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Maternal Depressive Symptoms and Children's Growth
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I. Introduction

A. Nature of the Research Problem

There has been an epidemic of obesity in the US in the past few decades among children. While earlier trends showed a rise in overweight mostly in school-age children and adolescents, more recent data show an increase for preschool children (Ogden, et al., 2002). Prevention of childhood obesity is important because obese children are likely to experience similar chronic medical and psychosocial problems related to obesity as adults (Drohan, 2002; Hodges, 2003, Kibbe, 2003). An emphasis on obesity, however, has eclipsed research on the lower end of the growth spectrum, young children with short stature or poor weight gain.

It is important to identify children at risk of becoming overweight or with reduced growth early when it is possible to intervene before long-term effects occur. We focused on maternal behavior as a risk factor for growth deviations in early childhood, particularly maternal depressive symptoms and related behaviors. There is considerable evidence of an impact of maternal depressive symptoms on mother-child interactions and children's behavior and development (Murray, 1992; Osofsky, 2000); little is known, however about their impact on children's growth in the US. Gaps in our knowledge include: 1) whether there is an association between maternal depressive symptoms and children's growth; 2) whether there are differential relations among sub-groups of children, e.g., for low income families or first time parents; and 3) whether the relation is mediated by other maternal behaviors.

B. Purpose, scope, and methods of the investigation

The overall objective of this study was to assess whether maternal depressive symptoms are associated with children's attained size and growth in the first 2 years. The 3 specific aims were to:

1) describe growth patterns in weight, length, and weight-for-length of children from birth to 2 years;

2) investigate whether maternal depressive symptoms at 2-4 months postpartum adversely affect children's attained size in length and weight-for-length at 6, 12, and 24 months of age, independent of the characteristic of the child, mother and family; and

3) investigate whether maternal depressive symptoms are related to trajectories in growth in length and weight-for-length in the first 2 years, independent of child, mother and family characteristics.

An ecologic model was used to frame the characteristics of the children and their mothers within the context of the family.

Data for this study were collected as part of the National Evaluation of the Healthy Steps (HS) for Young Children Program. HS, a new model of pediatric practice, was begun in 1996 and designed to improve the quality of pediatric care and to strengthen parents' knowledge, attitudes, and behaviors that promote their child's health, development, and behavior. The HS Evaluation followed a cohort of over 5000 families and children from birth to 32 months using two designs: a randomization design in 6 sites and a quasi-experimental design in 9 sites (Minkovitz,et al., 2001; Minkovitz,et al., 2003). Data were collected on: the child's health, behavior, and attained size; mother's health (including depressive symptoms), behaviors and practices; and the family's demographic and economic characteristics.

C. Nature of the findings (a brief general reference)

The study results suggest that maternal depressive symptoms are related to length for age among children under age 2, although some of the effect may be due to child, maternal and family characteristics, based on results for both Z-scores and the 10^{th} percentile of length for age. Longitudinal analyses show that these differences persist over the first two years of life. There also appears to be a relation of weight for length with depressive symptoms based on longitudinal analyses, although cross-sectional results suggest that the effect is not due to growth faltering.

II. Review of the Literature

A. Patterns of Growth In Young Children, Especially Obesity

An epidemic of obesity has been described among US children. Mei, et al. (1998), using CDC Pediatric Nutrition Surveillance System (PedNSS) data, reported an increase in the prevalence of children under 5 at risk for overweight (85^{th} to 95^{th} percentile of weight-for-height) from 18.6% in 1983 to 21.6% in 1995, and from 8.5% to 10.2% for overweight children (95 percentile or above). Ogden and colleagues (1997), using National Health and Nutrition Examination Survey (NHANES) and NHANES III data, found an increase in overweight among 4-5 year olds from 5.8% in 1971-74 to 10.0% in 1988-1994, but no rise in overweight for 1 or 2-3 years olds. Ogden et al. (2002) noted a rise in overweight among 2-5 year old children from 7.2% in 1988-1994 to 10.4 % for 1999-2000 using NHANES data. A

rise in underweight children was not shown in these studies, although selected groups, like poor children (Miller and Korenman, 1994) and children of mothers with depressive symptoms, may be at increased risk.

Obesity in preschool children is more common among Hispanic, native Indian and female children (Ogden, et al., 2002). Other risk factors are low levels of social support and living in a family headed by an unmarried mother (Gerald, et al., 1994). Two strong predictors of obesity in children are mother's education (Caliendo, et al., 1977; Gerald, et al., 1994) and her body mass index (BMI) (Hediger, et al, 2001). The literature on infant feeding practices and attained size is equivocal. Hediger, et al. (2000), using NHANES III data, found a 0.1 percent lower risk of overweight for each month that solid food introduction was delayed. Smaller studies (Baranowski, et al. 1990) found no relation of breastfeeding or introduction of solid foods with being overweight at 3-5 years.

Several studies have investigated the relation of social and psychosocial factors with growth faltering, as measured by either reduced weight or weight gain, or shortened stature. The findings for socioeconomic status (SES) are mixed. In Pakistan, Rahman, et al. (2004) showed a weak association of parental education, ownership of assets and relative poverty with weight and length, while Surkan and colleagues (2007) found an important effect of maternal education and SES on weight for age and weight for height in Brazil. Patel et al. (2003) also found an effect of maternal education in India. Using data from the Gateshead Millenium Baby (GMB) study, Wright et al. (2006) found no clear relation of maternal education with weight faltering. In the Avon Longitudinal Study of Parents and Children, Blair, et al. (2004) noted a relation of maternal age and use of a car at 6-8 weeks with weight gain and maternal height and parity at 9 months with weight gain. Birth weight was an important predictor of weight in South African children at 18 months (Tomlinson, et al., 2006), in Brazil (Surkan, et al., 2007) and in India (Patel, et al., 2003) at 6 months.

B. Maternal Depression Is Common and Affects Children Across the Lifespan

Depression is common among women; the lifetime prevalence of major depressive disorders (MDD) is estimated to be 21% (Johnson 2001). Postpartum depressive symptoms are common; 10% of women experience severe postpartum depression in their lifetime (Johnson 2001). In the first National Comorbidity Study, 13% of women were estimated to have an MDD in the past year (Kessler 1998). According to the *Healthy People 2010 Initiative*, major depression is the most common disorder among mental illnesses and a national priority (U.S. Department of Health, 2000).

Children of mothers with depressive symptoms are a vulnerable population; maternal depressive symptoms have been shown to negatively affect mother/child interactions. Mothers with depressive symptoms talk less to their infants, express fewer positive facial emotions, show less positive physical affection (Osofsky 2000; Murray, 1992), and have poorer preventive health practices (McLennan 2000). Maternal depressive symptoms are associated with bottle feeding (Yonkers, et al., 2001) and shorter duration of breastfeeding (Papinczak and Turner, 2000; Bick, et al., 1998).

The impact of maternal depressive symptoms on children's physical health, particularly their growth, has been addressed in several recent studies, many in developing countries (Patel, et al., 2005; Rahman, et al., 2004; Surkan, et al., 2007; Tomlinson, et al. 2006). These studies have evaluated the relation of psychosocial factors, particularly depression, and social support, with children's growth faltering or failure to thrive (O'Brien, et al., 2004; Rahman, et al., 2004; Surkan, et al., 2007; Wright, et al., 2006) The evidence is mixed in developed countries (Drewett, et al. 2004). There are no systematic large studies examining an association of maternal depressive symptoms with children's growth in a national US sample.

III. Study Design and Methods

A. Study Design

This research involved a secondary analysis of data from a study using an experimental/quasi-experimental design at 24 pediatric sites from the HS National Evaluation; families were followed to when the HS child was 32 month of age. Data sources included: parent enrollment questionnaires; telephone interviews with mothers at 2-4 months postpartum; and medical record audits of children.

B. Population studied

All study participants were mothers. Their racial and ethnic distribution generally mirrors the diversity of the US population. Close to 20 percent were Hispanic, over 20 percent were black, and about 4 percent were of Native American or Asian descent. The sample children were 50 percent

female, about 6 percent were low birth weight (LBW) and 77 percent of the mothers reported their infants in excellent health at 2-4 months. Only 16 percent of mothers reported less than a high school education, while 29 percent reported some college and 28 percent were college graduates. Two thirds of mothers were married and about half were first time mothers. Only 13 percent were under 20 and 36 percent were over 30; the respective percentages for fathers were 6 and 48 percent. Seventeen percent of mothers had depressive symptoms at 2-4 months. Seventeen percent reported at 2-4 months that they had smoked since their infant was born, 42 percent had given them water, and 63 percent talked to their infants while working at home.

C. Sample selection

The HS national evaluation enrolled 5565 infants/families across the US. A total of 4749 of these infants had mothers who reported depression scores at 2-4 months and had visits to 24 pediatric sites, as recorded in medical records, between birth and 30 months. Four children were excluded because no length or weight was reported in their records; 4745 children comprised the study sample.

D. Instruments Used

An ecological model, similar to that of Caliendo, et al. (1977), framed the study. Caliendo, et al. (1977) argued that children's nutritional status does not occur in isolation, but is affected by environmental factors, and that failure to address these factors may result in misleading conclusions about appropriate interventions. The ecological framework enabled us to capitalize on the richness of the data from the HS Evaluation by including factors hypothesized to be associated with children's attained size and growth within the context of the child and his/her environment.

Data sources for the study were: parent enrollment questionnaires; telephone interviews with mothers at 2-4 months; and medical record audits of children. Enrollment forms provided data about the characteristics of the infant, mother, father and family, health behaviors of the mother and father at enrollment and the child's sex, birth weight and length of nursery stay. The form was self-administered by the parent or by an interviewer in the hospital before to discharge or in the office of the HS provider within the first 28 days postpartum. Virtually all respondents were the mother.

Medical records provided data on weight and length from birth to 30 months for children whose mothers reported data about depressive symptoms from a modified Center for Epidemiologic Studies Depression (CES-D) scale at 2-4 months. The children had 66,015 observations in the medical records, and all had at least a length or weight recorded at a visit between 23 September 1996 and 6 April 2001. The number of visits ranged from 1 to 74..

Telephone interviews in English and Spanish, were conducted at 2-4 months with parents, 99% of whom were mothers. The interviews asked information about the child's general health status, hospitalization, and behavior since birth. Mother's demographic characteristics were marital status, education, home ownership, and race/ethnicity, and her parenting behaviors included infant feeding patterns and reported interactions with the infant. Data were available about the father's behavior, including smoking and helping with infant feeding. The interview included a modified 14-item CES–D (Radloff, 1977) used to measure maternal depressive symptoms, with a reliability coefficient of 0.85.

E. Statistical techniques employed

Cleaning and editing the weight and length data from medical records was needed. Although errors were relatively few, they were either committed in coding or entry of weight or height data or in conversion of data from pounds and ounces or inches to metric indices. These errors were corrected as were obvious outliers and duplicate records on the same date. A data file was created that contained length and weight data for each child by age in months and date of visit and Z-scores and percentiles for weight for age, length for age, and weight for length, based on the 2000 CDC growth charts (Kuczmarski, et al., 2002). This file was merged with one from the enrollment and interview data that contained variables hypothesized to be related to attained size and growth.

The next step was the bivariate analysis of the relation of maternal depressive symptoms and the child, maternal and family characteristics with attained size. Z-scores and percentiles for each child were taken at the age closest to the ideal (6, 12 or 24 months) for this analysis. These relations were assessed for Z-scores for weight for age, length for age and weight for length for 6, 12 and 24 months using analysis of variance. Maternal depressive symptoms and other characteristics were then related to the percentiles for weight for age, length for age and weight for length at each age using the Chi square test for significance.

We estimated multiple regression models for Z-scores for length for age and weight for length at 6, 12 and 24 months for several models with variables grouped by the ecologic framework. They were (1) child's sex, birth weight, length of nursery stay, and health status at 2-4 month; (2) mother's feeding practices and interactions with the infant; (3) maternal demographic characteristics; and (4) paternal demographic characteristics. A model with maternal depressive symptoms and each group of variables was estimated. Full models were estimated with depressive symptoms and all significant variables for length for age and weight for length for 6, 12 and 24months. These models helped us to determine if the impact of the covariates changed as the child aged.

We also evaluated the effect of aspects of the HS evaluation design. Because of clustering within sites, analyses accounted for the fact that subjects within sites tend to respond more similarly than those at other sites. There also was considerable site variation in the characteristics the mothers and children. A site variable was included as a fixed effect for estimates of the relation of depressive symptoms and attained size. Fixed effects models take into account unmeasured differences between sites, but do account for unmeasured variation among respondents within sites. The bivariate analysis showed no effect of the HS intervention on attained size.

The next analysis step was to test specific hypotheses related to depressive symptoms at 2-4 months and children's attained size, as measured by below the 10^{th} percentile, the 85^{th} to 95^{th} percentile and above the 95^{th} percentile for weight-for-length, and below the 10^{th} percentile for length at 6, 12, and 24 months. Similar models to those for Z-scores were estimated for the percentile variables, assuming an unadjusted relation of depressive symptoms with each percentile variable.

Hypothesis testing also evaluated whether maternal depressive symptoms influenced the trajectory of growth for children from birth to 24 months. We compared growth curves for children whose mothers did and did not have depressive symptoms at 2-4 months. Growth trajectories of length (in centimeters (cm) and weight-for-length (grams per cm) were examined using random-effects growth models to take account of the interdependence of repeated measures for each child. The growth curve model showed individual-level growth trajectories. Covariates, as specified above, were included in the growth trajectories models. We tested whether the relation of depressive symptoms with growth was sustained when the covariates were included in the model. We also included a site fixed effect.

IV. Presentation of Findings (detailed)

Table 1 shows the data for each attained size age windows. The number of children with length and weight measurements is given in the table. At 6 months, 89 percent of child had data on weight and length, while 79 and 56 percent had data at 12 and 24 months, respectively.

Table 1. Number of Children Who Had Visits with Both Weight and Length Measurements

	6 month visit	12 month visit	24 month visit
Number of kids	4210	3757	2634
Percent of total kids	88.7	79.2	55.5
Mean age (months)	6.1	12.2	24.2
Age range (months)	4.0 – 7.9	9.0 – 14.9	20.0 – 27.9
Mean weight	7.5 kg	9.8 kg	12.7 kg
Mean length	67.4	75.7	87.1
Mean Z-score, weight for age	0.21	- 0.16	0.10
Mean Z-score, length for age	0.38	0.29	0.14
Mean Z-score, weight for length	- 0.02	0.09	0.27

The study children's Z-scores for weight for age and weight for length were quite similar to the CDC standard population. The results suggest that the HS children were somewhat longer at 6 and 12 months than the CDC population, although they were within 0.4 Z-scores in value. More extensive analyses suggested that weight for age was strongly influenced by length for age; as a result, only height for age and weight for height were included in further analyses.

Table 2. Z-scores for Length-for-Age at 6, 12, and 24 months by Depressive Symptoms

Age Window	Depressive Symptoms		
	Scores > 11	Scores 11-15	Scores 16+
6 months	-0.12[c] (-0.20; -0.05)	-0.15[b] (-0.25; -0.04)	-0.10[a] (-0.21; 0.001)
12 months	-0.14[b] (-0.22; -0.05)	-0.14[b] (-0.26; -0.03)	-0.13[a] (-0.25; -0.01)
24 months	-0.12[b] (-0.21; -0.02)	-0.12* (-0.24; 0.01)	-0.11 (-0.25; 0.02)

[a] $p < 0.05$; [b] $p < 0.01$; [c] p , 0.001; * $p < 0.10$

Table 3. Z-scores for Weight-for-Length at 6, 12, and 24 months by Depressive Symptoms

Age Window	Depressive Symptoms		
	Scores > 11	Scores 11-15	Scores 16+
6 months	-0.01 (-0.10; 0.08)	-0.05 (-0.17; 0.07)	0.02 (-0.10; 0.15)
12 months	-0.03 (-0.13; 0.08)	-0.02 (-0.16; 0.11)	-0.03 (-0.17; 0.12)
24 months	-0.06 (-0.19; 0.06)	-0.05 (-0.21; 0.11)	-0.08 (-0.25; 0.09)

At 6, 12 and 24 months, maternal depressive symptoms were related to length for age Z-scores (Table 2), but not with weight for length (Table 3). They also showed an increased odds of length for age less than the 10th percentile at 6 and 24 months for children whose mothers had scores above 11 on the modified CES-D. There was no dose-response relation with increasing scores. The reduction in the odds ratio at 12 months was not due to attrition of mothers with high depressive scores, using the reduced 12 month and 24 month samples to evaluate the odds ratios at 6 months for children whose mothers had symptoms (Table 4).

Table 4. Logistic Regression of 10% Length-for-Age at 6 months using 6, 12, and 24 Months Samples at 12 and 24 Months for Depressive Symptoms

Age Window	Depressive Symptoms					
	Scores >11 Odds		Scores 11-15 Odds		Scores >16 Odds	
	Ratio	(95% CI)	Ratio	(95% CI)	Ratio	(95% CI)
6 months	1.92[c]	(1.36; 2.69)	2.03[b]	(1.32; 3.12)	1.80[a]	(1.14; 2.84)
12 months sample	1.81[b]	(1.23; 2.66)	2.02[b]	(1.25; 3.27)	1.59	(0.93; 2.71)
24 months sample	1.86[b]	(1.18; 2.91)	2.05[a]	(1.18; 3.56)	1.64	(0.86; 3.10)
12 months	1.29	(0.93; 1.79)	1.33	(0.87; 2.05)	1.24	(0.80; 1.94)
24 months	1.55[a]	(1.06; 2.26)	1.40	(0.85; 2.31)	1.72[a]	(1.05; 2.82)

[a] $p<0.05$; [b] $p<0.01$; [c] $p<0.001$

When evaluated by family income, Z-scores for length for age were significantly lower for children at 6 and 24 months whose mothers had depressive symptoms only for low to middle income families, and not for high income families (Table 5). The odds of length for age under the 10th percentile also was statistically significant only at 6 and 24 months for low to medium income families, adjusted for site (Table 6). It was inconsistent for high income families across age groups.

We found no relation of maternal depressive symptoms with weight for length percentiles less than 10, 85-95 and above 95 percentiles at 6, 12 or 24 months, adjusting for site (Table 7). When adjusted for covariates, there was a reduced odds of weight for length of 85-95 percentile at 24 months for maternal depressive symptoms (Table 10).

Table 5. Regression of z-scores for Length-for-Age on Maternal Depressive Symptoms at 6 Months, 12 months, and 24 months of Age, Adjusting for Site

	6 Months		12 Months		24 Months	
Depressive Symptoms	**Coefficient**	**(SD)**	**Coefficient**	**(SD)**	**Coefficient**	**(SD)**
High Income	-0.066	(0.086)	-0.175	(0.092)	0.023	(0.105)
Low/Medium Income	-0.128	(0.045)[b]	-0.114	(0.052)[a]	-0.143	(0.056)[a]
Depressive Symptoms						
High Income						
11-15	-0.029	(0.114)	-0.166	(0.123)	0.123	(0.139)
16+	-0.110	(0.123)	-0.185	(0.130)	-0.095	(0.151)
Low/Medium Income						
11-15	-0.160	(0.060)[b]	-0.122	(0.068)	-0.176	(0.074)[a]
16+	-0.096	(0.060)	-0.105	(0.070)	-0.108	(0.077)

[a] $p<0.05$; [b] $p<0.01$

Table 6. Logistic Regression of the Tenth Percentile or Less of Length-for-Age on Maternal Depressive Symptoms, at 6, 12, and 24 Months of Age Adjusted for Site by Family Income

	6 Months		12 Months		24 Months	
Depressive Symptoms	**OR**	**(95% CI)**	**OR**	**(95% CI)**	**OR**	**(95% CI)**
High Income	1.36	(0.55; 3.35)	1.21	(0.46; 3.19)	0.70	(0.21; 2.41)
Low/Middle Income	1.95	(1.36; 2.87)[c]	1.28	(0.90; 1.82)	1.65	(1.10; 2.47)[a]
Depressive Symptoms						
High Income						
11-15	0.89	(0.21; 3.84)	0.97	(0.22; 4.19)	0.97	(0.22; 4.30)
16+	1.86	(0.62; 5.54)	1.45	(0.42; 4.96)	0.45	(0.06; 3.51)
Low/Middle Income						
11-15	2.21	(1.40; 3.50)[c]	1.34	(0.85; 2.10)	1.18	(0.67; 2.09)
16+	1.74	(1.05; 2.88)[a]	1.22	(0.75; 1.96)	1.76	(1.01; 3.06)[a]

[a] $p<0.05$; [c] $p<0.001$

Table 7. Logistic Regression of 10th, 85th-95th and 95th Percentile of Weight-for-Length on Depressive Symptoms at 6, 12, and 24 Months

	Depressive Symptoms					
	Scores > 11		Scores 11-15		Scores 16+	
Age Window	**Odds Ratios**	**(CI)**	**Odds Ratios**	**(CI)**	**Odds Ratios**	**(CI)**
	10TH Percentile					
6 months	1.14	(0.89; 1.45)	1.14	(0.83; 1.58)	1.13	(0.81; 1.58)
12 months	1.16	(0.88; 1.52)	1.10	(0.77; 1.58)	1.22	(0.85; 1.77)
24 months	1.04	(0.73; 1.48)	1.01	(0.64; 1.60)	1.07	(0.65; 1.75)
	85TH – 95TH Percentile					
6 months	0.82	(0.66; 1.02)	0.86	(0.65; 1.15)	0.78	(0.58; 1.06)
12 months	0.89	(0.67; 1.17)	0.89	(0.61; 1.29)	0.89	(0.61; 1.30)
24 months	0.86	(0.66; 1.13)	0.91	(0.63; 1.29)	0.82	(0.56; 1.20)

	95TH PERCENTILE					
6 months	1.00	(0.71; 1.41)	0.94	(0.59; 1.50)	1.07	(0.68; 1.67)
12 months	0.94	(0.67; 1.32	0.95	(0.60; 1.50)	0.93	(0.59; 1.47)
24 months	1.08	(0.79; 1.47)	0.95	(0.60; 1.50)	0.99	(0.65; 1.52)

We estimated multiple regression models for the Z-scores for length for age and weight for length at 6, 12 and 24 months for models with variables grouped based on the ecologic framework. They were: child's sex, birth weight, length of nursery stay, and health status at 2-4 months, parent feeding practices, maternal interactions with the infant, maternal demographic characteristics, and paternal demographic characteristics. There was no relation of Z-scores for length for age with maternal depressive symptoms in the total sample after adjustment for site and covariates. There was, however, a significantly reduced Z-score for maternal depressive symptoms at 24 months among low to middle income families (Table 8). The odds of length for age scores less than the 10 percentile remained significantly increased at 6 months for children whose mothers had depressive symptoms, but not at 24 months. This increase was significant only for low to middle income families (Table 9).

Table 8. Regression of Z-scores for Length-for-Age on Maternal Depressive Symptoms, Adjusted for Covariates+ and Site at 6, 12, and 24 Months of Age for the Total, High Income and Low to Middle Income Samples

	Depressive Symptoms at Age Windows:					
	6 MONTHS		12 MONTHS		24 MONTHS	
SAMPLE	Regression Coefficient	(SE)	Regression Coefficient	(SE)	Regression Coefficient	(SE)
Total	-0.055	(0.039)	-0.078	(0.445)	-0.067	(0.050)
High Income*	-0.048	(0.084)	-0.163	(0.092)	0.035	(0.106)
Low/Middle Income	-0.061	(0.044)	-0.064	(0.051)	-0.114	(0.056)[a]

[a] $p < 0.05$

+ Covariates include low birth weight, excellent health, irritable baby, female, first time mom, mother smoked since birth and father's age

* Father's age was not included in the model for high income families

Table 9. Logistic Regression of 10th Percentile of Length-for-Age at 6, 12, and 24 Months on Depressive Symptoms, Adjusted for Covariates+ and Site for the Total, High Income and Low to Middle Income Families

	Depressive Symptoms at Age Windows:					
	6 MONTHS ODDS		12 MONTHS ODDS		24 MONTHS ODDS	
SAMPLE	RATIO	(95% CI)	RATIO	(95% CI)	RATIO	(95% CI)
Total	1.61[a]	(1.11; 1.24)	1.09	(0.77; 1.56)	1.27	(0.85; 1.90)
High Income	1.38	(0.54; 3.54)	1.35	(0.50; 3.65)	0.79	(0.23; 2.73)
Low/Middle Income	1.65[a]	(1.10; 2.48)	1.08	(0.74; 1.58)	1.41	(0.92; 2.16)

[a] $p < 0.05$

+ Adjusted for low birth weight, excellent health, irritable baby, female, first time mom, and mother smoked since birth; total sample also included income and low/medium income sample also included father's age

Table 10. Logistic Regression of the 10th, 85th – 95th and 95th Percentile of Weight-for-Height at 6, 12, and 24 Months on Depressive Symptoms, Adjusted for Covariates+ and Site

	Depressive Symptoms at Age Windows:					
	6 MONTHS ODDS		12 MONTHS ODDS		24 MONTHS ODDS	
PERCENTILE	RATIO	(95% CI)	RATIO	(95% CI)	RATIO	(95% CI)
10th	1.12	(0.87; 1.43)	1.10	(0.84; 1.46)	1.09	(0.76; 1.56)

85th – 95th	1.11	(0.85; 1.43)	1.03	(0.78; 1.36)	0.68[a]	(0.48; 0.97)
95th	1.07	(0.76; 1.51)	0.94	(0.66; 1.32)	1.06	(0.78; 1.45)

[a] $p < 0.05$

[+] Adjusted for low birth weight, gave water, talked to infant, low/middle income, mother's age, female infant

In the multivariate regression (not presented) girls had higher z-scores for length for age at all 3 ages, adjusting for site and covariates. LBW infants had markedly lower Z-scores for length for age at all 3 ages, although differences became smaller with age. Z-scores for length for age at 12 and 24 months were significantly greater for those whose mothers reported them in excellent health, but were lower for children whose mothers reported them as fussy or irritable at 2-4 months.

The children of first time mothers had increased Z-scores for length for age for all ages, while those with teenage fathers had significantly lower Z-scores at 6 and 12 months. Children from low income families also had lower Z-scores but only at 24 months. Children of mothers who had smoked since the child was born had lower Z-scores for length for age at 6 months. Most relations persisted among low to middle income families but not for high income families. Only birth weight was significant for high income families across all ages, and sex differences were evident at 12 months.

The relations of the covariates with the 10th percentile of length of age (not shown) in the logistic regression models mirrored those for Z-scores, although fewer covariates were statistically significant. LBW infants and females had increased odds of being at the 10th percentile for all ages. Children in low income families had an increased odds as well but only at 24 months, as did children of teenage fathers at both 12 and 24 months. There was no significant relation of the 10th percentile of length for age with the infant's health or being described by the mother as irritable, or for first time mothers or those who smoked since the baby's birth. When the analyses were conducted by income, only LBW was significant for children in high income families at 6 and 12 months. It was significant for all three ages for low to middle income families as well as for female children. Having a teenage father also significantly increased the odds of being of short stature at 6 and 12 months.

We also looked at Z-scores for weight for length in relation to the covariates. Girls had lower Z-scores for weight for length and LBW infants had markedly lower Z-scores at all 3 age windows. There were no other significant relations for the child, maternal and family characteristics

In the final analysis step, we compared growth curves for length for age (Table 11) and weight for length (Table 12) for children of mothers with and without depressive symptoms at 2-4 months over the first two years of life using longitudinal modeling techniques. Growth trajectories of length in centimeters (cm) and weight-for-length in grams (gms) per cm were examined using random-effects growth models in which age in months was an independent variable. Covariates will be included in the growth trajectories models, as was site as a fixed effect. The data points for growth started with measures taken at 4 months and only children with at least two measures at 4 months or older were included.

Table 11. Regression of Length (in cm) on Depressive Symptoms, Adjusted for Covariates and Site, from 4 to 28 Months

	Regression Coefficient	**(95% CI)**
Depressive Symptoms	- 0.194[a]	(-0.369; -0.019)
Low Birth Weight	- 3.242[c]	(-3.502; -2.981)
Excellent Health	0.314[c]	(0.159; 0.670)
Irritable Baby	- 0.289[c]	(-0.422; -0.157)
Female	1.314[c]	(1.186; 1.441)
First Time Mom	0.146[a]	(0.013; 0.280)
Father's Age ≤ 19	- 0.361[a]	(-0.655; -0.067)
Father's Age 20-24	0.060	(-0.242; 0.123)
Smoked Since Birth	- 0.241[b]	(-0.421; -0.061)

Child's Age in Months	1.483[c]	(1.478; 1.488)
Low Income	- 0.332[b]	(-0.537; -0.126)
Middle Income	- 0.161	(-0.329; 0.008)

[a] p<0.05; [b] p<0.01; [c] p<0.001

The results of the longitudinal analysis for length (Table 11) show strong effects of depressive symptoms as well as for several covariates. Depressive symptoms showed a reduction of about 0.2 cm in length when adjusted for the covariates, site and age. Length increased with age at a rate of about 1.5 cm per month. LBW was associated with over a 3 cm decrease in length; being reported as an irritable baby also showed a decrease in length by about 0.3 cm. Females were longer by over I cm, infants in excellent reported health were about 0.3 cm longer, and children of first time mothers had increased length by about 0.15 cm. Having a teenage father and a mother who smoked since birth as well as living in a low income family were related to a 0.2 to 0.3 cm reduction in length. The results were similar regardless of whether the model was fit with an random intercept term only or also with a random slope.

Table 12. Results of Regression of Weight for Length (gms per cm) on Maternal Depressive Symptoms from 4 to 28 Months

	Random Intercept		Random Intercept and Slope	
	Coefficient	**(95% CI)**	**Coefficient**	**(95% CI)**
Low Birth Weight	- 10.76[c]	(-11.89; -9.62)	- 10.76[c]	(-11.90; -9.62)
Gave Water to Infant	0.52	(-0.07; 1.12)	0.51	(-0.09; 1.11)
Talked to Infant	0.64[a]	(0.06; 1.23)	0.66[a]	(0.09; 1.25)
Female	5.11[c]	(4.55; 5.67)	5.12[c]	(4.57; 5.68)
Age of Child (Mos.)	2.97[c]	(2.95; 2.99)	2.97[c]	(2.95; 2.99)
Depressive Symptoms	- 0.94[a]	(-1.69; -0.20)	- 0.99[a]	(-1.77; -0.20)

[a] p<0.05; [c] p<0.001

In the longitudinal analysis, children of mothers with depressive symptoms were significantly lighter than those with no symptoms (0.9 grams/cm). LBW was strongly related to weight for length; these infants were almost 11 gm per cm lighter than normal birth weight infants, and females were about 5 gm per cm heavier. Weight-for-height increased by about 3 gm per cm per month between ages 4 and 28 months. Infants whose mothers frequently talked to them while at home were heavier by over 0.6 gm per cm.

V. Discussion of Findings

A. Conclusions to be drawn from findings (with reference to data supporting each).

At 6, 12 and 24 months, maternal depressive symptoms were strongly related to Z-scores for length for age, but not to weight for length. They also were significantly related to length for age less than the 10th percentile at 6 and 24 months. The odds of length for age less than 10th percentile was statistically significant only for low to medium income families. There was no relation of Z-scores for length for age in the total sample after adjustment for site and covariates; the Z-score for maternal depressive symptoms was significantly reduced at 24 months in low to middle income families. The odds of length for age scores under the 10 percentile remained significantly increased at 6 months for children whose mothers had depressive symptoms, but not at 24 months. This increase was significant only for low to middle income families. There was no relation with depressive symptoms for percentiles less than 10, 85-95 and above 95 percentile at 6, 12 or 24 months, adjusting for site.

The results of the longitudinal analysis for length showed strong effects of depressive symptoms and the covariates reported for Z-scores for the cross-sectional analysis. Depressive symptoms indicated a reduction of about 0.2 cm in length when adjusted for the covariates, site and age. In the

longitudinal analysis, maternal depressive symptoms were significantly related to weight for length (-0.9 gm/cm)

B. Explanations of limitations or possible distortion of findings

A major limitation of our study is the potential for residual confounding related to the effect of maternal depressive symptoms on the child's growth. The anthropometric characteristics of the mother and father were not available, nor were data on direct observations of the mother and child in a feeding situation. These latter data would have been helpful in assessing whether mothers with depressive symptoms were less likely to pick up feeding cues from the infant. We also were constrained by site variation when analyzing data by family income. Because in four sites the sample was primarily upper income and in four others it was largely low income, it was necessary to collapse sites in adjusting for the fixed effect of site for the two income groups. It also was not possible to include father's age as a variable in the analysis for high income families because of small numbers of teenage fathers.

Another limitation is that the study findings are not generalizable to the US population. Although diverse, the HS sample was somewhat more highly educated and older, with a lower LBW rate than the US birth population. The sample was similar in growth measures to the CDC population, and the CDC population also had a lower LBW rate than the general population.

C. Comparison with findings of other studies

Most prior studies of maternal postpartum depression have studied feeding interactions (Feldman, et al., 2004; Ammanti et al.,2004) or growth faltering, as measured by weight for age or weigh gain. Patel, et al, (2003) also looked at length as did Rahman, et al. (2004) and Surkan, et al., 2007). The studies showing an effect of postpartum depressive symptoms on growth faltering come from both developed (O'Brien, et al., 2004; Wright, et al., 2006)) and developing counties (Patel, et al., 2003; Rahman,et al., 2004). Surkan et al. (2007) and Tomlinson, et al. (2006) found no effect in Brazil or South Africa, nor did Drewett, et al. (2004) in England. Feldman, et al. (2004) found no relation of maternal depressive symptoms with feeding disorders, although their sample size was small, but Ammanti, et al. (2004) found an effect in Italy.

D. Possible application of findings to actual MCH health care delivery situations (including recommendations when appropriate)

Our study informs important aspects of policy and practice regarding whether we should increase provider training to recognize maternal depressive symptoms in office settings and for developing systems to link health care for mothers and their children. It has been suggested that traditional pediatric services be extended to meet the needs of families (FOPE II, 2000; AAP, 2003). In particular, the Future of Pediatric Education II Task Force (2000) identified the need to "collaborate with families and other child health professionals to identify and address challenges and barriers to the health and well-being of children." Although the Task Force suggested modification of existing clinical practices to address unmet needs of families, little is known about how best to do this. A recent study (Tam, et al.,2002) suggests that it is difficult to recruit mothers for screening for depression at well child visits. Our findings suggest greater commitment to family health, including better use of screening tools to assess maternal mental health, more effective systems of referral, and development of partnerships between adult and pediatric providers.

E. Policy Implications

Both maternal depressive symptoms and children's attained size and growth were of interest to us, especially the extremes of the distribution of children's growth parameters. The prominence of postpartum depression in the news media as well as its emergence as an important factor related to the well being of children make this an important time to capitalize on a study that links depressive symptoms to an important health problem in children. Given a link between maternal depressive symptoms and children's risk of being of short stature, current recommendations for increased screening for postpartum depressive symptoms can be reinforced as well as for counseling of screened women about the risks of growth deviations in their young children. Despite the negative influences of maternal depressive symptoms on children's health and development, pediatricians do little to identify maternal depressive symptoms and refer for treatment (Heneghan, 2000).

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