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Infant Growth and Child Cognition at 3 Years of Age

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Abstract

BACKGROUND—Infancy is a critical period for brain development. Few studies have examined the extent to which infant weight gain is associated with later neurodevelopmental outcomes in healthy populations.

OBJECTIVE—The purpose of this work was to examine associations of infant weight gain from birth to 6 months with child cognitive and visual-motor skills at 3 years of age.

PATIENTS AND METHODS—We studied 872 participants in Project Viva, an ongoing prospective, longitudinal, prebirth cohort. We abstracted birth weight from the medical chart and weighed infants at 6 months of age. We used the 2000 Centers for Disease Control and Prevention growth charts to derive weight-for-age *z* scores. Our primary predictor was infant weight gain, defined as the weight-for-age *z* score at 6 months adjusted for the weight-for-age *z* score at birth. At 3 years of age, we measured child cognition with the Peabody Picture Vocabulary Test III and visual-motor skills with the Wide Range Assessment of Visual Motor Abilities.

RESULTS—Mean Peabody Picture Vocabulary Test III score was 104.2, and mean Wide Range Assessment of Visual Motor Abilities test score was 102.8. Mean birth weight *z* score was 0.21, and mean 6-month weight *z* score was 0.39. In multiple linear regression adjusted for child age, gender, gestational age, breastfeeding duration, primary language, and race/ethnicity; maternal age, parity, smoking status, and cognition; and parental education and income level, we found no association of infant weight gain with child Peabody Picture Vocabulary Test III score (−0.4 points per *z* score weight gain increment, 95% confidence interval −1.3, 0.6) or total Wide Range Assessment of Visual Motor Abilities standard score (−0.4 points, 95% confidence interval −1.2, 0.5).

CONCLUSIONS—Slower infant weight gain was not associated with poorer neurodevelopmental outcomes in healthy, term-born 3-year-old children. These results should aid in determining optimal growth patterns in infants to balance risks and benefits of health outcomes through the life course.

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Keywords

infant growth; neurodevelopment

The third trimester of pregnancy through ≥ 2 years postterm is a critical period for brain development.¹ During that time, the brain develops rapidly through the processes of neurogenesis, axonal and dendritic growth, synaptogenesis, cell death, synaptic pruning, myelination, and gliogenesis.² These developmental processes build on each other over time so that a small disruption in any of the processes may have wide and long-lasting effects on brain structure and function.³

In ecological⁴ and interventional^{5,6} studies in developing countries with extensive childhood malnutrition, studies of children with failure to thrive (FTT),⁷ and studies of children born preterm,^{8–10} slower infant weight gain is associated with poorer cognition later in life. However, there are few studies of infant weight gain and cognitive development in healthy populations. One study¹¹ from the United Kingdom found that lower infant weight between 9 and 24 months was associated with only marginally lower cognitive and achievement test scores at 10 years of age. Another United Kingdom study¹² found a small, linear relationship of slower weight gain from birth to 8 weeks of age with lower IQ at 8 years of age but no appreciable relationship of weight gain from 8 weeks to 9 months of age with later IQ.

It is important to know whether slower infant weight gain is associated with poorer cognition in healthy populations of infants, because rapid weight gain may carry some harms, including an increase in the risk of obesity and related disorders later in life.^{13–19} Promoting slower infant weight gain might help to prevent these disorders, which are rising rapidly, even among the very young.²⁰

The aim of this study was to examine the extent to which infant weight gain in the first 6 months of life is associated with cognition and visual-motor skills at 3 years of age. We hypothesized that slower infant weight gain would not be associated with poorer cognitive or visual-motor skills in generally healthy, term-born children.

PATIENTS AND METHODS

Study Design and Participants

We studied participants in Project Viva, a prospective, longitudinal cohort study originally designed to examine multiple prenatal factors in relation to outcomes of pregnancy and child health. We recruited pregnant women into Project Viva at their first prenatal visit at Harvard Vanguard Medical Associates, a large multispecialty group practice in eastern Massachusetts. Exclusion criteria included multiple gestation, inability to answer questions in English, plans to move from the area before delivery, and gestational age >22 completed weeks at the initial prenatal clinical appointment. Additional details of recruitment and follow-up have been published elsewhere.²¹ Human subject committees of Harvard Pilgrim Health Care, Brigham and Women's Hospital, and Beth Israel Deaconess Medical Center (Boston, MA) approved the study protocols, and mothers of all of the participating children gave informed consent.

For this analysis, we included children with complete exposure and outcome data at birth, 6 months, and 3 years, and excluded children born <37 completed weeks' gestation. Of the 2128 women who delivered a live infant, 1579 had children eligible for the 3-year follow-up, and we performed in-person examinations on 1292 (82%). Of these 1292 children, we excluded 83 who were born before 37 completed weeks' gestation and 311 with missing exposure and/or outcome data. Thus, our sample for this analysis was 872 children and their mothers.

Measurements

Infant Anthropometry—Research assistants abstracted birth weight from the medical chart, weighed infants at 6 months of age with a digital scale (Seca Model 881, Seca Corporation, Hamburg, Germany), and measured infants' length at 6 months using a Shorr measuring board (Shorr Productions, Olney, MD). We also performed medical chart review to obtain data on participant weight at 8 weeks of age.

Child Cognition—Research assistants followed a standardized protocol to administer the Peabody Picture Vocabulary Test III (PPVT-III) and the Wide Range Assessment of Visual Motor Abilities (WRAVMA) to children at the 3-year study visit. The PPVT-III is a test of receptive language and is highly correlated with intelligence tests such as the Wechsler Intelligence Scale for Children III (Pearson $r = 0.90$ with the full-scale IQ score).²² The WRAVMA measures visual-motor, visual-spatial, and fine motor skills and is composed of drawing, matching, and pegboard tests.²³

Covariates—We collected data from mothers regarding parental and child demographic, social, economic, and health information through self-administered questionnaires and interviews at study visits during pregnancy, shortly after delivery, and when the child was 6 months and 3 years old. Details about the source of information for most of these variables have been described elsewhere.^{21,24} We measured maternal cognition using the PPVT-III at the child's 3-year study visit.

Analysis

Our primary outcomes were the PPVT-III and total WRAVMA standard scores, and our secondary outcomes were the WRAVMA drawing, matching, and pegboard scores. We used the 2000 Centers for Disease Control and Prevention growth charts^{25,26} to derive weight and weight-for-length z scores at birth and 6 months of age. Our primary predictor was the weight z score at 6 months of age, adjusted for the birth weight z score. We refer to this expression as “infant weight gain from birth to 6 months of age,” because it is algebraically identical to the change in weight z score from birth to 6 months, adjusted for the birth weight z score. We chose our approach for ease of statistical modeling and interpretation. In addition, to allow comparison with another study,¹² we examined infant weight gain from birth to 8 weeks and from 8 weeks to 6 months of age as predictors of our cognitive outcomes.

We used multivariable linear regression to estimate associations of infant weight gain with our cognitive outcomes. To control for confounding, in our final model we included parental and child covariates that are associated with infant weight gain and/or child cognition, including the child's gestational age, breastfeeding duration, race or ethnicity, and English as a second language status; the mother's age, parity, smoking status, and PPVT-III score; the parents' educational levels; and household income. We also controlled for child gender and age at cognitive testing. Additional adjustment for maternal gestational weight gain, depression, or parental marital status did not change the estimates, so we did not include them in our final model. We performed all of the data analyses with SAS 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

Table 1 lists participant characteristics. The mean (SD) PPVT-III score at 3 years of age was 104.2 points (14.4 points), similar to the standardized test mean of 100 points and SD of 15 points. The range of PPVT-III scores was 64 to 148 points. The total WRAVMA standard score is the sum of the WRAVMA drawing, matching, and pegboard test scores, standardized to a mean of 100 and SD of 15 points. In our sample, the mean (SD) total WRAVMA standard score was 102.8 (11.2), and the range was 57 to 151. The mean (SD) weight z score at birth

was 0.21 (0.94) and at 6 months was 0.39 (0.96). Mean (SD) breastfeeding duration was 6.7 months (4.5 months).

Compared with the 1579 mother-child pairs who were eligible for the 3-year follow-up, mothers in this analysis were more likely to be of white race (76% vs 69%), better educated (73% vs 68% with college or graduate degree), and more likely to have an annual household income exceeding \$70 000 (67% vs 62%) but were of similar age (32.6 vs 32.1 years). Children in this analysis had similar mean birth weight (3.58 vs 3.55 kg) and gestational age (39.9 vs 39.8 weeks) compared with all of the eligible children.

In unadjusted linear regression analyses (Table 2), we found that, for each z score increment in birth weight, the PPVT-III score was 2.3 points higher (95% confidence interval [CI]: 1.3 to 3.3 points), and the total WRAVMA standard score was minimally higher (0.6 points [95% CI: -0.2 to 1.5 points]). Similarly, for each z score increment in birth weight for gestational age (a measure of fetal growth), the PPVT-III score was 2.4 points higher (95% CI: 1.4 to 3.5 points), and the total WRAVMA standard score was 0.7 points higher (95% CI: -0.1 to 1.6 points). There was no association of infant weight z score at 6 months with PPVT-III score (-0.1 points per z score increment [95% CI: -1.1 to 0.9 points]) or total WRAVMA standard score (-0.4 points per z score increment [95% CI: -1.2 to 0.5 points]). There was also no association of infant weight-for-length z score at birth or 6 months with the outcomes.

Table 3 shows the results of our multivariable linear regression models. Weight z score at 6 months adjusted for birth weight z score represents infant weight gain from birth to 6 months. For each z score increment in infant weight gain, the PPVT-III score was 1.1 points lower (95% CI: -2.2 to 0.0 points), and the total WRAVMA standard score was 0.9 points lower (95% CI: -1.7 to 0.0 points). Adjustment for gestational age (model 2) minimally affected these estimates, whereas additional adjustment for breastfeeding duration (model 3) attenuated the association of infant weight gain with PPVT-III score to -0.4 points (95% CI: -1.5 to 0.7 points). Adjustment for parental and child covariates (model 4) minimally affected the association of infant weight gain with the cognitive test scores. In our fully adjusted model (model 4), the association of breastfeeding duration with the cognitive outcomes was 0.3 PPVT-III points per month breastfed (95% CI: 0.1 to 0.5 points) and 0.0 total standard WRAVMA points per month breastfed (95% CI: -0.2 to 0.2 points).

We performed secondary analyses examining infant growth in weight for length, a measure of adiposity. After adjustment for the same covariates as in model 4, associations of infant growth in weight for length with PPVT-III and WRAVMA scores were similar to associations of infant weight gain with PPVT-III and WRAVMA scores (data not shown).

In another secondary analysis, we divided our cohort into gender-specific deciles of infant weight gain and estimated the mean PPVT-III score in each decile (Fig). Adjusting for the same covariates as in model 4, we found that mean PPVT-III scores were 104.0 and 101.3 points in the lowest and highest deciles of weight gain, respectively.

To allow comparison with another study,¹² we examined infant weight gain in 2 separate intervals: from birth to 8 weeks and from 8 weeks to 6 months of age. Unlike the other study, we did not find that faster weight gain from birth to 8 weeks predicted higher 3-year PPVT-III scores (Table 4). In fact, the adjusted PPVT-III score in the lowest decile was slightly higher, at 104.5 points, than in the highest decile, at 102.7 points. Like-wise, we found no association of weight gain from 8 weeks to 6 months with PPVT-III score (Table 4).

DISCUSSION

We found that, in our cohort of generally healthy, term-born children, slower infant weight gain in the first 6 months of life was not associated with lower cognitive or visual-motor test scores at 3 years of age. We also found no evidence that children with the slowest weight gain had poorer test scores than children with the fastest weight gain.

Most investigations of infant weight gain and later cognition in developed countries have focused on children with and without FTT⁷ and have generally found that the children with FTT have lower IQ and other cognitive and achievement test scores. However, most of those studies draw cases of FTT from inpatient wards, specialty clinics, or primary care clinics serving predominantly poor children, so the results are not generalizable to the general population of infants. Some population-based studies^{27–29} of FTT and later cognition focus exclusively on economically deprived communities and are also limited because they do not account adequately for factors such as the infant's gestational age, breastfeeding status, or for maternal cognition. These factors may be important predictors of postnatal weight gain and child-hood neurodevelopment even within the range of “normal” birth weights^{30–33} and, thus, potential confounders of the relationship between infant weight gain and later cognition.

The results of our study are similar to 2 others^{11,12} from the United Kingdom that, like ours, examined child neurodevelopment across a spectrum of infant weight gain in a generally healthy population, rather than exclusively in children with and without FTT. In 1 of those studies,¹¹ cognitive and school achievement test scores (standardized test mean: 50 points [SD 10 points]) at 10 years of age were 0.3 to 0.7 points lower for each SD score of slower infant weight gain; and in the other,¹² adjusted IQ at 8 years of age was 0.2 points lower per SD score of slower weight gain from birth to 9 months. These effect sizes and our own are too small to support an effect of infant weight gain on neurodevelopment in a healthy population that is of clinical or public health significance.

One of the United Kingdom studies¹² also examined weight gain separately from birth to 8 weeks and from 8 weeks to 9 months of age. In contrast to our findings, those authors found a small, linear association of weight gain from birth to 8 weeks of age with IQ at 8 years of age (0.8 points per SD weight gain [95% CI: 0.4 to 1.3 points]). They also found that the IQ of infants in the slowest weight gain category (less than -1.5 SDs) was ~ 3 points lower than the IQ of those in the highest weight gain category (>1.5 SDs). In secondary analyses of our data, we found no association of early weight gain with our cognitive outcome, the PPVT-III score, which is highly correlated with IQ. In addition, in our study, children in the lowest category of weight gain from birth to 8 weeks did not have lower PPVT-III scores than children in the highest category of weight gain. Thus, one must consider the possibility that their findings were attributable to chance.

Also in contrast to our findings, studies of preterm infants^{8–10} suggest that slower infant weight gain does lead to poorer cognitive development in that population. One possible explanation for the adverse effect of slower infant weight gain on neurodevelopment in preterm infants is that they experience a degree of undernutrition and energy imbalance in the first months after birth³⁴ that is substantially greater than healthy, term infants in developed countries typically experience. In addition, the preterm brain may be more vulnerable to the effects of poor weight gain.^{35,36} Alternatively, there may be shared determinants of poor weight gain and neurodevelopmental impairment in preterm infants, such as perinatal neurologic injury, that lead both to feeding difficulties and to impaired cognitive function.

Mounting evidence suggests that rapid infant weight gain may have harmful consequences, including increasing the risk of obesity,^{13–15} high blood pressure,^{16,19} and insulin resistance.¹⁷ These disorders are on the rise and seem to have origins early in life.^{18,37} Promoting slower

infant weight gain may be an effective strategy to prevent these disorders, and our results suggest that, within the range of weight gain that we examined, there do not seem to be harmful effects of slower infant weight gain on cognition at 3 years of age in generally healthy, term-born children. However, other potential adverse effects of slower infant weight gain, such as increased susceptibility to infection³⁸ and decreased adult height,¹⁴ also need to be evaluated in healthy populations of infants.

An important strength of our study is that we carefully measured and controlled for numerous potentially confounding covariates, including gestational age, breastfeeding duration, maternal intelligence, and socioeconomic variables. However, we did not have specific information about infant-caregiver interaction patterns or family functioning, so residual confounding is possible. Our findings should be applied to generally healthy term-born children, not preterm children or children with extremely poor weight gain, such as those with FTT. We confirmed others' findings in healthy populations that higher birth weight is associated with higher cognitive test scores,^{30–33} suggesting that ours is a representative cohort, although generalizability of our findings may be limited by the relatively high socioeconomic status of our participants and the preferential loss to follow-up of participants in lower socioeconomic status and minority racial and ethnic groups. In addition, although we assessed cognition and visual-motor skills using well-validated instruments, our study cannot exclude associations of infant weight gain with other aspects of neurodevelopment, such as executive function and behavior. Finally, although cognitive function at 3 years of age is correlated with later intelligence, testing at ≥ 5 years of age is likely to yield a more stable measure of intelligence.³⁹ We are currently collecting cognitive data on our cohort at 7 years of age.

CONCLUSIONS

In this study of healthy term-born children, we found that slower infant weight gain is not associated with poorer neurodevelopmental outcomes at 3 years of age. These results should aid in determining optimal growth patterns in infants to balance risks and benefits of health outcomes through the life course.

What's Known on This Subject

In children with FTT and children born preterm, slower weight gain is associated with poorer neurodevelopmental outcomes. Little is known about the extent to which infant weight gain is associated with neurodevelopment in healthy, term-born populations.

What This Study Adds

Slower weight gain was not associated with poorer neurodevelopment in healthy, term-born 3-year-old children. Children with the slowest weight gain did not have lower cognitive test scores than children with the fastest weight gain.

Abbreviations

FTT, failure to thrive; PPVT-III, Peabody Picture Vocabulary Test III; WRAVMA, Wide Range Assessment of Visual Motor Abilities; CI, confidence interval.

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FIGURE 1.

Estimated Peabody Picture Vocabulary Test III (PPVT-III) score (standard error) within deciles of infant weight z-score at 6 months (A) and 8 weeks (B). Range of 6 month weight z-scores within deciles for boys: D1(− 2.1, − 0.9), D3(− 0.5, − 0.2), D5(0.0, 0.3), D7(0.5, 0.8), D9(1.1, 1.4), D10(1.4, 3.2); and for girls D1(− 2.6, − 0.8), D3(− 0.4, − 0.1), D5(− 0.2, 0.4), D7(0.7, 1.0), D9(1.4, 1.8), D10(1.8, 3.6). Range of 8 week weight z-scores within deciles for boys: D1(− 2.2, − 0.5), D3(− 0.1, 0.1), D5(0.4, 0.6), D7(0.9, 1.1), D9(1.5, 1.8), D10(1.8, 4.3); and for girls D1(− 2.1, − 0.5), D3(− 0.1, 0.1), D5(0.4, 0.6), D7(0.8, 1.1), D9(1.4, 1.8), D10(1.8, 3.1). Estimates are adjusted for child birth weight z score, sex, age at cognitive assessment, gestational age, breastfeeding duration, race/ethnicity, and English as a second language status; maternal age, parity, smoking status, and PPVT-III score; parental educational levels; and annual household income.

TABLE 1**Characteristics of 872 Participants in Project Viva**

Characteristic	Measure
Mother, mean (SD)	
Age, y	32.6 (4.9)
PPVT-III score	107.1 (14.9)
Parity, <i>n</i> (%)	
0	411 (47.1)
1	317 (36.4)
≥2	144 (16.5)
Smoking status, <i>n</i> (%)	
Former	181 (21.2)
3 mo before or during pregnancy	81 (9.5)
Never	591 (69.3)
Education, <i>n</i> (%)	
High school diploma or less	52 (6.0)
Some college	181 (20.8)
Bachelor's degree	318 (36.5)
Graduate degree	320 (36.7)
Father or partner, <i>n</i> (%)	
Education	
High school diploma	83 (9.5)
Some college	154 (17.7)
Bachelor's degree	307 (35.2)
Graduate degree	273 (31.3)
Don't know or missing	55 (6.3)
Household, <i>n</i> (%)	
Annual income, \$	
<40 000	83 (9.5)
40 001–70 000	172 (19.7)
>70 000	561 (64.3)
Don't know or missing	56 (6.4)
Child	
Birth weight mean (SD), kg	3.58 (0.47)
Gestational age, mean (SD), wk	39.9 (1.2)
Birth weight <i>z</i> score, mean (SD)	0.21 (0.94)
Birth weight-for-length <i>z</i> score, mean (SD)	0.49 (0.77)
Birth weight-for-gestational-age <i>z</i> score, mean (SD)	0.28 (0.93)
6-mo weight <i>z</i> score, mean (SD)	0.39 (0.96)
6-mo weight-for-length <i>z</i> score, mean (SD)	0.73 (0.96)
Breastfeeding duration, mean (SD), mo	6.7 (4.5)
PPVT-III score, mean (SD)	104.2 (14.4)
WRAVMA scores, mean (SD)	
Drawing	99.5 (11.3)

Characteristic	Measure
Matching	108.3 (13.4)
Pegboard	98.9 (10.5)
Total standard	102.8 (11.2)
Male, <i>n</i> (%)	434 (49.8)
Speaks English as a second language, <i>n</i> (%)	31 (3.6)
Race or ethnicity, <i>n</i> (%)	
White	624 (71.6)
Black	97 (11.1)
Hispanic	26 (3.0)
Other	125 (14.3)

Total WRAVMA standard score is the sum of the drawing, matching, and pegboard scores, standardized to a mean of 100 and an SD of 15.

Unadjusted Associations (95% CI and P Value) of Infant Size and Growth Variables With Cognitive Outcomes at 3 Years of Age

TABLE 2

Variable	PPVT-III	WRAYMA Drawing	WRAYMA Matching	WRAYMA Pegboard	Total WRAYMA
Birth					
Weight z score	2.3 (1.3 to 3.3)	0.3 (−0.5 to 1.1)	0.9 (−0.1 to 1.9)	0.4 (−0.3 to 1.2)	0.6 (−0.2 to 1.5)
Weight-for-length z score	0.2 (−1.4 to 1.8)	0.1 (−1.1 to 1.3)	−0.4 (−2.0 to 1.1)	−0.5 (−1.7 to 0.7)	−0.7 (−2.0 to 0.6)
Birth weight-for-gestational-age z score	2.4 (1.4 to 3.5)	0.3 (−0.5 to 1.1)	0.9 (−0.03 to 1.9)	0.5 (−0.2 to 1.3)	0.7 (−0.1 to 1.6)
6 mo					
Weight z score	−0.1 (−1.1 to 0.9)	0.1 (−0.6 to 0.9)	−0.6 (−1.5 to 0.3)	−0.2 (−0.9 to 0.6)	−0.4 (−1.2 to 0.5)
Weight-for-length z score	−0.7 (−1.7 to 0.3)	−0.3 (−1.1 to 0.5)	−1.7 (−2.7 to −0.7)	−0.4 (−1.2 to 0.3)	−1.2 (−2.0 to −0.3)

Numbers in the table represent the unadjusted increment in the cognitive test score per z score increment in the size or growth variable. Total WRAYMA standard score is the sum of the drawing, matching, and pegboard scores, standardized to a mean of 100 and SD of 15. All of the z scores were derived by using the 2000 lefts for Disease Control and Prevention growth charts²⁵, 26 except the birth weight-for-gestational-age z score, which was derived by using a national reference.⁴⁰

TABLE 3
Adjusted Associations of Infant Weight Gain From Birth to 6 Months With Child Cognitive Scores at 3 Years of Age

Variable	Cognitive Test			
	PPVT-III	WRAVMA Drawing	WRAVMA Matching	Total WRAVMA
Model 1				
Weight-for-age z score at 6 mo	-1.1 (-2.2 to -0.0)	-0.1 (-1.0 to 0.7)	-1.2 (-2.3 to -0.2)	-0.9 (-1.7 to 0.0)
Weight-for-age z score at birth	2.7 (1.6 to 3.8)	0.3 (-0.5 to 1.2)	1.4 (0.4 to 2.4)	1.0 (0.1 to 1.8)
Model 2: model 1 +gestational age				
Weight-for-age z score at 6 mo	-1.1 (-2.2 to -0.0)	-0.1 (-0.9 to 0.7)	-1.2 (-2.3 to -0.2)	-0.9 (-1.7 to -0.0)
Weight-for-age z score at birth	2.8 (1.6 to 4.0)	0.3 (-0.7 to 1.2)	1.3 (0.2 to 2.5)	1.0 (0.1 to 2.0)
Model 3: model 2 +breastfeeding duration				
Weight-for-age z score at 6 mo	-0.4 (-1.5 to 0.7)	-0.0 (-0.9 to 0.8)	-0.9 (-2.0 to 0.1)	-0.6 (-1.5 to 0.3)
Weight-for-age z score at birth	2.3 (1.2 to 3.5)	0.1 (-0.8 to 1.1)	1.2 (0.1 to 2.3)	0.9 (-0.1 to 1.8)
Model 4: model 3 +parental and SES variables				
Weight-for-age z score at 6 mo	-0.4 (-1.3 to 0.6)	-0.0 (-0.8 to 0.9)	-0.6 (-1.6 to 0.4)	-0.4 (-1.2 to 0.5)
Weight-for-age z score at birth	2.4 (1.4 to 3.5)	0.2 (-0.8 to 1.1)	0.9 (-0.3 to 2.0)	0.7 (-0.2 to 1.7)

Numbers in the table represent the increment in cognitive test score per z score increment in weight for age (95% CI) and *P* values. Total WRAVMA score is the sum of the drawing, matching, and pegboard scores, standardized to a mean of 100 and SD of 15. The 6-month weight-for-age z score adjusted for the birth weight-for-age z score represents weight gain in the first 6 months of life. All of the models are adjusted for child gender and age at cognitive assessment. SES indicates socioeconomic status. Parental and SES variables include the child's race or ethnicity and English as a second language status; the mother's age, parity, smoking status, and PPVT-III score; the parents' educational levels; and the annual household income.

TABLE 4

Adjusted Associations of Infant Weight Gain in 2 Intervals With Cognitive Test Scores at 3 Years of Age

Interval of Infant Weight Gain	Cognitive Test	
	PPVT-III	Total WRAVMA
Birth to 8 wk		
Weight z score at 8 wk	−0.2 (−1.4 to 1.1)	−0.5 (−1.6 to 0.7)
Birth weight z score	2.4 (1.0 to 3.7)	0.7 (−0.5 to 1.9)
8 wk to 6 mo		
Weight z score at 6 mo	−1.0 (−2.6 to 0.5)	−0.2 (−1.5 to 1.2)
Weight z score at 8 wk	1.9 (0.3 to 3.5)	0.0 (−1.4 to 1.4)

Numbers in the table represent the increment in cognitive test score per z score increment in weight for age (95% CI) and *P* values. Estimates are adjusted for child gender, age at cognitive assessment, gestational age, breastfeeding duration, race or ethnicity, and English as a second language status; maternal age, parity, smoking status, and PPVT-III score; parental educational levels; and annual household income.