health impact beyond overall economic conditions.

Our finding that income inequality did not moderate the childhood SES gradient is also novel. While income inequality has been found to moderate the adult SES-health gradient in several prior studies (Kahn et al., 2000; Lochner et al., 2001), few if any studies have examined childhood exposure to inequality as a moderator of the childhood SES-adult health gradient. That childhood exposure to inequality was a direct predictor of adult functional health—but not a moderator of the SES gradient—is somewhat surprising but speaks to the broader social ills affecting all groups (psychological mechanisms) that high levels of inequality may engender (Wilkinson and Pickett, 2017).

In the United States, state and local governments play a key role in shaping policies that impact the lives of their residents, particularly those from lower SES backgrounds (Montez and Grumbach, 2023; Woolf, 2022). For instance, state-level variation in Medicaid administration, tax credits (e.g., earned income and child tax credits), and safety net programs (SNAP, AFDC) differentially affect childhood poverty and inequality. Restrictive zoning laws further exacerbate social class segregation by limiting affordable housing (Rothwell and Massey, 2010), which shapes children's access to schools and labor markets (Owens, 2019; Owens et al., 2016). While research has begun to link state policy to health outcomes (Wolf et al., 2022; Woolf et al., 2023), critical gaps remain in understanding how policies interact with economic contexts to reduce socioeconomic health disparities. This study highlights how early economic exposures—alone and in combination with childhood family SES—shape adult health, but more detailed, integrated data and further research are clearly needed to disentangle the causal web of policy and economic influences.

Some caveats are important to mention. First, although our time-series database enabled estimation of exposures across the life span, we—like most studies without full residential histories—had to assume that participants remained in the same state. This assumption introduces the possibility of exposure misclassification due to interstate mobility. Approximately one-third of midlife adults in these cohorts are expected to have relocated across states, while two-thirds remained correctly classified (Long, 1988; U.S. Census Bureau, 2000. Under the extreme assumption that moves occurred entirely at random with no correlation between origin and destination states, such misclassification would attenuate associations by up to ~30 %, implying that our observed effects are conservative estimates of the true contextual influence (Carroll et al., 2006; Copeland et al., 1977). In practice, however, most interstate moves are regional and occur between states with correlated economic conditions (Frey, 2009; Molloy et al., 2011), with correlations in the range of $r \approx 0.55$–0.70 and often higher for adjacent states (Khan and Siddique, 2021; Rey and Janikas, 2005; Rey and Montouri, 1999). Taking this correlation into account raises effective measurement reliability to greater than 0.85, meaning that parameter estimates would be attenuated by only 10–15 %. In other words, bias from the assumption of non-mobility would be expected to make related estimates conservative by approximately this amount.

Second, it is important to note that our study is observational and descriptive and thus causality cannot be inferred. While reverse causality for childhood SES effects on adult health is not plausible (i.e., adult health could not causally impact on childhood SES), various possible confounders could be impacting the associations examined. Studies that leverage longitudinal data, natural experiments (e.g., staggered program rollouts), difference-in-differences designs, well-validated instrumental variables, or fixed-effects models to probe causal mechanisms would be helpful to address such limitations. With sufficiently detailed data, these studies could examine whether changes in state economic contexts shape changes in health outcomes or are associated with widening or narrowing of health differences across socioeconomic groups. Our results provide evidence that further consideration of such questions is warranted.

Lastly, although functional limitations are an established health

outcome in adult samples and are central to conceptualizations of aging (Colón-Emeric et al., 2013; Ferrucci et al., 2018), other health outcomes are important to consider. For example, objective indicators of physiological dysregulation such as allostatic load or epigenetic age acceleration will help to extend this work and could help illuminate the embodied health consequences of differential contextual exposures earlier in the life span. Despite these limitations, the findings extend prior work in several meaningful ways. They suggest that the role of childhood SES as a predictor of functional health in later life varies by state-level economic context—particularly as a function of state mean income—and that income inequality exposure in childhood has an enduring association with adult functional limitations.

CRediT authorship contribution statement

Thomas E. Fuller-Rowell: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Samia Sultana:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Carol D. Ryff:** Writing – review & editing, Methodology, Conceptualization. **Eric S. Kim:** Writing – review & editing, Methodology, Conceptualization. **Markus Jokela:** Writing – review & editing, Methodology, Conceptualization. **S.V. Subramanian:** Writing – review & editing, Methodology, Conceptualization. **Ichiro Kawachi:** Writing – review & editing, Methodology, Conceptualization.

Data used for this study are publicly available

MIDUS data from ICPSR (https://www.icpsr.umich.edu), and the time series economic data from the World Inequality Database (https://wid.world/) and the academic web page of its author (https://profiles.shsu.edu/eco_mwf/inequality.html). Merged data are available upon request.

Ethical approval statement

This study used secondary data from the Midlife in the United States (MIDUS) project and thus was classified as Exempt under 45 CFR §46.104(d)(4). Data from the Midlife in the United States (MIDUS) project, which are archived at the Inter-University Consortium for Political and Social Research (ICPSR). All original MIDUS data-collection protocols were reviewed and approved by the Education and Social/Behavioral Sciences and the Health Sciences Institutional Review Boards at the University of Wisconsin-Madison, and written informed consent was obtained from all participants.

Declaration of competing interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2025.118676.

Data availability

The data sources are publicly available. Links to the data will be provided in a data availability statement, which is not shown on the title page.

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