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Full Breastfeeding Duration and Risk for Iron Deficiency in U.S. Infants

CAROLINE J. CHANTRY,[1] CYNTHIA R. HOWARD,[2] and PEGGY AUINGER[2,3]

ABSTRACT

***Background*: National and international authorities recommend exclusive breastfeeding for an infant's first 6 months. Effects of these recommendations on iron status of U.S. children are unknown.**

***Objective*: To ascertain if full breastfeeding for 6 months versus 4 months places U.S. children at greater risk for iron deficiency.**

***Design/Methods*: Data regarding 2268 children ages 6 to <24 months from NHANES III, a nationally representative cross-sectional survey conducted from 1988–1994, were analyzed. Similar analyses were conducted for 526 children ages 12 to <24 months from NHANES 1999–2002. Anemia (low hemoglobin or history of anemia) and iron status (serum ferritin) were compared for five groups: formula fed only (n = 1142), or full breastfeeding for: <1 month "FullBF<1" (n = 425), 1 to <4 months "FullBF1–3+" (n = 343), 4 to <6 months "FullBF4–5+" (n = 222), and ≥ 6 months "FullBF6+" (n = 136). Laboratory data were available for children 12 to 24 months (n = 745). SUDAAN software was used to account for the complex sampling design. Logistic regression adjusted for confounding factors.**

***Results*: In unadjusted analyses (NHANES III), 10.0% of "FullBF6+" versus 2.3% of "FullBF4–5+" had a history of anemia (p = 0.007) but unadjusted between group serum ferritin and hemoglobin differences were insignificant in both surveys. Adjusting for birth weight and demography revealed persistently lower risk of history of anemia (NHANES III, odds ratio [OR] 0.20, confidence interval [CI] 0.06, 0.63) and low serum ferritin (NHANES 1999–2002, OR 0.19, CI 0.06, 0.57) but not low hemoglobin at time of survey "FullBF4–5+" versus "FullBF6+."**

***Conclusions*: Young children in the United States fully breastfed for 6 months may be at increased risk of iron deficiency. Adequate iron may not be provided by typical complementary infant foods. Healthcare providers should be vigilant to prevent iron deficiency in this group of infants.**

INTRODUCTION

The optimal duration of exclusive breastfeeding is not known with certainty.[1] Currently, most national and international authorities, including the American Academy of Pediatrics (AAP) Section on Breastfeeding,[2] the American Academy of Family Physicians,[3] the World Health Organization (WHO),[4] UNICEF,[5] and the Academy of Breastfeeding

[1]Department of Pediatrics, University of California—Davis Medical Center, Sacramento, California.
[2]University of Rochester School of Medicine and Dentistry, Rochester, New York.
[3]American Academy of Pediatrics Center for Child Health Research, Rochester, New York.

Medicine,[6] recommend exclusive breastfeeding for an infant's first 6 months. In 2001, when WHO changed their recommendations on duration of exclusive breastfeeding to 6 months, there was a call for more research because of a paucity of evidence regarding both benefits and risks of 4 versus 6 months of exclusive breastfeeding.[4]

There is evidence that iron deficiency can occur in susceptible infants who are exclusively breastfed for 6 months, including those born prematurely, with low birthweight, or in developing countries where newborn iron stores may be inadequate.[7] Iron deficiency in infants is of particular concern given the evidence that some developmental delays associated with iron deficiency may be irreversible.[8–11] Unfortunately, toddlers remain among the populations in the United States with greatest risk for iron deficiency, 7% in reports from 1999–2000.[12] Few data have evaluated the effect of current breastfeeding recommendations on the iron status of children in the United States.

This study was undertaken to investigate the risk of iron deficiency associated with the longer duration of exclusive breastfeeding in the United States. Specifically, the objective of this study was to evaluate whether 4 to <6 months compared to ≥6 months of full breastfeeding is an independent risk factor for iron deficiency anemia.

MATERIALS AND METHODS

Data regarding 2268 children aged 6 to <24 months from NHANES III,[13] a nationally representative cross-sectional survey of household residents 2 months of age and older conducted from 1988–1994, were analyzed. Anemia and iron status (serum ferritin) were compared for five groups: formula fed only "NoBF"($n = 1142$), or full breastfeeding for: <1 month "FullBF<1" ($n = 425$), 1 month to <4 mos "FullBF1-3+" ($n = 343$), 4 to <6 months "FullBF4-5+" ($n = 222$), and 6 months "FullBF6+" ($n = 136$). "Anemia" was defined for this study as either low hemoglobin at the time of survey or respondent (usually parental) report of the child having a history of anemia. Laboratory data were available for 745 children aged 12 to <24 months. Low hemoglobin was defined as <10.5 g % and low ferritin as $< 7\ \mu/L$.[14] The conservative cutoff of $7\ \mu/L$ of ferritin was used, rather than the more commonly used $10\ \mu/L$, as evidence suggests that values as low as $5\ \mu/L$ are normally found in iron-replete infants at 9 months of age.[15]

Full breastfeeding, receiving nothing other than breastmilk on a daily basis, was the breastfeeding variable considered. By standard definitions,[16] full breastfeeding is divided into two subcategories, exclusive (child receives no food or liquid other than breastmilk) and full almost exclusive (child occasionally receives other foods/liquids, but not on a regular or daily basis). Full breastfeeding was used for this study because it more accurately represents breastmilk as the overwhelming majority of the diet.

Median durations of full breastfeeding in the four breastfed groups were 5, 61, 122, and 182 days. Further analysis was performed dividing the "Full BF6+" into those fully breastfed for 182 days ($n = 92$) and those fully breastfed >182 days ($n = 44$). Children requiring neonatal intensive care were excluded.

SUDAAN[17] software was used to account for the complex sampling design. For bivariate analyses, chi-square analysis was used to compare prevalence of low hemoglobin, serum ferritin, or history of anemia between groups, and analysis of variance was used to compare mean values for continuous variables of those with or without abnormal laboratory values or history of anemia. Adjusted analyses were conducted using logistic regression when bivariate analysis demonstrated a between group difference with a p value of <0.10. Variables compared included gender, birth weight, race/ethnicity (White, African-American, Mexican-American, or other), poverty index (family income divided by the federal poverty level adjusted for family size), family size, two-parent household, educational level of the head of household, prenatal and household smoke exposure, and daycare attendance ≥10 hours/week. Analyses were performed with and without adjusting for recent use (past 30 days) of iron-containing supplements.

Analyses were also conducted using data from 526 children in NHANES 1999–2002,[18] but limited to children 12 to <24 months as parental report of anemia was only obtained in this later survey for children 1 year and older, further revised to query whether the child had been on treatment for anemia during the past 3 months (versus earlier survey asking if the child ever had anemia). Household questions including two-parent household, household education, and family size were no longer asked, and finally, the daycare question no longer specified a threshold number of hours per week. Group sizes for these years were: "NoBF"(n = 181), full breastfeeding for: <1 month "FullBF<1" (n = 113), 1 month to <4 months "FullBF1–3+" (n = 116), 4 to <6 months "FullBF4-5+" (n = 28), and 6 months "FullBF6+" (n = 88). Laboratory data were available for 294 children from this survey.

Reported p-values in this study are two sided; results are considered statistically significant when $p < 0.05$. For all comparisons, breastfeeding ≥6 months is the referent group. For logistic regressions where there is a significant independent association between anemia or iron status and a given variable in the model, adjusted odds and 95% confidence intervals are reported.

RESULTS

In unadjusted analyses from NHANES III, a greater percent of "FullBF6+" had a history of anemia compared to "FullBF4–5+", 10.0% versus 2.3%, (p = 0.007). In the "FullBF6+" group, there was not a significant difference in percent of children with a history of anemia of those fully breastfed 6 months (n = 92) versus those fully breastfed longer than 6 months (n = 44), 12.2% versus 5.7%, p = 0.33. Children with a history of anemia also had a lower mean birthweight and had families with less mean education and income compared to those without a history of anemia. Demographic characteristics of each breastfeeding group are summarized in Table 1, and history of anemia and abnormal laboratory values at survey are shown by breastfeeding and demographic group in Table 2.

Similarly, children with anemia at the time of survey also came from families who were poorer, than those who were not anemic. Those with iron deficiency when studied, as defined by low serum ferritin concentration, came from families who were larger, poorer and had less education than did those with normal serum ferritin values. At the time of survey, however, differences in laboratory values in NHANES III children were not statistically significant in "FullBF6+" compared to "FullBF4–5+." Low hemoglobin values were found in 1.7% versus 0.2% of the groups, respectively, and low ferritin values were noted in 9.9% versus 10.6%. Demographic characteristics of children with normal versus abnormal values and by anemia history are found in Table 3.

Adjusting for birth weight, ethnicity, poverty, two-parent household, and parental education revealed persistent decreased risk for a history of anemia in "FullBF4–5+" (odds ratio [OR] 0.20, confidence interval [CI] 0.06, 0.63), "FullBF1–3+" (OR 0.32, CI 0.11,0.94) and "NoBF"(OR 0.43, CI 0.19,0.96) compared to "FullBF6+." Adjusted odds are shown in Table 4. Eliminating infants fully breastfed >182 days from the "FullBF6+" group did not eliminate the increased risk for anemia by history in this group, that is, "FullBF4–5+" children still had less of a risk of having been anemic compared to those children fully breastfed 182 days (OR 0.14, CI 0.04,0.50).

After adjusting for potential confounders there was still no difference found in risk of low hemoglobin at the time of survey between the "FullBF6+" and "FullBF4–5+" groups. Furthermore, the "FullBF<1" and "FullBF1–3+" groups were actually at a significantly higher risk of low hemoglobin values. Adjusted risk of low ferritin did not differ between groups with the "Full BF6+" as referenced in NHANES III. Recent use of iron containing supplements did not affect the adjusted risks of low hemoglobin or ferritin values, or having a history of anemia.

Unadjusted analysis from NHANES 1999–2002 did not reveal a significant difference by breastfeeding group in any of the three outcomes of interest, history of anemia, or low hemoglobin or ferritin at the time of survey. There was a significantly lower percentage of children in this later survey who had a history of anemia compared to NHANES III, 1.5% versus

Table 1. Demographic Characteristics of NHANES III and NHANES 1999–2002 Children Ages 6–<24 Months by Breastfeeding Status

	No breastfeeding		*BF <1 mo*		*BF 1–3 mo*		*BF 4–5 mo*		*BF >6 mo*	
			NHANES		*NHANES*		*NHANES*		*NHANES*	
	III	*1999–2002*	*III*	*1999–2002*	*III*	*1999–2002*	*III*	*1999–2002*	*III*	*1999–2002*
	(n = *1,149*)	(n = *181*)	(n = *426*)	(n = *113*)	(n = *343*)	(n = *116*)	(n = *223*)	(n = *28*)	(n = *136*)	(n = *88*)
	Percent		*Percent*		*Percent*		*Percent*		*Percent*	
Age										
6–<12 months	34.7	0.0	36.7	0.0	33.0	0.0	34.7	0.0	23.5	0.0
12–<24 months	65.3	100.0	63.3	100.0	67.0	100.0	65.3	100.0	76.5	100.0
Gender										
Male	51.3	51.2	54.0	55.1	50.6	59.8	50.0	**82.1**	48.0	54.2
Female	48.7	48.8	46.0	44.9	49.4	40.2	50.0	**17.9**	52.0	45.8
Race/ethnicity										
White	**54.7**	49.1	**1.5**	**41.5**	76.6	65.1	77.4	56.9	79.3	63.4
African-American	**26.5**	**22.0**	9.3	13.0	7.3	6.4	7.2	6.2	7.8	8.4
Mexican-American	8.2	9.7	**16.4**	**31.7**	9.4	16.9	6.2	18.2	7.2	12.1
Other	10.7	19.2	12.9	13.8	6.7	11.6	9.2	18.7	5.7	16.2
2-Parent household	**70.6**	NA	**84.1**	NA	90.2	NA	88.9	NA	92.6	NA
Childcare‡	13.7	33.0	11.1	22.7	22.4	**42.7**	9.3	**7.6**	17.7	23.1
Smoke exposure										
Prenatal and postnatal	**26.7**	20.5	12.0	12.8	13.0	9.3	9.8	4.6	6.6	5.0
Prenatal only	4.5	6.2	3.4	9.9	3.3	**4.5**	1.3	0.0	2.8	10.5
Postnatal only	22.8	15.0	11.7	4.2	14.4	6.2	12.2	7.8	14.0	4.9
None	**46.0**	**58.3**	72.9	73.1	69.3	79.9	76.6	87.6	76.6	79.7
	Mean (Standard Error)		*Mean (Standard Error)*		*Mean (Standard Error)*		*Mean (Standard Error)*		*Mean (Standard Error)*	
Birthweight (kg)	**3.33**	3.30	**3.42**	3.40	**3.51**	3.39	**3.51**	3.53	3.64	3.43
	(0.02)	(0.07)	**(0.03)**	(0.07)	**(0.03)**	(0.05)	**(0.04)**	(0.09)	(0.06)	(0.07)
Poverty index	**1.7**	**1.4**	2.5	**1.9**	2.9	2.3	2.8	3.1	2.8	2.7
		(0.1)	(0.2)	**(0.2)**	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)	(0.3)
Head of household	**11.4**	NA	**12.6**	NA	13.5	NA	13.6	NA	14.1	NA
Education-years	**(0.02)**		**(0.02)**		(0.2)		(0.4)		(0.5)	
Family size	4.4	NA	4.3	NA	4.0	NA	4.1	NA	4.2	NA
	(0.1)		(0.1)		(0.1)		(0.1)		(0.1)	

Boldface indicates statistical significance compared to Full BF ≥ 6 as referent group.
‡NHANES III ≥ 10 hours/wk, 1999–2002 hours per week not stipulated.
BF = breastfed; NA = not available.

TABLE 2. PREVALENCE OF LOW HEMOGLOBIN, SERUM FERRITIN AND HISTORY OF ANEMIA IN NHANES III AND NHANES 1999–2002 CHILDREN BY BREASTFEEDING AND DEMOGRAPHIC STATUS

	Low serum ferritin[#] *(%)*		*Low hemoglobin*[#] *(%)*		*History of anemia*[†] *(%)*	
	NHANES III	*1999–2002*	*NHANES III*	*1999–2002*	*NHANES III*	*1999–2002*
Total	8.9	10.4	3.6	2.6	6.8	2.0
Breastfeeding group	*		***		**	
No BF	10.9	6.3	4.3	6.2	7.5	2.1
FullBF<1	6.4	17.4	3.2	1.2	8.8	2.4
FullBF1–3+	4.2	6.6	5.7	0.0	4.4	2.1
FullBF4–5+	10.6	5.8	0.2	0.0	2.3	1.1
FullBF6+	9.9	18.1	1.7	1.3	10.0	1.5
Gender	‡	*				
Male	10.8	14.3	3.7	3.4	6.0	2.3
Female	6.7	5.7	3.6	1.7	7.5	1.6
Race/ethnicity	**	**	‡		**	
White	5.7	11.0	2.5	2.5	5.4	1.4
African-American	11.2	2.9	7.4	5.6	8.7	1.7
Mexican-American	20.7	20.6	6.4	1.4	10.4	1.7
Other	13.4	3.9	1.3	1.4	9.2	4.6
Prenatal smoke						
Yes	12.0	21.2	2.7	4.2	7.0	0.9
No	8.0	7.7	3.9	2.2	6.7	2.2
Household smoke						
Yes	11.2	5.4	4.7	6.5	6.1	2.6
No	7.6	12.4	3.1	1.2	7.2	1.8
Daycare[¶]						
Yes	4.9	8.7	4.8	1.5	8.1	0.8
No	9.6	11.2	3.4	3.1	6.5	2.5
2-Parent household					**	
Yes	9.0	NA	3.8		5.7	
No	8.0		3.1		11.2	

[¶]NHANES III ≥ 10 hours/wk, 1999–2002 hours per week not stipulated; NA = not available.
[‡]$p < 0.01$, *$p < 0.05$, **$p < 0.001$, ***$p < 0.0001$, ****$p < 0.00001$; [#]12–<24 months of age; [†]NHANES III—history of anemia children 6–<24 months of age ($n = 2{,}268$); NHANES 1999–2002—history of anemia treated in past 3 months children 12–24 months of age ($n = 502$).

10.0%, $p < 0.00001$. After adjusting for birthweight and available demographic variables, however, there was a significantly lower risk of having a low ferritin level at the time of survey in the "FullBF4–5+" versus the "FullBF6+" group, OR 0.19, CI 0.06, 0.57; but there was still no significant difference between groups in low hemoglobin or history of anemia.

DISCUSSION

In a nationally representative sample of U.S. children between 6 and 24 months of age, we found that those fully breastfed for ≥6 months were at a three- to five-fold increased risk for having a reported history of anemia compared to those fully breastfed for shorter durations of 1 to <6 months. This finding is of great import to public health in the United States. The increased risk persisted after adjusting for factors known to be associated with iron deficiency—birthweight, race/ethnicity, gender, socioeconomic status, and education.[19–21] The group in NHANES III that was fully breastfed for ≥6 months, however, was not at risk for lower hemoglobin or serum ferritin levels at the time of survey between 1 and 2 years of age, and were, in fact, at less risk for low hemoglobin than children fully breastfed <4 months. This may reflect the fact that those diagnosed with anemia by standard screening at 9–12 months were treated, more likely to be partially iron repleted

Table 3. Demographic Characteristics of Children in NHANES III and NHANES 1999–2002 by Iron and Anemia Status

	Ferritin[#] *Low/normal*		*Hemoglobin*[#] *Low/normal*		*History of anemia*[†] *Yes/No*	
	NHANES III	*NHANES 1999–2002*	*NHANES III*	*NHANES 1999–2002*	*NHANES III*	*NHANES 1999–2002*
Family size	*		‡			
Mean (s.e.)	5.0 (0.3)/4.3 (0.1)	NA	4.9 (0.3)/4.4 (0.1)	NA	4.28 (0.2)/4.27 (0.1)	NA
Head of house	**				*	
edu (yrs)	10.4 (0.7)/12.5 (0.2)	NA	11.9 (0.7)/12.4 (0.2)	NA	11.4 (0.5)/12.5 (0.2)	NA
Mean (s.e.)						
Poverty index	*		**	***	****	****
Mean (s.e.)	1.78 (0.20)/2.24 (0.14)	1.79 (0.35)/1.90 (0.12)	1.55 (0.24)/2.22 (0.14)	0.82 (0.23)/1.90 (0.11)	1.58 (0.15)/2.32 (0.07)	0.90 (0.13)/2.07 (0.09)
Birthweight—(kg)	‡				*	
Mean (s.e.)	3.29 (0.07)/3.42 (0.03)	3.23 (0.13)/3.39 (0.05)	3.40 (0.03)/3.41 (0.09)	3.30 (0.26)/3.36 (0.05)	3.33 (<0.01)/3.43 (0.02)	3.23 (0.19)/3.38 (0.03)

NA = not available. ‡$p < 0.01$, *$p < 0.05$, **$p < 0.001$, ***$p < 0.0001$, ****$p < 0.00001$; #12–<24 months of age.

†NHANES III—history of anemia children 6–<24 months of age; NHANES 1999–2002—history of anemia treated in past 3 months children 12–24 months of age.

TABLE 4. ADJUSTED ODDS OF ANEMIA HISTORY AND LOW SERUM FERRITIN OR HEMOGLOBIN VALUES IN NHANES III AND NHANES 1999–2002 BY IRON AND ANEMIA STATUS

	Low serum ferritin[#]		*Low hemoglobin*[#]		*History of anemia*[†]	
	NHANES III n = *745*	*NHANES 1999–2002* n = *245*	*NHANES III* n = *742*	*NHANES 1999–2002* n = *202*	*NHANES III* n = *2268*	*NHANES 1999–2002* n = *476*
Breastfeeding group						
No BF	NS	0.21 (0.05, 0.94)	10.00 (1.24, 80.73)	NS	0.43 (0.19, 0.96)	NS
FullBF<1	NS	NS	11.80 (1.04, 133.93)	NS	NS	NS
FullBF1–3+	NS	0.16 (0.03, 0.76)	21.97 (2.40, 200.83)	NS	0.32 (0.11, 0.94)	NS
FullBF4–5+	NS	0.19 (0.06, 0.57)	NS	NS	0.20 (0.06, 0.63)	NS
FullBF6+	1.0	1.0	1.0	1.0	1.0	1.0
Gender						
Male	1.88 (1.03, 3.43)	3.44 (1.25, 9.47)	N/A	NS	N/A	NS
Female	1.0	1.0		1.0		referent
Poverty index	NS	NS	NS	NS	0.79 (0.65, 0.96)	0.42 (0.21, 0.85)
Race–ethnicity	NS	NS	NS	NS	NS	NS
Head household edu	NS	NA	N/A	NA	NS	NA
Family size	NS	NA	NS	NA	N/A	NA
Birth weight	NS	NS	N/A	NS	NS	NS

OR (−95%CI, +95%CI) given only when $p < 0.05$ versus referent group (FullBF 6+); [#]12–<24 months of age.
NS = not significant; NA = not available; N/A = not applicable.
[†]NHANES III—history of anemia children 6–<24 months of age; NHANES 1999–2002—history of anemia treated in past 3 months, children 12–24 months of age.

and therefore less likely anemic upon subsequent survey at 12–24 months. Despite being less likely to have a low hemoglobin at the time of survey, this finding is concerning given the risk for non reversible long-term cognitive deficits associated with iron deficiency.[8–11]

The increased risk of children in the later survey who were fully breastfed ≥6 months having a low ferritin without a lower hemoglobin concentration at the time of sampling represents an increase in preanemic iron deficiency. This finding supports that of the earlier survey, but actually documents poorer iron status in children whose mothers follow current recommendations regarding exclusive breastfeeding duration. It is not clear why the two surveys are discrepant with respect to ferritin status, but the finding of each survey suggests that the "FullBF6+" group is at greater risk for iron deficiency. The finding of greater risk of a history of anemia found in the prior survey was not found in the later survey, most likely because the question was substantively revised to query treatment of anemia only within the past 3 months in addition to the exclusion of children below a year of age.

It is well established that the iron content in breastmilk, while more bioavailable (12%–49% absorption) compared to that in fortified formula, is quite low, approximately 35–40 μg/dL. Iron needs during the first 6 months in breastfed infants are primarily supplied by the infant's stores at birth. Infants in well-nourished populations born at term and of normal birth weight typically have adequate stores at birth to prevent deficiency until 6 months of age, at which time iron-rich complementary foods are recommended. Later weaning has been described as a risk factor for iron deficiency anemia (IDA) in resource-limited countries, including Pakistan[22] and Mexico,[23] where infants are more likely to have lower stores at birth, have greater requirements early in infancy due to catch-up–growth, etc. Similarly, a previous study reports that iron supplementation given between 6 and 9 months reduces the risk of IDA among term, breastfed infants in a population with a high prevalence (Honduras), but not in one with low prevalence (Sweden) of IDA.[7] Our study suggests infants fully breastfed for 6 months in the United States are at increased risk despite an intermediate prevalence of IDA. In the latter study, the prevalence of IDA in the unsupplemented group at 9 months of age in Honduras was 29%, and in Sweden it was <3%. The prevalence of IDA in the United States specifically at 9 months is not available for comparison, but in NHANES III, the prevalence between 1 and 2 years was 3%, far closer to that in Sweden than in Honduras.[19] Presumably, the prevalence would be somewhat higher at 9 months, as typically stores are depleted by rapid growth during the first year, and then repleted by increased dietary diversity thereafter. Our findings concur with a recent report from a Massachusetts' Supplemental Food Program for Women, Infants, and Children (WIC) that children breastfed for >25 weeks were noted to have a greater increase in hemoglobin in the second year of life than those breastfed shorter durations; the authors of that report note that if efforts to increase breastfeeding duration are successful, efforts to prevent iron deficiency will have increasing import.[24]

The greater risk of iron deficiency amongst infants and toddlers fully breastfed for 6 months in the United States is perhaps not surprising, given that most children in the comparison group would have received iron-fortified infant formulas. Iron deficiency in fully breastfed infants is likely due, in part, to receiving suboptimal iron stores prenatally as the prevalence in women of childbearing age in NHANES III of iron deficiency was 11% and that of IDA 5%.[19] It has been demonstrated that predominantly breastfed newborns with low ferritin concentrations at birth continue to have low ferritin levels at 9 months of age, placing them at greater risk for the development of anemia.[25] Iron endowment at birth may also be affected by the timing of umbilical cord clamping. A recent randomized trial in Mexico documented greater ferritin levels at 6 months in infants whose cords were clamped at 2 minutes of age compared to those with immediate clamping.[26] Finally, these infants may not be receiving iron-rich complementary foods beginning at 6 months as currently recommended.

This study has several limitations. History of anemia was by respondent report; medical records were not reviewed. It is, however, unlikely that recall bias would differ by breastfeeding status. Another possibility is that those reporting a history of anemia were more likely to have been diagnosed due to greater access to care rather than greater likelihood of anemia. Controlling for race/ethnicity, socioeconomic status, and head-of-household education may not have fully adjusted for differences in access to care and resource utilization. There also may have been other differences between groups impacting iron status for which we were unable to adjust. Similarly, it is possible that the children fully breastfed ≥6 months were more likely to have hemoglobin checked because of the potential for increase in iron deficiency with prolonged breastfeeding, and for this reason they were more likely to be diagnosed. This phenomenon, however, could not explain the difference in ferritin status at the time of sampling in the latter survey. The study is further limited by incomplete information on iron supplements; information was given only for those received within the past 30 days so we are unable to confirm our hypothesis that those diagnosed were treated, accounting for a lower risk of anemia at the time of survey. Additionally, the study is limited by available laboratory data. History of anemia is obtained for children between 6 and 24 months, while laboratory data are only available for those 12–24 months of age.

The lack of concordance between those breastfeeding groups that had greater adjusted odds for low hemoglobin value at the time of survey not having greater odds for a low ferritin is unexpected. One possible explanation is that ferritin can be falsely elevated during acute infection or inflammation, but laboratory data to adjust for inflammation (C-reactive protein) was only available for children ≥3 years of age in NHANES, an acknowledged limitation of this dataset.[14] Of note, however, requiring two of three markers to be abnormal for iron deficiency in the NHANES resulted in defining 9% of toddlers aged 1–2 years as deficient versus 8.9% using ferritin alone in this study.[18] This may have been due to the lower level of ferritin concentration used in the current study, <7% versus <10% used in NHANES III.[19] Likewise, anemia in the presence of iron deficiency resulted in 3% of this age group defined as having IDA[19] versus 3.6% with anemia in our study, suggesting that in this more limited age range, anemia from other causes was not the primary culprit as it was for the NHANES III population 12 to 35 months of age.[27]

Healthy People 2010 goals include reduction of iron deficiency in toddlers 1–2 years of age from the 9% documented in NHANES III to 5% by 2010. We found children fully breastfed ≥6 months were at greater risk for having been diagnosed with anemia and/or having iron deficiency at the time of study than those fully breastfed for 1 to 6 months. Given the possible negative impact of even temporary iron deficiency, mechanisms of prevention should be thoroughly explored. The role of the physician in prevention is highlighted by a study in which a normal hemoglobin value in the child was highly correlated with maternal report of extensive nutritional discussion with a physician.[28] The need for prevention is also emphasized by reports of low- follow-up rates in children diagnosed with iron deficiency and/or anemia in both inner-city[29] and tertiary care pediatric clinics.[30]

Full or exclusive breastfeeding for 6 months provides greater protection against both respiratory[31] and gastrointestinal[32] infections than does shorter durations, and should continue to be recommended. The increased risk of anemia reported here for infants breastfed fully for 6 months in the United States needs confirmation, particularly given the noted discord between history and laboratory values at the time of survey. Meanwhile, physicians should stress the importance of beginning complementary foods rich in iron at 6 months of age. Routine delay in cord clamping for healthy newborns could also result in less susceptibility to iron deficiency. Efforts to prevent iron deficiency in women of childbearing age should be redoubled, as evidence suggests the prevalence in this age group may actually be increasing.[12]

CONCLUSIONS

Young children in the United States fully breastfed for 6 months may be at increased risk of iron deficiency and anemia. Adequate iron may not be provided by typical complementary infant foods. Further study will be required to ascertain factors predictive of anemia and mechanisms for prevention in this group of infants.

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Address reprint requests to:
Caroline J. Chantry, M.D.
Department of Pediatrics
University of California—Davis Medical Center
2516 Stockton Blvd.
Sacramento, CA 95817

E-mail: caroline.chantry@ucdmc.ucdavis.edu