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Exposure to secondhand smoke, exclusive breastfeeding, and infant adiposity at age 5 months in the Healthy Start study

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Abstract

Background—Infant adiposity may be influenced by several environmental risk factors, but few studies have explored these interactions.

Objective—To examine the interaction between exposure to secondhand smoke and breastfeeding exclusivity on adiposity at age 5 months.

Methods—We studied 813 mother–offspring pairs from the longitudinal Healthy Start study. Fat mass and fat-free mass were measured by air displacement plethysmography. Linear regression analyses were used to estimate the association between household smokers (none, any) with fat mass, fat-free mass, percent fat mass, weight-for-age z-score, weight-for-length z-score, and BMI-for-age z-score as separate outcomes. Interaction terms between household smokers and breastfeeding exclusivity (<5 months, ≥5 months) were added to separate models.

Results—The combination of exposure to secondhand smoke and a lack of exclusive breastfeeding was associated with increased adiposity at age 5 months. For example, within the not exclusively breastfed strata, exposure to secondhand smoke was associated with increased fat mass (0.1 kg; 95% CI:0.0–0.2; p=0.05). Conversely, within the exclusively breastfed strata, there was virtually no difference in fat mass between exposed and non-exposed infants (coefficient:-0.1; 95% CI:−0.3–0.1; p=0.25).

Conclusions—Our findings may inform new public health strategies with potential relevance for both smoking cessation and obesity prevention.

Introduction

Childhood obesity continues to be a major global health problem.[1] In the United States (U.S.), nearly one in four children will be classified as either overweight or obese by the time they enter kindergarten.[2] This increasingly early onset suggests that obesity may be primed in early life.[3]

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Exposure to secondhand smoke is a common early-life exposure that may contribute to obesity risk,[4] Exposure to secondhand smoke is associated with a 30% increase in risk for obesity,[5–8] independent of maternal smoking during pregnancy. These findings are supported by experimental animal studies.[9,10] Although these associations are fairly consistent across studies, no published studies have examined the association between exposure to secondhand smoke and obesity among children younger than age 3 years or using a direct measure of body composition.

A susceptible period in which exposure to secondhand smoke may have serious effects on obesity is during lactation and breastfeeding.[11] It is well-established that any duration of exclusive breastfeeding lowers future risk for obesity.[12,13] Breast milk provides infants with anti-inflammatory and antioxidant protection,[14] which may counteract the adverse physiologic responses induced by exposure to compounds found in tobacco smoke.[15] However, the potential role of breastfeeding as an effect modifier may be complicated by an infant's exposure to tobacco byproducts via breast milk,[16] particularly if the mother is an active smoker. At present, there is inconclusive evidence about the potential effect-modifying role of exclusive breastfeeding on the association between exposure to secondhand smoke and infant weight.[17,18,19]

In this analysis, we examined the association between exposure to secondhand smoke and infant adiposity, incorporating a direct measure of body composition. We hypothesized that exposure to secondhand smoke would be associated with increased adiposity and growth at age 5 months, particularly among infants who were not exclusively breastfed.

Methods

Study population

The Healthy Start study recruited 1,410 pregnant women aged ≥16 years with singleton pregnancies before 24 weeks of gestation from prenatal obstetrics clinics at the University of Colorado Hospital between 2010 and 2014. Participants completed research visits during early pregnancy (median 17 weeks), mid-pregnancy (median 27 weeks), immediately after delivery (median 1 day), and at age 5 months. The original protocol included a phone interview at age 5 months, which was converted to an in-person visit in January 2011. Additional inclusion criteria for this study included infants born ≥37 weeks of gestation and infants with complete size and body composition measures at birth and at age 5 months. All women provided written informed consent. The study was approved by the Colorado Multiple Institutional Review Board. The Healthy Start study was registered as an observational study at clinicaltrials.gov as NCT02273297.

Secondhand smoke assessment

During the phone interview at age 5 months, mothers were asked to report the number of adults in the household who were regular smokers. Responses to this question ranged from zero to six. Due to the low number of responses in some of these categories, we dichotomized this data into no household smokers and any household smokers.

Infant adiposity

Fat mass, fat-free mass, and percent fat mass were calculated from total mass and volume using whole body air displacement plethysmography (PEA POD, COSMED, Rome, Italy). Weight was measured to the nearest 0.1g using a mobile digital baby scale (Seca 334, Medical Measuring Systems and Scales, Hamburg, Germany). Length was measured to the nearest 0.1 cm using a recumbent infant board with stadiometer (O'Leary Length Board, Ellard Instrumentation Ltd, Monroe, Washington). Trained research personnel measured each offspring outcome twice, with a third measurement taken when percent fat mass differed by >2.0%, weight differed by >0.3 kg, or height differed by >0.5 cm. The average of the two closest readings was used for analysis. Body mass index (BMI) was calculated by dividing weight in kilograms by height in meters squared. Age- and sex-specific weight-for-age, weight-for-length, and BMI-for-age z-scores were calculated using the 2006 World Health Organization growth charts.[20]

Breastfeeding exclusivity

Women reported patterns of infant feeding at the in-person visit at age 5 months. Women were asked in separate questions if they were currently feeding their infant any breast milk, had ever fed their infant formula, or were currently feeding their infant formula. The majority of participants (n=623, 77%) provided data on infant feeding on the same day that offspring body composition was measured. The remaining 23% of women (n=190) provided this information by phone up to 2 weeks prior to the in-person body composition measurements. For these participants who reported exclusive breastfeeding at the time of the phone interview (n=190, 23%), we used data collected using the same questions at an 18 month in-person visit to confirm that exclusive breastfeeding continued until the time of the body composition measurements. The breastfeeding exclusivity variable was dichotomized as exclusively breastfed from birth to age 5 months (if they answered yes to the first question and no to the remaining questions) and not exclusively breastfed (if they indicated mixed or formula feeding).

Covariates

Mother and infant characteristics were collected during the research visits. Maternal age at delivery was calculated by subtracting the participant's date of birth from the date of delivery. Household income in the previous year, maternal education, and maternal race and ethnicity were obtained through study questionnaires. During the prenatal research visits, mothers were asked to report any smoking during mid- to late-pregnancy, and at delivery. For this analysis, we dichotomized maternal smoking during pregnancy as those who reported smoking at any of the three prenatal research visits and mothers who did not report smoking at any visit. Mothers were asked to self-report the age in which they first introduced their child to various foods, such as rice cereal and pureed fruits/vegetables. National guidelines advise that the introduction of solid foods be delayed until age 4 months.[21] Therefore, we dichotomized mothers who reported introducing solid foods before age 4 months and mothers who reported introducing solid foods at or after age 4 months.

Statistical analyses

Linear regression analyses were used to estimate the association between exposure to secondhand smoke with infant adiposity in separate models, with fat mass (kg), fat-free mass (kg), adiposity (percent fat mass), weight-for-age z-score, weight-for-length z-score, and BMI-for-age z-score as separate outcomes. For the interaction analyses, a product term of household smokers (none, any) and breastfeeding exclusivity (<5 months, ≥5 months) was added into the linear regression models.

Covariates were identified a priori based on the literature:[18,19,21,22] maternal race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), maternal education (<high school, high school diploma, some college), household income (<$40,000, $40,001 to $70,000, >$70,000, missing or do not know), maternal smoking during pregnancy (yes, no), offspring age at examination (months), offspring sex, age at introduction of solid foods (<4 months, ≥4 months), and the respective indicators at birth (e.g. fat mass at birth for model examining fat mass at age 5 months). Adjusted means and beta coefficients with corresponding 95% confidence intervals (CIs) were presented for the linear regression models. An alpha level of 0.05 was used to determine statistical significance for all analyses except interaction terms, which used an alpha level of 0.10.

Sensitivity analyses

Maternal smoking during pregnancy is a strong risk factor for childhood obesity[23] and may explain some of the variability as exposure to secondhand smoke. Therefore, in sensitivity analyses, we restricted our analyses to mothers who did not smoke during pregnancy to identify the critical window of exposure.[6]

Results

Of the 1,410 participants enrolled in Healthy Start, 1,102 participants were eligible for the 5-month in-person visit when it was added to the protocol in 2011. Of the 1,102 participants eligible, 925 participants completed the 5-month in-person visit (83% response rate). For the z-score analyses, we excluded 49 participants who were born <37 gestational weeks, 28 participants who had a birth length <45 cm, which prevented calculation of the weight-for-length z-score, and 35 participants who had missing data (self-report of household smokers, n=6; gestational weight gain, n=4; gestational age at delivery, n=22; or birth length=3). Therefore, 813 participants were included in the z-score analyses.

Of these 813 infants included in the z-score analyses, 9 participants declined PEA POD measurements, 67 participants were excluded because the PEA POD was unavailable at the 5 month visit, 2 were excluded because infants exceeded the 10kg PEA POD weight limit, and 39 participants were excluded because of missing PEA POD data at birth. Therefore, 696 participants were included in the body composition analyses.

Infants included in the z-score analyses (n=813) were similar to the eligible sample (n=1,102) with respect to maternal age, pre-pregnancy BMI, gestational weight gain, race/ethnicity, household income, education, maternal smoking during pregnancy, gestational age at birth, infant sex, birth weight, and z-scores (see Supplemental Table S1). Infants included

in the body composition analyses (n=696) were similar to the infants included in the z-score analyses (n=813) with respect to maternal age, pre-pregnancy BMI, gestational weight gain, race/ethnicity, household income, education, maternal smoking during pregnancy, breastfeeding exclusivity, age at introduction of solid foods, infant sex, gestational age at birth, birth weight, and z-scores (see Supplemental Table S1).

Maternal and infant characteristics are presented in Table 1. A majority of the participants included in our study reported living with no household smokers at age 5 months (n=684, 84%). Women who reported any household smokers tended to be younger ($p<0.01$), were more likely to have a household income <$40,000 per year ($p<0.01$), and were less likely to be white ($p<0.01$) or to have graduated from high school ($p<0.01$). Women were similar with respect to pre-pregnancy BMI ($p=0.58$) and gestational weight gain ($p=0.15$). Women who reported any household smokers were more likely to have smoked during pregnancy ($p<0.01$). Women who reported any household smokers were less likely to have exclusively breastfed from birth to age 5 months ($p<0.01$) and more likely to have started solid foods before age 4 months ($p=0.02$).

The gestational age at delivery was greater among women who reported no household smokers ($p=0.03$). Infants born to women who reported no household smokers had higher birth weights ($p<0.01$), fat-free mass ($p<0.01$), weight-for-age z-scores ($p<0.01$), weight-for-length z-scores ($p=0.04$), and BMI-for-age z-scores ($p<0.01$). There was little apparent difference in infant sex ($p=0.16$), fat mass at birth ($p=0.18$), or percent fat mass at birth ($p=0.42$).

Main Effect Analyses

Table 2 presents the results for exposure to secondhand smoke as the main predictor of infant adiposity. There was limited evidence of an association between exposure to secondhand smoke and infant adiposity.

Interaction Analyses

The interaction p-values suggest that exposure to secondhand smoke is associated with increased infant fat mass (kg), weight-for-age z-score, and BMI-for-age z-score only among infants who were not exclusively breastfed (Table 3). For example, infants who lived with any household smokers and were not exclusively breastfed had a 0.2-kg higher fat mass than infants who lived with no household smokers and were exclusively breastfed (95% CI: 0.0, 0.5; p for interaction=0.07). Within the strata of infants who were not exclusively breastfed, the adjusted mean fat mass was 0.2-kg higher among those who lived with any household smokers as compared to those who lived with no household smokers (95% CI: 0.0, 0.2; $p=0.05$). Conversely, there was virtually no difference in the adjusted mean fat mass among infants who were exclusively breastfed (adjusted beta coefficient: −0.1; 95% CI: −0.3, 0.1; $p=0.25$). Similar patterns were also present for fat-free mass, percent fat mas, and the weight-for-length z-score, but the interaction p-values were not statistically significant.

Sensitivity Analyses

The results were similar when we excluded mothers who reported smoking during pregnancy (n=59) from the analyses (results not presented).

Discussion

Our study provides evidence that the combination of exposure to secondhand smoke and a lack of exclusive breastfeeding are associated with infant adiposity. Our results support the hypothesis that breastfeeding exclusivity may reduce susceptibility to the obesogenic effects of exposure to secondhand smoke. Given that future risk for obesity may manifest as early as 2 months of age,[24] our results are interesting and important.

The relevant literature on this topic is limited and the evidence is mixed. Two of the published studies report that infants who were exclusively breastfed by smoking mothers had an increased weight at age 1 years, the first using cross-sectional data among 333 U.S. mother-infant pairs[17] and the second using longitudinal data among 23,571 mother-infant pairs from the U.S. Collaborative Perinatal Project.[19] A third published study found no significant increase in weight status among infants who were exclusively breastfed by smoking mothers, using longitudinal data from 2,151 mother-infant pairs in the Netherlands.[18] In contrast, our data suggest that the combination of any exposure to secondhand smoke and a lack of exclusive breastfeeding is associated with infant adiposity. There are several factors that could explain the discrepancies between the previously published studies and with our study. First, the definition of exposure to secondhand smoke varied. Two of the previous studies defined exposure in terms of self-report of maternal smoking at a postnatal visit,[17,18] whereas the U.S. Collaborative Perinatal Project used maternal smoking during pregnancy as a proxy because postnatal smoking data was not collected.[19] Very few women in our study self-reported smoking at the time of breastfeeding; therefore, we defined exposure in terms of household smokers. Second, Shenassa et al.[19] reported that exposure to tobacco byproducts specifically through breastfeeding was associated with weight gain only among infants born small-for-gestational age. Due to the limited number of infants in our sample who were born small-for-gestational age, we were unable to examine these associations within this vulnerable subgroup,. Finally, the discrepancy may be due to differences in outcome assessment. The previous studies included infant weight status as the primary outcomes[17,18,19] whereas our study incorporated a direct measure of body composition. Our study suggests that exposure to secondhand smoke and a lack of exclusive breastfeeding act synergistically to influence altered fat distribution, a finding that warrants further investigation.

The mechanisms through which breastfeeding may ameliorate the obesogenic effects of exposure to secondhand smoke are unknown. Both breastfeeding and secondhand smoke exposures are independently associated with obesity risk.[5–8,12] Breastfeeding may reduce the impact of secondhand smoke on obesity risk via behavioral mechanisms, such as appetite regulation.[14] Various data also support the role of breast milk in minimizing the oxidative stress[25] and inflammatory responses[26] induced by exposure to secondhand smoke. It is possible that biological and behavioral mechanisms work together to increase infant adiposity.

The primary limitation of our study is the use of self-reported measures. Self-report of household smokers may underestimate exposure due to reporting bias and the inability to capture exposures outside of the home (e.g. daycare, other households).[27] Previous work has examined the associations of self-reported and biological markers of exposure to secondhand smoke with obesity among 6–19 year olds.[8] Compared to the biological markers, self-report of household smokers tended to underestimate exposure and underestimate the association between exposure to secondhand smoke and obesity.[8] Therefore, non-differential misclassification of the exposure in our study may have attenuated the effect estimates. Similarly, mothers may have under-reported a lack of exclusive breastfeeding due to social desirability bias.[28] A distinct advantage of Healthy Start is the use of repeated assessments with a short recall period, which has been shown to provide more accurate measures of breastfeeding exclusivity.[28] Regardless, our effect estimates may be more conservative than would be expected if mothers had reported the duration of exclusive breastfeeding and the number of household smokers with 100% accuracy.

Another limitation of our study is that infants who lived with any household smokers were more likely to have other known risk factors for obesity (e.g. lower household income, less maternal education). Although our models adjusted for these covariates, we acknowledge that some potential for residual confounding remains. Finally, body composition measurements were not available for the entire cohort, which resulted in reduced statistical power.

An important strength of our approach is the use of a direct measure of body composition. Air-displacement plethysmography is an accurate and useful method for directly measuring body composition among infants.[29] This method has been validated against the gold standard hydrodensitometry and the four-compartment model.[29] Additionally, the prospective cohort design enabled us to collect detailed data about maternal smoking during pregnancy and other covariates that are not often available in other cohort studies, such as age at introduction of solid foods. By adjusting for these covariates, our results may provide a better characterization of the independent role of postnatal exposure to secondhand smoke on infant adiposity.

Conclusions

Many smoking cessation programs are designed to encourage mothers and their partners to quit smoking during pregnancy. Although many women successfully quit smoking during pregnancy, smoking relapse during the postpartum period is common.[30] Considering the serious health consequences for infants, it is imperative to promote smoking cessation before, during, and after pregnancy for mothers and other adults within the household. A key strategy for preventing smoking relapse in the postpartum period is to encourage breastfeeding, which has been shown to extend the timing of smoking relapse later into the postpartum period.[30] We provide evidence that exclusive breastfeeding may also mitigate the obesogenic effects of exposure to secondhand smoke on infant adiposity. Our findings may inform new public health strategies with potential relevance for both smoking cessation and obesity prevention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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BFM performed the statistical analyses and wrote the manuscript. KAS, APS, BMR, DHG, and BFM contributed to the data acquisition and interpretation. BMR and DHG provided suggestions for statistical analysis. DD, KAS, APS, BMR, and DHG provided critical revisions to the manuscript. All authors read and approved the final manuscript.

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1) What is already known about this subject?

Epidemiologic studies indicate that exposure to secondhand smoke may increase future risk for obesity by at least 30%, independent of maternal smoking during pregnancy. Although these associations are fairly consistent across studies, no published studies have examined the impact of exposure to secondhand smoke on adiposity among children younger than age 3 years or using a direct measure of body composition. Furthermore, the potential interactions between exposure to secondhand smoke and breastfeeding exclusivity have not been examined thoroughly.

2) What does this study adds?

We provide evidence that breastfeeding exclusivity for 5 months may mitigate the effects of exposure to secondhand smoke on infant adiposity. Our findings may inform new public health strategies with potential relevance for both smoking cessation and obesity prevention.

Table 1

Characteristics of mothers and infants in the Healthy Start study, n=813

		Self-report of household smokers		
	All (n=813)	**None (n=684)**	**Any (n=129)**	**p-value**
Mother characteristics				
Age (years)	29 (6)	30 (6)	25 (5)	p<0.01
Pre-pregnancy body mass index (kg/m^2)	26 (6)	26 (6)	26 (6)	p=0.58
Gestational weight gain (g)	14 (6)	14 (6)	14 (7)	p=0.15
Race/Ethnicity				
Non-Hispanic white	57%	59%	43%	
Non-Hispanic black	13%	11%	20%	
Hispanic	24%	24%	31%	
Other	6%	6%	6%	p<0.01
Household income				
<$40,000	28%	24%	44%	
$40,001 to $70,000	20%	21%	15%	
>$70,000	35%	39%	9%	
Don’t know	17%	16%	33%	p<0.01
Highest level of education				
<High school	13%	9%	30%	
High school degree	15%	14%	24%	
Some college	72%	77%	46%	p<0.01
Smoking during pregnancy				
No	93%	99%	65%	
Yes	7%	1%	35%	p<0.01
Exclusive breastfeeding				
≥5 months	45%	47%	20%	
<5 months	55%	53%	80%	p<0.01
Age at solid foods introduction				
≥4 months	97%	94%	98%	
<4 months	3%	6%	2%	p=0.02

	Self-report of household smokers			
	All (n=813)	**None (n=684)**	**Any (n=129)**	**p-value**
Infant characteristics at birth				
Male	50%	51%	46%	p=0.16
Gestational age (weeks)	40 (1)	40 (1)	39 (1)	p=0.03
Weight (kg)	3.3 (0.4)	3.3 (0.4)	3.1 (0.4)	p<0.01
Fat mass (kg)	0.3 (0.1)	0.3 (0.1)	0.3 (0.2)	p=0.18
Fat-free mass (kg)	2.8 (0.3)	2.9 (0.3)	2.7 (0.3)	p<0.01
Adiposity (% fat mass)	9.1 (3.9)	9.3 (3.8)	8.8 (4.0)	p=0.42
Weight-for-age z-score	−0.3 (0.8)	0.0 (0.9)	−0.4 (0.9)	p<0.01
Weight-for-length z-score	0.0 (1.1)	0.1 (1.3)	−0.3 (1.4)	p=0.04
BMI-for-age z-score	−0.4 (1.2)	0.1 (1.2)	−0.4 (1.2)	p<0.01

Continuous variables are expressed as means ± standard deviation. Independent samples t-tests were used to examine the differences in means by self-report of household smokers. Categorical variables are expressed as proportions of column totals. Chi-square tests were used to examine differences in proportions by self-report of household smokers.

Table 2

Adjusted means and 95% CIs for the association between self-report of household smokers and mean differences in indicators of adiposity/growth at age 5 months, the Healthy Start study, n=813[a]

	Model 1[b]			Model 2[c]		
	No household smokers	Any household smokers		No household smokers	Any household smokers	
Indicator	Adjusted mean (95% CI)	Adjusted mean (95% CI)	p-value	Adjusted mean (95% CI)	Adjusted mean (95% CI)	p-value
Fat mass (kg)	1.7 (1.6, 1.8)	1.6 (1.5, 1.7)	0.80	1.7 (1.6, 1.8)	1.6 (1.5, 1.7)	0.84
Fat-free mass (kg)	5.2 (5.1, 5.3)	5.3 (5.2, 5.4)	0.40	5.2 (5.1, 5.3)	5.3 (5.2, 5.4)	0.07
Adiposity (% fat mass)	24.2 (23.8, 24.6)	23.2 (22.3, 24.1)	0.86	24.2 (23.7, 24.6)	23.4 (22.3, 24.2)	0.99
Weight-for-age z-score	−0.4 (−0.5, −0.3)	−0.4 (−0.6, −0.3)	0.60	−0.5 (−0.6, −0.4)	−0.4 (−0.6, −0.3)	0.13
Weight-for-length z-score	−0.2 (−0.3, −0.1)	−0.2 (−0.4, 0.0)	0.46	−0.2 (−0.3, −0.1)	−0.2 (−0.4, 0.0)	0.52
BMI-for-age z-score	0.8 (0.7, 0.9)	0.8 (0.7, 1.0)	0.52	0.76 (0.70, 0.8)	0.8 (0.7, 1.0)	0.31

Abbreviations: BMI, body mass index; CI, confidence interval.

[a]The sample size for the body composition analyses was 696. The sample size for the z-score analyses was 813.

[b]Model 1 adjusted for maternal race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), maternal education (<high school, high school diploma, some college), household income (< $40,000, $40,001 to $70,000, >$70,000, missing or do not know), maternal smoking during pregnancy (yes, no), gestational weight gain (kg), pre-pregnancy BMI (kg/m^2), infant sex, infant age at examination (months), and age at solid foods introduction (<4 months, ≥4 months).

[c]Model 2 additionally adjusted for respective indicators at birth (e.g. fat mass at birth for model examining fat mass at age 5 months).

Table 3

Adjusted[a] means, beta coefficients, and 95% CIs for the indicators of adiposity/growth in relation to breastfeeding exclusivity and household smokers: interaction among infants in the Healthy Start study, n=813[b]

Breastfeeding exclusivity	Household smokers	n	Adjusted mean (95% CI)	Adjusted beta coefficient (95% CI)	Adjusted beta coefficient (95% CI) for household smokers within strata of breastfeeding exclusivity
			Fat mass (kg)	Fat mass (kg)	Fat mass (kg)
≥5 months	None	279	1.8 (1.7 1.9)	Reference	Reference
	Any	19	1.7 (1.5, 1.9)	−0.1 (−0.3, 0.1)	−0.1 (−0.3, 0.1); p=0.25
<5 months	None	303	1.5 (1.4, 1.6)	−0.2 (−0.3, −0.1)	Reference
	Any	95	1.7 (1.5, 1.8)	0.2 (0.0, 0.5)	0.2 (0.0, 0.2); p=0.05
p for interaction: 0.07					
			Fat-free mass (kg)	Fat-free mass (kg)	Fat-free mass (kg)
≥5 months	None	279	5.0 (4.9, 5.1)	Reference	Reference
	Any	19	5.0 (4.8, 5.1)	−0.1 (−0.2, 0.1)	−0.1 (−0.2, 0.1); p=0.42
<5 months	None	303	5.2 (5.1, 5.3)	0.2 (0.1, 0.3)	Reference
	Any	95	5.3 (5.2, 5.4)	0.2 (0.0, 0.4)	0.1 (0.0, 0.2); p=0.09
p for interaction: 0.10					
			Adiposity (% fat mass)	Adiposity (% fat mass)	Adiposity (% fat mass)
≥5 months	None	279	25.7 (25.1, 26.4)	Reference	Reference
	Any	19	25.0 (22.8, 27.1)	−0.8 (−3.0, 1.5)	−0.8 (−3.0, 1.5); p=0.50
<5 months	None	303	22.6 (22.1, 23.2)	−3.1 (−4.0, −2.2)	Reference
	Any	95	23.5 (22.3, 24.7)	1.6 (−1.0, 4.2)	0.9 (−0.6, 2.3); p=0.23
p for interaction: 0.23					
			Weight-for-age z-score	Weight-for-age z-score	Weight-for-age z-score
≥5 months	None	322	−0.4 (−0.5, −0.3)	Reference	Reference
	Any	25	−0.5 (−0.8, −0.2)	−0.1 (−0.2, 0.1)	−0.1 (−0.4, 0.3); p=0.71
<5 months	None	362	−0.5 (−0.5, −0.4)	−0.1 (−0.5, 0.2)	Reference
	Any	104	−0.2 (−0.4, 0.0)	0.4 (0.0, 0.8)	0.3 (0.0, 0.5); p=0.02
p for interaction: 0.07					
			Weight-for-length z-score	Weight-for-length z-score	Weight-for-length z-score

Breastfeeding exclusivity	Household smokers	n	Adjusted mean (95% CI)	Adjusted beta coefficient (95% CI)	Adjusted beta coefficient (95% CI) for household smokers within strata of breastfeeding exclusivity
≥5 months	None	322	−0.1 (−0.2, 0.0)	Reference	Reference
	Any	25	−0.2 (−0.6, 0.2)	−0.1 (−0.5, 0.3)	−0.1 (−0.6, 0.3); p=0.64
<5 months	None	362	−0.4 (−0.5, −0.3)	−0.3 (−0.5, −0.1)	Reference
	Any	104	−0.2 (−0.4, 0.0)	0.3 (−0.2, 0.8)	0.2 (−0.1, 0.4); p=0.21
p for interaction: 0.26					
			BMI-for-age z-score	BMI-for-age z-score	BMI-for-age z-score
≥5 months	None	322	0.9 (0.8, 1.0)	Reference	Reference
	Any	25	0.8 (0.4, 1.1)	−0.1 (−0.5, 0.2)	−0.1 (−0.5, 0.3); p=0.56
<5 months	None	362	0.7 (0.6, 0.8)	−0.2 (−0.4, −0.1)	Reference
	Any	104	0.9 (0.7, 1.1)	0.4 (−0.1, 0.8)	0.2 (0.0, 0.4); p=0.07
p for interaction: 0.09					

Abbreviations: BMI, body mass index; CI, confidence interval.

[a]Adjusted for maternal race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), maternal education (<high school, high school diploma, some college), household income (<$40,000, $40,001 to $70,000, >$70,000, missing or do not know), maternal smoking during pregnancy (yes, no), infant sex, infant age at examination (months), age at solid foods introduction (<4 months, ≥4 months), and respective indicators at birth (e.g. fat mass at birth for the model examining fat mass at age 5 months).

[b]The sample size for the body composition analyses was 696. The sample size for the z-score analyses was 813.