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Maternal-infant interaction as an influence on infant adiposity

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Abstract

Objectives—The aim of this research is to identify whether specific aspects of the early life psychosocial environment such as quality of home and maternal-infant interaction are associated with increased infant adiposity, in a disadvantaged population in the United States.

Methods—Data on 121 mother-infant pairs from the Albany Pregnancy and Infancy Lead Study (APILS) were analyzed using three multiple linear regression models with subscapular skinfold thickness (SST), triceps skinfold thickness (TST), and weight z-scores at 12 months of age as outcome variables. Maternal-infant interaction was indexed by the Nursing Child Assessment Teaching Scales (NCATS) and home environment quality was indexed by the Home Observation for Measurement of the Environment (HOME).

Results—In models including infant birth weight, cigarette use in second trimester, infant caloric intake at 9-12 months, size at birth for gestational age, infant sex, and mother's pre-pregnancy BMI, specific subscales of NCATs predicted infant adiposity z-scores. Poorer mother's response to infant distress was associated with greater SST (β=-0.20, p=0.02), TST (β=-0.19, p=0.04), and weight (β=-0.14, p=0.05). Better maternal sensitivity to infant cues was associated with larger SST (β=0.25, p<0.01), while mother's poorer social-emotional growth fostering predicted greater SST (β=-0.23, p<0.01) and weight (β=-0.16, p=0.03). Better scores on HOME Organization of the Environment were associated with greater SST (β=0.34, p=0.02) and TST (β=0.33, p=0.04).

Conclusions—Emotionally relevant aspects of the maternal-infant interaction predicted infant adiposity, though in different directions. This indicates that the psychosocial environment, through maternal behavior, may influence infant adiposity. However, the general home environment was not consistently related to infant adiposity.

Keywords

adiposity; developmental origins of health and disease; psychosocial stress; infancy; fat patterning; health disparities

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Introduction

Early life environment has consistently been shown to have significant influences on growth and development and later health and disease, as demonstrated by research in the framework of Developmental Origins of Health and Disease (Barker, 1994). This environment may be prenatal, infant, childhood, or adolescent periods, with many factors affecting development and future health (Hanson and Gluckman, 2008). The first 1000 days of life, including gestation and the first two years of age, is a period of significant influence in shaping the future well-being and productivity of individuals, setting them on a trajectory of growth and development that can have consequences throughout life (Martorell, 2017).

The roots of overweight and obesity are of particular concern in the United States today, given the association between increased adiposity and negative health outcomes. Weight gain early in life has been shown to be associated with later negative health outcomes, particularly obesity and overweight, throughout childhood and into adulthood (Osmond and Barker, 2000; Ong, 2010; Sovio et al., 2013; Jardim-Botelho et al., 2014). High adult adiposity is common in the United States and is associated with poor health and decreased function, as well as being a source of social stigma, stress, and discrimination (Sutton-Tyrrell et al., 2001; Stein et al., 2002; Brewis et al., 2011). Rapid infant weight gain and high adiposity is associated with poor health outcomes later in life, such as an increased risk of chronic disease, higher abdominal and whole body fat mass in adulthood, and increased risk of obesity after infancy (Baird et al., 2005; Adair, 2007; Demerath et al., 2009). Higher infant adiposity is associated with increased adiposity throughout development and poor health outcomes, such as childhood adiposity predicting increased blood pressure in adulthood (Sabo et al., 2010). Infancy is a stage of development that can influence childhood and adult obesity.

The wide range of postnatal influences on infant growth and weight have encompassed a wide range of exposures, including nutrition, pollutants, infant temperament, and gut microbiome (Owen et al., 2005; Darlington and Wright, 2006; Schell et al., 2009; Thompson, 2012). There also are strong prenatal maternal influences on newborn adiposity, including higher maternal adiposity associated with greater birth weight (Tikellis et al., 2012). This research further explores the transgenerational postnatal maternal influences on postnatal infant adiposity through the quality of the psychosocial environment and maternal-infant interaction. The goal of this research is to provide a more comprehensive analysis of early life influences on adiposity, in the context of low socioeconomic status, accounting for diet, prenatal growth, and psychosocial stress through the quality of maternal engagement with her infant. This analysis therefore focuses on the period of infancy, testing whether early life psychosocial environment operating through maternal behavior and emotional engagement may play an important role in infant adiposity.

Beyond strict exposure to psychosocial stress through maternal deficient or negative emotional and physical interaction, maternal interaction behavior can influence infant adiposity through infant feeding interactions. Less maternal sensitivity to infants' cues has been associated with greater infant weight gain by 12 months of age, likely due to overfeeding resulting from ignoring infant indications of satiation (Worobey et al., 2009).

However, the directions of the relationship between maternal feeding styles and infant weight and adiposity have been mixed (Hurley et al., 2011). This is likely due to variations in income and related confounders and breastfeeding rates. Maternal feeding behavior can be influenced by infant temperament as well, with mothers using food to soothe infants who are perceived to be high in temperamental negativity (Stifter et al., 2011). Use of food to soothe infants may be a pathway for maternal-infant interaction to increase infant weight gain (Stifter and Moding, 2015). Infant behavior as well may influence maternal feeding habits, leading to an increase in weight, such as mothers responding to infant fussing/crying episodes with feeding (Anzman-Frasca et al., 2013). In order to isolate the psychosocial and nurturing effects on infant adiposity independent of these potential differences in feeding behavior, this study also accounts for infant caloric intake.

Any emotional influence on child growth and development works in conjunction with other environmental factors, including food insecurity, high rates of illness, and other social stressors. Postnatal maternal mental health has been associated with infant immune system development in the context of adverse household ecology, including severe food insecurity (Decaro et al., 2016). As an extreme example of maternal disengagement, postpartum depression is expected to have a more severe influence on infant growth in environments that pose challenges to child rearing (Stewart, 2007). It is possible that the effect of maternal mental health on child growth will be more evident in a low socioeconomic environment, due to relative lack of resources and challenging environmental factors that accompany poverty.

This study analyzes a very common potential source of stress, the mother's quality of engagement with her infant in a socioeconomically disadvantaged context, to test whether this potential stressor is associated with infant adiposity. It further seeks to identify which specific aspects of the maternal-infant interaction and overall home environment are related to infant adiposity. Specifically, this analysis intends to answer the following questions: 1) Does the quality of the psychosocial environment in early life independently predict infant adiposity and weight? 2) Does a better psychosocial environment, such as better maternal-infant interaction, result in increased or decreased infant adiposity and weight? 3) Do specific aspects of the psychosocial environment and maternal-infant interaction have greater effects on infant adiposity and weight?

Methods

Participants

The participants analyzed here are drawn from the sample collected as part of the Albany Pregnancy Infancy Lead Study (APILS) Phase II. APILS is a longitudinal study conducted from 1992-1998 in Albany County in New York State, which collected complete data on maternal-infant interaction, along with data on diet and anthropometric measures, described in further detail in Schell et al. (2000, 2002, 2004) . The Institutional Review Boards of the New York State Department of Health, Albany Medical Center (AMC), and the State University of New York at Albany reviewed and approved all data collection methods and procedures. The mothers in this sample group are considered to be some of the most socioeconomically disadvantaged women in Albany County (Schell et al., 2004). The recruitment criteria specified participants had to meet the eligibility requirements for the Women, Infants, and Children program, which include income status at <185% of poverty level (United States Department of Agriculture Food and Nutrition Service, 2016). All participants had to be a resident of Albany County, less than 24 weeks pregnant at enrollment, and receiving prenatal care at the Albany County Department of Health Clinic or the Albany Medical Center.

Participants were excluded from the study if their births were not singletons, if their pregnancies were considered high risk for complications, if they had a child in the study, or if they were unable to speak English. English fluency was a requirement to complete spoken surveys including those used to evaluate maternal cognitive performance.

Of 317 eligible women who were recruited for the study, 71 discontinued study participation before giving birth (either moved, transferred care to another facility, or terminated the pregnancy), with an additional 34 women lost to follow-up before the 3-month postpartum visit. Of the 212 remaining participants, 121 continued in the study until the 12-month visit, completing all measures used in this analysis. This analytic sample is comprised of these 121 mother-infant pairs.

Anthropometry

Infant adiposity was measured using subscapular and triceps skinfold thickness, and weight at 12 months. Skinfolds were measured in triplicate by research staff trained in anthropometric methods and averaged to minimize intraobserver error. Skinfold thickness measurement is a more appropriate measure of subcutaneous adiposity than only weight or body mass index, and permits further analysis of differences in fat patterning. Centrality index, a measure of relative trunk and limb fat patterning (Davies and Cole, 1995), was derived from these skinfold measurements as subscapular skinfold thickness : triceps skinfold thickness.

Maternal-infant interaction

Maternal-infant interaction quality was measured using the Home Observation for Measurement of the Environment and the Nursing Child Assessment Teaching Scales. APILS staff members who were trained by New York State licensed psychologists completed the Home Observation for Measurement of the Environment (HOME) in the mother's and infant's home while the infant was awake, at an average of 42 ± 5.8 weeks of age, on average preceding the 12-month anthropometry measures by 8.4 weeks. The HOME assessment is a commonly used scale for evaluating the quality of stimulation, support, and structure available to children in the home (Bradley and Caldwell, 1980; Caldwell and Bradley, 1984), has a high degree of internal consistency, Cronbach's alpha = 0.90 (Bradley et al., 1988), and is unlikely to significantly change throughout infancy. Six subscales compose the measurement: Emotional and Verbal Responsivity of Mother, Avoidance of Restriction and Punishment, Organization of Environment, Provision of Appropriate Play Material, Maternal Involvement with Child, and Opportunities for Variety in Daily Stimulation. This analysis evaluates the four subscales that most directly capture the infant's psychosocial environment, described in Table 1. There are a variable number of items for each subscale. A higher score on any subscale indicates a more positive home environment and better quality of maternal engagement.

The Nursing Child Assessment Teaching Scales (NCATS) were also used to assess the quality of the mother-infant interaction. Two New York State licensed psychologists administered the NCATS at their office in collaboration with the APILS study when the infant was 12 months of age (average 51.7 ± 1.4 weeks of age, average .5 weeks prior to infants' anthropometry measurements). The NCATS are a reliable method of observation and scoring that describes the behavior of the mother-infant interaction during a teaching challenge and their responses to each other (Barnard et al., 1989). The NCATS have a total internal consistency reliability of Cronbach's alpha .87 and demonstrate stability on repeated tests over time (Barnard et al., 1989). The 73 items of the NCATS are organized into six subscales. Four subscales measure the mother's behavior and two measure the child's behavior. This analysis uses three subscales that assess the quality of the mother's interaction with her infant, described in Table 1. As in the HOME scale, higher scores in each subscale indicate better quality of maternal emotional engagement with her infant.

Measures of covariates

Infant caloric intake was estimated by a 24-hour diet recall reported by the mother or primary caregiver at 9 and 12 months of age. Nutritionist IV software (Version 2.0, Salem, OR) was used to compute calories, as well as macronutrients, vitamins, and minerals. As a single 24-hour dietary recall may not adequately reflect the variation in dietary intake, measures of the 9 and 12 month dietary recalls were averaged to represent infant dietary intake for 9-12 months of age (Schell et al., 2004).

Demographic data were self-reported by mothers at prenatal enrollment in the study, including educational attainment, marital status, and mother's age. Cigarette smoking throughout pregnancy was self-reported at each prenatal data collection, in second and third trimesters. Infant gestational age at birth, sex, and weight were collected from medical records.

Size for gestational age was determined using standards developed by Fenton and Kim (2013). This growth chart incorporates data on the growth of preterm infants and the World Health Organization growth standards to provide measures of size for gestational age by sex for infants born at term or preterm. Size for gestational age (completed weeks of gestation) was determined to be small-for-gestational age (SGA) as $<10^{th}$ percentile of weight for sex and large-for-gestational age (LGA) as $>90^{th}$ percentile.

Statistical analysis

Infant subscapular and triceps skinfold thickness measurements and weight were transformed into z-scores based on the World Health Organization's (WHO) growth references by sex and age in weeks. The WHO references were chosen as the reference population as the WHO growth standards are commonly used adiposity standards for infants around twelve months old (Miller, 2014). Creating z-scores based on a reference population permits standardization of data while providing reference for how these values compare to a broader population. Transforming skinfold thickness and weight variables in z-scores also minimizes any skewed distribution of the variables, allowing for the use of statistical measures necessitating normally-distributed data. It also facilitates comparison between this sample and the WHO growth references in standard deviations from the mean.

Three multiple linear regression models were created for dependent variables subscapular skinfold thickness z-scores, triceps skinfold thickness z-scores, and weight z-scores at an average of 52.7 weeks of age. Covariates were identified by creating a full model of the most common influences on child growth in the United States, including maternal-reported measures of infant dietary intake, birth weight derived from hospital records, maternal pre-pregnancy BMI, maternal self-reported cigarette use during the second trimester of pregnancy, size for gestational age at birth, and infant sex. Breastfeeding variables were not included as a negligible number of mothers in the study reported breastfeeding at any point during the infants' first year.

Multicollinearity of the covariates in the models were evaluated by determining the variance inflation factor (VIF). All potential covariates with a VIF less than 2 remained in the model. As HOME variables were collinear with each other, two subscales of minimal predictive contribution to the models were removed. The only potential covariate removed due to multicollinearity was a measure of infant protein intake from 9 to 12 months, as it was highly correlated with the more general measure of infant caloric intake from 9 to 12 months.

Results of the multiple linear regression models were further analyzed by self-identified maternal “race” (“black” vs. all other responses) and infant sex. Two-tailed t-tests of independent variables NCATS and HOME scores as well as infant outcomes determined whether means of these variables differed by race (black vs. non-black mothers) and infant sex. The previously detailed multiple linear regression models were also stratified by these groups to determine whether the relationships of NCATS and HOME scores with infant anthropometric outcomes varied by race and sex.

All statistical analyses were performed using the open source software R (R Core Team, 2012). Requests for the code used in analysis can be sent to the corresponding author.

Results

Women in the sample primarily came from populations that experience health disparities, with the majority reporting their race as black (47.1%) or Hispanic (14.0%) and with a high school degree or less level of education (82.7%) (Table 2). The mothers in the study were also overwhelmingly unmarried (86.8%). Of the 121 women in the sample, 33 (27.3%) reported smoking at least one cigarette every day during their second trimester. On average, scores on the NCATS and HOME subscales were relatively high, with scores of 8.23, 8.16, and 8.47 on the NCATS subscales (maximum possible score of 11), and 8.39 (maximum score of 11), 6.15 (maximum score of 8), 5.40, and 4.11 (maximum score of 6) on the HOME subscales.

Overall, infants in this sample showed greater adiposity and weight than the WHO references with positive average z-scores for weight, triceps, and subscapular skinfolds

(0.42, 0.67, and 0.45 respectively). The average centrality index (subscapular skinfold thickness : triceps skinfold thickness), a measure of the relative fat patterning of limbs compared to torso was 0.79. This demonstrates an average tendency in this sample for greater fat to be distributed on the limbs (triceps skinfolds) than the torso (subscapular skinfolds).

In multiple regression analyses, higher scores on the NCATS Response to Distress subscale were significantly associated with lower infants' subscapular skinfold thickness, lower triceps skinfold thickness and lower body weight (Table 3). Better scores on the NCATS Social-Emotional Growth Fostering subscale were significantly associated with lower subscapular skinfold thickness and body weight. Higher maternal scores on the NCATS Sensitivity to Infant's Cues subscale were significantly related to greater subscapular skinfold thickness and weight. A higher score on the HOME Organization of Environment scales was positively related to both subscapular and triceps skinfold thickness while HOME Maternal Involvement with Child was not related to weight, triceps or subscapular skinfold thickness. Birth weight had a significant but small association with infant's weight but was not significantly associated with infant's skinfold thickness. These relationships were not due to multicollinearity among subscales as they persisted even in regressions containing only one of the NCATS subscales.

The regression model of triceps skinfold thickness z-scores was not statistically significant (p=0.13). The model explained little of the variation in triceps skinfold thickness (adjusted R-squared=0.05). Only HOME Organization of Environment (β=0.33, p=0.04) and NCATS Response to Distress (β=-0.19, p=0.04) were significantly associated with triceps skinfold thickness indicating that better organization of the infant's environment and poorer maternal response to infant distress related to increased triceps adiposity. Infant's caloric intake from 9-12 months was a nearly significant predictor variable with a small effect size.

Infant caloric intake from 9-12 months of age, maternal pre-pregnancy BMI, maternal cigarette use in second trimester, and birth weight were not statistically significant predictor variables of subscapular skinfold thickness z-scores. Cigarette use was significantly related to greater subscapular skinfold thickness with a small effect size. Overall, the model was statistically significant with a p<0.01 but predicted a small percentage of the variation in subscapular skinfold thickness (adjusted R-squared=0.15). These results indicate that mothers who were reportedly more sensitive to their infant's cues or maintained a well-organized home environment had children with greater subscapular thickness. However, mothers who scored higher on the measure of their response to infant distress and their fostering of infant social-emotional growth were associated with lower infant subscapular skinfold thickness.

The regression model of weight was statistically significant (p<0.01) and explained some of the variation in weight at 12 months of age (adjusted R-squared=0.16). Birth weight was a significant positive predictor of weight at 12 months (β<0.01, p<0.01). Social-Emotional Growth Fostering (β=-0.16, p=0.03) and Response to Distress (β=-0.14, p=0.05) were negatively associated with weight at 12 months of age, meaning that poorer maternal interactions with her infant in these domains were associated with greater overall weight.

These models were further analyzed to assess whether these relationships persisted for both male and female infants and by self-identified "race" of mothers. Models were stratified by black and non-black mothers to determine whether relationships between independent and dependent variables changed. Overall, variables that were statistically significantly associated with infant growth measures among non-black mothers were frequently not significant among black mothers. However, these differences are likely not attributable to self-identified race. Mothers who identified as black had statistically significantly lower mean scores on all NCATS and HOME measures as assessed by Welch two-sample t-tests. There was a significant difference in the NCATS Sensitivity to Cues scores among black mothers (M=7.86, SD=2.02) and non-black mothers (M=8.53, SD=1.79); t(136)=42.83, p <0.01. This was also true for NCATS Response to Distress scores (Black mothers M=7.90, SD=1.61; non-black mothers M=8.38, SD=1.73; t(141)=48.00, p<0.01) and NCATS Social-Emotional Growth Fostering scores (Black mothers M=8.05, SD=1.80; non-black mothers M=8.81, SD=1.48; t(141)=50.27,p<0.01). This indicates that the models stratified by race were also stratified by scores on NCATS and HOME measures, and suggests that much of these relationships between NCATS and HOME scores and infant anthropometric outcomes are driven by the higher NCATS and HOME scores.

Stratified models by infant sex showed similar patterns to the complete models, though independent variables that were significant in the female infant models and final models were not significant in the male infant models. Stratified models by infant sex are not presented here as sex is included in the final models as a covariate. NCATS, HOME scores, and infant anthropometric measures all significantly differed by sex. Anthropometric variables differed by sex including weight z-scores (males M=0.31, SD=1.15; females M=0.55, SD=1.07; t(167)=-9.42, p<0.01), triceps skinfold thickness z-scores (males M=0.54, SD=1.20; females M=0.81, SD=1.42; t(154)=-6.29, p<0.01), and subscapular skinfold thickness z-scores (males M=0.26, SD=1.14; females M=0.66, SD=1.41; t(156)=-8.14, p<0.01). NCATS scores differed as well, with NCATS Sensitivity to Cues higher for male infants on average (males M=8.23, SD=1.92; females M=8.19, SD=1.95; t(136)=37.30, p<0.01), NCATS Response to Distress higher for female infants (males M=8.11, SD=1.62; females M=8.19, SD=1.77; t(141)=41.75, p<0.01), and NCATS Social-Emotional Growth Fostering higher for male infants (males M=8.66, SD=1.48; females M=8.23, SD=1.85; t(141)=43.98, p<0.01).

Discussion

The negative association of Social-Emotional Growth Fostering and Response to Distress scores on adiposity and weight indicate that poorer maternal-infant interaction is related to higher levels of adiposity and weight in this sample of infants. Though some previous research has indicated that a stressful and emotionally poor psychosocial environment is associated with decreased weight (Widdowson, 1951) including an association with maternal depression (Patel et al., 2003; O'Brien et al., 2004; Rahman et al., 2004; Darlington and Wright, 2006), in this sample the opposite relation is true. While the NCATS subscales are significant predictor variables of adiposity and weight, their relationships are weaker for the triceps skinfold. NCATS subscale variables were not consistently significantly associated with skinfold thicknesses although they were associated in the same direction and magnitude in both models. Differences in the pattern of relationships with the two skinfolds may partially be due to the fat patterning in this population, as they exhibit low centrality index scores which indicate higher peripheral than central adiposity. It is not clear why these effects of social-emotional growth fostering and response to distress are larger for subscapular skinfold thickness than triceps. While central adiposity as opposed to peripheral adiposity is associated with health outcomes such as immune function in adults (Wells and Cortina-Borja, 2013), further longitudinal research is needed to determine what central and peripheral adiposity in infants signifies for their later health.

All NCATS subscales are significant contributors in at least one model, and one, mother's response to distress is statistically significant for all three outcome variables. No other variable was as strongly associated with infant's adiposity and only birth weight was a larger predictor of infant weight. The mother's direct interactions with her child, measured through the NCATS, were correlated more strongly and consistently with adiposity and weight than the more general measure of the environment through the HOME scores. The quality of the attention given by a mother to her infant is a more direct psychosocial environmental factor than the more general, indirect measure provided by the HOME scores. Contrary to expectations, HOME Maternal Involvement with Child was not significant in any model, while HOME Organization of Environment was significantly associated with triceps and subscapular skinfold thickness with better scores predicting greater adiposity. The HOME Organization of Environment subscale may better capture the overall psychosocial environment with observations such as regularity of caretakers and the child regularly leaving the house, while HOME Maternal Involvement focuses more on encouraging mental development, such as the mother structuring play periods and providing mentally stimulating toys.

In line with previous research, a beneficial psychosocial environment as measured by a mother's sensitivity to infant cues is associated with higher levels of adiposity as measured by subscapular skinfold thickness and weight. This relationship is to be expected as it suggests that the better a mother is at noticing and interpreting her infant's cues, including cues indicating hunger, the more likely the infant is to have high levels of adiposity. This may indicate that the mother is more responsive to her infant's hunger cues or that she is more attentive to cues in general, or both, and will typically respond with feeding. However, these results contradict other research among a similar low-income population showing that mothers who are less responsive to their infants' cues have infants who gain more weight by one year of age (Worobey et al., 2009). Additionally, while sensitivity to cues may indicate more frequent maternal response with feeding, this does not seem to translate into increased infant caloric intake, as sensitivity to cues is not correlated with infant caloric intake between 9 and 12 months of age and caloric intake is not a significant predictor of infant adiposity in these models. This aspect of maternal interaction with her infant may therefore be operating through a different pathway than feeding behavior, as may also be the case in maternal response to infant distress.

The different directions of the influence of NCATS and HOME subscales on weight and adiposity may indicate that the type of maternal-infant interaction is as important as the quality of interaction in its influence on infant weight and adiposity. The positive relationship between maternal sensitivity to cues, HOME Organization of Environment, and infant adiposity and weight is expected. The negative relationship between maternal response to distress, social-emotional growth fostering, and infant weight and adiposity suggests that poorer interaction quality in these types of maternal-infant interactions is associated with increased adiposity and weight. It is possible that a mother who poorly responds to her infant's distress may use more food to calm her infant, leading to increased weight and adiposity. This is in line with previous research indicating that mothers may use food to soothe temperamental infants (Stifter et al., 2011; Anzman-Frasca et al., 2013; Stifter and Moding, 2015). However, as this relationship persisted even in the model with the maternal report of infant caloric intake, this explanation would require that mothers who handle their infant's distress poorly must also underreport infant food intake. An alternate explanation is that increased cortisol secretion resulting from continued infant distress leads to increased fat gain (Björntorp, 2001). Further research is required to determine whether there is a behavioral compensation for poor maternal-infant interaction that may result in increased infant adiposity and weight, or whether another mechanism is involved.

Previous research has indicated a sensitivity of weight, and by association adiposity, to a stressful psychosocial environment (e.g. Widdowson, 1951; Miller et al., 2009, 2013; Konishi et al., 2014). The results of this research confirm this sensitivity, even in commonplace situations, through lower quality of maternal-infant interaction. Furthermore, this research indicates that even low-levels of chronic stress as measured by poorer maternal engagement with her infant, can be a significant factor in the growth and development of infants. This model presents an analysis of multiple influential factors that can contribute to weight and adiposity in infancy, including diet, prenatal growth as measured by birth weight, maternal physical attributes, and quality of early life psychosocial environment. While the models showed a significant association between infant adiposity and early life psychosocial environment, they did not explain a large degree of the variation in adiposity and weight outcomes, despite the inclusion of other major factors associated with infant adiposity. Some of the remaining variance may be explained by differences in fatty acid ingestion (Anderson et al., 2010), variation in gut microbiota (Dogra et al., 2015), or infant physical activity (Wells and Ritz, 2001) which are not captured here. Though the effect sizes of these measures may seem small, they are similar in magnitude to other predictors of infant adiposity and weight like food intake (8% contribution to variance) and nutritive sucking behavior (9%) (Stunkard et al., 1999).

It is possible that these small effect sizes seen in the mid 1990s may not still be small in contemporary times with higher rates of obesity and overweight. Future research is needed to clarify whether the effect of maternal-infant interaction on infant weight and adiposity has increased or decreased since the time these data were collected. The strength of this analysis rests on the assessment of all of these factors demonstrating the significant contribution of maternal engagement with her infant to infant adiposity. As the data from this study are longitudinal, future research will assess the timing of these contributors in relation to adiposity gain and change over time.

The strengths of this study include diverse measures collected by trained researchers, rather than solely self-report or medical records. This ensures a high degree of accuracy in relevant measures, particularly in anthropometric measurements which require dedicated training to apply accurately. Additionally, this population was recruited to achieve a representation of women of low socioeconomic status who are likely to be particularly stressed and display variation in their maternal nurturing behaviors. This analysis also is able to address the influence of maternal-infant interaction on adiposity while controlling for other significant factors in adiposity, including nutrition. Limitations to this study include a significant percentage of women who were lost to follow-up by the time of the 12-month appointment, which may bias the data toward more financially secure, involved mothers with potentially better maternal-infant interaction. These data were collected in the mid 1990s, just at the beginning of the dramatic increase in rates of overweight and obesity, so further research is needed to identify whether these trends continue in the current economic, political, and nutritional environment. Additionally, a negligible number of women reported breastfeeding, overwhelmingly choosing formula-feeding for their babies, likely due to their qualification for the Women, Infants, and Children program which provided compensation for formula. As such, this study cannot address whether these patterns of associations continue among breastfed infants, which may have both nutritional as well as emotional influences on infant development.

5. Conclusion

The results of this study indicate that direct maternal engagement with her infant may influence adiposity in an impoverished environment in the United States. This study demonstrates that in this sample maternal engagement is as much of an influence on weight and adipose growth in infancy as other known influences such as diet. Further research should explore these relationships in a variety of populations and provide a more detailed exploration of the types of maternal-infant engagement and their influence on infant adipose development.

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Table 1

Description of subscales of NCATS and HOME scales used in analysis.

MEASURE SUBSCALES	DESCRIPTION OF SUBSCALE	SCORE RANGE
The Home Observation for Measurement of the Environment (HOME) Inventory Subscales		
Maternal Emotional and Verbal Responsivity (1)	Extent to which the parent responds to the child's behavior, offering verbal, tactile, and emotional reinforcement for desired behaviors and communicating freely through words and actions	0-11
Avoidance of Restriction and Punishment (2)	Parental acceptance of challenging child behavior and avoidance of restrictive or physically punishing behaviors	0-8
Organization of Environment (3)	Extent to which there is regularity and predictability in the family's schedule, to the safety of the physical environment	0-6
Maternal Involvement with Child (5)	Extent to which the mother is actively involved in the child's learning and provide stimulation for increasing mature behavior	0-6
Nursing Child Assessment Teaching Scales (NCATS) Subscales		
Sensitivity to Cues	Caregiver's ability to recognize and respond to the child's cues	0-11
Response to Distress	Caregiver's ability to soothe or quiet a distressed child	0-11
Social-Emotional Growth Fostering	Caregiver's ability to facilitate social and emotional growth, and the ability to communicate a positive feeling tone	0-11

Table 2

Descriptive statistics of variables in analysis and demographic profile of sample population. Abbreviations: HOME, Home Observation for Measurement of the Environment; NCATS, Nursing Child Assessment Teaching Scale. Characteristics reported as: number (%) for categorical variables or mean ± s.d. for continuous variables.

Variable	**N = 121**	**Range**
Mother's age, years	23.41 ± 5.3	15.2 – 38.7
Mother's pre-pregnancy BMI	25.95 ± 7.3	16.7 – 53.1
Female infants	57 (*47.1*)	
Mother's self-identified race		
White	40 (*33.1*)	
Black	57 (*47.1*)	
Hispanic	17 (*14.0*)	
Other	7 (*5.8*)	
Mother's highest level of education		
Grades 1-8	3 (*2.5*)	
Grades 9-11	45 (*37.2*)	
Grade 12	52 (*43.0*)	
Post-high school education	21 (*17.4*)	
Mother's marital status		
Single	95 (*78.5*)	
Married	16 (*13.2*)	
Separated/divorced	10 (*8.3*)	
Size for gestational age		
SGA	30 (*24.8*)	
AGA	85 (*70.2*)	
LGA	6 (*5.0*)	
Infant birth weight (g)	3246 ± 572.08	1.65 – 5.04
Infant subscapular skinfold thickness at 12 months z-scores	0.45 ± 1.29	-2.64 – 4.64
Infant triceps skinfold thickness at 12 months z-scores	0.67 ± 1.31	-2.72 – 3.65
Infant weight at 12 months z-scores	0.42 ± 1.11	-2.18 – 3.59
Infant centrality Index at 12 months	0.79 ± 0.16	0.44-1.33
NCATS Sensitivity to Cues Score	8.23 ± 1.92	2 – 11
NCATS Response to Distress Score	8.16 ± 1.68	4 – 11
NCATS Social-Emotional Growth Fostering Score	8.47 ± 1.67	3 – 11

Variable	N = 121	Range
HOME Maternal Emotional and Verbal Responsivity	8.39 ± 1.73	3 – 11
HOME Avoidance of Restriction and Punishment	6.15 ± 1.06	3 – 8
HOME Organization of Environment Score	5.40 ± 0.82	3 – 6
HOME Maternal Involvement with Child Score	4.11 ± 1.40	1 – 6
Mother's cigarette daily use during 2nd trimester (number of cigarettes)	2.53 ± 5.81	0 – 40
Infant caloric intake 9-12 months of age (kilocalories)	1119.0 ± 341.82	251.0 – 2798.0

Table 3

Results of multiple linear regression models. NCATS = Nursing Child Assessment Teaching Scales, HOME = Home Observation for Measurement of the Environment.

	Triceps Skinfold Thickness z-scores Model R-Squared 0.05 (p=0.13)		Subscapular Skinfold Thickness z-scores Model R-Squared 0.15 (p<0.01*)		Weight z-scores Model R-Squared 0.16 (p<0.01*)	
	β Estimate (Std. Error)	**p-value**	**β Estimate (Std. Error)**	**p-value**	**β Estimate (Std. Error)**	**p-value**
NCATS Sensitivity to Cues	0.10 (0.09)	0.23	0.25 (0.08)	<0.01*	0.12 (0.07)	0.07
NCATS Response to Distress	-0.19 (0.09)	0.04*	-0.20 (0.08)	0.02*	-0.14 (0.07)	0.05*
NCATS Social-Emotional Growth Fostering	-0.12 (0.09)	0.20	-0.23 (0.09)	<0.01*	-0.16 (0.07)	0.03*
HOME Maternal Responsivity	-0.001 (0.08)	0.99	-0.06 (0.07)	0.44	<0.01 (0.06)	0.98
HOME Avoidance of Restriction	0.03 (0.12)	0.81	0.04 (0.11)	0.71	-0.02 (0.09)	0.82
HOME Organization of Environment	0.33 (0.16)	0.04*	0.34 (0.14)	0.02*	0.15 (0.12)	0.23
HOME Maternal Involvement with Child	0.05 (0.10)	0.57	0.04 (0.09)	0.63	0.01 (0.08)	0.89
Birth weight (g)	<0.01 (0.25)	0.27	<0.01 (<0.01)	0.36	<0.01 (<0.01)	<0.01*
Cigarette Daily Use in Second Trimester	-0.004 (0.02)	0.87	0.04 (0.02)	0.04*	0.02 (0.02)	0.37
Pre-pregnancy BMI	0.01 (0.02)	0.63	<0.01 (0.02)	0.70	0.01 (0.01)	0.47
Infant Caloric Intake from 9-12 months of age	<0.01 (<0.01)	0.05	<0.01 (<0.01)	0.27	<0.01 (<0.01)	0.19
Size for gestational age	-0.29 (0.30)	0.34	-0.38 (0.28)	0.18	-0.10 (0.24)	0.67
Infant sex	0.42 (0.25)	0.10	0.53 (0.23)	0.02*	0.40 (0.20)	0.05*