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Maternal Behavior and Infant Weight Gain in the First Year

John Worobey, Maria Islas Lopez, and Daniel J Hoffman

The risk for overweight for low-income Hispanic children younger than age 5 in the United States is significantly higher than for non-Hispanic blacks, which in turn is higher than for non-Hispanic whites (1,2). Using the criterion of a Body Mass Index (BMI) $\geq$ the 95th percentile for age and sex for defining overweight, the prevalence among low-income young children age 2–4 years in the US as of the year 2000 was around 19% (3). Though the sample was not nationally representative, a review of over 20 years of records from a Massachusetts health maintenance organization on over 120,000 children found that the percentage of infants under 6-months who were overweight or at risk for overweight increased from approximately 10% in 1980–81 to 17% in 2000–01 (4). In that report, overweight was defined as weight for length $\geq$ the 95th percentile for age and sex; at risk for overweight as weight for length $\geq$ the 85th percentile for age and sex. In that same report, Hispanic infants were higher than black, who in turn were higher than white in prevalence as well as in relative increase of overweight. Using NHANES data, the National Center for Health Statistics reports that the prevalence of overweight for infants (children < 2-years-old) increased from 7.2% over 1976–80 to 11.5% over 2003–2004 (5). Such trends speak to the need for examining the factors that may contribute to excess weight gain in infancy, since there is accumulating evidence that the rate of infant growth may bear on childhood or later obesity (6).

To illustrate, recent work has sought to link patterns of infant growth to child obesity by relating infant characteristics to older weight outcomes, with some reporting a direct association between birth weight and BMI in young adulthood (7,8). For example, rapid weight gain by formula-fed infants in the first week of life was shown to relate to adult overweight status by Stettler et al. (9), while Dennison et al. (10) reported that the rate of weight gain during the first six months of life was associated with a significantly increased risk of overweight at 4-years. Several studies suggest an association between increased rates of weight gain during the first 4 to 24 months of life and risk of overweight during later childhood or early adulthood (11–14). The impact of weight gain during infancy on child overweight may therefore be substantial, but the factors that contribute to early weight gain are not completely understood.

Some research on weight gain in infancy has taken an energy balance approach. In an oft-cited study, Roberts et al. (15) studied 18 infants, two-thirds with obese mothers, and tracking the babies from birth to 1-year. The six infants who became overweight consumed 42% more energy at 6-months than the 12 infants who remained lean (16). As these six infants also had reduced total energy expenditure at 3-months of age, the authors argued that energy spent on activity played a more important role in infant overweight than energy intake. In contrast, and with a larger sample of infants and mothers, Stunkard et al. (17) reported that energy intake at 3-months accounted for 8% of the variability in five measures of body size and composition at 12-months, but that neither energy expenditure or maternal obesity were at all predictive.

Concerning mothers, Baker et al. (18) found that maternal pre-pregnant BMI was strongly associated with infant birth weight and infant weight gain from birth to 1-year, with women whose BMI exceeded 30 having infants who grew an average of 135 grams more over the first year than those of normal weight mothers. Women who are overweight before becoming pregnant are less likely to initiate breastfeeding than are women with a normal BMI, and those who do elect to breastfeed cease doing so two weeks sooner on the average (19). Although a pre-year 2000 literature review concluded that no consistent pattern could be discerned as to a relationship between infant feeding methods or duration of breastfeeding and later obesity (20), a more recent meta-analysis of some 60 studies that included odds-ratio estimates, reported an overall odds-ratio of 0.87 that favored breastfeeding as reducing the risk of later obesity (21), indicating that formula feeding increased the risk.

The question remains, however, if formula-feeding increases the likelihood of subsequent obesity, what may account for its effect? To be sure, the composition of breast milk and cow's milk-based infant formula do differ. For example, Miralles et al. (22), has recently reported that the amount of the hormone leptin present in breast milk at 1-month provided moderate protection from an excess of weight gain through 24-months in sample of 28 infants. But in contrast to a human milk hypothesis, the results of many reports suggest that overfeeding may be a more apt explanation, as outlined below.

To start with, a vigorous feeding style, where high energy intake results, has been correlated with greater adiposity in early childhood—even for breast fed infants (23). But overfeeding is more likely to occur when infants are formula-fed, where the mother may respond to the visual cue of an unfinished bottle and ignore her infant's satiety signals (24). Gillman et al. (25) have proposed that a mother who breastfeeds may be more responsive to her infant's signals for both the frequency and volume of feeding; inferring that a formula-feeding mother may be less sensitive to her infant's cues. The real possibility of overconsumption of calories by formula-fed infants may induce adipose tissue hyper-cellularity (26) and they may in turn self-regulate their energy intake at a higher level (27), with either process resulting in more body fat. Indeed, it has been commonly reported that formula-fed infants begin to surpass breast-fed infants in terms of weight gain by 2–3-months (28).

In the present study, a cohort of low-income, black and Hispanic mother-infant dyads that chose to formula-feed exclusively were seen on repeated occasions over the first year of the infants' lives. These selection criteria were used because of the aforementioned literature that established low-income (3), minority status (1,4), and formula-feeding (20,21) as factors that heighten the risk for childhood obesity. Mothers were observed in feeding their infants and also kept a diary of their infants' behavior. Demographic information, as well as information on maternal weight and feeding attitudes, was also collected. The purpose of the study was to examine the relative contributions of maternal characteristics and behaviors in predicting infant weight gain over the first year of postpartum life. It was hypothesized that aside from certain birth characteristics, maternal attitudes and behaviors related to feeding would influence infant weight gain.

Methods

All the procedures of the present investigation were approved by our university's Institutional Review Board prior to the start of any subject recruitment or data collection. Permission for subject recruitment was also obtained through a letter of agreement from the cooperating WIC center. Recruiters were bilingual in English and Spanish. Two females conducted each home visit, at least one of whom was black or bilingual, depending on the family to be visited. All materials were available in English and Spanish, and questions were read to Hispanic mothers who could not read Spanish.

Subjects and Procedures

Mothers were recruited at their initial postpartum visit to a community WIC Center, which served a low income and largely minority population, many of whom were recent immigrants from Latin American countries. The staff receptionist at the center, as part of the intake interview, solicits demographic information from each mother and additionally asks what method of feeding she employs. At this center, it was estimated that 55% of the mothers indicate that they formula-feed exclusively, 5% breast fed exclusively, and 40% do both. If a mother indicated she was formula-feeding exclusively, the receptionist alerted the research recruiter of her eligibility, and the recruiter approached the mother after the mother's WIC visit was completed. Mothers, as well as WIC staff, were told that we were studying maternal feeding practices and infant growth and development. Mothers were informed of the study's longitudinal nature, and if willing to participate, were given a \$10 gift certificate for use at a local grocery store. After obtaining informed consent, demographic, attitudinal, and contact information was then recorded, as well as the mothers' and infants' height/length and weight measures as just determined by the WIC staff. (WIC staff members were trained in anthropometric measurement by personnel from the state Department of Health and Senior Services).

Home visits were conducted when the infants reached the ages of 3-, 6-, and 12-months, when the battery of measures described below was implemented. As noted above, the home visitors/research assistants were female, with at least one of each pair black or bilingual. As with the mothers, their concept of the investigation was a study of feeding practices by minority mothers and infant growth, with a focus on formula feeders for ease in determining energy intake. For each mother–infant dyad, a time at which the mother anticipated her infant would shortly awaken was chosen for Day 1 of the home visit to ensure a feeding could be observed, with the mother interviewed regarding feeding and her infant's temperament in the minutes surrounding or after the feeding bout. On Day 2, the infant was weighed and measured by one home visitor while the other home visitor checked the diet diary for omissions or to clarify ambiguities. Home visitors were trained to reliability in the assessment procedures of Gibson (29) by a Registered Dietitian. At the conclusion of the home visit, the mother was paid \$30 in cash.

Through recruiting efforts at the WIC center, 242 mothers initially agreed to participate. Given the low-level of education and transitory nature of the population, however, numerous mothers either lost interest or could not be contacted as time passed before home visits were to be scheduled—indeed, 83 mothers were unable to be scheduled for even the first home visit at 3-months. By the 6-month visit, 40 mothers could not be reached, and 23 more subjects were additionally lost by 12-months. Hence, the present sample consists of the 96 mother-infant dyads who were seen at enrollment and for whom all three home visits were conducted. A *post hoc* analysis of the 146 mothers who were lost versus the 96 mothers who completed the study revealed no differences in age, education or race/ethnicity between groups.

Measures

Maternal Feeding Attitudes (MFA; 30)—The MFA is a 10-item questionnaire with established reliability that asks the mother what type of behavior she would exercise with respect to 10 feeding issues. A higher score on the MFA indicates a “pushier” feeding attitude—pushier as in an inclination to feed the infant irrespective of the infant's expressed hunger. As used in its validation study (31), the MFA was completed at the time of recruitment. The measure has been used with minority mothers of overweight infants (32).

Infant Diet Record—At the initial home visit, mothers were asked to indicate the method they used to feed their infant (to confirm formula feeding). At this and subsequent visits, the

number and length of feeds per day, the number of ounces and brand of formula per day, any other liquid supplements, the time of introduction of any solid foods, and the type and amount of such foods per day were recorded. Any feeding-related problems or issues (e.g., formula intolerance, regurgitation, colic) were also recorded.

Maternal Sensitivity to Infant Cues (33)—The NCAST Feeding Scale is a 76-item checklist that describes mother-infant behavior and the contingency of their responses on each other, as observed in the context of the mother feeding the infant. Scores are derived for subscales such as maternal sensitivity to infant cues, cognitive growth fostering, and infant responsiveness to the caregiver. The Feeding Scale has shown good reliability by health professionals in a variety of settings, and has demonstrated validity with both minority and food-insecure mother-infant dyads (34,35). Its use requires trained observers, and we adhered to this requirement with home visitors who had achieved certification with the procedures. At the 3- and 6-month home visits, the full Feeding Scale was employed as per the NCAST guidelines. Since the study's purpose was to examine maternal behavior in the context of feeding, only the Maternal Sensitivity to Cues subscale was used for analysis. This subscale consists of 16 items, and credits the caregiver with attending while feeding, notably slowing, pausing or terminating the feeding when the infant disengages or shows satiation cues.

Statistical Analyses

Data were analyzed to determine normality of the variables studied, with linear regression analyses then conducted to determine the relative influence of specific variables, independent of potential confounding factors. An *a priori* calculation for sample size for multiple regression was computed, and indicated that a sample of 87 subjects or more would achieve a power level of .80 with an alpha level of $p < 0.05$, using as many as nine predictor variables. The following models were constructed using backwards linear regression analysis:

Model 1: To identify the antenatal characteristics that predicted infant weight gain from birth to 3-months, birth weight, gender, race/ethnicity, maternal age, education, country of origin, BMI before pregnancy, and weight gain during pregnancy were included as independent variables.

Model 2: To identify the antenatal characteristics that predicted infant weight gain from 3- to 6-months, birth weight, maternal BMI, infant weight gain from birth-3 months, infant length gain from birth-3 months, the estimated number of feeds per day, the month that solid foods were introduced, and the mothers' sensitivity to the infants' signals at 3-months were entered as independent variables.

Model 3: To identify the antenatal characteristics that predicted infant weight gained from 6- to 12-months, birth weight, maternal BMI, infants' weight gain from 3–6-months, infant length gain from 3–6-months, maternal sensitivity to infant signals at 6-months, and the estimated number of feeds/day at 6-months were entered as the independent variables.

For all regression analyses, independent variables that were not statistically significant were deleted from the model unless the variables were determined to be highly associated with the dependent variable (e.g., maternal BMI). Statistical significance was set at $p < 0.05$. All analyses were conducted using SPSS 16.0 for Windows (SPSS, Inc. Chicago, IL).

Results

Descriptive statistics for the sample appear in Tables 1 and 2. Demographic data indicate that the sample is approximately one-fourth black and three-fourths Hispanic, with two-thirds of this subgroup of mothers having been born in Mexico. The other third, also immigrants,

reported they were from Columbia, Peru, Honduras, Nicaragua, and the Dominican Republic. Mothers ranged in age from 15 to 42 years, with an average age of 26 years. Education level also varied widely, from 3 years of elementary schooling to two years of college. Maternal BMI indicated the average mother to be overweight, but BMI ranged from just over 17 to above 41. Table 2 also displays the percentage of infants who were at or above the percentile scores that indicate “at risk for overweight” (www.cdc.gov/growthcharts/) at the ages of measurement.

To identify the antenatal characteristics that predicted infant weight gain from birth to 3-months, a regression analysis was run that included the predictor variables listed above under Model 1. In addition, the maternal attitude score on the MFA administered when the mothers were recruited was also included. None of these variables served to predict infant weight gain over the first 3-months.

For the second regression, the predictor variables listed above under Model 2 were entered to examine their relation to infant weight gain from 3- to 6-months. Similar to Model 1, none of the variables were predictive.

For the final regression, the predictor variables listed above under Model 3 were entered to examine their relation to infant weight gain from 6- to 12-months. The results are summarized in Table 3. As seen in Part A of the table, number of feeds per day at 6-months approached significance in predicting weight gain from 6–12 months, and maternal sensitivity to the infants’ signals reached predictive significance, but in a negative direction—indicating that mothers who were less sensitive to satiety cues had infants who gained more weight. Part B of the table displays the results of the backward regression analysis, and shows that both number of feeds per day at 6-months and maternal sensitivity (inversely) were significantly related to weight gain from 6–12 months.

Discussion

In the present study, a number of maternal and infant characteristics were examined for their possible role in contributing to what may be deemed excessive weight gain in early human development. Obesity in America has rather suddenly, but unmistakably, become a serious problem. The factors that account for the recent increase in its rise are numerous, and as shown by rates of children who already overweight, the problem is only getting worse. As children have an eating history that precedes their reaching an overweight state, the present study was aimed at examining some of the feeding-related factors that may contribute to excess weight gain in infancy. However, it is not without its limitations. Obviously, it is limited to formula-fed infants of low-income minority mothers, yet overweight is also seen in middle-class, white children who have been breastfed. Future work must acknowledge that the prevalence of overweight in black and Hispanic children is not the same, and that less acculturated Hispanic subgroups also differ in preference for infant chubbiness” (36). Furthermore, fat infants do not necessarily become fat children—obesity tracks more certainly from adolescence to adulthood, with weaker associations from childhood to adolescence. Nevertheless, recent evidence strongly suggests that being overweight as early as age 2 may predict overweight some 10 years later. Specifically, the National Institute of Child Health and Human Development Early Care Research Network indicated that children who were ever categorized as overweight (defined as BMI $\geq$ 85th percentile) just once at 24-, 36- or 54-months were more than 5X as likely to be overweight at 12-years than those who were under the 85th percentile at all three measurement points (37). Two in five children whose BMIs were $\geq$ the 50th percentile by age 3-years were overweight at age 12-years. From this perspective, a partial understanding of the myriad factors that relate to early overweight in infancy was considered to be worthy of exploration.

While the lay public and most mothers have long perceived the “baby fat” of a chubby infant as benign, cute, or even desirable, the prospect of early fatness tracking into toddler or childhood is now viewed as foreshadowing later health problems. Infants of today do appear to be more likely to be overweight, perhaps as much as 70% more than 20 years ago if we can extrapolate from the recent report that estimated the problem at 17% (4). In contrast to that study, the cohort of infants followed in the present investigation was exclusively black and Hispanic, and would thus be predicted to be at the higher end of any averaged percentages. In fact, 19% of the infants of the present cohort were at or above the 85th percentile of weight-for-length for sex at birth, increasing to 30% at 3–6 months, and to 40% at 1-year. Although these percentages are quite alarming, they must not be taken as representative of the prevalence of infant overweight in the minority population. Aside from being a convenience sample, families were recruited from a WIC Center so by definition were additionally of low-income. Nevertheless, since food insecurity and obesity appear to correlate in low-income minority families (38), the high percentage of 12-month-old infants in the at-risk for overweight category may not be far off from the prevalence for similar subgroups.

Aside from highlighting the overrepresentation of overweight infants among these 12-month-olds, the present study sought to identify which infant, mother, and caregiving factors might relate to the weight gain they exhibited. A number of neonatal and maternal characteristics, including infant birth weight, maternal BMI, maternal attitudes toward feeding, etc., were entered into a regression analysis to predict the infants’ weight gain from birth to 3-months; somewhat surprisingly, not one of the factors was associated with infant weight gain. Measures obtained at 3-months, including diet and mother-infant interaction while feeding, were next regressed onto weight gain from 3-months to 6-months; similar to the previous analysis, none of the factors was associated with infant weight gain. Finally, the 6-month versions of the previous measures were regressed onto weight gained from 6-months to 12-months; in this regression daily feeds were found to be predictive. More impressive, however, mothers who were less sensitive to their infants’ cues had infants who gained more weight by one year. These results suggest that feeding played an important role in promoting the higher weight gain of these infants, since the mothers’ reporting of feeding frequency, as well as their lessened sensitivity to the infants’ cues, were salient in determining that these infants may have been regularly overfed.

More frequent feedings, particularly with formula, are an easy culprit on which to assign blame. But maternal sensitivity to the infant’s feeding state as reflected by the Feeding Scale scores suggest that an unwillingness to slow the pace of feeding or terminate the feeding when the infant shows satiation cues may be overriding the infant’s ability to self-regulate its intake. If such a feeding dynamic characterizes most feedings on most days, it is understandable that infants will likely ingest more formula than they desire or need, and accelerated weight gain will occur. To be sure, other factors that may contribute to early excess infant weight gain cannot be ruled out, for example, genetic predispositions, differences in metabolism, or the cumulative effect of nutrient-dense table foods later in the first year (39). However, in the present study at least, which included measures of birth weight and maternal BMI, gender, and observed and reported caregiving behavior, it was the mother’s actions with respect to the act of feeding that most directly related to weight gain.

Implications for Practice

The results of this study strongly suggest that maternal feeding behavior, as displayed through frequency and insensitivity, may influence the rate of infant weight gain. To use this knowledge to better inform low-income/educated mothers, indeed, mothers of any background who have settled in on a feeding method could pose a daunting challenge. Feeding an infant is a primal behavior, and to suggest to a new mother that she is feeding her infant too often, too much, or

worse yet, is not very good at reading her infant's signals, would require an extremely skilled nurse or social worker. Giving counsel after watching a mother feed her infant might be seen as threatening, or at the very least meddling, and just pointing it out could be construed as an accusation of "poor mothering." As lactation consultants are not in the business of guiding mothers who formula feed, an alternate approach could be through nutrition education efforts made available in the weeks preceding birth.

Nationwide, WIC currently works to promote breastfeeding as the optimal method of infant feeding, but for those mothers who formula-feed, it provides 90% of their infants with iron-fortified formula (40). At the center where this study's participants were recruited, 95% of the mothers were estimated as exclusively or partially formula feeding their infants. Rose et al. (41) have recently explored the link between WIC's provision of infant formula and child obesity, as the incentive of free formula may discourage breastfeeding. Clearly, efforts to encourage and support breastfeeding should continue at WIC centers. But for those mothers who may inevitably elect to use formula, modest interventions may be tried to demonstrate optimal feeding styles. For example, at the time of their first enrollment at WIC expectant mothers could view an educational video program that showcases infant behaviors that bear on feeding. If enrolling after motherhood, the video could be required as a condition of receiving their vouchers. Alternately or in addition, trained counselors could step up their guidance to mothers in feeding their infants, whether breast or bottle, by helping them to recognize hunger signals and respond to satiety cues. Such efforts will not stop the child obesity crisis, but may be a first step in slowing the prevalence of overweight that is already so apparent in our youngest Americans.

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Table 1

Descriptive statistics for mothers, N = 96. (Standard Deviations in parentheses)

Age in years	26.43 (5.92)
Race/ethnicity	24% black, 76% Hispanic
Country of origin	27% USA, 54% Mexico, 12% Dominican Republic, 7% Puerto Rico, Columbia, Honduras, and Peru
Highest year of schooling	9.35 (3.28)
BMI before pregnancy	25.97 (4.74)
Weight gain during pregnancy in kg	14.12 (6.38)
Parity	39% firstborn, 31% 2 nd , 21% 3 rd , 9% 4 th or more
Feeding attitude scale (20-maximum)	12.51 (2.93)
<u>3-months</u>	
Maternal sensitivity (16-maximum)	11.82 (2.21)
Number of feeds/day	6.33 (2.05)
<u>6-months</u>	
Maternal sensitivity (16-maximum)	11.43 (2.44)
Number of feeds/day	6.21 (1.69)
Age solid foods introduced (in months)	4.23 (1.17)

Table 2
Descriptive statistics for infants (Standard Deviations in parentheses)

<u>Birth</u>	
Sex	49 female, 47 male
Birth weight in kg	3.29 (.58)
Percent $\geq 85^{\text{th}}$ percentile weight/length age/sex	19%
<u>3-months</u>	
Weight at 3-months in kg	6.32 (.84)
Weight gain from birth–3 months in kg	3.01 (.73)
Length gain from birth–3 months in cm	11.41 (5.30)
Percent $\geq 85^{\text{th}}$ percentile weight/length age/sex	30%
<u>6-months</u>	
Weight at 6-months in kg	8.07 (.98)
Weight gain from 3–6 months in kg	1.73 (.69)
Length gain from 3–6 months in cm	6.74 (4.18)
Percent $\geq 85^{\text{th}}$ percentile weight/length age/sex	30%
<u>12-months</u>	
Weight at 12-months in kg	10.21 (1.20)
Weight gain from 6–12 months in kg	2.15 (.71)
Percent $\geq 85^{\text{th}}$ percentile weight/length	40%

Table 3

Predictors of infant weight gain from 6–12 months

A. Change in weight from 6–12 months (Linear regression)			
Multiple $R^2 = 0.269$			
Variables	B-Coefficient	Standard Error	p-value
(Constant)	1.144	.883	.20
Maternal BMI before pregnancy	.011	.018	.56
Infant's birth weight	.256	.170	.14
Number of feeds per day	.117	.063	.07
Maternal sensitivity to infant cues	-.127	.037	.001
Infant weight gain from 3–6-months	.142	.140	.32
Infant length gain from 3–6-months	.041	.027	.13
B. Change in weight from 6–12 months (Backward regression)			
Multiple $R^2 = 0.202$			
Variable	B-Coefficient	Standard Error	p-value
(Constant)	2.545	.526	.000
Number of feeds per day	.152	.060	.015
Maternal sensitivity to infant cues	-.121	.037	.002