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Utilize administrative data to assess impact of individual-level and neighborhood-level socioeconomic status on childhood health in a longitudinal study

Huong D. Meeks^{1,2}, David Zhe Yu², Alison Fraser², Thomas N. Maloney³, Karen Curtin^{2,4}, Mike Newman², Ken R. Smith⁵

¹Department of Pediatrics, University of Utah School of Medicine, Salt Lake City, UT

²Pedigree and Population Resources, Huntsman Cancer Institute, Salt Lake City, UT

³Department of Economics, University of Utah, Salt Lake City, UT

⁴Department of Internal Medicine, University of Utah School of Medicine, Salt Lake City, UT

⁵Department of Family and Consumer Studies, University of Utah, Salt Lake City, UT

Abstract

Objectives: Our study aims to 1) propose an approach to standardize individual-level and neighborhood-level socioeconomic status (SES) measures from administrative records across three decades, 2) determine the degree of agreement between individual-level and neighborhood-level SES measures, and 3) compare the associations of individual-level and neighborhood-level SES measures and childhood health.

Study Design: Retrospective observational study

Methods: Our cohort included children born in Utah during 1978-2008. Parental SES indicators including education, occupation, and area household income corresponding to maternal addresses were collected from birth certificates. Spearman rank correlation tests were used to determine the correlation between SES measures. Cox regression models and causal mediation analyses were used to assess the association between three childhood health outcomes- mortality, failure-to-thrive, and asthma- and three SES

measures: highest education level and occupational status score of parent(s) and area household income.

Results: 819,108 children were included in the final analysis. We observed moderate agreement (r ranges 0.43-0.49) between individual-level SES measures (education and occupation) and weak

Corresponding author: Huong D. Meeks, huong.meeks@hsc.utah.edu, Department of Pediatrics, Critical Care Division, University of Utah Spencer F. Eccles School of Medicine, 295 Chipeta Way, Salt Lake City, UT 84108.

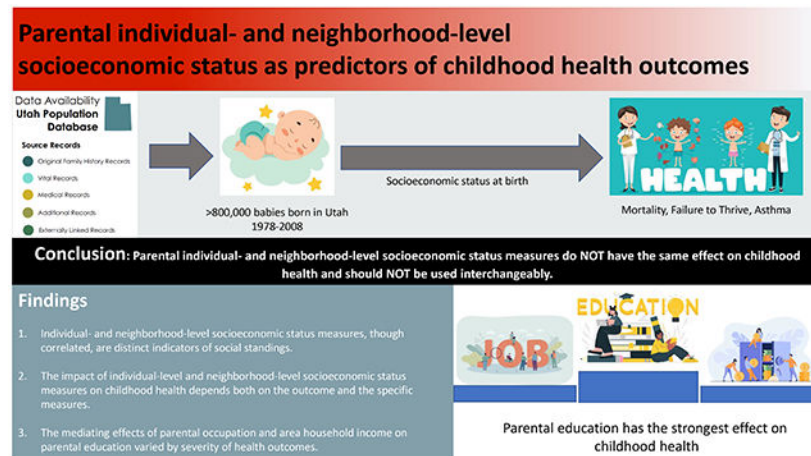
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Declaration of Competing Interest:
None declared

agreement (r ranges 0.19-0.25) between these measures and neighborhood-level SES measures. Parental education had the strongest association with childhood health. The associations of parental occupation and area household income with childhood health, and their mediating effects on parental education, varied by the severity of health outcomes.

Conclusions: We introduced an approach to standardize SES measures from administrative records for longitudinal analyses. We confirmed that individual-level and neighborhood-level SES measures are distinct indicators of social standing and validated the importance of the choice of SES measures when analyzing childhood health.

Graphical Abstract



Keywords

Administrative records; Socioeconomic Status; Childhood Health; Longitudinal Study; Occupational Status Score; ACS; Education; Fundamental Cause Theory; Causal Mediation Analyses

Introduction:

Administrative data, including electronic health and vital records, have proven useful in epidemiologic research for several reasons [1]. First, they are readily available and inexpensive to acquire as opposed to data traditionally collected by prospective studies, which are costly and time-consuming. Second, they typically include rich longitudinal data on entire regional populations, which make tracking of disease onset and progression possible. Third, they allow comprehensive observation of individuals across systems from birth to adulthood. Digitization of administrative data has allowed researchers to perform linkages not only between multiple records but also among household members and to contextual data via geographic information systems [2], which is especially useful for studying complex diseases.

One challenge of using administrative data for epidemiologic research is that they were originally intended for other purposes. Individual-level and neighborhood-level socioeconomic status (SES) is rarely directly evaluated despite being shown to be

consistently associated with childhood health via its influence on household residential choices, access to and use of healthcare services, and parenting practices [3–5]. Common SES measures from administrative data are education and occupation as proxies for individual-level SES and characteristics of residential areas drawn from census data. Occupation in administrative records is stored as text strings and thus is difficult and expensive to codify. Income is typically collapsed into large categories and top-coded, which then requires complex adjustments to make year-to-year comparisons meaningful in longitudinal studies. Due to the lack of availability and arduous efforts to access individual-level SES measures in administrative records, neighborhood-level SES measures have commonly been used as surrogates [6]. Several studies have assessed the agreement between individual-level and neighborhood-level SES measures [7–9], but few have focused specifically on childhood health [10, 11] and none has utilized SES measures reported in administrative records.

When utilizing SES measures to examine direct effects of SES on health outcomes or as effect modifiers of other risk factors, many longitudinal studies do not account for the instability and inconsistency of these measures across time and places. Researchers often take a cross-sectional approach to describe neighborhood-level SES such as using SES variables from cross-sectional public surveys including the decennial censuses and the American Community Survey (ACS) [12]. Researchers also adopt a categorical approach where individual-level SES is depicted in broad categories, such as unemployed versus employed, or manual versus skilled occupations [13].

Neighborhood-level SES is dynamic [14], and aggregating occupations into small numbers of broad categories or classes assumes that workers within a large category are relatively homogenous and that they were members of these categories for the same amount of time [15]. Various methodologies have been developed to ensure the comparability of neighborhood-level SES measures across populations, places, and time [16], but have not been utilized often in pediatric health research [17]. Kachmar et al (2019) conducted a scoping review of SES measures in pediatric studies in the United States between 1999 and 2018 [6]. Of 228 studies, only 22 (9.6%) included employment/occupation as a measure of SES, aggregated into groupings such as employment status and occupation types, and 58 (25.4%) included census-derived income. No study employed occupational measures or harmonized census-derived variables across long periods of time.

Our study aims were to: 1) propose a new approach to standardize individual-level and neighborhood-level SES measures from administrative records across multiple decades to support longitudinal analyses; 2) determine the degree of agreement between individual-level and neighborhood-level SES measures; and 3) compare the association of individual-level and neighborhood-level SES measures and childhood health outcomes.

Material and Methods:

Data:

This retrospective observational study utilized data drawn from the Utah Population Database (UPDB), one of the world's richest sources of linked population-based information

[18]. Currently, the UPDB contains demographic, genealogical, and health data on over 11 million individuals from the late 18th century to the present, representing Utah's population that appear in a range of administrative records. UPDB data is continually updated and linked at the individual-level and family-level as annual statewide birth and death certificates, hospitalizations, ambulatory surgeries, and driver licenses become available. This study is approved by the University of Utah's Resource for Genetic and Epidemiologic Research, the body that governs use of UPDB data, and its Institutional Review Board (IRB #00043524).

Study Population:

Eligible children included those born in Utah from 1978 to 2008 with informative parents, defined as those with known birth year and duration of Utah residency. We chose the study period of 1978-2008 because parental education and occupation information as well as maternal residence and mailing addresses were available from Utah birth certificates, allowing us to measure family and neighborhood SES from these records. Additional inclusion criteria were: 1) Utah residency; 2) known birth month/year and sex; and 3) known birth order, birth county, and maternal marital status. We excluded stillbirths and adoptions, as data for these are not consistently available in the UPDB. Children whose parents were informative but lacked information on education, occupation, and maternal addresses were excluded because this information was deemed essential in determining SES. We also excluded children from military families because of their unique life experiences due to factors such as reassignments, deployments, and the frequency of location changes. Eligible children were followed from birth until death, age 18, or last date residing in Utah, whichever occurred first.

Outcomes:

Death month/year and month/year of first asthma and failure-to-thrive (FTT) diagnoses were collected for all eligible children. Childhood mortality was determined from Utah death certificates and was defined as death prior to age 18. Asthma diagnosed prior to age 18 and FTT diagnosed prior to age 2 were of interest and chosen specifically because they are among the most common issues in children for which socioeconomic status has been demonstrated to be a risk factor [19–21]. These diagnoses were determined from UPDB's healthcare facility database using the appropriate International Classification of Disease codes version 9 and 10 (Supplemental Table 1).

SES measures:

Our study used parental education attainment(s) and occupation(s) to measure individual-level SES and Census median household income estimates to measure neighborhood-level SES. All SES measures were ascertained from birth certificates and via their addresses. Parental education included the maximum of paternal and maternal education and was categorized into five groups: less than high school, high school graduate, some college, college graduate, and post college. Parental occupation was derived from parental occupational status and the Nam-Powers-Boyd occupation status scores (NPBOSS). Children were assigned into quartiles based on the highest NPBOSS of the two parents; children from households where both parents were unemployed were categorized into a

distinct category. Area household income was categorized into quartiles based on the median household income associated with the maternal residential addresses at the time of the child's birth. Further details on the imputations of SES measures were provided in the Appendix.

Confounders:

The list of confounders was informed by prior literature and included the following demographic characteristics of the child: birth year, sex, race (whether White), ethnicity (whether Hispanic), birth order (whether first born), and the following maternal characteristics at the child's birth: residential county classification (whether urban, rural, or frontier), age, and marital status (whether married) [22].

Statistical Analysis:

Spearman rank correlation tests were used to determine the association between the following SES measures: maximum education obtained by each parent individually and combined, parental occupation, and area household income. All parental education measures were ranked from one to five, with one being the lowest level (less than high school). Parental occupation was ranked from one to five, with families whose parents were unemployed ranked as one and families in the fourth quartile ranked as five. Area household income was ranked from one to four, with neighborhoods in the first quartile received the ranking of one.

We investigated the relationship between childhood health and the three SES measures. First, we treated these SES measures as continuous variables and performed seven Cox regression models with increasing levels of adjustment for each outcome: models 1-3 adjusted for each SES measure separately, models 4-6 adjusted for pairs of SES measures, and model 7 included all three SES measures simultaneously. Second, we conducted causal mediation analyses based on a counterfactual framework to evaluate whether parental occupation and area household income mediated the effect of parental education [23]. Single mediation models were performed for each mediator, along with a multiple mediation model incorporating both mediators. Each mediation analysis included two components: a Cox regression model estimating the direct effect of parental education adjusting for mediator(s), and a linear regression model assessing the association between parental education and the mediator(s). Sensitivity analyses incorporating exposure-mediator interactions were performed for all models. Third, findings from the causal mediation analyses were used to inform the development of Cox regression models examining the relationship between SES measures, treated as categorical variables, and childhood health.

Cox regression was chosen in order to take time and observation periods of differing lengths into consideration and fitted with the sandwich estimator to account for clustering induced by multiple births within families. We did not consider fixed-effect models as parental measures within sibship clusters do not vary. All models were adjusted for covariates described earlier. Statistical analyses were conducted using R version 4.3 (R Core Team, 2022) with the packages tidyverse [24] and CMARver [25].

Results:

Of the initial 1,234,088 children born in Utah between 1978 and 2008, 1,144,250 matched our eligibility criteria. After excluding those with missing key socioeconomic information, a total of 819,108 children were included in the final analysis (Supplemental Figure 1).

The mean (standard deviation [SD]) follow-up time is 15.9 (4.1) years. There were 8,134 (1.0%) children who died prior to age 18, 25,281 (3.1%) children diagnosed with FTT prior to age 2, and 35,594 (4.4%) children diagnosed with asthma prior to age 18.

Sociodemographic characteristics at birth are presented in Table 1. For 29.0% children, maximum parental education was high school graduate or less. Most children came from dual-income and single-income families (49.0% and 47.7% respectively); among single-income families, the majority had fathers being the sole workers outside of the home (44.5%).

Spearman Correlations of SES measures:

Individual-level SES measures were moderately correlated with each other and weakly correlated with neighborhood-level SES measure [26] (Figure 1; all $p < 0.001$). Paternal education was moderately correlated with maternal education ($r = 0.63$), with fathers generally reporting higher education than mothers. Parental occupation was moderately correlated with all three measures of parental education (r ranges 0.43-0.49). Area household income was weakly correlated with parental education measures (r ranges 0.16-0.19) and occupation ($r = 0.25$).

Associations between SES measures and childhood health:

Tables 2 summarizes the associations of parental education, occupation, and area household income with childhood health. Overall, children from lower SES backgrounds showed significantly higher rates of mortality and morbidity compared to those from higher SES backgrounds. The magnitudes of hazard ratios (HRs) were generally consistent whether SES measures were adjusted individually or jointly, except for parental occupation, which was significant in models with asthma as the outcome and excluding parental education but not in those including it.

Parental occupation mediated the association between parental education and childhood mortality (Proportion Mediated [PM] [95% Confidence Interval {CI}] = 20.6 [14.3-27.9], $p < 0.001$) and FTT (PM [95%CI] = 8.9 [3.2-15.4], $p < 0.001$) but not childhood asthma (Supplemental Table 2). Area household income mediated the association between parental education and all health outcomes, though with marginal effect (PM ranges 0.6-3.1%). Sensitivity analyses confirmed the mediating effect of parental occupation and area household income on the relationship between parental education and childhood mortality, with reduced estimates (PM [95%CI] = 13.6 [7.2-21.3] and 2.2 [1.2-3.6], respectively), but not on other outcomes (Figure 2, Supplemental Table 3).

All three SES measures were included in the final Cox models (Table 3). Compared to children of parents with a high school degree, children of parents with less than a high school education had higher HRs of mortality and FTT while those whose parents had some

college education or more had lower HRs of mortality and morbidity. Compared to children with parents of highest occupational status, children with unemployed parents had higher HRs for mortality but not FTT while those with parental NPBOSS in the 1st quartile had higher HRs for both mortality and FTT. We did not observe significant association between parental occupation and childhood asthma. Children living in the poorest neighborhoods consistently had higher HRs for both mortality and morbidity compared to children living in the wealthiest neighborhoods.

Discussion:

This study is one of only a few studies that standardized multiple individual-level and neighborhood-level socioeconomic measures collected in administrative records across a three-decade study period to examine their associations with childhood health. We observed moderate agreement between parental education and occupation and weak agreements between these measures and area household income. The magnitude of the relationship between SES measures at birth and childhood health differed depending on not only the choices of SES measures but also the outcomes, with parental education showing the most consistent effects.

Our observed low to moderate correlations between SES measures at birth are consistent with previous literature [8, 27] and confirm that SES measures, either between individual-level and neighborhood-level or within the same level often do not overlap fully and are distinct indicators of social standing. Parental education, parental occupation, and area household income each represent unique aspects of a child's socioeconomic background. Parental education indicates the level of knowledge and skills obtained through formal education, which can affect parents' ability to support their child's development. Parental occupation reflects the nature of employment, which is consistently linked to income security, earnings stability, and economic prospects. It might also act as a proxy for social standing, potential networks, and the resources accessed through the occupational social environment, while also reflecting job-related exposures that a parent may pass on to their child. Area household income provides a measure of the overall economic environment for a neighborhood and can impact child health through various pathways, including access to healthcare and environmental quality. Relying on a single SES indicator will likely risk overlooking the diverse ways in which socioeconomic background influences childhood health [28, 29].

Parental education was associated with all three childhood outcomes, whereas the association of parental occupation and area household income with childhood health varied by the outcomes. Children of highly educated parents have lower mortality and morbidity compared to children of parents with lower educational attainment. This finding supports the Fundamental Cause Theory (FCT) hypothesis, which suggests that people of higher SES have more health advantages due to flexible resources, irrespective of health conditions [30]. Our study lends credence to the use of FCT as a conceptual framework for the exploration of health disparities in early childhood [31–33]. Interestingly, our study found a significant difference in mortality but not morbidity between children with unemployed parents and those with parents of highest occupational status. We hypothesized that this is due to the

underdiagnoses in children of unemployed parents and the overdiagnoses in children with parents of higher occupational status. Our finding of higher mortality and morbidity risks in children in areas with lowest household income suggests the presence of structural disparities likely resulting from a lack of resources in less affluent neighborhoods [34].

The magnitudes of the effects of SES measures vary by outcomes, emphasizing the importance of tailoring the choice of measure when investigating connections between SES and specific outcomes [6]. Among the three SES measures at birth, parental education consistently has the strongest effect regardless of the outcomes. Parental occupation and area household income explained about 14.3% of the mortality risk related to parental education. Previous research on the mediating effect of occupation on education has primarily focused on adult populations, with reported PM ranging from 11.0% to 49.9% [35–39]. The modest mediating effects of parental occupation and area household income on the relationship between parental education and childhood mortality- and the absence of such effects on childhood morbidities- observed in our study could be due to how SES impacts child health differently from adult health. Our recommendation for future research on childhood health that seeks to control for or examine the influence of socioeconomic background is to apply a multidimensional SES perspective which incorporates multiple and distinct resource indicators. Additionally, employing advanced statistical models that enhance the causal interpretation is warranted for a deeper understanding of both the direct and indirect effects of each SES dimension as well as the overall SES-outcome relationship.

Limitations of our study include the absence of household-level income data [40] and the use of census tract-level median household income as the sole area-based SES measure. Using a variety of area-based measures of education, poverty, and occupation in addition to income or a summary score of area socioeconomic environment to characterize neighborhood would help increase our understanding of the impact of childhood residency on health outcomes [41, 42]. Another limitation is the lack of adjustments for place-based built, social, and natural environments, particularly applicable to childhood asthma [43]. However, given the interrelations between multiple area-based measures [44] and the long study period, standardizing multiple SES measures or developing a valid summary score harmonized over three decades is outside the scope of this study.

The study offers several advantages and strengths. Our approach of examining SES takes advantage of the publicly available harmonized SES measures, which is useful in longitudinal research due to its simplicity and ease of interpretability. In addition, our cohort is taken from a very large and comprehensive population database that includes all persons in Utah. Thus, we are able to control for important confounding and mediating factors while assessing the role of SES at birth on childhood health.

In conclusion, our study introduced an approach to standardize individual-level and neighborhood-level SES measures from administrative data to support longitudinal analyses and confirmed the importance of choosing SES measures attentively when analyzing childhood health. We aim to investigate potential variations in the correlations between individual-level and neighborhood-level SES measures over time in future research. In

addition, we encourage the routine collection of socioeconomic data in state and federal vital statistics to monitor and reduce social inequalities in health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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List of Abbreviations and Acronyms:

ACS	American Community Survey
CI	Confidence Interval
FTT	Failure-to-thrive
ICD	International Classification of Disease
HR	Hazard Ratio
NPBOSS	Nam-Power-Boyd Occupational Status Score
PM	Proportion Mediated
SD	Standard Deviation
SES	Socioeconomic Status
UPDB	Utah Population Database

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Highlights:

- Introduce approaches to standardize multiple SES measures from administrative data across multiple decades to support longitudinal analyses.
- Individual-level and neighborhood-level SES measures, though correlated, are distinct indicators of social standing.
- The impact of SES measures on childhood health depends both on the outcomes and the specific SES measures.
- Parental occupation and area household income mediate the effect of parental education on childhood mortality but not failure-to-thrive and childhood asthma.

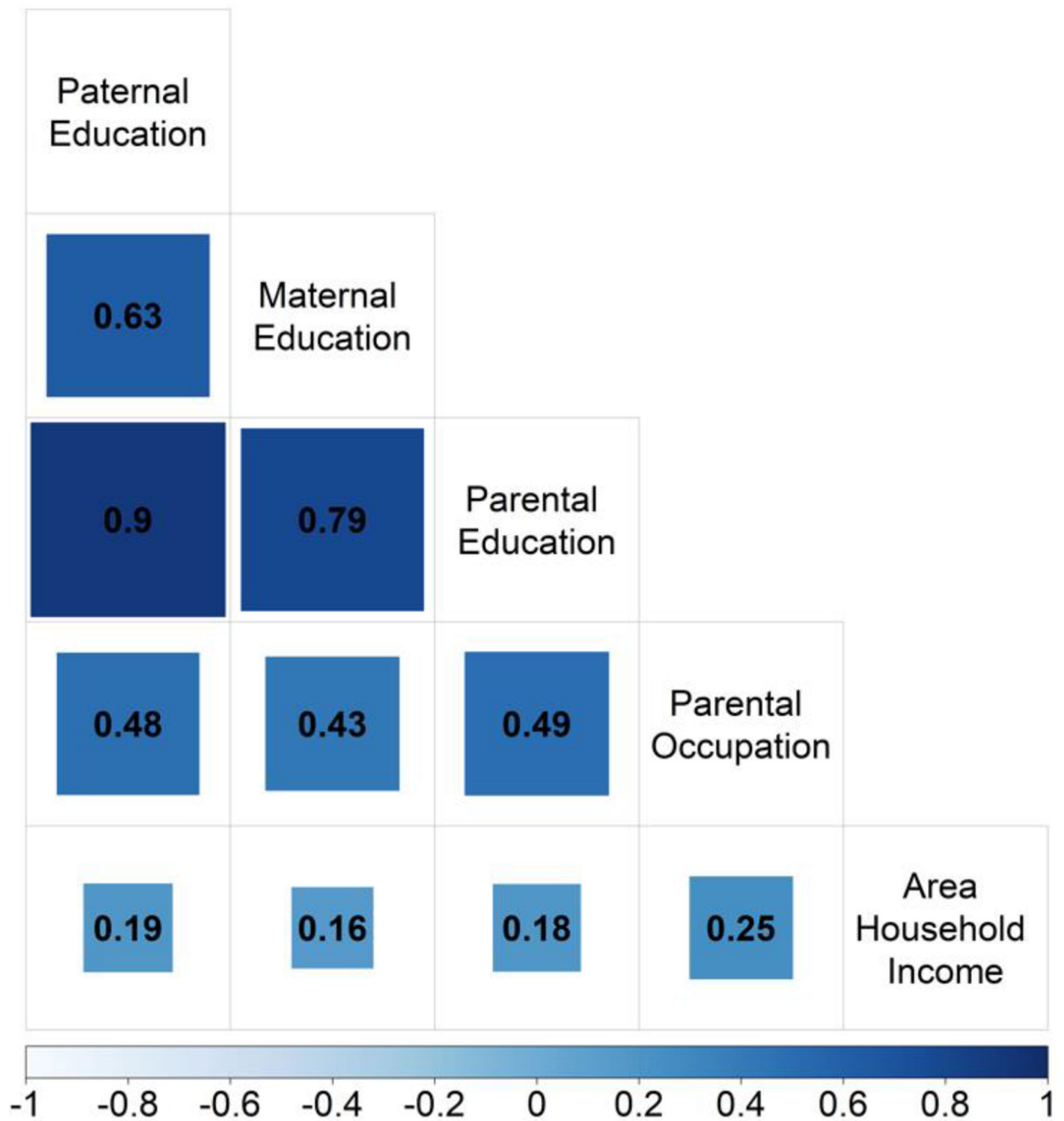


Figure 1:
Spearman Correlation matrix for measures of parental socioeconomic status.

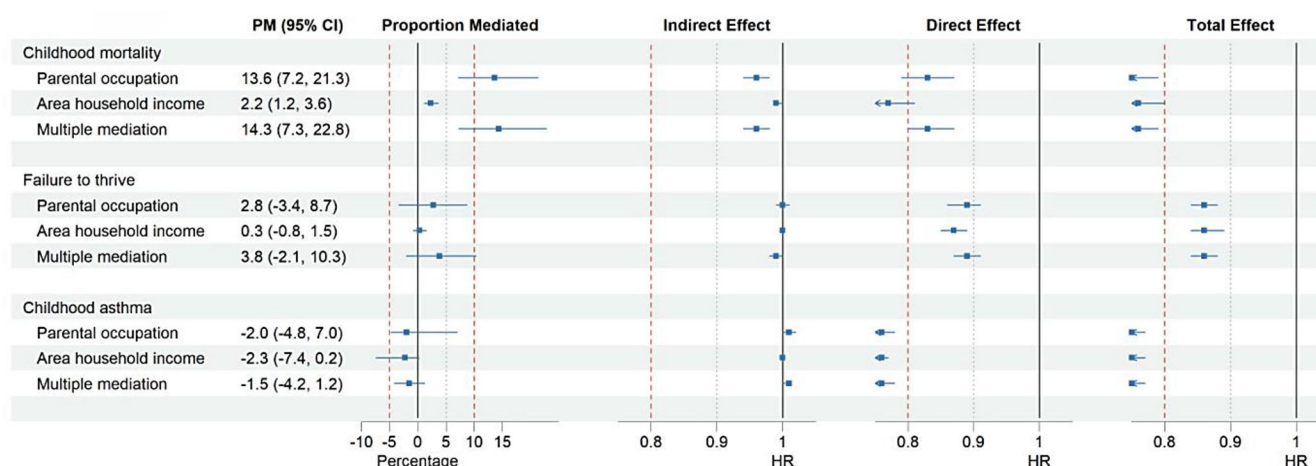


Figure 2:

Mediation of the associations between parental education and childhood health outcomes by parental occupation and area household income including exposure-mediator interaction.

Abbreviation: PM: Proportion Mediated, HR: Hazard Ratio, CI: Confidence Interval

Note:

1. Single mediation models were performed for each mediator, along with a multiple mediation model incorporating both mediators. Each mediation analysis included two components: a Cox regression model estimating the direct effect of parental education adjusting for mediator(s), and a linear regression model assessing the association between parental education and the mediator(s). All models were additionally adjusted for child's birth year, sex, race (whether Caucasians), ethnicity (whether Hispanic), birth order (whether first born), and maternal characteristics, which include her residential county classification (whether urban, rural, or frontier), age at birth, and marital status at time of birth (whether married).
2. The indirect effect is the effect between exposure (parental education) and outcome (childhood mortality, failure to thrive, and childhood asthma) caused by the mediating variable(s) (parental occupation and area household income). The direct effect is the effect of the exposure (parental education) on the outcome (childhood mortality, failure to thrive, and childhood asthma) absent of the mediator(s). The total effect is the sum of the indirect effect and the direct effect. Proportion mediated is how large part of the total effect that is explained by the indirect effect.

Table 1:

Sociodemographic characteristics as reported in birth certificates of analysis cohort

	All	Childhood mortality	Failure-to-thrive	Childhood asthma
N	819,108	8,134	25,281	35,594
Age of outcome occurrence	-	3.5 (5.7)	0.1 (0.2)	8.2 (5.6)
Median (IQR)	-	0.3 (0, 4.3)	0 (0, 0)	7.3 (2.8, 13.5)
Demographic characteristics				
Male	420,733 (51.4%)	4,848 (59.6%)	13,468 (53.3%)	21,011 (59.0%)
Birth year	1995.3 (9.3)	1992.2 (9.6)	2004.1 (3.5)	1999.0 (6.4)
Median (IQR)	1997 (1986, 2003)	1993 (1983, 2001)	2005 (2002, 2007)	2000 (1996, 2004)
Whether Caucasian				
Yes	713,243 (87.1%)	7,602 (93.5%)	21,484 (85.0%)	31,820 (89.4%)
No	36,344 (4.4%)	453 (5.6%)	1,265 (5.0%)	2,517 (7.1%)
Unknown	69,521 (8.5%)	79 (1.0%)	2,532 (10.0%)	1,257 (3.5%)
Whether Hispanic				
No	565,184 (69.0%)	7,273 (89.4%)	17,703 (70.0%)	26,943 (75.7%)
Yes	86,994 (10.6%)	731 (9.0%)	4,001 (15.8%)	5,429 (15.2%)
Unknown	166,930 (20.4%)	130 (1.6%)	3,577 (14.1%)	3,222 (9.0%)
Whether first-born	260,814 (31.8%)	2,487 (30.6%)	9,857 (39.0%)	11,533 (32.4%)
Maternal residence county classification ¹				
Urban	698,354 (85.3%)	6,903 (84.9%)	20,912 (82.7%)	29,698 (83.4%)
Rural	108,530 (13.2%)	1,110 (13.6%)	3,964 (15.7%)	5,197 (14.6%)
Frontier	12,224 (1.5%)	121 (1.5%)	405 (1.6%)	699 (2.0%)
Whether born to single mothers	54,432 (6.6%)	676 (8.3%)	3,267 (12.9%)	4,557 (12.8%)
Maternal age	27.3 (5.3)	26.9 (5.7)	27.6 (5.4)	26.9 (5.4)
Median (IQR)	26.7 (23.4, 30.8)	26.2 (22.7, 30.6)	27.0 (23.6, 31.1)	26.3 (22.9, 30.4)
Socioeconomic characteristics				
Paternal education attainment				
Less than high school	72,015 (8.8%)	970 (11.9%)	3,180 (12.6%)	4,855 (13.6%)
High school graduate	229,042 (28.0%)	2,672 (32.8%)	7,360 (29.1%)	12,471 (35.0%)
Some college	236,087 (28.8%)	2,305 (28.3%)	6,631 (26.2%)	9,348 (26.3%)
College graduate	149,301 (18.2%)	1,145 (14.1%)	4,227 (16.7%)	4,649 (13.1%)
Post college	132,663 (16.2%)	1,042 (12.8%)	3,883 (15.4%)	4,271 (12.0%)
Maternal education attainment				
Less than high school	82,645 (10.1%)	1,211 (14.9%)	3,283 (13.0%)	5,438 (15.3%)
High school graduate	264,119 (32.2%)	2,985 (36.7%)	7,821 (30.9%)	13,085 (36.8%)
Some college	270,796 (33.1%)	2,418 (29.7%)	7,416 (29.3%)	10,319 (29.0%)
College graduate	141,380 (17.3%)	1,065 (13.1%)	4,369 (17.3%)	4,376 (12.3%)
Post college	60,168 (7.3%)	455 (5.6%)	2,392 (9.5%)	2,376 (6.7%)

	All	Childhood mortality	Failure-to-thrive	Childhood asthma
Parental education attainment				
Less than high school	42,140 (5.1%)	591 (7.3%)	1,952 (7.7%)	2,781 (7.8%)
High school graduate	195,759 (23.9%)	2,445 (30.1%)	6,388 (25.3%)	11,281 (31.7%)
Some college	240,439 (29.4%)	2,421 (29.8%)	6,708 (26.5%)	10,318 (29.0%)
College graduate	180,610 (22.0%)	1,403 (17.2%)	5,161 (20.4%)	5,732 (16.1%)
Post college	160,160 (19.6%)	1,274 (15.7%)	5,072 (20.1%)	5,482 (15.4%)
Parental occupational status				
Both unemployed	26,306 (3.2%)	296 (3.6%)	749 (3.0%)	948 (2.7%)
Only mother employed	26,609 (3.2%)	276 (3.4%)	784 (3.1%)	838 (2.4%)
Only father employed	364,784 (44.5%)	3,868 (47.6%)	10,638 (42.1%)	14,134 (39.7%)
Both employed	401,409 (49.0%)	3,694 (45.4%)	13,110 (51.9%)	19,674 (55.3%)
Parental occupation ²				
Unemployed	26,306 (3.2%)	296 (3.6%)	749 (3.0%)	948 (2.7%)
NPBOSS Quartile 1 (1-38)	210,978 (25.8%)	2,655 (32.6%)	7,196 (28.5%)	10,865 (30.5%)
NPBOSS Quartile 2 (39-61)	185,804 (22.7%)	1,920 (23.6%)	5,101 (20.2%)	8,493 (23.8%)
NPBOSS Quartile 3 (62-85)	246,942 (30.1%)	2,097 (25.8%)	7,595 (30.0%)	9,699 (27.2%)
NPBOSS Quartile 4 (86-100)	149,078 (18.2%)	1,166 (14.3%)	4,640 (18.4%)	5,589 (15.7%)
Area household income ³				
Quartile 1	204,856 (25.0%)	2,256 (27.7%)	6,909 (27.3%)	9,397 (26.4%)
Quartile 2	204,190 (24.9%)	2,153 (26.5%)	6,107 (24.2%)	9,319 (26.2%)
Quartile 3	205,257 (25.1%)	1,961 (24.1%)	6,145 (24.4%)	8,817 (24.8%)
Quartile 4	204,805 (25.0%)	1,764 (21.7%)	6,120 (24.2%)	8,061 (22.6%)

¹Classified by Utah Department of Health and Human Services using 2018 data. Urban counties have a population density of > 100 people per sq. mile; Rural counties have a population density of <99 and > 6 people per sq. mile and Frontier counties have < 6 people per sq. mile. (<https://ruralhealth.health.utah.gov/portal/county-classifications-map/>)

²Parental occupation based on parental occupational status and Nam-Power-Boyd occupational status score (NPBOSS). Detailed on how this variable was derived can be found in the Method and Appendix sections.

³Area household income based on maternal residential addresses (or mailing addresses if residential addresses are missing). Detailed on how this variable was derived can be found in the Method and Appendix sections.

Note: N (%) was reported for categorical variables; Mean (Standard Deviation [SD]) and Median (Interquartile Range [IQR]) was reported were continuous variables.

Table 2: Associations between parental socioeconomic status (SES) measures as continuous variables with childhood health outcomes.

	Hazard Ratio (95% Confidence Interval)						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Childhood mortality							
Parental education	0.87 (0.85, 0.89)*	-	-	0.90 (0.88, 0.92)*	0.88 (0.86, 0.90)*	-	0.90 (0.88, 0.92)*
Parental occupation	-	0.89 (0.97, 0.91)*	-	0.92 (0.90, 0.94)*	-	0.90 (0.88, 0.91)*	0.93 (0.91, 0.95)*
Area household income	-	-	0.92 (0.90, 0.94)*	-	0.93 (0.91, 0.95)*	0.94 (0.92, 0.96)*	0.94 (0.92, 0.96)*
Failure to thrive							
Parental education	0.93 (0.92, 0.94)*	-	-	0.94 (0.92, 0.95)*	0.93 (0.92, 0.94)*	-	0.94 (0.92, 0.95)*
Parental occupation	-	0.96 (0.95, 0.97)*	-	0.98 (0.97, 0.99)#	-	0.96 (0.95, 0.97)*	0.98 (0.97, 1.00)≠
Area household income	-	-	0.97 (0.96, 0.98)*	-	0.98 (0.97, 0.99)*	0.98 (0.97, 0.99)*	0.98 (0.97, 0.99)*
Childhood asthma							
Parental education	0.87 (0.86, 0.88)*	-	-	0.87 (0.86, 0.88)*	0.87 (0.86, 0.88)*	-	0.87 (0.86, 0.88)*
Parental occupation	-	0.95 (0.94, 0.96)*	-	1.00 (0.99, 1.01)	-	0.95 (0.94, 0.96)*	1.00 (0.99, 1.01)
Area household income	-	-	0.97 (0.97, 0.98)*	-	0.99 (0.98, 1.00)#	0.98 (0.97, 0.99)*	0.99 (0.98, 1.00)#

* denotes p-value < 0.001;

denotes p-value < 0.01;

≠ denotes p-value < 0.05

Note: All Cox-proportional hazard models were additionally adjusted for child's birth year, sex, race (whether Caucasians), ethnicity (whether Hispanic), birth order (whether first born), and maternal characteristics, which include her residential county classification (whether urban, rural, or frontier), age at birth, and marital status at time of birth (whether married) and fitted with the sandwich estimator to account for clustering induced by multiple births within families. Models 1-3 adjusted for individual SES measure, models 4-6 adjusted for pairs of SES measures, and model 7 included all three SES measures simultaneously.

Table 3: Associations between parental socioeconomic status (SES) measures as categorical variables with childhood health outcomes.

	Childhood mortality		Failure to thrive		Childhood asthma	
	HR (95% CI)	p-value	HR (95% CI)	p-value	HR (95% CI)	p-value
Parental education						
Less than high school	1.23 (1.12, 1.35)	<0.001	1.12 (1.06, 1.18)	<0.001	1.00 (0.96, 1.05)	0.860
High school graduate (ref)	1.00		1.00		1.00	
Some college	0.86 (0.81, 0.91)	<0.001	0.92 (0.89, 0.95)	<0.001	0.83 (0.81, 0.85)	<0.001
College graduate	0.75 (0.69, 0.80)	<0.001	0.82 (0.78, 0.85)	<0.001	0.63 (0.61, 0.65)	<0.001
Post college	0.79 (0.73, 0.85)	<0.001	0.85 (0.81, 0.89)	<0.001	0.67 (0.65, 0.70)	<0.001
Parental occupation						
Both parents unemployed	1.29 (1.13, 1.47)	<0.001	1.00 (0.92, 1.08)	0.917	0.95 (0.89, 1.02)	0.167
NPBOSS Quartile 1 (1-38)	1.22 (1.13, 1.32)	<0.001	1.06 (1.02, 1.11)	0.007	0.98 (0.95, 1.02)	0.384
NPBOSS Quartile 2 (39-61)	1.04 (0.96, 1.13)	0.281	0.98 (0.94, 1.03)	0.400	1.01 (0.98, 1.05)	0.484
NPBOSS Quartile 3 (62-85)	1.00 (0.93, 1.08)	0.914	1.01 (0.97, 1.05)	0.709	0.97 (0.94, 1.01)	0.131
NPBOSS Quartile 4 (86-100) (ref)	1.00		1.00		1.00	
Area household income						
Quartile 1	1.20 (1.12, 1.28)	<0.001	1.06 (1.03, 1.10)	0.001	1.04 (1.01, 1.08)	0.012
Quartile 2	1.12 (1.05, 1.19)	<0.001	0.98 (0.95, 1.02)	0.423	1.04 (1.01, 1.07)	0.013
Quartile 3	1.05 (0.98, 1.12)	0.147	0.99 (0.95, 1.02)	0.424	1.01 (0.98, 1.04)	0.608
Quartile 4 (ref)	1.00		1.00		1.00	

Abbreviation: Nam-Power-Boyd Occupational Status Scores (NPBOSS), HR: Hazard Ratio, CI: Confidence Interval

Note: All Cox-proportional hazard models were additionally adjusted for child's birth year, sex, race (whether Caucasians), ethnicity (whether Hispanic), birth order (whether first born), and maternal characteristics, which include her residential county classification (whether urban, rural, or frontier), age at birth, and marital status at time of birth (whether married) and fitted with the sandwich estimator to account for clustering induced by multiple births within families.