

Supplemental Content

Combined environmental and social exposures during pregnancy and associations with neonatal size and body composition: the Healthy Start study

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Conflicts of Interest

The authors have no conflicts to declare.

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Reproducibility

Code used to generate the exposure indices will be made available upon request. Personal health and geographical data are protected under an IRB protocol and are not available for distribution.

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Analysis of odds of living in a high exposure census tract by race/ethnicity and maternal education

We found that maternal race/ethnicity and educational attainment were predictors of living in high ENV, SOC, and CEI census tracts, but that relationships differed based on the index used (eTable 6). Average SOC, and CEI scores were higher for non-Hispanic White (NHW) mothers and mothers with low educational attainment relative to white mothers and mothers with advanced degrees, respectively (Figure 4 in the main paper). Latina, African American, and other race/ethnicity mothers had statistically significantly higher odds of living in a census tract with SOC and CEI scores above the 75th percentile relative to NHW mothers (eTable 6). Unadjusted odds ratios for living in high SOC census tracts were highest for Latina mothers (OR = 3.4, 95% CI: 2.4 – 4.9), and unadjusted odds ratios for living in high CEI census tracts were highest for African American mothers (OR = 2.7, 95% CI: 1.8 – 4.1). No relationships between race/ethnicity and odds of living in a high ENV census tract were observed. When using the 95th percentile as a cutoff for “high” exposure census tracts, odds ratios remained similar for SOC and became non-significant for CEI, suggesting the strongest associations are between SOC and race/ethnicity (eTable 7).

Similar patterns for associations between SOC and CEI were observed for mothers with lower educational attainment. Unadjusted odds of living in high SOC and CEI census tracts for mothers with less than a high school education were 4.2 (95% CI: 2.5 – 7.0) and 3.5 (2.1 – 5.8) times higher, respectively, than for mothers with a graduate or professional degree. As with the associations with race/ethnicity, associations with SOC were similar when using the 95th percentile cut-point and associations with CEI became non-significant (eTable 7).

In contrast to the SOC and CEI, non-white race and lower maternal education tended to be associated with lower odds of living in a high ENV census tract, though relationships between race/ethnicity and ENV were not statistically significant. For example, mothers with a high school education had an odds ratio of 0.6 (0.4 – 1.0) relative to mothers with a graduate or professional degree. eFigure 2 shows how Healthy Start mothers are categorized by educational attainment and ENV score.

Supplemental Tables

eTable 1. Comparison of outcome variables and potential covariates for dyads with and without exposure data based on the location of the first known address

Variable		With exposures (n = 1151)	No exposures (n = 259)	p-value ^a
Maternal Race/Ethnicity				
Hispanic/Latina	n (%)	312 (27)	39 (15)	< 0.001
White non-Hispanic	n (%)	571 (50)	180 (69)	
African American	n (%)	194 (17)	25 (10)	
Other	n (%)	74 (6)	15 (6)	
Maternal age (years)	mean (SD)	27.5 (6.3)	29.3 (5.67)	< 0.001
Mean CPSS Score	mean (SD)	18.7 (3.2)	19.3 (3.1)	0.007
Mean EPDS Score	mean (SD)	4.3 (3.4)	4.6 (3.7)	0.254
Pre-pregnancy body mass index (kg/m²)				
Underweight (< 18.5)	n (%)	38 (3)	6 (2)	0.679
Normal (18.5 - 25)	n (%)	590 (51)	137 (54)	
Overweight (25 - 30)	n (%)	288 (25)	67 (26)	
Obese (> 30)	n (%)	234 (20)	46 (18)	
Maternal education level				
Less than high school	n (%)	179 (16)	25 (10)	0.060
High school or GED	n (%)	218 (19)	41 (16)	
Some college/Associate's	n (%)	268 (23)	66 (25)	
Bachelor's Degree	n (%)	243 (21)	66 (25)	
Graduate Degree	n (%)	243 (21)	61 (24)	
Household level income				
Less than \$40,000	n (%)	348 (30)	66 (25)	0.066
\$40,000 - \$70,000	n (%)	209 (18)	51 (20)	
Greater than \$70,000	n (%)	360 (31)	100 (39)	
Missing or Don't Know	n (%)	234 (20)	42 (16)	
Any smoking during pregnancy?				
Yes	n (%)	101 (9)	23 (9)	1.000
No	n (%)	1,050 (91)	236 (91)	
Any SHS exposure during pregnancy?				
Yes	n (%)	271 (26)	43 (21)	0.172
No	n (%)	765 (74)	159 (79)	
Infant sex				
Male	n (%)	585 (52)	111 (53)	0.751
Female	n (%)	548 (48)	98 (47)	
Gestational age (weeks)	mean (SD)	39.2 (2.0)	39.3 (1.5)	0.399
Term status				
Pre-term (< 37 weeks)	n (%)	82 (7)	8 (4)	0.337
Early Term (37 to < 39 weeks)	n (%)	272 (24)	59 (28)	
Full Term (39 to < 41 weeks)	n (%)	676 (59)	126 (59)	
Late Term (41 to < 42 weeks)	n (%)	108 (9)	18 (8)	
Post-term (>= 42 weeks)	n (%)	13 (1)	2 (1)	
Birth weight (g)	mean (SD)	3,197.7 (550.5)	3,242.0 (461.3)	0.213
Low birth weight (< 2500 g)	n (%)	90 (8)	14 (7)	0.613
Days from delivery to PEA POD (n)	mean (SD)	1.6 (2.3)	2.2 (3.0)	0.008
Body mass (g)	mean (SD)	3,121.4 (448.5)	3,160.2 (403.3)	0.264
Fat mass (g)	mean (SD)	293.8 (154.2)	308.8 (141.6)	0.217
Fat free mass (g)	mean (SD)	2,827.3 (355.9)	2,852.2 (327.7)	0.375

Adiposity (%)	mean (SD)	9.1 (4.0)	9.6 (3.8)	0.155
Weight for length z-score	mean (SD)	-0.4 (1.0)	-0.4 (0.9)	0.619

^a Chi square test for categorical variables; Student's t test for continuous variables

Abbreviations: CPSS: Cohen Perceived Stress Scale; EPSD: Edinburgh Postnatal Depression Scale; SHS: secondhand smoke

eTable 2. Mean (SD) exposure index values by race/ethnicity and maternal educational attainment for all mothers with complete exposure, outcome, and covariate data (n = 897)

Race/Ethnicity	ENV			SOC		CE	
	n	Mean (SD)	p value ^a	Mean (SD)	p value ^a	Mean (SD)	p value ^a
Latina	238	31.7 (8.9)	0.474	43.3 (14.9)	<0.001	13.8 (6.2)	<0.001
African American	154	32.1 (9.2)	0.848	41.1 (14.4)	<0.001	13.4 (7)	<0.001
Other	60	30.5 (8.4)	0.276	38.2 (17.1)	0.002	11.8 (6.3)	0.104
Non-Hispanic White	445	32.8 (9.8)	Ref.	30.7 (15.5)	Ref.	10.4 (6.7)	Ref.
Educational Attainment		Mean (SD)	p value ^b	Mean (SD)	p value ^b	Mean (SD)	p value ^b
No HS Diploma	137	31.3 (8.8)	0.019	44.9 (13.1)	<0.001	14.1 (5.7)	<0.001
HS Diploma	166	31 (8.8)	0.004	42.4 (15.5)	<0.001	13.5 (7.2)	<0.001
Some College / AA	208	31.8 (8.9)	0.031	38.2 (16.1)	<0.001	12.4 (6.8)	0.011
College Degree	196	32 (10.1)	0.067	30.3 (15)	0.897	10.0 (6.4)	0.994
Advanced Degree	190	34.5 (9.9)	Ref.	29 (15.1)	Ref.	10.3 (6.7)	Ref.

^a p values for Tukey's test for multiple comparisons using non-Hispanic white as the reference group

^b p values for Tukey's test for multiple comparisons using Advanced Degree as the reference group

eTable 3. Sensitivity analysis of associations (95% CI) between exposure indices and birth outcomes using all births. SOC and ENV include the additional variables percentage of the population that is persons of color and median income at the census tract level. Effect estimates (and 95% confidence intervals) are reported for a 10 unit increase in ENV, SOC and CE.

Outcome	Model	n	ENV	SOC	CE
Birth weight (g)	Crude	897	-13.3 (-50.0, 23.3)	-37.7 (-57.9, -17.6)	-82.3 (-131.4, -33.2)
	Adjusted ^a	897	-13.4 (-40.8, 14)	-22.4 (-38.4, -6.3)	-51.8 (-88.7, -14.8)
	Reduced ^{b, c, d}	897	—	-26.1 (-40.8, -11.4)	-54.2 (-90.4, -18.1)
Adiposity (%)	Crude	780	-0.1 (-0.3, 0.2)	-0.1 (-0.3, 0.0)	-0.4 (-0.8, 0.0)
	Adjusted ^a	780	-0.1 (-0.4, 0.2)	-0.2 (-0.4, 0.0)	-0.5 (-0.9, -0.1)
	Reduced ^{e, f}	780	—	-0.2 (-0.4, -0.1)	-0.6 (-0.9, -0.2)
Weight-for-length z-score	Crude	770	0.0 (-0.1, 0.1)	0.0 (0.0, 0.1)	0.1 (0.0, 0.2)
	Adjusted ^a	770	0.0 (-0.1, 0.1)	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.1)
	Reduced	770	—	—	—

^a Adjusted for gestational age (weeks), infant sex, maternal age at delivery, average CPSS score across pregnancy, average EPDS score across pregnancy, maternal pre-pregnancy BMI, gravidity, season of birth, self-reported smoking during pregnancy, maternal race/ethnicity, and maternal education. Models for adiposity also adjusted for number of days between delivery and air displacement plethysmography (PEA POD) measurements.

^b ENV model adjusts for gestational age (weeks), infant sex, gravidity, pre-pregnancy BMI, any smoking during pregnancy, SHS exposure during pregnancy, and non-white race

^c SOC model adjusted for gestational age (weeks), infant sex, gravidity, pre-pregnancy BMI, any smoking during pregnancy, exposure to SHS during pregnancy, and African American race

^d CE model adjusted for gestational age (weeks), infant sex, gravidity, pre-pregnancy BMI, any smoking during pregnancy, exposure to SHS during pregnancy, and Latina and African American race

^e SOC model adjusts for gestational age (weeks), number of days between delivery and PEA POD measurements, infant sex, gravidity, maternal age, average EPDS score across pregnancy, pre-pregnancy BMI, any smoking during pregnancy, and education level below a 4-year degree

^f CE model adjusts for gestational age (weeks), number of days between delivery and PEA POD measurements, infant sex, gravidity, maternal age, average EPDS score across pregnancy, pre-pregnancy BMI, any smoking during pregnancy, Latina and other race, and education level below a 4-year degree

Abbreviations: BMI: body mass index; CE: combined exposure index; CPSS: Cohen Perceived Stress Scale; EPDS: Edinburgh Postnatal Depression Scale ENV: environmental exposure index; SOC: social exposure index; SHS: secondhand smoke

eTable 4. Associations (95% CI) between ENV and SOC when categorized into tertiles. For each model, the reference group are participants with ENV and SOC in the lowest tertile (n = 116).

Exposure group	n	Model	Birth weight (g) ^a	Adiposity (%) ^b	WLF and sex z-score
ENV low, SOC mid	102	Crude	-95.9 (-235, 43.1)	-0.5 (-1.7, 0.6)	0.0 (-0.3, 0.2)
		Adjusted	-45.2 (-143.5, 53)	-0.2 (-1.3, 0.8)	—
ENV low, SOC high	87	Crude	-202.0 (-347.3, -56.7)	-0.3 (-1.5, 0.8)	0.1 (-0.2, 0.4)
		Adjusted	-94.0 (-198.5, 10.5)	-0.5 (-1.6, 0.6)	—
ENV mid, SOC low	98	Crude	-142.6 (-283.2, -2.0)	-0.6 (-1.7, 0.6)	-0.1 (-0.3, 0.2)
		Adjusted	-48.6 (-149.7, 52.5)	-0.1 (-1.2, 1)	—
ENV mid, SOC mid	99	Crude	-69.0 (-209.2, 71.2)	0.1 (-1.0, 1.2)	0.1 (-0.2, 0.4)
		Adjusted	-12.6 (-112.7, 87.4)	0.2 (-0.9, 1.2)	—
ENV mid, SOC high	93	Crude	-240.9 (-383.5, -98.3)	-1.7 (-2.9, -0.6)	0.1 (-0.2, 0.3)
		Adjusted	-101.5 (-206.3, 3.2)	-1.6 (-2.7, -0.5)	—
ENV high, SOC low	81	Crude	-91.1 (-239.4, 57.3)	0.1 (-1.0, 1.3)	-0.1 (-0.4, 0.2)
		Adjusted	-26.5 (-132.7, 79.6)	0.3 (-0.8, 1.4)	—
ENV high, SOC mid	92	Crude	-60.5 (-203.5, 82.6)	0.2 (-1.0, 1.3)	0.1 (-0.2, 0.4)
		Adjusted	-6.0 (-108.2, 96.3)	0.3 (-0.8, 1.4)	—
ENV high, SOC high	129	Crude	-225.9 (-357, -94.7)	-0.8 (-1.9, 0.2)	0.1 (-0.2, 0.3)
		Adjusted	-160.7 (-256.2, -65.1)	-1.0 (-2.0, 0.1)	—

^a Birth weight model is adjusted for gestational age (weeks), infant sex, birth season, gravidity, pre-pregnancy BMI, any smoking during pregnancy, exposure to SHS during pregnancy, and race/ethnicity

^b Adiposity model is adjusted for gestational age (weeks), infant sex, birth season, days between delivery and PEA POD measurements infant sex, gravidity, maternal age, average EPDS score across pregnancy, pre-pregnancy BMI, any smoking during pregnancy, race/ethnicity, and maternal education

Abbreviations: BMI: body mass index; EPDS: Edinburgh Postnatal Depression Scale ENV: environmental exposure index; SOC: social exposure index; SHS: secondhand smoke; WFL: weight-for-length

eTable 5. Comparison of linear regression coefficients (SE) for linear models of the relationship between each of the exposure indices and birth weight or adiposity when controlling for the other indices and an interaction term for ENV × SOC. Table reports the change in outcome (in grams, percentage points, or z-score) per unit change in index score.

Index	Co-Indices ^a	Birth weight (g)	Adiposity (%)
ENV	—	-1.9 (1.3)	-0.01 (0.02)
ENV	SOC	-0.6 (1.4)	-0.01 (0.02)
ENV	SOC + CE	1.7 (3.0)	0.03 (0.03)
ENV	SOC + ENV × SOC	1.7 (3.0)	0.03 (0.03)
SOC	—	-2.4 (0.8)	-0.02 (0.01)
SOC	ENV	-2.3 (0.9)	-0.02 (0.01)
SOC	ENV + CE	-0.2 (2.5)	0.01 (0.03)
SOC	ENV + ENV × SOC	-0.2 (2.5)	0.01 (0.03)
ENV × SOC	ENV + SOC	-0.06 (0.07)	-0.0011 (0.0008)
CE	ENV + SOC	-6.4 (7.3)	-0.11 (0.08)

^a Models are also adjusted for gestational age (weeks), infant sex, maternal age at delivery, average CPSS score across pregnancy, average EPDS score across pregnancy, maternal pre-pregnancy BMI, gravidity, self-reported smoking and secondhand smoke exposure during pregnancy, maternal race/ethnicity, maternal education, and season of birth. Models for adiposity also adjusted for number of days between delivery and air displacement plethysmography (PEA POD) measurements.

Abbreviations: WLF: sex-specific weight-for-length

eTable 6. Odds ratios (95% CI) of living in a high exposure index census tract (index > 75th percentile) by race/ethnicity and maternal education.

Characteristic		ENV	SOC ^a	CE ^a
Race/Ethnicity	n			
Latina	238	0.83 (0.58 - 1.20)	3.45 (2.41 - 4.94)	2.73 (1.90 - 3.94)
African American	154	0.75 (0.49 - 1.16)	2.71 (1.79 - 4.10)	2.56 (1.68 - 3.88)
Other	60	0.66 (0.34 - 1.29)	2.32 (1.28 - 4.23)	1.67 (0.89 - 3.15)
Non-Hispanic White	445	Ref.	Ref.	Ref.
Maternal Education	n			
No high school diploma	137	0.60 (0.37 - 1.00)	4.20 (2.50 - 7.07)	3.47 (2.06 - 5.83)
High school graduate	166	0.57 (0.35 - 0.92)	3.31 (2.00 - 5.49)	2.37 (1.42 - 3.94)
Some college/AA degree	208	0.62 (0.40 - 0.96)	2.47 (1.51 - 4.04)	2.16 (1.32 - 3.54)
College graduate (BA/BS)	196	0.67 (0.43 - 1.04)	1.00 (0.58 - 1.75)	0.96 (0.56 - 1.67)
Graduate or professional	190	Ref.	Ref.	Ref.

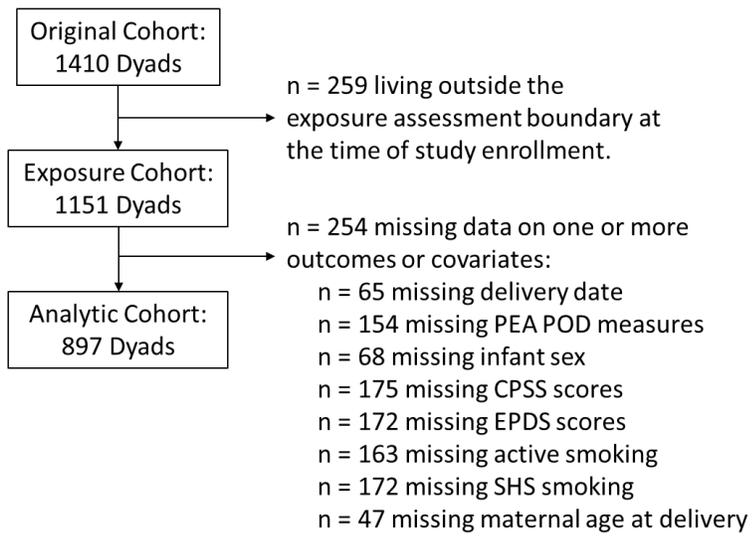
^aSOC and CE exclude the census tract indicators of percentage of the population that is persons of color and median household income

eTable 7. Sensitivity analysis for the odds of living in a high exposure index census tract. Odds ratios (95% CI) are based on the odds of living in a high exposure census tract (index > 95th percentile) by race/ethnicity and maternal education level.

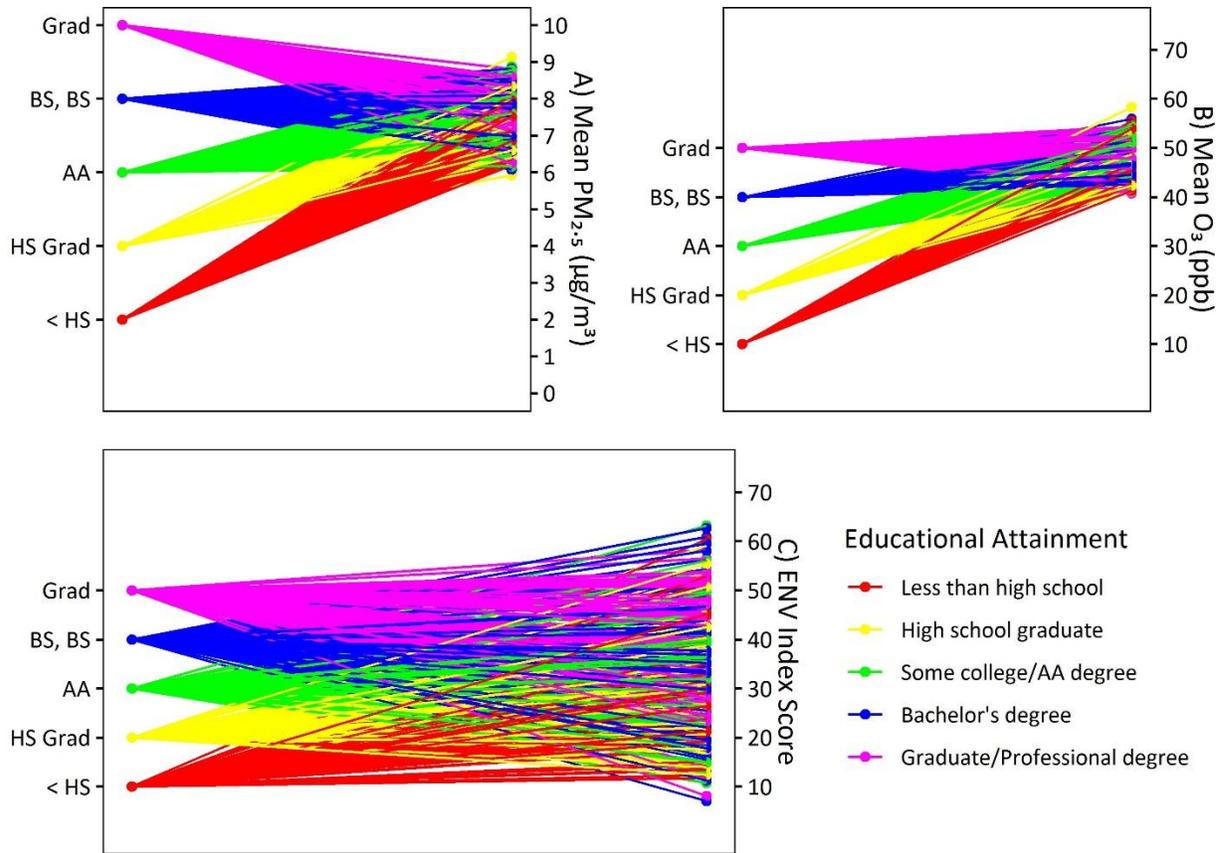
Characteristic		ENV	SOC ^a	CE ^a
Race/Ethnicity	n			
Latina	238	0.39 (0.17 - 0.90)	4.02 (1.91 - 8.44)	1.23 (0.63 - 2.41)
African American	154	0.34 (0.12 - 0.99)	2.45 (0.99 - 6.03)	0.87 (0.37 - 2.08)
Other	60	0.45 (0.10 - 1.91)	3.59 (1.20 - 10.7)	NA
Non-Hispanic White	445	Ref.	Ref.	Ref.
Maternal Education	n			
No high school diploma	137	0.20 (0.06 - 0.70)	4.46 (1.41 - 14.2)	0.68 (0.25 - 1.86)
High school graduate	166	0.34 (0.13 - 0.87)	4.28 (1.38 - 13.3)	0.85 (0.35 - 2.07)
Some college/AA degree	208	0.22 (0.08 - 0.61)	3.10 (0.99 - 9.68)	0.83 (0.36 - 1.92)
College graduate (BA/BS)	196	0.59 (0.28 - 1.25)	0.97 (0.24 - 3.93)	0.55 (0.21 - 1.43)
Graduate or professional	190	Ref.	Ref.	Ref.

^aSOC and CE exclude the census tract indicators of percentage of the population that is persons of color and median household income

Supplemental Figures



eFigure 1. Chart showing the inclusion and exclusion of mother-child dyads in the final analytic cohort



eFigure 2. Spaghetti plots comparing maternal educational attainment to a) mean PM_{2.5} exposures (µg/m³) across pregnancy; b) average daily 8 hour max ozone exposure (ppb) across pregnancy; and c) ENV scores. Includes all mothers with complete exposure, outcome, and covariate data (n = 897)