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Predictors of vitamin D supplementation amongst infants in Ireland throughout the first year of life

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Abstract

Aim: To investigate predictors of compliance with the recommendation that all infants in Ireland are supplemented daily from birth to 12 months of age with 5 micrograms (µg) of vitamin D.

Subjects and methods: A prospective observational study was completed. Self-complete questionnaires recorded socio-demographic characteristics, health behaviours and supplementation practices for 158 mother-infant dyads at 4, 9 and 12 months post-partum. A 2-day food diary was also obtained on 12-month-old infants to examine the contribution of diet to vitamin D intakes.

Results: At 4, 9 and 12 months of age, 57.6% (*n*91), 34.2% (*n*54) and 23.4% (*n*37) of infants, respectively, were supplemented as recommended. In multivariate analyses, receiving supplementation advice from health professionals in the early post-partum period was the most significant predictor of correctly supplementing 4-month-old (p<0.01, odds ratio (OR): 61.94 [95% confidence interval (CI): 11.53-332.83]), 9-month-old (p<0.01, OR: 10.30 [95% CI: 2.29-46.27]) and 12-month-old (p=0.04, OR: 3.85 [95% CI: 1.05-14.08]) infants. Amongst 12-month-olds, even intakes from diet and supplementation combined (7.6±4.7µg/day) were suboptimal.

Conclusion: Suboptimal vitamin D supplementation practices were evident throughout infancy. Dietary intakes of vitamin D did not compensate for suboptimal supplementation practices. Supplementation practices may improve if health professionals advocate safe supplementation during routine infant health checks.

Keywords

Vitamin D supplementation; Infancy; Supplementation policy; Infant bone health; Non-compliance

Introduction

While an infant's food intake should ideally meet all of their nutritional needs, it has been consistently observed that the diets of many infants in Ireland lack sufficient vitamin D (Food Safety Authority of Ireland [FSAI] 2007). The chief functions of vitamin D are the regulation of calcium homeostasis and bone mineral metabolism (Institute of Medicine [IOM] 2010). Across the lifespan, the most accelerated rates of growth and bone mineral accretion occur in infancy (Gallo *et al.* 2012), with evidence indicating that maximising bone accretion during this time benefits bone health at later stages of the life cycle (Cooper *et al.* 2002; Gallo *et al.* 2012).

Therefore, vitamin D deficiency adversely affects bone health, with chronic deficiency resulting in bone demineralisation. If the deficiency is particularly severe, the resulting demineralisation can reduce bone rigidity, causing rickets, a condition which manifests in infancy as deformed arms, legs and rib cage. Rickets is the most severe manifestation of vitamin D deficiency in infancy, and although a small number of cases have re-emerged in Ireland in recent years, it remains an uncommon condition (FSAI 2007). However, chronic mild vitamin D deficiency may be more widespread due to inadequate dietary vitamin D intakes and compliance with the recommended practice of not exposing infants to sunlight (FSAI 2007; Irish Universities Nutrition Alliance [IUNA] 2012).

In light of the attention called to vitamin D deficiency in infancy, it was recommended that all infants in Ireland are supplemented with 5 micrograms (µg) of vitamin D every day from birth to their first birthday (FSAI 2007;

Health Service Executive [HSE] 2010). Although this recommendation was devised in 2007 (FSAI 2007) and implemented as national policy in 2010 (HSE 2010), compliance with the policy has not yet been assessed.

In addition, given the history of non-compliance with supplementation policies amongst Irish women (McKeating *et al.* 2015), it is important to identify factors which increase the likelihood of Irish mothers correctly supplementing their infants with vitamin D.

Therefore, to assess the effectiveness of strategies currently in place to safeguard infant bone health in Ireland, this study aimed to assess compliance with recommendations for vitamin D supplementation in infancy and to investigate the predictors of a mother supplementing her infant as recommended.

Methods

Ethical approval for this prospective observational study was obtained from the Coombe Women and Infants University Hospital, and Our Lady's Children's Hospital Crumlin and Dublin Institute of Technology.

Women were recruited to this study whilst waiting in antenatal clinics in the Coombe Women and Infants University Hospital between October 2013 and August 2014. Women were eligible to participate in the study if they: had a healthy singleton pregnancy; were at least 24 weeks pregnant; and were willing to be contacted in the post-partum period for follow-up. Written informed consent was obtained from all women. A questionnaire was administered in clinic by the lead author for participants to self-complete. This questionnaire collected socio-demographic and health behaviour data, to include: age; nationality; parity; education level; marital status; risk of deprivation; antenatal folic acid supplementation practices; and smoking status.

To build rapport with participants and reduce drop-out rates, study participants were followed-up in hospital after giving birth to ensure that they were still amenable to being contacted by the lead author for a home visit at 4, 9 and 12 months post-partum. Therefore, each morning during data collection, the lead author checked hospital records to identify those women who had given birth to a healthy term infant in the previous 24 hours and who had consented to participate in this study. Upon identifying such women, the lead author visited them on the ward, re-introduced herself and reminded mothers of the study, asking them if they were still happy to be contacted by the researcher in the post-partum period. Home visits were arranged by phone approximately one week before the infant turned 4, 9 or 12 months of age. During each home visit, a quantitative questionnaire on infant feeding and supplementation practices was self-completed by mothers. Closed-ended questions on vitamin D supplementation practices at 4, 9 and 12 months post-partum included: whether a mother was supplementing her infant with vitamin D; the frequency of vitamin D supplementation; the brand name of the supplement; and whether advice had been received from a recognised health professional (*e.g.* medical doctor or public health nurse) on vitamin D supplementation.

In addition to completing a questionnaire at 12 months post-partum, mothers also completed a 2-day food diary for their 12-month-old infant using standard household measures. Food diaries were not completed at any other point of data collection. There is no national policy in Ireland on vitamin D supplementation for individuals aged over one year. Therefore, the food diaries were obtained to examine the separate contributions of food and supplements to vitamin D intakes and to compare vitamin D intakes from food alone with the recommended intake of 10µg/d (IOM 2010); this was important to assess the adequacy of vitamin D intakes from food alone as the first year of life draws to a close and guidance on supplementation is no longer provided. In the diary, mothers recorded the: time of eating occasion; source of food or drink; brand of food eaten (if applicable); volume of food or drink consumed using standard household measures; cooking methods used; and condiments added (if any). Data were entered into *Nutritics* Nutrition Analysis Software (*Nutritics*, Dublin, Ireland). The *Nutritics* software calculated mean energy and nutrient intakes for each infant and the resulting figures were entered into IBM SPSS for Windows, version 22.0 (IBM, New York, United States).

IBM SPSS for Windows, version 22.0 (IBM, New York, United States) was used for analysis. Normally distributed data were summarised numerically using the mean and standard deviation (SD). Variables associated with vitamin D supplementation practices at 4, 9 and 12 months of age were examined in univariate analyses. Such variables included: maternal age (years); education (college-educated/not college-educated); social class (high/middle/low); parity (primiparous/multiparous); first milk (breast/formula); breastfeeding duration (days); age of weaning (weeks); smoking status at conception (yes/no); smoked all throughout pregnancy (yes/no); smoking at time of questionnaire completion (yes/no); consumed alcohol in pregnancy (yes/no); correctly supplemented with folic acid (yes/no); and recalled receiving vitamin D supplementation advice from a qualified health professional (yes/no).

Associations with normally distributed continuous variables were assessed by an Independent Samples *t*-test. Associations between categorical variables were assessed using cross-tabulations and the Chi-squared statistics test assessed statistical significance. Variables which were significantly associated with recommended supplementation practices in univariate analyses were included in multivariate analyses. Binary logistic regression was used to predict recommended supplementation practices at 4, 9 and 12 months of age. The Forced Entry Method was used, whereby all predictor variables were tested in one block to assess their predictive ability whilst controlling for the effects of other predictors in the model. Statistical significance was taken at $p<0.05$.

Results

Baseline characteristics of participants

One-hundred-and-seventy-two pregnant women were recruited for this study. Of these, 158 mothers (91.9% follow-up rate) allowed the lead researcher to conduct a home visit at 4, 9 and 12 months post-partum. There were no significant differences in the socio-demographic characteristics and health behaviours of mothers who did and did not withdraw from the study. The mean age of the 158 participating women upon giving birth was 32.0 (SD ± 4.9) years and the mean gestational age of infants was 40.3 (SD ± 1.2) weeks.

Participating mothers were either of Irish (98.1%, *n*155) or British (1.9%, *n*3) nationality. Almost three-quarters (73.4%, *n*116) had planned their pregnancy and 43.0% (*n*68) were primiparous. Two-thirds (65.2%, *n*103) were college-educated and 86.7% (*n*137) were married or cohabiting. Almost a third (32.3%, *n*51) smoked around the time of conception, but only 8.2% (*n*13) smoked all throughout pregnancy. Almost all (99.4%, *n*157) took folic acid in pregnancy to some degree, but less than a third (32.3%, *n*51) supplemented with folic acid in line with national recommendations.

Vitamin D supplementation practices

The proportions of infants being supplemented with vitamin D in line with recommendations at 4, 9 and 12 months of age were 57.6% (*n*91), 34.2% (*n*54) and 23.4% (*n*37), respectively (**Figure I**).

Predictors of recommended vitamin D supplementation practices

As shown in the statistically significant adjusted model (χ^2 (5, *n*158) = 55.42, $p<0.01$) in **Table I**, the strongest predictor of correctly supplementing an infant with vitamin D at 4 months post-partum was receiving advice from a health professional on doing so. Mothers who recalled receiving advice from a health professional on supplementation were almost 62 times (OR: 61.94 [95% CI: 11.53-332.83]) more likely to correctly supplement their infant when compared with mothers who did not receive supplementation advice (**Table I**). Maternal education also significantly predicted supplementation at this time; mothers who were college-educated were significantly ($p=0.03$) less likely to supplement their 4-month-old infant as recommended (OR: 0.37 [95% CI: 0.15-0.92]).

At 9 months post-partum, the strongest predictor of correctly supplementing an infant with vitamin D was receiving advice from a health professional on doing so. Mothers who recalled receiving supplementation advice in the early post-partum period were ten times (OR: 10.30 [95% CI: 2.29-46.27]) more likely to correctly supplement their 9-month-old infant when compared with mothers who did not receive this advice (**Table II**). As shown in the statistically significant adjusted model (χ^2 (5, *n*158) = 28.48, $p<0.01$) in **Table II**, smoking status in pregnancy also significantly ($p=0.02$) predicted vitamin D supplementation; mothers who did not smoke antenatally were 2.5 times more likely to correctly supplement their 9-month-old infant (OR: 2.57 [95% CI: 1.13-5.81]).

At 12 months post-partum, the strongest predictor of correctly supplementing an infant with vitamin D was receiving advice from a health professional on doing so. As shown in the statistically significant adjusted model (χ^2 (5, *n*158) = 12.34, $p=0.03$) in **Table III**, mothers who recalled receiving advice on supplementation in the early post-partum period were almost four times (OR: 3.85 [95% CI: 1.05-14.08]) more likely to correctly supplement their 12-month-old infant when compared with mothers who did not receive advice at this time (**Table III**). Maternal education also significantly ($p=0.04$) predicted supplementation practices, where mothers who were college-educated were significantly less likely to supplement their 12-month-old infant as recommended (OR: 0.42 [95% CI: 0.19-0.95]).

Dietary vitamin D intakes at 12 months of age

The mean age at which complementary feeding commenced in this study was 20.7 (SD ± 4.6) weeks. The mean intake of vitamin D from food and beverages amongst 12-month-old infants (*n*153) was 6.3 (SD ± 4.4) µg per day. When vitamin D from supplementation was included, the mean daily intake of vitamin D from all sources increased to 7.6 (SD ± 4.7) µg.

Discussion

The current recommended dietary allowance (RDA) for vitamin D amongst infants is 10µg per day (IOM 2010). To help achieve this intake, it is recommended that all infants in Ireland consume 5µg of vitamin D by supplementation each day from birth to their first birthday (HSE 2010).

However, despite the development of a widely disseminated policy to promote daily vitamin D supplementation for all infants in Ireland (HSE 2010), supplementation practices in this study were suboptimal throughout the first year of life. At age one year, less than a quarter of infants were being correctly supplemented and their vitamin D intakes from diet alone were inadequate to meet the RDA. Therefore, it is clear that this is an aspect of paediatric health which should continue to receive attention.

It is notable that the advice of health professionals was the most consistent and significant predictor of recommended vitamin D supplementation practices in this study, surpassing many maternal sociodemographic characteristics and health behaviours. Mothers who recalled receiving supplementation advice from a health professional in the weeks following their infant's birth were significantly more likely to correctly supplement their infant for the remainder of the first year of life. The strength of this association waned as the first year of life progressed; however, better adherence to recommendations may result if health professionals are reminded to advocate supplementation and appropriate food sources of vitamin D during routine infant health checks. During infant health checks, it is expected that a public health nurse or medical officer will discuss child and family health issues and assess an infant's general physical health, to include developmental progress and growth (HSE 2017). A brief discussion on the importance of vitamin D supplementation would fall within the remit of such health checks and would be a cost-effective approach to promoting adherence to recommended supplementation practices.

Although varying degrees of effectiveness have been reported (Arditi *et al.* 2012), electronic clinical reminders have generally been shown to achieve small to modest improvements in healthcare quality (Gandhi *et al.* 2003; Sequist *et al.* 2005; Vashitz *et al.* 2009). It has been observed that if health professionals receive specific reminders to do so, they are more likely to promote adherence to particular health guidelines amongst their patients (Sequist *et al.* 2005). However, while the research to date has examined the use of reminders with health issues such as vaccinations (Kersting and Weltermann 2016) and health screenings (Kenealy *et al.* 2005), the use of reminders to encourage health professionals to promote adherence to supplementation policies has not been investigated. Given the positive impact of advice from health professionals in this study on supplementation practices, future research should investigate whether a reminder system (Shojania *et al.* 2010) for health professionals in primary care elicits improved adherence to recommended supplementation practices in infancy.

Interestingly, mothers with a college education were significantly less likely to supplement their infant as recommended. Using the Health Belief Model (Abraham and Sheeran 2005), it could be argued that these mothers felt confident in the nutritional adequacy of the diet which they provided to their infant, and therefore were less likely to believe that supplementation was necessary to avoid poor health outcomes (Fulford *et al.* 2014; Malek *et al.* 2016; Touskova *et al.* 2015). However, given the small number of foods which are both a source of vitamin D and appropriate for infants (FSAI 2011), educational campaigns should state that even a high quality varied diet does not circumvent the need for vitamin D supplementation (Fulford *et al.* 2014; FSAI 2007).

Mothers who smoked during pregnancy were also less likely to supplement their infant in line with recommendations. It has been suggested (Fulford *et al.* 2014) that women who engage in adverse health behaviours but have seemingly healthy births may perceive themselves and their offspring to be invulnerable to poor health outcomes and therefore may not see a need to invest in certain protective health behaviours (Barbour *et al.* 2012). However, given the insidious and often silent progression of bone demineralisation over the life course (Touskova *et al.* 2015), public health campaigns must emphasise to all parents that no infant is exempt from the need for vitamin D supplementation.

As expected, vitamin D intakes from diet alone were insufficient to meet the RDA, and this further underpins the need to emphasise appropriate supplementation practices as soon as is practicable. Since approximately half of the maternal stores of vitamin D are transferred to the foetus during pregnancy (Cooper *et al.* 2002), health professionals could advise pregnant women on appropriate vitamin D-rich foods and safe vitamin D supplementation (FSAI 2011). Educating women during pregnancy on the value of vitamin D for mother and infant could help parents to establish positive supplementation practices which optimise infant bone health from the earliest days of development (Bener *et al.* 2013; Christesen *et al.* 2012).

Limitations of this study

The data presented here were collected as part of a longitudinal observational study conducted by one researcher in Dublin and its surrounding counties. Although inter-observer variation is not a concern, the results are not nationally representative and causal inferences cannot be made due to the observational study design (Grimes and Schulz 2002). The study population was limited to participants who were Caucasian and of Irish or British nationality, and therefore future research should investigate vitamin D supplementation practices amongst a nationally representative sample. Future research should also triangulate supplementation practices amongst parents with the perspectives of health professionals and the directives issued by health authorities. Once the views of all stakeholders have been considered, a better understanding of the most effective means of promoting adherence to recommendations (to include the timing, frequency, content and mode of delivery of reminders) should become clearer.

Dietary intakes amongst 12-month-old infants were measured using estimated household measures. Weighed measures would be considered preferable to assess food intake in infants (Burrows *et al.* 2010; Smith 2011), but this was not feasible when study resources and participant burden were considered. Nevertheless, the food diaries used did obtain detailed data on the foods consumed and measuring spoons were provided to help carers to complete the diary.

The carer who made an entry in the diary (*e.g.* mother, father, childminder) was recorded for each eating occasion. To account for the possibility of different carers completing the diary, clear instructions were included to reduce variation in the method of recording the food consumed. Finally, although estimated household measures were used, the vitamin D intakes in this study were comparable to those reported by the nationally representative National Preschool Nutrition Survey (IUNA 2012) for 12-month-olds, in which weighed measures were used to assess dietary intakes.

Conclusion

Dietary practices throughout the first year of life have received considerable attention in Ireland (Bennett *et al.* 2012; Tarrant *et al.* 2010). However, to the authors' knowledge, this is the first study to examine compliance with recommended vitamin D supplementation practices amongst Irish infants since the implementation of a national policy in 2010 (HSE 2010).

This study highlights the degree to which compliance with recommendations is suboptimal, and provides insights into potentially modifiable factors which affect compliance, in addition to identifying sub-groups at which educational campaigns could be specifically targeted. The identification of strategies which promote adherence to supplementation policy is challenging (McKeating *et al.* 2015). However, the development of such strategies is made possible by a better understanding of the factors which help or hinder adherence to supplementation policy (Patience 2015). This study has contributed to our understanding of factors which potentially impact bone health during a time of immeasurable investment into life-long health.

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Compliance with Ethical Standards

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committees and with the 1964 Helsinki declaration and its later amendments.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Conflict of interest: The authors have no conflict of interest to declare.

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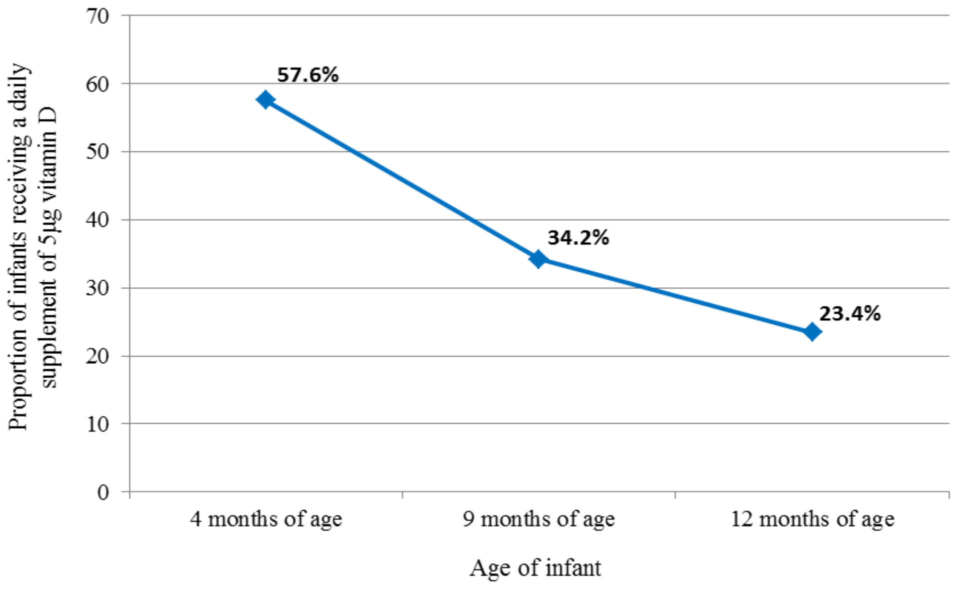

Figure I. Proportion of infants receiving a daily supplement of 5 micrograms (µg) of vitamin D during the first year of life

Table I. Binary logistic regression model examining factors associated with recommended vitamin D supplementation amongst 158 4-month-old infants

Characteristic	β	*n*	OR	95% CI	*p*-value*
Maternal third level education					
Yes	-	103	0.37	0.15 – 0.92	**0.03**
No		55	1.0	Ref.	
Recommended folic acid supplementation					
Yes	+	51	1.56	0.67 – 3.64	0.30
No		107	1.00	Ref.	
Smoking in pregnancy					
Yes	+	51	1.00	Ref.	0.32
No		107	1.51	0.67 – 3.41	
Vitamin D advice from health professional					
Yes	+	127	61.94	11.53 – 332.83	**<0.01**
No		31	1.0	Ref.	
Maternal age	-	158	0.92	0.84 – 0.99	0.06

Model summary:
R^2 = 0.29, Cox & Snell R Square = 29.6, Nagelkerke R Square = 39.8, 74.7% predictive of variance

* *p*-value <0.05 was significant **OR:** Odds ratio **CI:** Confidence interval

Table II. Binary logistic regression model examining factors associated with recommended vitamin D supplementation amongst 158 9-month-old infants

Characteristic	β	*n*	OR	95% CI	*p*-value*
Maternal third level education					
Yes	-	103	0.67	0.31 – 1.46	0.32
No		55	1.0	Ref.	
Recommended folic acid supplementation					
Yes	+	51	2.06	0.95 – 4.45	0.07
No		107	1.00	Ref.	
Smoking in pregnancy					
Yes	+	51	1.00	Ref.	**0.02**
No		107	2.57	1.13 – 5.81	
Vitamin D advice from health professional					
Yes	+	127	10.30	2.29 – 46.27	**<0.01**
No		31	1.0	Ref.	
Maternal age	+	158	1.04	0.96 – 1.12	0.40

Model summary:
R^2 = 0.23, Cox & Snell R Square = 16.5, Nagelkerke R Square = 22.8, 71.5% predictive of variance

* *p*-value <0.05 was significant **OR:** Odds ratio **CI:** Confidence interval

Table III. Binary logistic regression model examining factors associated with recommended vitamin D supplementation amongst 158 12-month-old infants

Characteristic	β	*n*	OR	95% CI	*p*-value*
Maternal third level education					
Yes	-	103	0.42	0.19 – 0.95	**0.04**
No		55	1.0	Ref.	
Recommended folic acid supplementation					
Yes	+	51	1.21	0.53 – 2.80	0.65
No		107	1.00	Ref.	
Smoking in pregnancy					
Yes	+	51	1.00	Ref.	0.09
No		107	2.16	0.88 – 5.33	
Vitamin D advice from health professional					
Yes	+	127	3.85	1.05 – 14.08	**0.04**
No		31	1.0	Ref.	
Maternal age	+	158	1.03	0.94 – 1.12	0.56

Model summary:
R^2 = 0.16, Cox & Snell R Square = 7.5, Nagelkerke R Square = 11.3, 77.8% predictive of variance

* *p*-value <0.05 was significant **OR:** Odds ratio **CI:** Confidence interval