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# Adherence to Vitamin D Recommendations Among US Infants

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## KEY WORDS

American Academy of Pediatrics, vitamin D, Infant Feeding Practices Study II, supplement

## ABBREVIATIONS

AAP—American Academy of Pediatrics  
IOM—Institute of Medicine  
IFPS II—Infant Feeding Practices Study II  
NSFG—National Survey of Family Growth

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**WHAT'S KNOWN ON THIS SUBJECT:** There have been few data on the prevalence of US infants meeting AAP vitamin D recommendations.



**WHAT THIS STUDY ADDS:** We estimated the prevalence of breastfed, formula-fed, and mixed-fed infants who met the 2003 and 2008 AAP vitamin D recommendations. Most infants, not just those who are breastfed, will need to receive an oral vitamin D supplement to meet the 2008 AAP recommendation.

## abstract

**OBJECTIVES:** In November 2008, the American Academy of Pediatrics (AAP) doubled the recommended daily intake of vitamin D for infants and children, from 200 IU/day (2003 recommendation) to 400 IU/day. We aimed to assess the prevalence of infants meeting the AAP recommended intake of vitamin D during their first year of life.

**METHODS:** Using data from the Infant Feeding Practices Study II, conducted from 2005 to 2007, we estimated the percentage of infants who met vitamin D recommendations at ages 1, 2, 3, 4, 5, 6, 7.5, 9, and 10.5 months ( $n = 1952-1633$ ).

**RESULTS:** The use of oral vitamin D supplements was low, regardless of whether infants were consuming breast milk or formula, ranging from 1% to 13%, varying by age. Among infants who consumed breast milk but no formula, only 5% to 13% met either recommendation. Among mixed-fed infants, 28% to 35% met the 2003 recommendation, but only 9% to 14% would have met the 2008 recommendation. Among those who consumed formula but no breast milk, 81% to 98% met the 2003 recommendation, but only 20% to 37% would have met the 2008 recommendation.

**CONCLUSIONS:** Our findings suggest that most US infants are not consuming adequate amounts of vitamin D according to the 2008 AAP recommendation. Pediatricians and health care providers should encourage parents of infants who are either breastfed or consuming <1 L/day of infant formula to give their infants an oral vitamin D supplement. *Pediatrics* 2010;125:627-632

The role of vitamin D in calcium and phosphorus homeostasis and bone metabolism has been well established; however, the presence of vitamin D receptors in many cell types suggests that vitamin D has other physiologic functions.<sup>1</sup> For example, vitamin D deficiency has been associated with respiratory infections, type 1 diabetes, cardiovascular diseases, and cancer in later life,<sup>1–3</sup> which emphasizes the importance of vitamin D nutrition throughout the life span. In children, nutritional rickets typically occurs in severe cases of vitamin D deficiency, causing softening and weakening of the bones, and is associated with impaired growth, developmental delays, lethargy, and hypocalcemic seizures.<sup>4</sup> In addition to being obtained through the diet, vitamin D is synthesized endogenously in the skin after exposure to ultraviolet light. The American Academy of Pediatrics (AAP) advises that children younger than 6 months be kept out of the sun altogether and that those aged 6 months or older wear protective clothing and sunscreen to minimize sun exposure.<sup>5</sup> Some researchers recommend short episodes of sun exposure as a way of obtaining vitamin D; however, the safety of this method for infants with regard to future skin cancer is not known.<sup>6,7</sup> In addition, one's ability to produce vitamin D is affected by latitude, season, sunscreen use, skin pigmentation, and air pollution, which make sun exposure an unreliable source of vitamin D. Thus, infants need to obtain vitamin D either primarily or entirely from their diet. In 1997, the Institute of Medicine (IOM) recommended that 200 IU/day be considered "adequate intake" of vitamin D for infants, although it did not have sufficient information to determine a recommended dietary allowance.<sup>8</sup> In 2003, the AAP released vitamin D—consumption guidelines in line with those of the IOM and recommended that all children be-

gin consuming 200 IU/day of vitamin D during their first 2 months of life.<sup>4</sup>

Although there currently is no national surveillance of nutritional rickets in the United States, cases of rickets among hospital patients continue to be reported.<sup>9,10</sup> The prevalence of poor vitamin D status among US infants also remains high by most measures, although data on infant vitamin D status can be difficult to interpret because of a lack of consensus on optimal vitamin D levels or on what constitutes vitamin D deficiency. Depending on the definitions used, vitamin D deficiency has been reported in 10% to 65% and insufficiency in 40% to 56% of US neonates, infants, and toddlers,<sup>11–13</sup> which suggests that vitamin D levels may not be optimal in these groups. Given the growing evidence that the level of vitamin D consumption it recommended in 2003 may not be sufficient, in November 2008 the AAP released a new recommendation that all children receive 400 IU/day of vitamin D from their first few days of life through adolescence.<sup>14</sup> The IOM is also reviewing its current recommendations for vitamin D consumption and plans to release a report on the findings of this review in May 2010.

Although breast milk is the best single source of food for infants,<sup>15</sup> it only contains <25 to 78 IU/L of vitamin D<sup>14</sup> and, thus, is insufficient, by itself, to provide adequate levels of vitamin D for infants. Foods that are good sources of vitamin D include oily fish, egg yolks, and fortified foods such as infant formula and milk.<sup>16</sup> Most infants, however, will not consistently consume these foods during their first year of life unless they are primarily fed infant formula. All infants require a supplemental source of vitamin D from an oral vitamin D supplement, fortified infant formula, or both.

Our objective for this analysis was to estimate the prevalence of adherence

to both the 2003 and 2008 AAP vitamin D recommendations among infants during their first year of life. Because infants' level of vitamin D consumption would likely differ by the extent to which they were formula fed, we produced separate prevalence estimates for infants who were breastfed, formula fed, and "mixed fed" (both breastfed and formula fed).

## METHODS

We analyzed data from the Infant Feeding Practices Study II (IFPS II), a longitudinal survey of US mothers of healthy singletons, followed from late pregnancy through the first year of their infant's life, which was conducted from 2005 through 2007 by the US Food and Drug Administration in collaboration with the Centers for Disease Control and Prevention.<sup>17</sup> The sample was drawn from a consumer-opinion mail panel that was nationally distributed but not nationally representative. Women were recruited in their third trimester of pregnancy; mothers at least 18 years of age, mothers and infants without medical conditions that would affect feeding, and infants who were born after at least 35 weeks' gestation and weighed at least 5 lb were included in the study. Extensive details of the IFPS II methodology, the IFPS II sample, and a comparison of the IFPS sample with a nationally representative sample of women from the National Survey of Family Growth (NSFG) have been published previously.<sup>18</sup> Generally, IFPS II participants were older and more educated, had a higher income and fewer children, were breastfed longer, and were more likely to be white than those in the NSFG sample.

Each IFPS II participant was mailed 1 prenatal and 10 postnatal questionnaires at approximately monthly intervals that asked about various infant feeding and care practices. We ana-

lyzed data collected about infants at ages 1, 2, 3, 4, 5, 6, 7.5, 9, and 10.5 months as if the data were from separate cross-sectional surveys; sample sizes ranged from 1952 mothers of infants at 3 months to 1633 mothers of infants at 10.5 months. Regarding supplement use, mothers were asked on each monthly questionnaire, "Which of the following was your baby given in vitamin or mineral drops or pills at least 3 days a week during the past 2 weeks? If your baby was given drops or pills that contained more than 1 of the items listed, please mark each of the separate items." If the mother checked the box for vitamin D, the infant was categorized as having received an oral vitamin D supplement. Thus, our estimate of vitamin D supplementation was not of daily administration, but of a minimum of 3 days per week.

On each of the postpartum surveys, mothers were also asked to estimate the average number of ounces of formula their infants consumed at each feeding (response options were 1–2, 3–4, 5–6, 7–8, and >8 oz) and the average number of feedings per day or week for both breast milk and formula. In our analyses, we used the midpoint of the formula consumption response options reported (1.5, 3.5, 5.5, 7.5, and 8.5 oz) and the average number of feedings per day to estimate average daily formula consumption, converting ounces to milliliters. We also used the reported frequency of breast milk and formula feedings to divide infants into 3 mutually exclusive feeding-practice groups: breast milk (consumed breast milk only); mixed (consumed breast milk and formula); and formula (consumed formula only). These classifications referred only to consumption of breast milk and formula; infants may also have been consuming other foods or liquids, such as water or juice. Almost no children consumed cow's milk until 10.5 months of age. Fourteen per-

**TABLE 1** Percentage of Infants Fed According to Each of Three Feeding Practices by Age

Infant Age, mo (wk)	No.	Breast Milk, %	Mixed, %	Formula, %
1 (3 to <7)	1804	42.5	31.6	25.9
2 (7 to <11)	1714	42.8	24.1	33.1
3 (11 to <15)	1952	41.6	20.2	38.2
4 (15 to <19)	1837	38.2	19.5	42.4
5 (19 to <24)	1927	36.3	18.0	45.7
6 (24 to <29)	1870	33.6	17.1	49.3
7.5 (29 to <36)	1862	31.8	14.7	53.5
9 (36 to <43)	1790	29.4	12.8	57.8
10.5 (43 to <51)	1633	27.1	11.0	61.9

Feeding-practice categories are mutually exclusive and based only on consumption of breast milk and formula.

cent of infants at 10.5 months were consuming any cow's milk; for half of these infants, consumption frequency was less than once per day. When we compared the results of our analysis for all infants aged 10.5 months with results for the same group excluding those reported to have consumed any cow's milk, we found no significant differences.

The IFPS II data were collected from 2005 to 2007, at which time the 2003 AAP recommendation would have been current. We used both the 2003 and 2008 recommendations in this analysis to obtain estimates of the prevalence of infants who were meeting the 2003 recommendation and the prevalence of infants who would meet the 2008 recommendation without any behavior changes. Infants' multivitamin and vitamin D—only preparations available in the United States supply 400 IU/day; thus, infants who receive an oral vitamin D supplement would obtain enough vitamin D to meet both the 2003 and 2008 recommendations.<sup>14</sup> Therefore, we classified infants as meeting the 2003 recommendation (which recommended beginning supplementation at 2 months of age and thus does not apply for infants younger than 2 months) if they were either receiving an oral vitamin D supplement or consuming at least 500 mL/day of vitamin D—fortified infant formula, which in the United States is fortified at a level of 400 IU/L.<sup>14</sup> We classified infants as having met the 2008

recommendation (which applies to infants beginning within their first few days of life) if they were either receiving an oral vitamin D supplement or consuming at least 1 L/day of formula.<sup>4,14</sup>

## RESULTS

At 1 month of age, 43% of the infants were breastfed, 32% were mixed fed, and 26% were formula fed (Table 1). With increasing age, the percentage of infants who were breastfed decreased, and the percentage who were formula fed increased; by 10.5 months of age, 27% of the infants were breastfed, 11% were mixed fed, and 62% were formula fed. Throughout the first year of life, mean formula intake ranged from 310 to 352 mL/day in the mixed-fed group, with little variation by age, and from 770 to 987 mL/day in the formula-fed group, with formula intake generally increasing with age until peaking at 4 to 6 months and then decreasing.

Overall, only 4% to 7% of the infants were receiving an oral vitamin D supplement (Table 2), with infants 1 month of age having the lowest prevalence of supplement use. The prevalence of oral supplement use ranged from 5% to 13% in the breastfed group and from 4% to 11% in the mixed-fed group. Only 1% to 4% of the infants in the formula-fed group were receiving an oral supplement.

We estimated that over the first year of life, 44% to 58% of infants met the 2003

**TABLE 2** Percentage of Infants Who Received an Oral Vitamin D Supplement According to Feeding Practice by Age

Infant Age, mo (wk)	Total, %	Breast Milk, %	Mixed, %	Formula, %
1 (3 to <7)	3.9	5.3	4.3	1.1
2 (7 to <11)	5.5	9.4	5.1	0.9
3 (11 to <15)	6.8	10.3	8.9	1.7
4 (15 to <19)	6.8	10.8	9.8	1.7
5 (19 to <24)	7.3	12.6	9.8	2.0
6 (24 to <29)	7.0	12.1	9.4	2.6
7.5 (29 to <36)	6.9	11.3	11.0	3.1
9 (36 to <43)	6.0	11.2	7.9	2.9
10.5 (43 to <51)	6.7	11.1	10.7	3.9

Classification as having received a vitamin D supplement indicates that infants received an oral supplement at least 3 days/week during the previous 2 weeks. Feeding-practice categories are mutually exclusive and based only on consumption of breast milk and formula.

**TABLE 3** Percentage of Infants Who Met the 2003 AAP Vitamin D Recommendation and the Percentage Who Would Have Met the 2008 Recommendation According to Feeding Practice by Age

Infant Age, mo (wk)	Total, %		Breast Milk, %		Mixed, %		Formula, %	
	2003	2008	2003	2008	2003	2008	2003	2008
1 (3 to <7)	NA <sup>a</sup>	11.4	NA <sup>a</sup>	5.3	NA <sup>a</sup>	8.7	NA <sup>a</sup>	24.8
2 (7 to <11)	43.6	16.4	9.4	9.4	29.8	8.5	98.1	31.2
3 (11 to <15)	48.5	20.1	10.3	10.3	33.5	12.4	98.0	34.9
4 (15 to <19)	52.2	22.1	10.8	10.8	33.0	12.6	98.2	36.6
5 (19 to <24)	55.4	23.7	12.6	12.6	35.3	13.0	97.4	36.7
6 (24 to <29)	56.3	25.0	12.1	12.1	31.6	14.4	95.0	37.4
7.5 (29 to <36)	57.8	19.6	11.3	11.3	29.3	13.9	93.3	26.0
9 (36 to <43)	57.9	16.9	11.2	11.2	28.0	12.2	88.2	20.9
10.5 (43 to <51)	57.0	16.8	11.1	11.1	33.3	13.3	81.3	19.9

2003 AAP recommendation: receive an oral vitamin D supplement or consume 500 mL/d of infant formula beginning at 2 months; 2008 recommendation: receive an oral vitamin D supplement or consume 1 L/d of infant formula beginning at birth. Feeding practice categories are mutually exclusive and based only on consumption of breast milk and formula.

<sup>a</sup> The 2003 recommendation does not apply to infants in this age category.

AAP recommendation that they consume 200 IU/day of vitamin D, whereas only 11% to 25% would have met the 2008 recommendation of 400 IU/day of vitamin D (Table 3). Among breastfed infants, who must have received an oral vitamin D supplement to meet either of the AAP recommendations, only 9% to 13% were receiving enough vitamin D at 2 to 10.5 months of age to meet the 2003 or 2008 recommendation. The 2008 recommendation (but not the 2003 recommendation) applies to infants at 1 month; only 5% of 1-month-old infants who were breastfed received an oral vitamin D supplement and, thus, would have met the 2008 recommendation. Among mixed-fed infants, 28% to 35% met the 2003 recommendation, but only 9% to 14%

would have met the 2008 recommendation; those who met the 2003 recommendation did so primarily through formula intake, whereas those who met the 2008 recommendation did so primarily with the use of an oral vitamin D supplement, suggesting that few mixed-fed infants consume enough formula to obtain 400 IU/day of vitamin D. More than 90% of formula-fed infants aged 2 to 7.5 months met the 2003 recommendation, as did >80% of formula-fed infants aged 9 and 10.5 months. However, only 20% to 37% of these infants would have met the new 2008 recommendation at any month of age. Because use of an oral vitamin D supplement was very low among formula-fed infants, most who were meeting the 2008 recommendation

were doing so by consuming at least 1 L/day of formula. Thus, the pattern of formula-fed infants who achieved AAP 2008 recommended levels of vitamin D followed a pattern similar to that of formula intake, increasing with age until peaking at 4 to 6 months and then decreasing.

## DISCUSSION

At the time the IFPS II data were collected, the 2003 AAP recommendation was the current guideline regarding vitamin D intake for the prevention of vitamin D deficiency and rickets. Although we found that most formula-fed infants were meeting the recommendation, we also found that only approximately one-tenth of breastfed infants and one-third of mixed-fed infants were meeting it. This poor adherence to the 2003 recommendation was because of both low prevalence of oral vitamin D supplement use and most mixed-fed infants not consuming enough formula to meet the recommended consumption level of 200 IU/day. Our estimates regarding the 2008 recommendation provide a sense of the prevalence of infants among the various feeding-practice groups who would meet the new recommendation if there was no change in behavior regarding vitamin D intake. Fewer than 15% of the infants in both the breastfed and mixed-fed groups would have met the 2008 recommended level of vitamin D consumption.

The difference in the percentage of infants who met the 2 recommended intake levels was particularly striking among formula-fed infants. Whereas most formula-fed infants were consuming the 500 mL/day of formula required to obtain 200 IU of vitamin D, only approximately one-third were consuming the 1 L/day required to obtain 400 IU. Among this group, adherence peaked at ~4 to 6 months, which is when many infants would begin to

consume complementary foods and reduce their formula intake. The 2008 AAP guideline suggests that most infants older than 1 month will consume the 1 L/day of formula required to obtain 400 IU/day of vitamin D<sup>14</sup>; however, our results did not support this assumption and indicated instead that most infants, not just those who are breastfed, would likely need to receive an oral vitamin D supplement to consume enough vitamin D to meet the 2008 recommendation.

The very low prevalence of oral vitamin D supplementation among infants is concerning if infants are to meet current recommendations. Results from the 1999–2002 National Health and Nutrition Examination Survey showed a similarly low prevalence of vitamin D supplement use among US infants: only 8.7% of infants aged 0 to 11 months had received a vitamin D supplement in the previous 30 days.<sup>19</sup> Pediatricians and allied health care providers are uniquely positioned to help increase the percentage of infants who receive adequate amounts of vitamin D, because parents are more likely to give their children vitamin D supplements if they are advised to do so by a health care professional.<sup>20</sup> It is unfortunate that many health care professionals are not recommending vitamin D supplements for infants.<sup>21–23</sup> Reasons that they are not doing so include beliefs that rickets is rare,<sup>23</sup> that infants receive sufficient sunlight,<sup>22,23</sup> and that breast milk has adequate levels of vitamin D.<sup>21–23</sup> Because physicians' knowledge of the AAP recommendations has been positively associated with the likelihood of their recommending vitamin D supplements,<sup>22</sup> both health care providers and parents need to be educated about the AAP guidelines and the importance of vitamin D nutrition, including that infants should not be exposed to sun-

light and, thus, need an alternate source of vitamin D.

Although the IFPS II included women from around the country, the sample was not nationally representative. Among other characteristics, women in this sample had achieved higher levels of education, had fewer children, and had breastfed longer than women in the NSFG,<sup>18</sup> all of which may have been associated with formula and supplement use. Another limitation of our study was that all data were self-reported and required mothers to recall information about their infants' feedings over the previous 7 days and supplement use over the previous 2 weeks. Although the validity of this self-reported data is unknown, our estimates of daily formula intake among infants of IFPS II participants were consistent with, or only slightly higher than, those from other studies.<sup>24–27</sup> Other study limitations included our inability to determine the exact quantity of vitamin D that infants obtained from oral supplements and our definition of supplement use as use of a supplement on at least 3 days/week rather than more frequently. Our estimates of the prevalence of supplement use would likely have been even lower had we used a definition that required more days per week of use. These data were collected from 2005 to 2007, so our estimate of meeting the 2008 AAP recommendation assumed no change in behavior since that time. Because new vitamin D research is continually being generated, it is possible that increased media attention on vitamin D has increased the use of vitamin D supplements among infants. Despite these limitations, IFPS II was one of the largest infant-feeding studies in the United States and provides valuable data that are not available from any other data source to date, including assessment of supplement use and food intake at multiple time points during the first

year of life and at as early as 1 month of life.

According to the 2008 AAP recommendation, all breastfed, mixed-fed, and formula-fed infants who consume <1 L/day of formula should receive an oral vitamin D supplement. Our findings suggest that few infants are consuming at least 1 L/day of formula; thus, many may need to receive oral vitamin D supplements to meet the 2008 AAP recommendation that they consume at least 400 IU/day. This finding should be confirmed in other studies. Parents may need support in providing supplementation for their infants. Supporting adherence in this context is challenging because of the long duration of vitamin D supplementation, the lack of tangible health effects after starting supplementation, the need for an adult to administer the daily dose, and the need for a willing infant to accept the supplement. Overall, adherence to prescriptions from health care providers is poor, even among adults, and is generally worse the longer the regimen duration is.<sup>28</sup> Pediatricians and other health care providers can support and promote daily oral vitamin D supplementation of infants by explaining to parents the purpose and benefits of vitamin D supplementation, reminding parents at each visit to give vitamin D supplements to their children, suggesting that parents develop a daily intake routine to help them remember to administer the supplement, asking parents about any adverse effects of supplementation or barriers to giving their infants supplements, and helping parents to overcome any barriers that they report.<sup>29</sup>

## CONCLUSIONS

We found that most infants, not just those who are breastfed, may require an oral vitamin D supplement

daily, beginning within their first few days of life, to meet the 2008 AAP recommendation that infants consume at least 400 IU/day of vitamin D.

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