ARTICLE

Secular Trends in the Prevalence of Iron Deficiency Among US Toddlers, 1976-2002

Jane M. Brotanek, MD, MPH; Jacqueline Gosz, MS; Michael Weitzman, MD; Glenn Flores, MD

Objective: To examine secular trends in iron deficiency among US children 1 to 3 years old.

Design: Secular trend analyses of the National Health and Nutrition Examination Survey II-IV.

Setting: Large-scale national survey conducted by the National Center for Health Statistics from 1976 to 2002.

Participants: US children 1 to 3 years old.

Outcome Measure: Prevalence of iron deficiency.

Results: Between 1976 and 2002, there was no change in iron deficiency prevalence in US toddlers. Iron deficiency prevalence remained unchanged in Hispanic and white toddlers but decreased among black toddlers. Across all 3 survey waves, racial/ethnic disparities in iron deficiency persisted between Hispanic and white toddlers, with a disparity ratio of at least 2. Iron deficiency prevalence remained high (20%-24%) in overweight toddlers, significantly higher than in those at risk for overweight (11%) and in normal weight or underweight toddlers (8%). Iron deficiency prevalence decreased from 22% to 9% in toddlers in poor households but remained unchanged in toddlers in nonpoor households (7%). In multivariable analyses, Hispanic, younger, and overweight toddlers had higher odds of iron deficiency.

Conclusions: Despite the decline in iron deficiency prevalence among 1-year-old, black, and poor children, iron deficiency prevalence in US toddlers overall has not changed in the last 26 years and remains elevated in certain high-risk groups: Hispanic, younger, and overweight toddlers. Efforts to reduce the prevalence of iron deficiency in infancy and early childhood are urgently needed and should target high-risk groups.

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IRON-DEFICIENCY ANEMIA IN INfancy and early childhood is associated with impaired neurodevelopment, resulting in learning difficulties,[1,2] socioemotional problems,[3] and lower scores on mental and motor development tests[4,5]; evidence is accumulating that these effects appear to be long lasting.[3-8] Several studies also indicate an association between iron deficiency without anemia and adverse effects on neurocognitive development[4,9-11]; however, evidence on the adverse consequences of iron deficiency without anemia remains limited. In the United States, iron deficiency is the most common childhood nutritional deficiency.[12] The prevalence of iron deficiency without anemia is markedly higher than the prevalence of iron-deficiency anemia; therefore, the prevention and treatment of iron deficiency hold promise for a significant public health impact. Children in their first year of life are at an especially high risk of iron deficiency, as infants' iron stores at birth are depleted during this period of rapid growth.[9,13] Although iron deficiency prevalence is higher in developing countries, a substantial iron deficiency prevalence continues to exist in the United States, especially among toddlers and young women.[14,15] One Healthy People 2010 objective is to reduce iron deficiency in 1- to 2-year-old children to 5% (compared with the 1988-1994 baseline prevalence of 9%) and in 3- to 4-year-old children to 1% (compared with the 1988-1994 baseline prevalence of 4%).[16]

Improvements in infant nutrition in the United States during the past 30 years, including introduction of iron-fortified formulas and cereals, have led to a decreased prevalence of iron-deficiency anemia in the first year of life.[17] Despite these changes, however, the prevalence of iron deficiency and anemia remains relatively high among low-income, preschool-age children.[18] A few studies have demonstrated a decline in the prevalence of iron-deficiency anemia among middle-class populations of toddlers[19] (herein, *toddlers* refers to children

Author Affiliations: Division of General Pediatrics, Department of Pediatrics, University of Texas Southwestern Medical Center, and Children's Medical Center, Dallas (Drs Brotanek and Flores); St Andrew's School, Boca Raton, Florida (Ms Gosz); and Department of Pediatrics, New York University School of Medicine, New York, New York (Dr Weitzman).

12-47 months old, and *infants* to those <12 months old[20]) and toddlers in certain states.[21,22] In contrast, other research has documented a persistently high iron deficiency prevalence among high-risk groups of toddlers, including poor, minority, and overweight children. In 2002, the US Centers for Disease Control and Prevention reported an iron deficiency prevalence of 7% for children 1 to 2 years old from all income levels, whereas the prevalence of iron deficiency was 17% for 1- to 2-year-old Mexican American children and 12% for 1- to 2-year-old children in low-income households.[23] In the United States, the prevalence of iron deficiency was found to be 6% among white toddlers, 8% among black toddlers, and 17% among Mexican American toddlers in another study.[24] An iron deficiency prevalence of 20% has been found among overweight children 1 to 3 years old in the United States.[25]

No studies, however, have examined national secular trends in iron deficiency among US toddlers. The objective of this study was to examine secular trends in iron deficiency among US children 1 to 3 years old overall and in groups at high risk for iron deficiency, including poor, minority, and overweight toddlers.

METHODS

DATA SOURCE

The data source was the National Health and Nutrition Examination Survey (NHANES) II-IV, a large-scale national survey conducted by the National Center for Health Statistics[26-29]; NHANES II spans the years 1976 through 1980; NHANES III, 1988 through 1994; and NHANES IV, 1999 through 2002. The first survey wave, NHANES I (1971-1974), was not analyzed, because it contains an inadequate sample size of toddlers (N=54). Participants in NHANES are asked to complete an extensive household interview and an examination in a mobile health center. In all 3 survey waves, results were weighted to adjust for nonresponse and to provide national estimates.[30]

The NHANES II included a nationwide probability sample of 27 801 persons 6 months to 74 years old. The overall response rate was 73%. Of the total sample, 25 286 persons were interviewed and 20 322 were examined.[28] Administered from 1988 through 1994 in 2 phases of equal length and sample size, NHANES III included 33 994 persons. The household interview response rate was 86%, and the medical examination response rate was 78%.[29] The National Center for Health Statistics released public use data from the continuous NHANES in 2-year groupings: NHANES 1999-2000 and NHANES 2001-2002. For NHANES 1999-2000, 12 160 persons were selected, 9965 (82%) were interviewed, and 10 477 (80%) were examined.[26] For NHANES 2001-2002, 13 156 persons were selected, 11 039 (84%) were interviewed, and 10 477 (80%) were examined.[27]

Survey instruments were available in Spanish and English for NHANES III and IV; NHANES II, however, was not translated into Spanish. In this wave, the primary language spoken at home was ascertained instead of parental interview language. In NHANES III, questionnaires were translated into Spanish and checked for accuracy in both languages during pretests.[29] In NHANES IV, questionnaires were translated into Spanish and administered in computer-assisted personal interview format along with the English versions.[26,27] Although NHANES uses written Spanish translations of surveys, the translations have never been examined systematically or tested for validity via independent back-translations by qualified translators.[31]

INDEPENDENT VARIABLES

Independent variables analyzed included age and gender. Socioeconomic status was dichotomized as below the federal poverty threshold vs at or above the federal poverty threshold, based on family size and the federal poverty threshold at the time of the survey.[26-29] The children's race/ethnicity included non-Hispanic white, non-Hispanic black, and Hispanic. Because of small sample sizes, Asian/Pacific Islander, Native American, other, and multiple race/ethnic groups were excluded from analyses. Other independent variables analyzed included weight-for-height status (using age- and gender-specific weight-for-length percentiles, with at risk for overweight defined as a weight-for-length status in the 85th to 94th percentile and overweight defined as a weight-for-length status at or above the 95th percentile [body mass index was not used because only weight-for-length measurements were available for children 1 to 3 years old]); primary language spoken at home (English vs a non-English language) in NHANES II; parental interview language (English vs a non-English language) in NHANES III and IV; birth weight (<2500 vs ≥2500 g); and blood lead level (≥10 vs <10 μg/dL [to convert to μmol/L, multiply by 0.0483]). It was not possible to include caretaker educational attainment and bottle-feeding duration, since these variables were not included or made publicly available in all survey waves. Daycare and/or preschool attendance was not included because of small sample sizes in NHANES II. Laboratory values were measured using standard measurement assays, the details of which have been provided elsewhere.[32]

DEFINITIONS OF IRON DEFICIENCY

For NHANES III and IV, we used definitions of iron deficiency and anemia from a prior analysis of anemia prevalence in NHANES III.[13,33] The diagnosis of iron deficiency was based on 3 laboratory tests of iron status: transferrin saturation, free erythrocyte protoporphyrin, and serum ferritin. An individual was considered iron deficient if any 2 of these 3 values were abnormal for age and gender. For 1- to 2-year-old children, cutoff values for iron status tests were less than 10% transferrin saturation, less than 10 μg/L serum ferritin, and greater than 1.42 μmol/L red blood cells erythrocyte protoporphyrin. For 3-year-old children, cutoff values were less than 12% transferrin saturation, less than 10 μg/L serum ferritin, and greater than 1.24 μmol/L red blood cells erythrocyte protoporphyrin. For NHANES II, a different standard was used, as serum ferritin was not measured in 1- to 2-year-old children. Instead, the mean corpuscular (MCV) model was used, in which MCV, rather than ferritin, is the third of the 3 iron status indicators; this model was developed specifically for use with NHANES by an expert scientific working group.[34] Mean corpuscular volume cutoff values are less than 73 fL for 3-year-old children and less than 75 fL for 2-year-old children.

STATISTICAL ANALYSIS

In bivariate analyses, iron deficiency prevalence was determined for toddlers in different risk categories of each independent variable. Differences in prevalence estimates were compared across the 3 surveys using the Pearson χ^2 test. To account for the complex NHANES design, the χ^2 statistic was turned into an *F* statistic with noninteger *df* using a second-order Rao and Scott correction.[35,36]

Table 1. Sociodemographic Characteristics of US Children 1 to 3 Years Old, NHANES II-IV (1976-2002)[a]

Characteristic	NHANES Wave, % II (1976-1980) (n=2201)	III (1988-1994) (n=3875)	IV (1999-2002) (n=1641)
Age, y			
1	32	35	37
2	32	35	37
3	36	31	26
Annual combined family income < poverty threshold	24	38	37
Race/ethnicity			
White	61	32	30
Hispanic	9	37	39
Black	17	30	26
Other	11	2	6
Parental interview language			
English	86	82	71
Non-English	14	18	16
Spanish	8	18	16
Other	5	0.4	0.7
Weight-for-height status			
Normal/underweight (< 85th percentile)	85	73	65
At risk for overweight (85th-94th percentile)	9	11	11
Overweight (≥ 95th percentile)	6	7	8
Gender			
M	53	49	54
F	48	51	46
Blood lead level, μg/dL[b]			
≥ 10	5	7	2
< 10	50	66	63
Low birth weight, g			
≥ 2500	91	87	87
< 2500	8	8	11

Abbreviation: NHANES, National Health and Nutrition Examination Survey.
SI conversion factor: To convert blood lead level to micromoles per liter, multiply by 0.0483.
[a] Some cells add up to less than 100% owing to data not being available on all toddlers.
[b] Not all toddlers interviewed underwent laboratory testing.

The SAS software, version 9.1 (SAS Institute Inc, Cary, North Carolina), was used for all analyses. Sample weights were applied to account for unequal probabilities of selection, oversampling, and nonresponse, and to estimate SEs using the Taylor series linearization method. χ^2 Tests were used to test for differences in proportions, and logistic regression was used for multivariable analyses. Only those independent variables significant in bivariate analyses during any given NHANES year or with significant secular trends across all 3 survey waves were entered into a pair of forced multivariable models (without/with primary language spoken at home) in which the outcome variable was iron deficiency.

RESULTS

SECULAR TRENDS IN IRON DEFICIENCY

Selected sociodemographic features of the study population are summarized in **Table 1**. In all 3 NHANES waves, about one-third of US children 1 to 3 years old fell into each of the 3 age groups studied. About one-quarter of toddlers lived in poor households in NHANES II and about one-third lived in poor households in NHANES III and IV. Of the 2201 toddlers in NHANES II, 61% were white, 9% were Hispanic, and 17% were black. Of the 3875 toddlers in NHANES III, 32% were white, 37% were Hispanic, and 30% were black. Of the 1641 toddlers in NHANES IV, 30% were white, 39% were Hispanic, and 26% were black. The parental interview language was a non-English language for 14% of NHANES II interviews, 18% of NHANES III interviews, and 16% of NHANES IV interviews. Six percent of children 1 to 3 years old in NHANES II, 7% in NHANES III, and 8% in NHANES IV were overweight. About half of the toddlers in all 3 NHANES waves were female, and less than 2% to 7% had a lead level greater than 10 μg/dL. Eight percent of toddlers in NHANES II, 8% in NHANES III, and 11% in NHANES IV had a low birth weight.

Between 1976 and 2002, there was no statistically significant change in iron deficiency prevalence in US children 1 to 3 years old (**Table 2**). The prevalence of iron deficiency was 10% and 8% in NHANES II and NHANES IV, respectively. Among 1-year-old children, iron deficiency prevalence decreased from 23% in 1976-1980 to 12% in 1999-2002 (P=.02). In 2- and 3-year-old children, however, there was no change in iron deficiency prevalence. The significant difference in iron deficiency prevalence between 1- and 2- to 3-year-old children in 1976-1980 diminished by 1988-1994 and then disappeared in 1999-2002 (**Figure 1**).

Iron deficiency prevalence decreased from 22% to 9% in 1- to 3-year-old children in poor households (P=.02), but remained unchanged, at 7%, in toddlers in nonpoor households (Table 2; **Figure 2**). The marked elevation in iron deficiency prevalence in NHANES II for poor toddlers disappeared in NHANES III and IV (Figure 2).

In Hispanic and white children 1 to 3 years old, there was no significant change in iron deficiency prevalence between NHANES II and IV, but the prevalence decreased among black toddlers from 16% to 6% (P=.006) (**Figure 3**). In each NHANES wave, racial/ethnic disparities in iron deficiency prevalence persisted between Hispanic and white toddlers, with a disparity ratio of about 2 during all 26 years (P<.03) (Figure 3). In contrast, black toddlers experienced a sharp decline in iron deficiency prevalence over time. Toddlers of parents interviewed in a non-English language had a significantly higher iron deficiency prevalence than toddlers of parents interviewed in an English language, except in NHANES II (**Figure 4**).

Iron deficiency rates were consistently and substantially higher among overweight toddlers (20%-25%) compared with both toddlers at risk for overweight and normal weight or underweight toddlers (**Figure 5**). In NHANES III, iron deficiency prevalence was significantly higher among low–birth weight toddlers vs those with a birth weight of 2500 g or greater (**Figure 6**). No significant secular trends in iron deficiency were observed among different categories of birth weight, lead level, or gender.

Table 2. Changes Over Time in Prevalence Rates of Iron Deficiency in US Children 1 to 3 Years Old, NHANES II-IV (1976-2002)

Characteristic	% With Iron Deficiency in NHANES Wave: II (1976-1980)	III (1988-1994)	IV (1999-2002)	Absolute Difference, NHANES II-IV	*P* Value
Total sample	10.1	9.1	8.0	−2.1	.41
Age, y					
1	22.8	16.4	11.5	−11.3	.02
2	6.8	5.7	7.6	0.8	.58
3	5.6	5.9	5.6	0	.98
Poverty status					
≥Poverty threshold	7.0	7.5	7.5	0.5	.96
<Poverty threshold	21.6	12.1	8.9	−13	.02
Race/ethnicity					
White	6.8	5.7	6.2	−0.6	.86
Hispanic	17.7	15.9	12.2	−5.5	.44
Black	15.5	7.9	6.3	−9.2	.006
Parental interview language					
English	9.0	7.8	7.4	−1.6	.64
Non-English	16	21	14	−2	.46
Weight-for-height status					
Normal/underweight (<85th percentile)	9.0	7.6	7.2	−1.8	.60
At risk for overweight (85th-94th percentile)	12.7	10.5	8.6	−4.1	.74
Overweight (≥95th percentile)	23.6	24.0	20.3	0.4	.92
Low birth weight, g					
≥2500	9.6	8.3	7.6	−2.0	.52
<2500	14.1	17.8	8.2	−5.9	.24
Lead level, μg/dL					
≥10	9.8	9.5	11.4	1.6	.94
<10	11.7	9.0	8.0	−3.7	.64
Gender					
M	13.3	9.3	8.2	−5.1	.09
F	6.6	8.8	7.8	1.2	.59

Abbreviation: NHANES, National Health and Nutrition Examination Survey.
SI conversion factor: To convert blood lead level to micromoles per liter, multiply by 0.0483.

MULTIVARIABLE ANALYSIS

In multivariate analyses, Hispanic ethnicity, poverty, younger age, and overweight status were associated with significantly greater adjusted odds of iron deficiency (**Table 3**, model 1). Hispanic children were 2 times more likely to be iron deficient than white children. Two- and 3-year-old children were more than 3 times less likely than 1-year-old children to have iron deficiency. Children in poor households were 1.4 times more likely to be iron deficient than children in nonpoor households. Overweight toddlers had triple the odds of iron deficiency vs normal weight or underweight toddlers. Poverty was no longer significantly associated with iron deficiency after adjustment for parental interview language/primary language spoken at home, though there was a nonsignificant trend toward greater odds for toddlers in poor households (Table 3, model 2).

COMMENT

This study comprehensively examined national secular trends in iron deficiency prevalence among US children 1 to 3 years old. Findings reveal that there has been no significant change in iron deficiency prevalence among US toddlers during the past 26 years, with rates ranging from 8% to 10%. Although low in comparison to the worldwide prevalence of iron deficiency, the persistently high iron deficiency prevalence in US toddlers may be due to recent increases in overweight and in Hispanic toddlers, who are at high risk of iron deficiency.[24,25] Hispanic children are the largest minority group of children in the United States, numbering more than 15 million and comprising more than 20% of children younger than 18 years.[37] In addition, between 1976 and 2002, the prevalence of overweight in US children doubled.[38] The data suggest that health education and public health programs have not been reaching toddlers at high risk of iron deficiency.

Since 1976, iron deficiency prevalence has decreased in certain subgroups of US children: 1-year-old children, black toddlers, and those living in poor households. Iron deficiency prevalence declined from 23% to 12% in 1-year-old children, but the prevalence is still higher than the Healthy People 2010 target of 5%. These data are consistent with national surveillance data from the 1980s, documenting a decline in the prevalence of iron deficiency and iron-deficiency anemia among children during the first year of life.[39,40] This decline followed the introduction of guidelines to fortify infant formula and foods with iron in the late 1960s and the emergence of the national Women, Infants and Children Program in the 1970s.[41,42] An emphasis on breastfeeding and delayed introduction of cow's milk may have

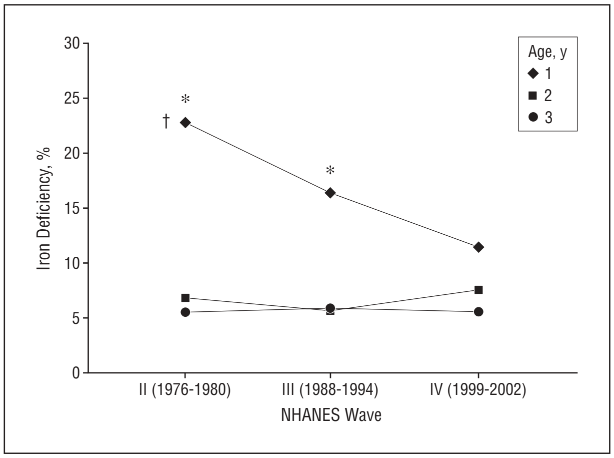

Figure 1. Secular trends in iron deficiency prevalence by age among US children 1 to 3 years old. NHANES indicates National Health and Nutrition Examination Survey; *, $P < .005$ for differences between 1-year-old children and other age groups; †, $P = .02$ for secular trend, 1976 to 2002.

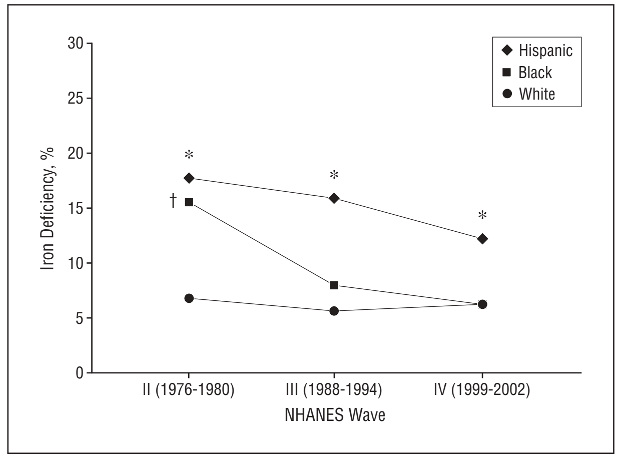

Figure 3. Secular trends in iron deficiency prevalence by race/ethnicity among US children 1 to 3 years old. NHANES indicates National Health and Nutrition Examination Survey; *, $P < .05$ for differences between Hispanic and white toddlers; †, $P = .006$ for secular trend, 1976 to 2002.

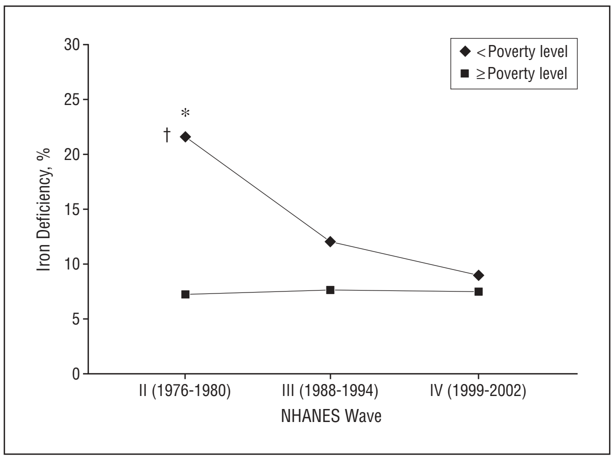

Figure 2. Secular trends in iron deficiency prevalence by poverty status among US children 1 to 3 years old. NHANES indicates National Health and Nutrition Examination Survey; *, $P < .001$ for difference between toddlers in households below the federal poverty threshold vs those in households at or above the federal poverty threshold; †, $P = .02$ for secular trend, 1976 to 2002.

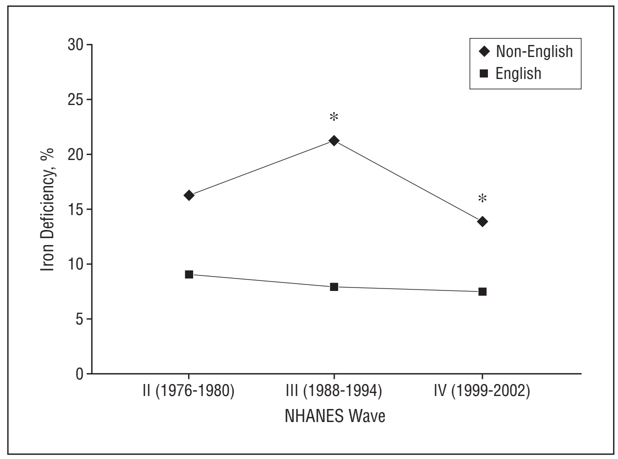

Figure 4. Secular trends in iron deficiency prevalence by parental interview language/primary language spoken at home among US children 1 to 3 years old. NHANES indicates National Health and Nutrition Examination Survey; *, $P \leq .01$ for difference between the 2 groups.

contributed to the decline in iron-deficiency anemia among children during their first year of life.[42-44] Despite these improvements in infant nutrition, our findings indicate that there has been no change in iron deficiency prevalence in 2- to 3-year-old children between 1976 and 2002. After weaning from breast milk or formula, children's nutrition may be inadequate owing to nutritional practices, such as excessive cow's milk intake, prolonged bottle-feeding, diets poor in iron-rich foods, and junk food consumption.[45,46]

Between 1976 and 2002, iron deficiency prevalence decreased from 22% to 9% in poor toddlers, but remained about the same in toddlers in households at or above the federal poverty threshold. In several studies, poverty has been identified as a risk factor for childhood iron deficiency.[45,47,48] Our findings of declining rates of iron deficiency among poor US toddlers since 1976 are consistent with studies published in the 1980s documenting improvements in nutritional status among low-income children.[49,50] Iron deficiency decreased among black toddlers from 16% to 6% between 1976 and 2002. This is the first study (to our knowledge) to document such a marked decline in iron deficiency prevalence in black toddlers. This is consistent with data from 2 studies documenting a lower prevalence of severe iron deficiency in the late 1990s among African Americans.[51,52] This marked decline in iron deficiency prevalence among black toddlers has been attributed to implementation of the Women, Infants and Children Program, which targets poor households and provides food supplements to income-eligible families.[53,54] Enrollment in the Women, Infants and Children Program grew dramatically in the 1970s and 1980s, with predominantly blacks and whites enrolled before 1992.[54] These improvements in childhood nutrition are a testament to the concerted effort of the pediatric community in the 1970s to educate parents about improved infant feeding practices to prevent iron deficiency.[50,55,56]

Iron deficiency prevalence remains unchanged in Hispanic and overweight toddlers. In contrast to black tod-

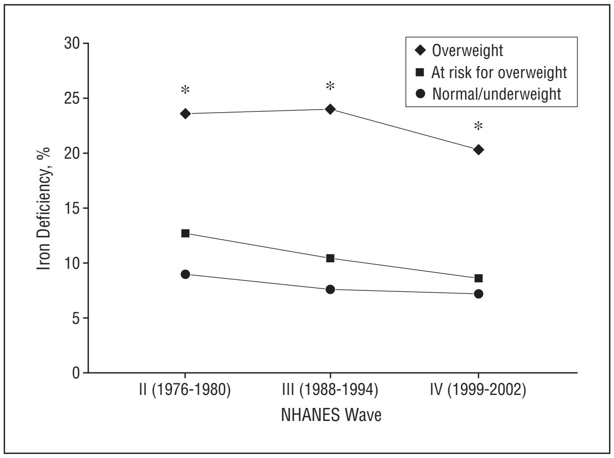

Figure 5. Secular trends in iron deficiency prevalence by weight-for-height status among US children 1 to 3 years old. NHANES indicates National Health and Nutrition Examination Survey; *, $P < .03$ for difference between overweight and normal/underweight toddlers.

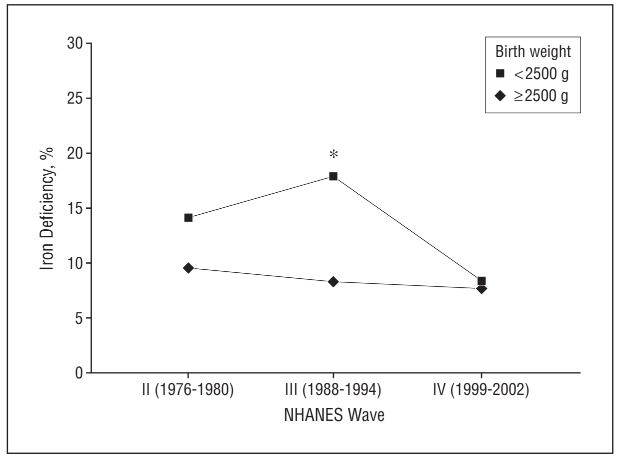

Figure 6. Secular trends in iron deficiency prevalence by birth weight among US children 1 to 3 years old. NHANES indicates National Health and Nutrition Examination Survey; *, $P = .01$ for difference between the 2 groups.

dlers, Hispanic toddlers did not experience a statistically significant decrease in iron deficiency prevalence between 1976 and 2002. Indeed, there was a significant disparity in iron deficiency prevalence between Hispanic and white toddlers that persisted across all 26 years, with a consistent disparity ratio of 2:1. The persistence of iron deficiency among Hispanic toddlers may be due to cultural influences contributing to prolonged bottle-feeding and excessive milk intake, important risk factors for iron deficiency. Hispanic toddlers have high rates of prolonged bottle feeding, which is associated with iron deficiency,[24,57] and a recent study showed that Mexican American parents often lack essential knowledge regarding infant feeding practices and iron deficiency, including when to stop bottle-feeding, how much milk to give to children older than 1 year, and health problems caused by prolonged bottle-feeding.[58] Our study findings suggest that efforts to improve iron intake in Hispanic children should include nutritional education in clinics on healthy infant feeding practices and community-based interventions based on a comprehensive assessment of infant feeding beliefs, knowledge, and behaviors among Hispanic parents. Cultural influences contributing to prolonged bottle-feeding and excessive cow's milk intake have also been described among Southeast Asian and Hmong toddlers.[58-60] Culturally sensitive programs that bridge language and cultural barriers are needed to improve early childhood nutrition and decrease iron deficiency prevalence among Hispanic and other minority groups.[61]

Overweight children have triple the odds of iron deficiency compared with normal weight or underweight children. From 1976 to 2002, iron deficiency prevalence remained consistently high for overweight toddlers, at 20% to 24%. During this period, the prevalence of overweight among US children continued to increase. Among 2- to 5-year-old children, overweight prevalence increased from 7% in 1988-1994 to 10% in 1999-2000.[62] Given the substantial increase in overweight in recent decades, the study findings suggest that the number of cases of iron deficiency and anemia could also substantially rise. Because it occurs in 1 in 5 overweight toddlers,[25] iron deficiency should be added to the list of overweight comorbidities, and screening for iron deficiency and nutritional counseling should be considered for all overweight toddlers.

Table 3. Multivariate Analyses of Factors Associated With Iron Deficiency Among US Children 1 to 3 Years Old, NHANES II-IV (1976-2002)[a]

Characteristic	Odds Ratio (95% Confidence Interval) for Iron Deficiency: Model 1	Model 2
Race/ethnicity		
White	1 [Reference]	1 [Reference]
Black	1.3 (0.7-2.3)	1.3 (0.7-2.2)
Hispanic	2.2 (1.4-3.3)	1.7 (1.02-2.9)
Age, y		
1	1 [Reference]	1 [Reference]
2	0.3 (0.2-0.5)	0.3 (0.2-0.5)
3	0.3 (0.2-0.5)	0.3 (0.2-0.5)
Family income <poverty threshold	1.4 (1.01-1.9)	1.4 (0.97-1.9)
Weight-for-height status		
Normal/underweight (<85th percentile)	1 [Reference]	1 [Reference]
At risk for overweight (≥85th-94th percentile)	1.3 (0.9-2.0)	1.3 (0.9-2.0)
Overweight (≥95th percentile)	2.9 (1.8-4.7)	2.8 (1.7-4.3)
Low birth weight, <2500 g	1.5 (0.9-2.6)	1.6 (0.9-2.6)
Non-English parental interview language/primary language spoken at home		1.6 (0.8-3.0)

Abbreviation: NHANES, National Health and Nutrition Examination Survey.
[a] Adjusted for NHANES survey wave and low birth weight.

Certain study limitations should be noted. Analyses of iron deficiency among Native American and Asian and Pacific Islander toddlers were not possible because of small sample sizes. Certain known risk factors for iron deficiency, such as prolonged bottle-feeding and low maternal educational attainment, could not be analyzed, since

NHANES data are no longer collected for these key measures. Finally, secular trends could only be examined through 2002, because the Centers for Disease Control and Prevention no longer collect transferrin saturation and erythrocyte protoporphyrin measurements in 1- to 2-year-old children and are using a new measure of iron deficiency, the ratio of serum transferrin receptor to ferritin, beginning with NHANES 2003-2004. This ratio has been shown to be a useful tool for estimating total body iron stores.[63,64] However, more work is needed to validate the use of serum transferrin receptor and to establish age-specific reference ranges for this new measure in children.[64-70] We suggest that NHANES reintroduce the ferritin model and resume collection of transferrin saturation and erythrocyte protoporphyrin in 1- to 2-year-old children, while keeping serum transferrin receptor. In this way, it would be possible to monitor iron deficiency in all US children using a well-founded method, while studying serum transferrin receptor and correlations with established iron indicators. Unless an effective and useful national surveillance mechanism is in place to ensure continuous monitoring and evaluation of iron status in US toddlers, it will be difficult, if not impossible, to reach the Healthy People 2010 objectives.

In conclusion, although there has been a decline in the prevalence of iron deficiency among 1-year-old, black, and poor children in the United States, iron deficiency prevalence among US toddlers has not changed in the last 26 years and remains elevated in certain high-risk populations. Hispanic, 1-year-old, and overweight toddlers continue to have a particularly high iron deficiency prevalence relative to other groups in the United States. New approaches, including community-based outreach efforts, educational programs in clinics, policy changes, modified screening practices,[71] and public health initiatives, are needed to address the problem of iron deficiency in all US children and especially in high-risk groups. Concerted efforts by government agencies, schools, daycares, physicians, and the Women, Infants and Children Program will be instrumental in effecting these changes. If the Healthy People 2010 objective for iron deficiency is to be reached, efforts to reduce childhood iron deficiency prevalence are urgently needed.

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Correspondence: Jane M. Brotanek, MD, MPH, Department of Pediatrics, University of Texas Southwestern Medical Center, 5323 Harry Hines Blvd, Dallas, TX 75390-9063 (jane.brotanek@utsouthwestern.edu).
Author Contributions: Dr Brotanek had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design*: Brotanek, Flores, and Weitzman. *Acquisition of data*: Brotanek and Gosz. *Analysis and interpretation of data*: Brotanek, Gosz, Flores, and Weitzman. *Drafting of the manuscript*: Brotanek, Gosz, and Flores. *Critical revision of the manuscript for important intellectual content*: Brotanek, Flores, Gosz, and Weitzman. *Statistical Analysis*: Brotanek, Gosz, and Flores. *Obtained funding*: Brotanek and Flores. *Administrative, technical, or material support*: Flores. *Study supervision*: Brotanek and Flores
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