Title

The Revised WIC Food Package and Child Development: A Quasi-Experimental Study

Journal
Pediatrics, 147(2)

ISSN
0031-4005

Authors
Guan, Alice
Hamad, Rita
Batra, Akansha
et al.

Publication Date
2021-02-01

DOI
10.1542/peds.2020-1853

Peer reviewed

The Revised WIC Food Package and Child Development: A Quasi-Experimental Study

Alice Guan, MPH,[a] Rita Hamad, MD, PhD,[b,c] Akansha Batra, MAS,[a] Nicole R. Bush, PhD,[d,e] Frances A. Tylavsky, DrPH, MS,[f] Kaja Z. LeWinn, ScD[d,e]

abstract

BACKGROUND AND OBJECTIVES: The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), one of the largest US safety net programs, was revised in 2009 to be more congruent with dietary guidelines. We hypothesize that this revision led to improvements in child development.

METHODS: Data were drawn from a cohort of women and children enrolled in the Conditions Affecting Neurocognitive Development and Learning in Early Childhood study from 2006 to 2011 (Shelby County, TN; N = 1222). Using quasi-experimental difference-in-differences analysis, we compared measures of growth, cognitive, and socioemotional development between WIC recipients and nonrecipients before and after the policy revision.

RESULTS: The revised WIC food package led to increased length-for-age z scores at 12 months among infants whose mothers received the revised food package during pregnancy (β = .33, 95% confidence interval: 0.05 to 0.61) and improved Bayley Scales of Infant Development cognitive composite scores at 24 months (β = 4.34, 95% confidence interval: 1.11 to 7.57). We observed no effects on growth at age 24 months or age 4 to 6 years or cognitive development at age 4 to 6 years.

CONCLUSIONS: This study provides some of the first evidence that children of mothers who received the revised WIC food package during pregnancy had improved developmental outcomes in the first 2 years of life. These findings highlight the value of WIC in improving early developmental outcomes among vulnerable children. The need to implement and expand policies supporting the health of marginalized groups has never been more salient, particularly given the nation's rising economic and social disparities.

Departments of [a]Epidemiology and Biostatistics, [b]Family and Community Medicine, and [d]Psychiatry and Behavioral Sciences, [c]Philip R. Lee Institute for Health Policy Studies, and [e]Weill Institute for Neurosciences, University of California, San Francisco, San Francisco, California; and [f]Department of Preventive Medicine, The University of Tennessee Health Science Center, Memphis, Tennessee

Ms Guan conceptualized this study, conducted the initial analysis, and drafted the initial manuscript; Dr Hamad conceptualized this study, supervised the analysis, and reviewed and revised the manuscript; Dr LeWinn conceptualized this study, designed the data collection instruments and coordinated and supervised data collection, and reviewed and revised the manuscript; Ms Batra contributed to data organization, data analysis, and code review; Drs Bush and Tylavsky designed the data collection instruments and coordinated and supervised data collection; and all authors critically reviewed the manuscript for important intellectual content and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: https://doi.org/10.1542/peds.2020-1853

Accepted for publication Nov 5, 2020

WHAT'S KNOWN ON THIS SUBJECT: Researchers in previous studies have demonstrated that revisions to the Special Supplemental Nutrition Program for Women, Infants, and Children in October 2009 led to improved healthy food access, dietary quality, and birth outcomes among low-income families.

WHAT THIS STUDY ADDS: Using unique cohort data and a quasi-experimental design, we found that the 2009 revisions to the Special Supplemental Nutrition Program for Women, Infants, and Children also improved early childhood developmental outcomes, suggesting that nutritional interventions during pregnancy may reduce intergenerational transmission of health disparities.

To cite: Guan A, Hamad R, Batra A, et al. The Revised WIC Food Package and Child Development: A Quasi-Experimental Study. *Pediatrics*. 2021;147(2):e20201853

Maternal nutrition plays a critical role in fetal growth and development.[1–5] Suboptimal maternal nutrition during pregnancy may shape the programming of fetal tissues, which is thought to increase chronic disease risk in childhood and adulthood.[6–9] To ensure optimal birth outcomes, child growth, and brain development, the nutritional demands of fetal development need to be met. In the United States, the unequal distribution of health care, social support, and access to healthy food has led to racial and socioeconomic disparities in maternal nutrition.[10–12] Evidence suggests that nutritional interventions during pregnancy could substantially improve birth outcomes and subsequent child health and development, including cognitive development and physical growth.[13–17] As such, targeted policies and programs that improve access to healthy foods in at-risk communities could be a promising approach for addressing social disparities in child outcomes that have been associated with maternal nutrition during pregnancy.[16,17]

Established in the 1970s, the US Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) was created to safeguard the health of women, infants, and children up to the age of 5 living in low-income households[18] in part through the provision of healthy foods. WIC serves approximately half of all infants, 30% of all children aged <5, and approximately one-third of all pregnant and postpartum women.[19] In 2019, >$5 billion was spent to aid ~6.4 million women, infants, and children enrolled in WIC nationwide.[20] WIC serves marginalized communities, with ~50% of children being Hispanic or Latino and 20% being African American.[21] In 2009, the WIC food packages for both women and children were revised for the first time to better align it with national dietary guidelines.[22,23] This revision included healthier food options (eg, fruits and vegetables), restrictions to less-healthy options (eg, requiring milk to be low-fat and bread to be whole grain), and incentives for breastfeeding.[19] Importantly, the revised WIC food package introduced $10-per-month vouchers for purchase of fresh fruits and vegetables.

Extant literature has found that the revised WIC food package improved healthy food availability,[24–27] maternal and child dietary quality,[28–31] perinatal and birth outcomes,[32] and breastfeeding.[33–35] However, no researchers, to our knowledge, have evaluated effects of this revision on downstream child health or development. In this study, we address this gap in our understanding of one of the largest US safety net programs by examining the association between the revised food package and several early childhood developmental outcomes. By employing a quasi-experimental difference-in-differences (DiD) design, we estimated effects of the revised food package on child growth, socioemotional, and neurodevelopmental outcomes. We hypothesized that children whose mothers received the revised WIC food package during pregnancy would have better developmental outcomes.

METHODS

Data

The sample consisted of mothers and their children from the Conditions Affecting Neurocognitive Development and Learning in Early Childhood (CANDLE) longitudinal cohort study, which enrolled 1503 pregnant women from Memphis and surrounding Shelby County, Tennessee during 2006–2011.[36] Longitudinal data collection occurred during pregnancy and throughout childhood. We included data from the baseline survey during pregnancy to capture key covariates and later survey waves that included the outcomes of interest. The sample was restricted to children for whom valid data were collected on these outcomes (Fig 1).

Variables

Exposure

The main exposure was whether women received the revised WIC food package during pregnancy. Because the revision was implemented in October 2009, women who gave birth after this date were considered to be exposed during their pregnancy.[37] Participation in WIC during pregnancy was self-reported retrospectively during postpartum survey waves. Unfortunately, CANDLE did not ask women about their receipt of WIC during the postpartum period, during which they would have also been eligible for breastfeeding assistance, so in this study we focused on WIC receipt during pregnancy as the primary exposure.

Outcomes

We considered 3 core child developmental outcome domains measured at 1, 2, and 4 to 6 years of age, each of which has been previously linked with maternal nutrition: child growth, cognitive development, and socioemotional development. Below, we describe in detail those outcomes that fulfilled the assumptions of our statistical methods and were therefore included in our analyses (see Supplemental Information for more details on outcomes not included).

Child Growth, calculated by using Centers for Disease Control and Prevention growth charts,[38] was assessed by using length-for-age z scores at 12 months, weight-for-age and weight-for-length z scores at 24 months, and height-for-age z scores at 4 to 6 years. Researchers in several studies have documented potential long-term consequences of failure to thrive in infancy, including adverse

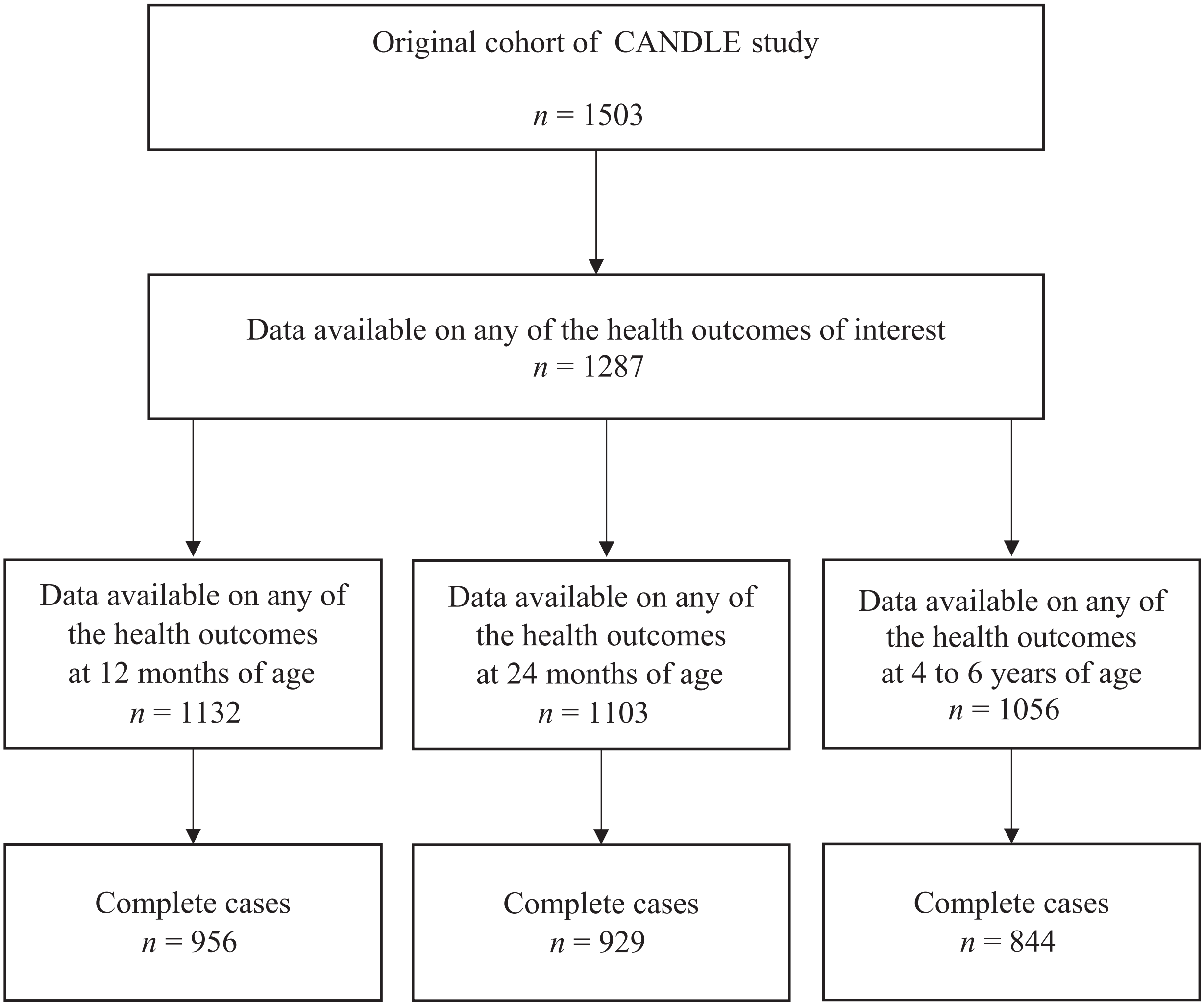

FIGURE 1
Sample flowchart.

cognitive outcomes.[39,40] Early childhood growth has also been linked to subsequent growth and height in adulthood,[41,42] which has been found to be correlated with improved adult outcomes even in high-income countries.[43,44] Other anthropometric measures (eg, length for age at 24 months) were not included because they did not meet the assumptions of statistical models (see Supplemental Information).

Socioemotional development was measured with the Brief Infant Toddler Social Emotional Assessment (BITSEA).[45] Assessments were conducted by a licensed psychologist or advanced graduate student in psychology at both 12 and 24 months of age; we include each of these time points as a separate outcome. The BITSEA consists of 2 multiitem scales: the competence score for socioemotional abilities and the problem total scale for behavioral problems and emotional dysregulation. Socioemotional development at age 4 to 6 years, measured by the Child Behavior Checklist, was also assessed but not included because of violations of the statistical model assumptions (see Supplemental Information).

Cognitive development was assessed at age 24 months by a licensed psychologist using the Bayley Scales of Infant Development (Bayley).[46] The Bayley at 24 months is correlated with full-scale IQ and school readiness during preschool.[47] Correlations are especially strong among children at developmental risk.[48,49] We included 3 Bayley scores: the cognitive composite score, receptive communication subtest scaled score, and total language subtest composite score. We also included a standardized full-scale child IQ score, assessed at 4 to 6 years of age by trained psychologists using the Stanford-Binet Intelligence Scales (SB-5).[50] The SB-5 has been validated in large, diverse populations and serves as a reliable assessment of intellectual and cognitive abilities. The Bayley expressive communication subtest was also assessed but not included because of violations to the statistical models (see Supplemental Information).

Covariates

Models included covariates that might confound the relationship between receipt of the revised WIC food package and the outcomes: mother's age, educational attainment, marital status, race, receipt of Medicaid during pregnancy, household size, household income, and total number of pregnancies and child's sex. We included indicator variables for birthyear in all models to account for secular trends.

Main Analysis

First, we calculated descriptive statistics stratified by WIC receipt during pregnancy. Then, we estimated the effects of the revised food package using DiD analysis. DiD analysis is a quasi-experimental technique, ideally suited to examine the effects of policy changes while accounting for secular trends.[51] We leveraged the fact that revisions to the WIC food package in October 2009 were unlikely to be confounded by participant characteristics. Thus, we compared outcomes before and after the policy revision among WIC recipients, "differencing out" secular trends in outcomes among nonrecipients, which included both noneligible individuals and eligible nonrecipients. We chose this as our primary comparison group rather than WIC-eligible participants because CANDLE collected income as a crude categorical rather than a continuous variable; this would have introduced significant measurement error in identifying WIC-eligible families. We included a comparison with families likely to be WIC eligible as a sensitivity analysis (see below). Additional details on the DiD model, including the equation and testing of standard assumptions, are included in the Supplemental Information.

Sensitivity Analyses

We conducted several analyses to test the robustness of the results. First, we used WIC eligibility as the exposure, rather than WIC receipt (n = 967, n = 937, and n = 879 for outcomes measured at age 12 months, 24 months, and 4–6 years, respectively). WIC eligibility is defined by income standards up to 185% of the federal poverty threshold, enrollment in other social assistance programs, and nutrition risk. Roughly 50% of pregnant women in the United States who are eligible actually receive WIC benefits,[52] so this analysis is analogous to an intent-to-treat approach. This analysis allowed us to correct for potential bias from "nonadherence," because eligible women who enroll in WIC could differ from eligible women who do not enroll. By using CANDLE's categorical income data, eligibility was computed by using WIC eligibility guidelines for income, household size, and Medicaid receipt. Second, we restricted the sample to women whose pregnancies did not include the WIC revision date (October 2009) to examine associations among women exposed to the revised WIC package throughout their entire pregnancy (n = 749, n = 727, n = 668 for outcomes measured at age 12 months, 24 months, and 4–6 years, respectively). Third, we restricted our analysis to women who made <$75 000 per year to be more reflective of women eligible for WIC (n = 777, n = 758, and n = 701 for outcomes measured at age 12 months, 24 months, and 4–6 years, respectively). Fourth, visual inspection of the parallel trends plots indicated that trends in outcomes between WIC recipients and nonrecipients were most comparable in the 20 months before the WIC revision. Thus, we restricted the sample to observations occurring within 20 months of the WIC revision (n = 918, n = 894, n = 818 for outcomes measured at age 12 months, 24 months, and 4–6 years, respectively).

RESULTS

Sample Characteristics

More than half (56.9%) those who received WIC during pregnancy gave birth after October 2009 (Table 1). Overall, 87.2% of WIC recipients and 33.1% of nonrecipients were Black. Additionally, 24.2% of WIC recipients had more than a high school education, compared with 70.8% of nonrecipients. WIC recipients were more likely to be younger (24.6, SD: 5.1) compared with nonrecipients (29.0, SD: 4.9).

Association of Revised WIC Package With Child Development

Compared with infants whose mothers did not receive the revised WIC food package during pregnancy, those whose mothers received the revised WIC food package had greater length-for-age z scores at age 12 months (β = .33, 95% confidence interval [CI]: −0.05 to 0.61) and higher Bayley cognitive composite score at age 24 months (β = 4.34, 95% CI:1.11 to 7.57) (Table 2). We observed no statistically significant association between receipt of the revised WIC package with child growth at 24 months or 4 to 6 years of age, measures of socioemotional development at both 12 and 24 months, or measures of cognitive development at 4 to 6 years of age.

Sensitivity Analyses

When we considered WIC-eligible individuals as the treatment group (rather than recipients) (Table 3, model 1), and when we excluded pregnancies including October 2009 (model 2), results for length for age remained similar to the primary analysis. However, we noted an attenuated effect size and a CI that included the null for the Bayley

TABLE 1 Sample Characteristics

Characteristic	No WIC in Pregnancy, n = 525		WIC in Pregnancy, n = 700	
	Mean (SD)	%	Mean (SD)	%
Gave birth after October 2009	—	43.1	—	56.9
Sociodemographic				
Mother's age	29.0 (4.9)		24.6 (5.1)	
Mother's marital status	—	86.3	—	37.1
Annual household income				
$0–$9999	—	6.3	—	31.7
$10 000–$24 999	—	7.3	—	32.3
$25 000–$44 999	—	15.3	—	21.0
$45 000–$74 999	—	33.3	—	12.7
$75 000+	—	37.8	—	2.0
Female child	—	51.0	—	49.6
Mother's race				
Black	—	33.1	—	87.2
White or other[a]	—	66.9	—	12.9
Mother's education				
Less than high school	—	4.3	—	14.0
High school	—	25.0	—	61.8
More than high school	—	70.8	—	24.2
Medicaid or TennCare	—	21.6	—	82.2
Total No. pregnancies	2.4 (1.4)	—	2.7 (1.8)	—
No. people in household	4.0 (1.2)	—	4.6 (1.6)	—
Child health outcomes at age 12 mo				
Length-for-age z score	0.05 (1.2)	—	0.04 (1.2)	—
BITSEA: problem total	8.0 (4.9)	—	10.9 (6.1)	—
Child health outcomes at age 24 mo				
Wt-for-age z score	2.1 (1.1)	—	2.0 (1.1)	—
Wt-for-length z score	0.4 (1.2)	—	0.4 (1.2)	—
BITSEA: problem total	8.3 (5.5)	—	11.3 (6.7)	—
BITSEA: competency total	18.5 (2.4)	—	17.7 (2.7)	—
Bayley: cognitive composite score	102.5 (14.1)	—	94.4 (10.9)	—
Bayley: receptive communication subtest	10.5 (3.1)	—	8.8 (2.4)	—
Bayley: total language subtest	103.3 (17.0)	—	94.8 (12.6)	—
Child health outcome at 4–6 y of age				
Height-for-age z score	0.41 (1.0)	—	0.48 (1.3)	—
Cognitive test score	106.3 (14.7)	—	96.2 (13.7)	—

N = 1287 (data on WIC receipt were missing for 62 participants). Sample includes children enrolled in the CANDLE Study, Shelby County, Tennessee, 2006–2011. —, not applicable.
[a] Less than 2% of the sample were Hispanic or other race or ethnicity. Thus, they were included in the "white" category to avoid unstable estimates due to small cell sizes.

cognitive composite score. When we excluded women with incomes of $75 000 or more (model 3), the association with the cognitive score remained similar to the primary analysis. However, we noted a decreased effect size and CI that included the null for length for age. When we excluded observations occurring >20 months before the revision, the results remained similar to the primary analysis (model 4).

DISCUSSION

In this study, we leveraged a quasi-experimental design to provide some of the first evidence of the effects of maternal receipt of the revised WIC food package during pregnancy on developmental outcomes in early childhood. These results suggest that the revised food package resulted in improved length for age at age 12 months and cognitive development at age 24 months.

Maternal nutrition could lead to lasting epigenetic modifications to the fetal genome through a process termed "fetal programming" and may result in developmental adaptations that change the physiology of the offspring in a lasting manner.[53–55] Previous literature has shown that the WIC revision affected outcomes during several stages of fetal growth and development. Namely, the revised food package was found to improve dietary quality and nutrient intake during pregnancy[28,56] as well as downstream perinatal and birth outcomes.[32] With our study, we suggest that effects of a mother's receipt of the WIC revision during pregnancy could be observed into early childhood, up to 24 months of age.

The magnitude of the findings in this study represents clinically relevant effect sizes and provides evidence that one of the largest US safety net policies improves developmental outcomes among low-income and marginalized children. We found a 4.3-point increase in the Bayley

TABLE 2 Effects of the Revised WIC Food Package on Child Health Outcomes

	Outcomes at Age 12 mo		Outcomes at Age 24 mo							Outcomes at Age 4–6 y	
	Length-for-Age *z* Score	BITSEA: Problem Total	Wt-for-Age *z* Score	Wt-for-Length *z* Score	BITSEA: Problem Total	BITSEA: Competency Total	Bayley: Cognitive Composite Score	Bayley: Receptive Communication Subtest	Bayley: Total Language Subtest	Height-for-Age *z* Score	Cognitive Test Score
WIC × Postrevision	0.33** (0.05 to 0.61)	−0.46 (−1.85 to 0.94)	0.20 (−0.10 to 0.51)	0.18 (−0.16 to 0.52)	−0.49 (−2.11 to 1.12)	−0.12 (−0.80 to 0.57)	4.34*** (1.11 to 7.57)	−0.21 (−0.91 to 0.49)	−0.39 (−4.13 to 3.35)	0.10 (−0.20 to 0.39)	−0.07 (−3.59 to 3.45)
WIC	−0.18 (−0.44 to 0.08)	0.29 (−1.02 to 1.60)	−0.15 (−0.44 to 0.14)	−0.09 (−0.41 to 0.23)	0.61 (−0.93 to 2.15)	−0.04 (−0.69 to 0.61)	−3.53** (−6.60 to −0.46)	0.26 (−0.40 to 0.92)	0.84 (−2.71 to 4.40)	0.03 (−0.25 to 0.31)	0.43 (−2.86 to 3.71)
Postrevision	0.16 (−0.16 to 0.48)	0.26 (−1.34 to 1.85)	0.23 (−0.10 to 0.57)	0.37* (−0.00 to 0.75)	−0.82 (−2.62 to 0.99)	−0.02 (−0.79 to 0.74)	−2.54 (−6.14 to 1.06)	0.06 (−0.71 to 0.84)	0.37 (−3.80 to 4.54)	0.11 (−0.24 to 0.45)	0.09 (−3.92 to 4.09)

Sample includes children enrolled in the CANDLE Study, Shelby County, Tennessee, 2006–2011. n = 956 for outcomes assessed at age 12-months, n = 929 for outcomes assessed at age 24-months, n = 844 for outcome assessed at 4–6 years old. The above estimates represent β coefficients with 95% CIs in parentheses. The effect estimate of interest is the coefficient on the interaction term. Analyses involved regressing each of the outcomes listed above on an indicator for WIC receipt, an indicator for whether the birth occurred after October 2009, and the interaction between the two. The models additionally adjusted for mother's age, educational attainment, marital status, race, receipt of Medicaid during pregnancy, household size, household income, and total number of pregnancies and child's sex.

*** $P < .01$; ** $P < .05$; * $P < .10$

cognitive composite score, which represents approximately one-third of an SD. These results are consistent with previous studies, in which researchers found improvements in neurodevelopmental outcomes for children whose families participated in WIC.[57–59] However, previous work was cross-sectional in nature or evaluated effects of WIC participation more generally rather than the WIC revision. With our study, we advance this understanding by providing quasi-experimental evidence to strengthen the causal interpretation of this association. This provides evidence that policies to improve maternal nutrition during pregnancy can have long-term consequences for child health. Moreover, shifts in the population distribution of Bayley scores, which may be observed in response to far-reaching safety net programs such as WIC, could ultimately lead to reductions in the number of children at risk for developmental delay. We found that there was no association of the revised WIC food package with cognitive scores at ages 4 to 6 years, suggesting that the effects of the revised WIC food package in pregnancy may wane over time. This is also consistent with previous literature suggesting that socioeconomic gaps in cognitive performance widen with age and that even gains in cognitive test scores in response to interventions designed specifically to improve cognitive performance fade over time (although other benefits of early intervention are often observed).[60] Furthermore, there are notable measurement differences between the Bayley and SB-5 that reflect large developmental differences between ages 2 to 3 and 4 to 6; correlations between these scores are at best modest within the same, typically developing children.[61] Thus, it is possible that improvements in the WIC package do have longer-term impacts on early childhood developmental outcomes not measured in this study.

We additionally found that the revised WIC food package was associated with increased length-for-age *z* scores at age 12 months by approximately one-fifth of an SD. There is a positive correlation between height in childhood and adulthood,[62] so improvements in linear growth could potentially contribute to later life height potentials. Although body height is largely determined by genetic factors, environmental factors including nutrition could explain up to 20% of the height variation in high-income nations.[63] There is a well-known association between height in adulthood and higher earnings even in high-income countries,[43,44] and height is thought to be a proxy for improved socioeconomic status in childhood more generally. For example, taller children have been found to have higher average cognitive test scores[64] and later life educational attainment.[44]

There was no observed effect of the revised WIC food package on child growth beyond age 12 months, cognitive development at age 4 to 6 years, or measures of socioemotional developoment for across all age ranges included. There are several potential explanations for why we were unable to detect an association. First, it may be that revisions to the WIC food package were too modest to influence these outcomes, which may be associated with more proximal aspects of the social environment, such as parental stress and mental health.[65] Relatedly, child language is associated with the home language environment,[66] which may overshadow more distal associations with prenatal nutrition. Second, it may be that effect sizes were too small to detect given of the sample size. Third, pregnant women's receipt of the modest revision to WIC could have limited benefits to child development over time. Finally, although there are hypothesized mechanisms through which improved

TABLE 3 Sensitivity Analyses: Effect of the Revised WIC Food Packages on Child Health Outcomes

	Outcomes at Age 12 mo		Outcomes at Age 24 mo							Outcomes at Age 4–6 y	
	Length-for-Age *z* Score	BITSEA: Problem Total	Wt-for-Age *z* Score	Wt-for-Length *z* Score	BITSEA: Problem Total	BITSEA: Competency Total	Bayley: Cognitive Composite Score	Bayley: Receptive Communication Subtest	Bayley: Total Language Subtest	Height-for-Age *z* Score	Cognitive Test Score
Model 1: WIC eligible											
WIC × Postrevision	0.39*** (0.10 to 0.67)	−0.08 (−1.51 to 1.35)	0.29* (−0.02 to 0.60)	0.12 (−0.23 to 0.46)	−0.68 (−2.33 to 0.97)	−0.03 (−0.73 to 0.66)	1.87 (−1.43 to 5.17)	−0.28 (−0.99 to 0.43)	−0.33 (−4.13 to 3.47)	0.13 (−0.18 to 0.43)	−1.75 (−5.30 to 1.81)
WIC	−0.03 (−0.57 to 0.51)	0.85 (−1.84 to 3.53)	0.04 (−0.53 to 0.62)	0.16 (−0.49 to 0.81)	2.07 (−1.03 to 5.17)	0.46 (−0.86 to 1.77)	3.68 (−2.52 to 9.88)	0.89 (−0.45 to 2.22)	4.97 (−2.17 to 12.11)	−0.04 (−0.59 to 0.52)	5.16 (−1.35 to 11.67)
Postrevision	0.15 (−0.16 to 0.46)	0.07 (−1.50 to 1.64)	0.21 (−0.12 to 0.54)	0.41** (0.04 to 0.78)	−0.73 (−2.50 to 1.04)	−0.07 (−0.82 to 0.68)	−1.27 (−4.81 to 2.28)	0.10 (−0.67 to 0.86)	0.39 (−3.68 to 4.47)	0.10 (−0.25 to 0.44)	0.87 (−3.08 to 4.82)
Observations	967	967	866	912	937	937	937	937	937	879	865
Model 2: exclude October 2009 pregnancies											
WIC × Postrevision	0.30* (−0.01 to 0.61)	−0.02 (−1.54 to 1.49)	0.23 (−0.09 to 0.56)	0.13 (−0.25 to 0.51)	−0.41 (−2.12 to 1.31)	−0.17 (−0.92 to 0.59)	3.64** (0.07 to 7.20)	−0.49 (−1.26 to 0.28)	−1.42 (−5.56 to 2.71)	0.15 (−0.18 to 0.48)	0.52 (−3.41 to 4.44)
WIC	−0.21 (−0.49 to 0.07)	0.23 (−1.14 to 1.59)	−0.18 (−0.48 to 0.12)	−0.10 (−0.44 to 0.25)	0.38 (−1.17 to 1.93)	0.13 (−0.55 to 0.81)	−3.52** (−6.74 to −0.29)	0.39 (−0.31 to 1.08)	1.56 (−2.18 to 5.30)	−0.03 (−0.32 to 0.27)	0.32 (−3.11 to 3.76)
Postrevision	−0.01 (−0.50 to 0.47)	−1.96 (−4.31 to 0.39)	−0.04 (−0.57 to 0.50)	0.42 (−0.19 to 1.02)	−3.79*** (−6.49 to −1.10)	0.68 (−0.52 to 1.87)	−2.30 (−7.92 to 3.31)	1.69*** (0.48 to 2.91)	6.89** (0.38 to 13.41)	0.03 (−0.47 to 0.52)	4.91* (−0.93 to 10.75)
Observations	746	747	666	703	726	726	726	726	726	668	654
Model 3: exclude income ≥$75 000											
WIC × Postrevision	0.26 (−0.06 to 0.57)	−0.18 (−1.87 to 1.50)	0.18 (−0.18 to 0.53)	0.15 (−0.24 to 0.54)	−0.65 (−2.63 to 1.33)	0.18 (−0.63 to 0.99)	4.72** (1.03 to 8.41)	−0.27 (−1.04 to 0.50)	−0.20 (−4.33 to 3.93)	0.01 (−0.34 to 0.35)	−0.46 (−4.56 to 3.64)
WIC	−0.09 (−0.37 to 0.19)	0.06 (−1.43 to 1.55)	−0.10 (−0.41 to 0.22)	−0.01 (−0.36 to 0.34)	0.72 (−1.04 to 2.49)	−0.25 (−0.97 to 0.48)	−4.09** (−7.39 to −0.79)	0.27 (−0.42 to 0.95)	0.29 (−3.40 to 3.97)	0.04 (−0.27 to 0.34)	0.83 (−2.73 to 4.40)
Postrevision	0.14 (−0.24 to 0.51)	−0.10 (−2.10 to 1.91)	0.28 (−0.13 to 0.69)	0.50** (0.05 to 0.96)	−0.92 (−3.23 to 1.39)	−0.37 (−1.32 to 0.58)	−1.62 (−5.93 to 2.69)	0.26 (−0.64 to 1.15)	0.52 (−4.30 to 5.35)	0.13 (−0.29 to 0.54)	1.13 (−3.73 to 5.98)
Observations	775	774	694	733	755	755	755	755	755	701	690
Model 4: exclude observations >20 mo prerevision											
WIC × Postrevision	0.39*** (0.10 to 0.67)	−0.41 (−1.81 to 1.00)	0.25 (−0.07 to 0.56)	0.22 (−0.12 to 0.56)	−0.77 (−2.40 to 0.86)	−0.03 (−0.72 to 0.67)	4.46*** (1.13 to 7.80)	−0.21 (−0.93 to 0.51)	−0.63 (−4.46 to 3.20)	0.15 (−0.16 to 0.45)	−0.58 (−4.14 to 2.97)
WIC	−0.23 (−0.50 to 0.05)	0.21 (−1.13 to 1.54)	−0.18 (−0.48 to 0.11)	−0.13 (−0.46 to 0.20)	0.95 (−0.61 to 2.51)	−0.16 (−0.83 to 0.50)	−3.70** (−6.89 to −0.51)	0.26 (−0.43 to 0.94)	0.99 (−2.67 to 4.65)	−0.00 (−0.29 to 0.29)	0.68 (−2.67 to 4.03)
Postrevision	0.13 (−0.19 to 0.45)	0.25 (−1.32 to 1.82)	0.22 (−0.12 to 0.55)	0.36* (−0.02 to 0.73)	−0.67 (−2.46 to 1.12)	−0.07 (−0.83 to 0.70)	−2.57 (−6.23 to 1.08)	0.06 (−0.72 to 0.85)	0.45 (−3.75 to 4.65)	0.08 (−0.26 to 0.43)	0.37 (−3.61 to 4.35)
Observations	916	916	829	868	892	892	892	892	892	818	805

Sample includes children enrolled in the CANDLE Study, Shelby County, Tennessee, 2006–2011. The above estimates represent β coefficients with 95% CIs in parentheses. The effect estimate of interest is the coefficient on the interaction term. Analyses involved regressing each of the outcomes listed above on an indicator for WIC receipt, an indicator for whether the birth occurred after October 2009, and the interaction between the two. The models additionally adjusted for mother's age, educational attainment, marital status, race, receipt of Medicaid during pregnancy, household size, household income, and total number of pregnancies and child's sex.

* $P < .10$; ** $P < .05$; *** $P < .01$.

maternal nutrition in pregnancy could influence socioemotional development,[17,56,67] the current evidence remains correlational and largely inconclusive,[68–70] and it may be that there is in fact no effect for this particular outcome.

This study has several strengths. We are among the first to test the effects of the revised WIC food package on downstream child health. In this study, we leveraged a natural experiment to produce rigorous estimates of the effects of the revised food package on several outcomes, strengthening the growing body of evidence that supports the positive association between WIC and multiple health outcomes. Furthermore, by examining a variety of outcomes related to child growth and development, in this study we provide a more-comprehensive illustration of the different pathways through which improved maternal nutrition affects child growth and development. Finally, this study was conducted with data from the CANDLE cohort, providing rich longitudinal data on both pregnancy and later child health, which is rare in the United States.

This study has several limitations. Although the WIC food package is standardized at the federal level, food availability and access and the characteristics of women and children in Tennessee may differ from other states. Therefore, results may not be generalizable to other states. However, CANDLE participants share characteristics with other, majority-Black communities in the urban South that are underrepresented in studies of child development and face high levels of social disadvantage. Additionally, income, WIC receipt, and other covariates were self-reported and may suffer from reporting bias. Next, the findings were not uniformly robust to sensitivity analyses, although the sensitivity analyses were not considered to be the main analyses because of their own limitations (eg, the sensitivity analysis using WIC eligibility as the treatment group was subject to measurement error because income was collected as a crude categorical variable). Furthermore, because most sensitivity analyses led to reduced sample size, this may have resulted in reduced power to detect effects. Also, children whose mothers were eligible for WIC in pregnancy may themselves be eligible for WIC after birth, so part of the effect that we are capturing may reflect continued receipt of the revised WIC package during childhood. This is likely to bias the results toward the null, because some children born soon before the revision who technically fall into the control group could then receive the revised WIC food package as children, therefore making them more similar to the treatment group. This also makes it difficult to disentangle the specific aspect of the WIC revision that led to the results found in this study. Additionally, because we evaluate several outcomes, multiple hypothesis testing could have led to a false rejection of the null hypothesis. Finally, we observed potential differences in receipt of Medicaid or TennCare and household size among WIC participants and nonparticipants over time. Although the analyses were adjusted for these factors, we cannot rule out confounding by unmeasured factors. Finally, there may be additional effects of WIC on childhood development (eg, socioemotional development at 4–6 years) that were not evaluated in this current study because violations of the statistical models.

CONCLUSIONS

Findings from this study suggest that revisions to WIC, one of the largest United States public health programs, resulted in downstream child health benefits among a high-risk, understudied population. These findings provide timely and critical evidence for the role that WIC plays in improving the health of the nation's most vulnerable populations, suggesting meaningful impacts of the revised WIC food package on child development. It provides rigorous scientific evidence that the WIC program may be essential to minimizing the burden of poor health experienced by the most socially disadvantaged members of society. Given the substantial reach of WIC among vulnerable populations, this study has implications for future WIC policy decisions and other related safety net programs, especially given the decrease in program funding for this upcoming fiscal year.[71,72] Specifically, considering the relatively modest scope of the 2009 revision, more-substantial updates to the program based on up-to-date nutritional guidance may have substantial effects on improving the health of WIC recipients. Additionally, considering that half of eligible pregnant women do not participate in WIC, increasing enrollment may be a useful strategy for reducing the intergenerational transmission of health disparities in communities facing poverty and social disadvantage.

ABBREVIATIONS

Bayley: Bayley Scales of Infant Development
BITSEA: Brief Infant Toddler Social Emotional Assessment
CANDLE: Conditions Affecting Neurocognitive Development and Learning in Early Childhood
CI: confidence interval
DiD: difference-in-differences
SB-5: Stanford-Binet Intelligence Scales
WIC: Special Supplemental Nutrition Program for Women, Infants, and Children

Address correspondence to Alice Guan, MPH, Department of Epidemiology and Biostatistics, University of California, San Francisco, 550 16th St, 2nd Floor, San Francisco, CA 94143. E-mail: alice.guan@ucsf.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded by the National Institutes of Health (National Heart, Lung, and Blood Institute grant K08HL132106, National Institute on Aging grant T32AG049663); the University of California, San Francisco, National Center of Excellence in Women's Health; and the Urban Child Institute. The funders of this study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

1. Barker DJP, Thornburg KL. The obstetric origins of health for a lifetime. *Clin Obstet Gynecol*. 2013;56(3):511–519
2. Belkacemi L, Nelson DM, Desai M, Ross MG. Maternal undernutrition influences placental-fetal development. *Biol Reprod*. 2010;83(3):325–331
3. Cohen JFW, Rifas-Shiman SL, Young J, Oken E. Associations of prenatal and child sugar intake with child cognition. *Am J Prev Med*. 2018;54(6):727–735
4. Jen V, Erler NS, Tielemans MJ, et al. Mothers' intake of sugar-containing beverages during pregnancy and body composition of their children during childhood: the Generation R Study. *Am J Clin Nutr*. 2017;105(4):834–841
5. Tielemans MJ, Steegers EAP, Voortman T, et al. Protein intake during pregnancy and offspring body composition at 6 years: the Generation R Study. *Eur J Nutr*. 2017;56(6):2151–2160
6. Proctor SL, Kyle J, Fefer K, Lau QC. Examining racial microaggressions, race/ethnicity, gender, and bilingual status with school psychology students: the role of intersectionality. *Contemp Sch Psychol*. 2018;22(3):355–368
7. Canani RB, Costanzo MD, Leone L, et al. Epigenetic mechanisms elicited by nutrition in early life. *Nutr Res Rev*. 2011;24(2):198–205
8. Hanley B, Dijane J, Fewtrell M, et al. Metabolic imprinting, programming and epigenetics - a review of present priorities and future opportunities. *Br J Nutr*. 2010;104(suppl 1):S1–S25
9. Lowensohn RI, Stadler DD, Naze C. Current concepts of maternal nutrition. *Obstet Gynecol Surv*. 2016;71(7):413–426
10. Braveman PA, Egerter SA, Mockenhaupt RE. Broadening the focus: the need to address the social determinants of health. *Am J Prev Med*. 2011;40(1 suppl 1):S4–S18
11. Karp RJ, Cheng C, Meyers AF. The appearance of discretionary income: influence on the prevalence of under- and over-nutrition. *Int J Equity Health*. 2005;4(1):10
12. Viswanath K, Bond K. Social determinants and nutrition: reflections on the role of communication. *J Nutr Educ Behav*. 2007;39(suppl 2):S20–S24
13. Gresham E, Byles JE, Bisquera A, Hure AJ. Effects of dietary interventions on neonatal and infant outcomes: a systematic review and meta-analysis. *Am J Clin Nutr*. 2014;100(5):1298–1321
14. Gresham E, Bisquera A, Byles JE, Hure AJ. Effects of dietary interventions on pregnancy outcomes: a systematic review and meta-analysis. *Matern Child Nutr*. 2016;12(1):5–23
15. Grieger JA, Clifton VL. A review of the impact of dietary intakes in human pregnancy on infant birthweight. *Nutrients*. 2014;7(1):153–178
16. Nyaradi A, Li J, Hickling S, Foster J, Oddy WH. The role of nutrition in children's neurocognitive development, from pregnancy through childhood. *Front Hum Neurosci*. 2013;7:97
17. Black RE, Victora CG, Walker SP, et al.; Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries [published correction appears in *Lancet*. 2013;382(9890):396]. *Lancet*. 2013;382(9890):427–451
18. US Department of Agriculture, Food and Nutrition Service. WIC eligibility requirements. 2018. Available at: https://www.fns.usda.gov/wic/wic-eligibility-requirements. Accessed February 28, 2020
19. Oliveira VJ. *The WIC Program: Background, Trends, and Economic Issues*. Darby, PA: DIANE Publishing; 2009
20. US Department of Agriculture, Food and Nutrition Service. WIC data tables, national summary. 2020. Available at: https://www.fns.usda.gov/pd/wic-program. Accessed February 28, 2020
21. Geller DM, Harrington M, Huang G. *National Survey of WIC Participants II: Participant Characteristics Report*. Alexandria, VA: US Department of Agriculture, Food and Nutrition Service, Office of Research and Analysis; 2012
22. Institute of Medicine; Food and Nutrition Board; Committee to Review the WIC Food Packages. *WIC Food Packages: Time for a Change*. Washington, DC: National Academy of Sciences; 2019
23. Yaktine AL, Murphy SP. Aligning nutrition assistance programs with the *Dietary Guidelines for Americans*. *Nutr Rev*. 2013;71(9):622–630
24. Zenk SN, Odoms-Young A, Powell LM, et al. Fruit and vegetable availability and selection: federal food package revisions, 2009. *Am J Prev Med*. 2012; 43(4):423–428
25. Cobb LK, Anderson CAM, Appel L, et al. Baltimore city stores increased the availability of healthy food after WIC policy change. *Health Aff (Millwood)*. 2015;34(11):1849–1857

26. Andreyeva T, Luedicke J, Middleton AE, Long MW, Schwartz MB. Positive influence of the revised Special Supplemental Nutrition Program for Women, Infants, and Children food packages on access to healthy foods. *J Acad Nutr Diet*. 2012;112(6):850–858

27. Lu W, McKyer ELJ, Dowdy D, et al. Evaluating the influence of the revised special supplemental nutrition program for Women, Infants, and Children (WIC) food allocation package on healthy food availability, accessibility, and affordability in Texas. *J Acad Nutr Diet*. 2016;116(2):292–301

28. Hamad R, Batra A, Karasek D, et al. The impact of the revised WIC food package on maternal nutrition during pregnancy and postpartum. *Am J Epidemiol*. 2019; 188(8):1493–1502

29. Schultz DJ, Byker Shanks C, Houghtaling B. The impact of the 2009 special supplemental nutrition program for women, infants, and children food package revisions on participants: a systematic review. *J Acad Nutr Diet*. 2015;115(11):1832–1846

30. Odoms-Young AM, Kong A, Schiffer LA, et al. Evaluating the initial impact of the revised Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) food packages on dietary intake and home food availability in African-American and Hispanic families. *Public Health Nutr*. 2014;17(1):83–93

31. Tester JM, Leung CW, Crawford PB. Revised WIC food package and children's diet quality. *Pediatrics*. 2016; 137(5):e20153557

32. Hamad R, Collin DF, Baer RJ, Jelliffe-Pawlowski LL. Association of revised WIC food package with perinatal and birth outcomes: a quasi-experimental study. *JAMA Pediatr*. 2019;173(9): 845–852

33. Li K, Wen M, Reynolds M, Zhang Q. WIC participation and breastfeeding after the 2009 WIC revision: a propensity score approach. *Int J Environ Res Public Health*. 2019;16(15):2645

34. Langellier BA, Chaparro MP, Wang MC, Koleilat M, Whaley SE. The new food package and breastfeeding outcomes among women, infants, and children participants in Los Angeles County. *Am J Public Health*. 2014;104(suppl 1): S112–S118

35. Wilde P, Wolf A, Fernandes M, Collins A. Food-package assignments and breastfeeding initiation before and after a change in the Special Supplemental Nutrition Program for Women, Infants, and Children. *Am J Clin Nutr*. 2012;96(3):560–566

36. Sontag-Padilla L, Burns R, Shih R, et al. *The Urban Child Institute CANDLE Study: Methodological Overview and Baseline Sample Description*. Santa Monica, CA: RAND Corporation; 2015

37. Food and Nutrition Services (FNS); USDA. Final rule. "Special supplemental nutrition program for Women, Infants, and Children (WIC): revisions in the WIC food packages." Part II. *Fed Regist*. 2014;79(42):12274–12300

38. Grummer-Strawn LM, Reinold C, Krebs NF; Centers for Disease control and Prevention (CDC). Use of World Health Organization and CDC growth charts for children aged 0-59 months in the United States [published correction appears in *MMWR Recomm Rep*. 2010;59(36):1184]. *MMWR Recomm Rep*. 2010;59(RR-9): 1–15

39. Rudolf MCJ, Logan S. What is the long term outcome for children who fail to thrive? A systematic review. *Arch Dis Child*. 2005;90(9):925–931

40. Corbett SS, Drewett RF. To what extent is failure to thrive in infancy associated with poorer cognitive development? A review and meta-analysis. *J Child Psychol Psychiatry*. 2004;45(3):641–654

41. Cole TJ, Wright CM. A chart to predict adult height from a child's current height. *Ann Hum Biol*. 2011;38(6): 662–668

42. Binkin NJ, Yip R, Fleshood L, Trowbridge FL. Birth weight and childhood growth. *Pediatrics*. 1988;82(6):828–834

43. Böckerman P, Viinikainen J, Vainiomäki J, et al. Stature and long-term labor market outcomes: evidence using Mendelian randomization. *Econ Hum Biol*. 2017;24:18–29

44. Rietveld CA, Hessels J, van der Zwan P. The stature of the self-employed and its relation with earnings and satisfaction. *Econ Hum Biol*. 2015;17:59–74

45. Briggs-Gowan MJ, Carter AS, Irwin JR, Wachtel K, Cicchetti DV. The Brief Infant-Toddler Social and Emotional Assessment: screening for social-emotional problems and delays in competence. *J Pediatr Psychol*. 2004; 29(2):143–155

46. Bayley N. *Bayley Scales of Infant Development and Toddler Development: Administration Manual*, 3rd ed. San Antonio, TX: PsychCorp, Harcourt Assessment; 2006

47. Månsson J, Stjernqvist K, Serenius F, Ådén U, Källén K. Agreement between bayley-III measurements and WISC-IV measurements in typically developing children. *J Psychoed Assess*. 2019;37(5): 603–616

48. Patrianakos-Hoobler AI, Msall ME, Huo D, Marks JD, Plesha-Troyke S, Schreiber MD. Predicting school readiness from neurodevelopmental assessments at age 2 years after respiratory distress syndrome in infants born preterm. *Dev Med Child Neurol*. 2010;52(4):379–385

49. Bode MM, D'Eugenio DB, Mettelman BB, Gross SJ. Predictive Validity of the Bayley, Third Edition at 2 Years for Intelligence Quotient at 4 Years in Preterm Infants. In: *J Dev Behav Pediatr*, vol. 35. 2014:570–575

50. Roid GH, Pomplun M. Contemporary Intellectual Assessment: Theories, Tests, and Issues. In: Flanagan DP, Harrison PL, eds. *The Stanford-Binet Intelligence Scales*. New York, NY: The Guilford Press; 2012:249–268

51. Dimick JB, Ryan AM. Methods for evaluating changes in health care policy: the difference-in-differences approach. *JAMA*. 2014;312(22): 2401–2402

52. US Department of Agriculture. WIC 2016 eligibility and coverage rates. 2019. Available at: https://www.fns.usda.gov/wic/wic-2016-eligibility-and-coverage-rates. Accessed February 28, 2020

53. Indrio F, Martini S, Francavilla R, et al. Epigenetic matters: the link between early nutrition, microbiome, and long-term health development. *Front Pediatr*. 2017;5:178

54. Mühlhäusler BS, Adam CL, McMillen IC. Maternal nutrition and the programming of obesity: the brain. *Organogenesis*. 2008;4(3):144–152

55. Wu G, Bazer FW, Cudd TA, Meininger CJ, Spencer TE. Maternal nutrition and fetal development. *J Nutr*. 2004;134(9): 2169–2172

56. Whaley SE, Ritchie LD, Spector P, Gomez J. Revised WIC food package improves diets of WIC families. *J Nutr Educ Behav*. 2012;44(3):204–209

57. Lakshmanan A, Song AY, Flores-Fenlon N, et al. Association of WIC participation and growth and developmental outcomes in high-risk infants. *Clin Pediatr (Phila)*. 2020;59(1):53–61

58. Jackson MI. Early childhood WIC participation, cognitive development and academic achievement. *Soc Sci Med*. 2015;126:145–153

59. Bolbocean C, Tylavsky FA, West JE. *U.S. Safety Net Programs and Early Life Skills Formation: Results from a Prospective Longitudinal Cohort Study*. Cambridge, MA: National Bureau of Economic Research, Inc; 2018

60. von Stumm S, Plomin R. Socioeconomic status and the growth of intelligence from infancy through adolescence. *Intelligence*. 2015;48:30–36

61. Kamppi D, Gilmore L. Assessing Cognitive Development in Early Childhood: A Comparison of the Bayley-III and the Stanford-Binet, Fifth Edition. In: *Aust Educ Dev Psychol*, vol. 27. 2010: 70–75

62. Power C, Lake JK, Cole TJ. Body mass index and height from childhood to adulthood in the 1958 British born cohort. *Am J Clin Nutr*. 1997;66(5): 1094–1101

63. Silventoinen K. Determinants of variation in adult body height. *J Biosoc Sci*. 2003;35(2):263–285

64. Case A, Paxson C. Stature and status: height, ability, and labor market outcomes. *J Polit Econ*. 2008;116(3): 499–532

65. Palmer FB, Anand KJS, Graff JC, et al. Early adversity, socioemotional development, and stress in urban 1-year-old children. *J Pediatr*. 2013;163(6): 1733–1739.e1

66. Huttenlocher J, Vasilyeva M, Cymerman E, Levine S. Language input and child syntax. *Cognit Psychol*. 2002;45(3): 337–374

67. Bellisle F. Effects of diet on behaviour and cognition in children. *Br J Nutr*. 2004;92(suppl 2):S227–S232

68. Arons A, Bolbocean C, Bush NR, Tylavsky FA, LeWinn KZ. Participation in the special supplemental nutrition program for women, infants, and children is not associated with early childhood socioemotional development: results from a longitudinal cohort study. *Prev Med Rep*. 2016;4:507–511

69. Rush D, Sloan NL, Leighton J, et al. The national WIC evaluation: evaluation of the special supplemental food program for women, infants, and children. V. Longitudinal study of pregnant women. *Am J Clin Nutr*. 1988;48(suppl 2): 439–483

70. Kowaleski-Jones L, Duncan GJ. Effects of participation in the WIC food assistance program on children's health and development: evidence from NLSY children. Madison, WI: Wisconsin University, Madison Institute for Research on Poverty. Available at: https://eric.ed.gov/?id=ED445158. Accessed February 20, 2020

71. National WIC Association. *House Unveils FY 2021 Appropriations Bills, Including WIC Funding*. Washington, DC: National WIC Association; 2020

72. National WIC Association. *White House Releases President's Budget for Fiscal Year 2021*. Washington, DC: National WIC Association; 2020