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Low Vitamin D Status and Inadequate Nutrient Intakes of Elementary School Children in a Highly Educated Pacific Northwest Community

Abstract

Are Extension healthy youth programs needed in highly educated U.S. communities? To answer this question, 175 children from four public elementary schools in Corvallis, Oregon, self-reported in a cross-sectional study their dietary intake, and 71 children provided a blood sample for measuring vitamin D concentrations. Most children had insufficient blood vitamin D and reported a diet insufficient in fiber, essential fatty acids, potassium, and vitamin E and excessive in saturated fatty acids and sodium. Our data indicate a need for Extension to provide youth programs in highly educated U.S. communities to improve nutrient intakes and vitamin D status in children.

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Introduction

The foundation for a healthy life is laid in childhood, as the body has increased demands of nutrients for growth and development of organs to achieve optimum function. Nutrient recommendations and guidelines have been established by experts and government officials for specific age groups, including 4-8 and 9-13 year-old children, stratified by sex (FNB & IOM, 2005; USDA & HHS, 2010). Vitamin D status depends mainly on sun exposure of the skin (Adams, Clemens, Parrish, & Holick, 1982); however, in areas with low sun exposure, such as the Pacific Northwest, dietary intake becomes very important. Various healthy youth programs have been provided by Extension professionals to improve nutrient intakes in U.S. elementary school-aged children with a focus on low-income families because of their limited resources; however, improvements were limited (Rabe, Ohri-Vachaspati, & Scheer, 2006; Roth-Yousey, Caskey, May, & Reicks, 2007; Jensen, Kattelmann, Ren, & Wey, 2009).

In U.S. population surveys, most elementary school-aged children report nutrient intakes low in fiber and vitamin E and high in saturated fat and sodium (Rhodes, Clemens, Goldman, Lacomb, & Moshfegh, 2012) with insufficient vitamin D concentrations in blood (Kumar, Muntner, Kaskel, Hailpern, & Melamed, 2009; Mansbach, Ginde, & Cargo, 2009), regardless of household income. These studies, however, do not break down nutrient intakes and vitamin D concentrations by communities but rather by demographics of individuals. Some of the challenges to achieve adequate nutrient intakes and vitamin D status in school-aged children are: a) limited access to nutrient-rich foods and beverages in the community and at home (Ogden, Lamb, Carroll, & Flegal, 2010; SEARCH, 2007); b) school meals that are low in whole grains, legumes, fiber, and vitamin E and high in saturated fat and sodium (Condon, Crepinsek, & Fox, 2009; Gordon & Fox, 2007, 2012); c) limited sun exposure (Bose et al., 2013), and d) the consumption of high-simple carbohydrate, low-fiber, and low-vitamin-D foods and beverages, which increases as children become teenagers (Ballew, Kuester, & Gillespie, 2000; Bowman, Gortmaker, Ebbelin, Pereira, & Ludwig, 2004; Evans, Springer, Evans, Ranjit, & Hoelscher, 2010).

Most public funding and scientific studies for Extension programs focus on communities with limited access to nutrient-rich foods and beverages in the community and at home and lower education level because of their limited resources. Given budget constraints, the question arises: Are Extension healthy youth programs needed in highly educated U.S. communities? To answer, we need to know whether vitamin D status and nutrient intakes are adequate in highly educated communities. Such communities have adequate access to nutrient-rich foods and beverages, because multiple grocery stores with a wide variety of fruits and vegetables are in close proximity to schools and homes. Information about the vitamin D status and nutrient intake of children in such communities is lacking. Therefore, we compared in a cross-sectional study food and nutrient intake of elementary school-aged children from four public elementary schools in Corvallis, a college town in the Pacific Northwest, with dietary guidelines and their blood vitamin D levels. Using generally used vitamin D cut-off values for children (Gilbert-Diamond et al., 2010), the proportion of children with vitamin D levels (sum of 25-hydroxyvitamin D2 and 25-hydroxyvitamin D3) below 30 and 20 ng/mL were considered insufficient and deficient, respectively.

Methods

The study was reviewed and approved by the Oregon State University Institutional Review Board (IRB Permit Number: 4841; "Micronutrient Intake of Elementary School Children"). Corvallis (population size: 52,396 in 2010; 83% White, 8% Asian, 1% Black or African American, and 8% Hispanics or other), Oregon, is a town with one of the highest education levels in the U.S.: 30.2% of the population have completed a bachelor's degree (U.S. average: 17.5%), and 26.4% have completed a graduate degree (U.S. average: 9.8%) (Corvallis Oregon Demographics, 2013). In 2010, the median household income in Corvallis was $47,339, which was below the median U.S. household income of $55,970.

After receiving approval from the school district and school principals, four public elementary schools in Corvallis participated in the study. Grocery stores that carry a broad variety of fruits and vegetables are within 2 miles of each of the four elementary schools. The proportion of children from low income households, as defined by the Oregon Department of Education, was 11%, 17%, 19%, and 48% for the four schools, respectively (ODE, 2013). All children who attended the schools, aged 5-11 years, were eligible.

The study staff (the program manager and a dietetics student) visited each class room in the four elementary schools, explained the study objective and demonstrated to children how to fill out the Block Kids Food Screener (BKFS) and how parents would collect blood by finger prick and administer it to the vitamin D test. The visit of the first school took place in October 2009 and did not include the vitamin D test. The remaining three schools were visited between April and December 2011 and included the vitamin D test. At the end of the demonstration, students received an information package for their parents that included information on the study, how to fill out the BKFS, how to administer the vitamin D test, as well as informed parent consent and student assent forms.

Upon return of the signed forms, the vitamin D test was sent out by ZRT Laboratory (Beaverton, OR) to parents, who completed the test with their child and sent it back to ZRT Laboratory, a certified, diagnostic laboratory for measuring human blood samples using standard reference materials. Dried blood spot samples for the vitamin D test were returned by 71 children (7% of children in the three elementary schools), and the results were included in the statistical analysis. Of the 71 children with a vitamin D blood test, 38 were 5-8 years old (13 boys and 25 girls), and 33 were 9-11 years old (14 boys and 19 girls). Nearly all children (67 of 71 children) with a blood vitamin D test had at the same time also filled out the BKFS. Vitamin D concentrations were measured as previously described (Newman et al., 2009). The inter- and intra-assay coefficients of variation were 10.4% and 8.7%, respectively.

The BKFS, developed by Nutrition Quest (Berkeley, California), is a 41-item, two-page food frequency questionnaire (FFQ) that asks for frequency (six categories from none to every day) and quantity of dietary intakes (four categories) of the most commonly consumed food items by children during the past week (Hunsberger, O'Malley, Block, & Norris, 2012). The food screener has been described and validated for 2-17 year-old U.S. children (Garcia-Dominic et al., 2012; Hunsberger et al., 2012). We did not specify that the children had to fill out the BKFS without the help of adults. A total of 179 children, which accounted for 13% of all children in the four elementary schools, completed the BKFS and returned it by mail to the study staff.

The completed BKFS were analyzed by Nutrition Quest for food servings and nutrient intakes. Food codes were linked to the USDA Food and Nutrient Database for Dietary Studies and the USDA My Pyramid Equivalents Data Base to calculate food group and nutrient intakes. Results from four BKFS were not included in the statistical analysis because the reported energy consumption was more than three standard deviations different from the mean. Of the 175 children included in the analysis, 75 were 5-8 years old (28 boys and 47 girls), and 100 were 9-11 years old (45 boys and 55 girls).

Because FFQs are known to underestimate food and nutrient intake, the calculated food group and nutrient intakes were calorie-adjusted and expressed per 1,000 Kcal. To calculate the proportion of children not meeting recommendations, calorie-adjusted intakes were multiplied by the estimated energy requirements for each age and gender group (FNB & IOM, 2005) and then compared to governmental dietary guidelines and recommendations (USDA & HHS, 2010). The recommended food group intakes differ by caloric consumption, and the nutrient intakes differ by sex and age group and, thus, are not shown.

Statistical analyses were performed using SAS version 9.2 software (SAS Institute, 2009). Food group servings, nutrient intakes, and vitamin D concentrations were compared between age groups (5-8 year-old *versus* 9-11 year-old) using PROC GLM for calorie-adjusted values and PROC GLIMMIX for proportions meeting recommendations. Values presented in the manuscript are raw means and their standard errors (SEM). We tested the effects of season and school on nutrient intakes and vitamin D status. The effects were not significant and were not included in the model. All statistical tests were two-sided. Statistical significance was declared at $P \leq 0.05$.

Results and Discussion

The results of our cross-sectional study document that low vitamin D status and inadequate nutrient intake in elementary school-aged children is prevalent even in a highly educated community with adequate access to stores with nutrient-rich foods and beverages. Regarding vitamin D status (Table 1), 69 ± 6% of children had vitamin D concentrations < 30 ng/mL, which are considered insufficient, and 8 ± 3% had vitamin D concentrations considered deficient (< 20 ng/mL). Older children had lower vitamin D concentrations than younger children. To explore the relationship between blood vitamin D concentrations and food group intakes, we used multivariate regression. We did not have dietary vitamin D results. Consumption of dairy products but no other food group was significantly associated with increased serum vitamin D concentrations (β = 2.2 ± 1.0 cups/1,000 Kcal; P = 0.04). Simulation studies indicate that consumption of dairy products is important for providing sufficient dietary vitamin D, calcium, phosphorus, magnesium, and potassium to U.S. children (Gao, Wilde, Lichtenstein, & Tucker, 2006; Fulgoni, Keast, Auestad, & Quann, 2011).

Table 1.

Blood Vitamin D Concentrations of Elementary School Children in a Highly Educated Community in the Pacific Northwest

Serum Vitamin D	**5-8 years old (n = 38)**	**9-11 years old (n = 33)**	***P*-value[1]**
	Mean ± SEM		
Concentrations (ng/mL)	28.0 ± 1.0	24.7 ± 1.0	0.03
Range (ng/mL)	15 – 42	12 - 37	
25(OH) Vitamin-D Levels	**% of Children ± SEM**		
< 15 ng/mL	0 ± 0	6 ± 4	0.21
< 20 ng/mL	5 ± 4	12 ± 6	0.32
< 30 ng/mL	61 ± 8	79 ± 7	0.11

1 P-value for difference between age groups

Older children also consumed fewer dairy products compared to younger children, and 26 ± 3% of all children did not meet the recommendations (adjusted for total caloric intake) for the consumption of dairy products (USDA & HHS, 2010; Table 2). Coinciding with the lower consumption of dairy products in older children, 45 ± 5% of the older children consumed calcium below dietary guidelines, and 12 ± 3% of older children consumed less phosphorus than recommended (Table 3).

Table 2.

Self-Reported Daily Food Group Consumption of Elementary School Children in a Highly Educated Community in the Pacific Northwest

Food Groups	5-8 years old (n = 75)	9-11 years old (n = 100)	*P*-value[1]
Consumption/Content	**Mean ± SEM[2]**		
Fruit (cup/1,000 Kcal))	1.39 ± 0.08	1.49 ± 0.07	0.30
Vegetables (cup/1,000 Kcal)	0.87 ± 0.04	1.13 ± 0.05	0.0005
Potatoes (cup/1,000 Kcal)	0.158 ± 0.013	0.220 ± 0.014	0.003
Legumes (cup/1,000 Kcal)	0.074 ± 0.011	0.088 ± 0.010	0.39
Other Vegetables (cup/1,000 Kcal)	0.64 ± 0.03	0.82 ± 0.04	0.002
Whole Grains (oz/1,000 Kcal)	0.68 ± 0.04	0.61 ± 0.04	0.26
Meat/Poultry/Fish (oz/1,000 Kcal)	1.69 ± 0.09	1.67 ± 0.08	0.89
Dairy (cup/1,000 Kcal)	1.75 ± 0.08	1.55 ± 0.07	0.05
Not Meeting Recommendations	**% of Children ± SEM[3]**		
Fruit	8 ± 3	8 ± 3	1
Vegetables	33 ± 5	12 ± 3	0.001
Potatoes	69 ± 5	39 ± 5	0.0001
Legumes	100 ± 0	100 ± 0	1
Other Vegetables	23 ± 5	13 ± 3	0.10
Whole Grains	83 ± 4	74 ± 4	0.18
Meat/Poultry/Fish	23 ± 5	19 ± 4	0.55
Dairy	24 ± 5	27 ± 4	0.65

1 P-value for difference between age groups

2 The estimated food group intake was calculated by multiplying the self-reported consumption (in cup or oz/1,000 Kcal) by the estimated energy requirement.

3 % of children was calculated by comparing the recommended with the

estimated food group consumption per 1,000 Kcal for the respective age and gender group.

Table 3.

Self-Reported Daily Mineral Consumption of Elementary School Children in a Highly Educated Community in the Pacific Northwest

Minerals	5-8 years old 6- (n = 75)	9-11 years old 10- (n = 100)	*P*-value[1]
Consumption/Content	**Mean ± SEM2**		
Calcium (mg/1,000 Kcal)	704 ± 21	665 ± 18	0.17
Phosphorus (mg/1,000 Kcal)	795 ± 14	762 ± 13	0.08
Magnesium (mg/1,000 Kcal)	152.7 ± 2.1	156.1 ± 2.3	0.29
Iron (mg/1,000 Kcal)	7.95 ± 0.22	8.22 ± 0.23	0.40
Zinc (mg/1,000 Kcal)	6.73 ± 0.13	6.65 ± 0.12	0.62
Copper (µg/1,000 Kcal)	561 ± 10	602 ± 9	0.002
Selenium (µg/1,000 Kcal)	54.6 ± 0.9	50.2 ± 0.8	0.0002
Potassium (mg/1,000 Kcal)	1651 ± 28	1742 ± 32	0.04
Sodium (mg/1,000 Kcal)	1524 ± 25	1509 ± 22	0.66
Not Meeting Guidelines	**% of Children ± SEM3**		
Calcium (<EAR)	16 ± 4	45 ± 5	0.0001
Phosphorus (<EAR)	0 ± 0	12 ± 3	0.001
Magnesium (<EAR)	0 ± 0	3 ± 2	0.26
Iron (<EAR)	0 ± 0	0 ± 0	1
Zinc (<EAR)	0 ± 0	0 ± 0	1
Copper (<EAR)	0 ± 0	0 ± 0	1
Selenium (<EAR)	0 ± 0	0 ± 0	1
Potassium (<AI)	100 ± 0	99 ± 1	1
Sodium (>UL)	92 ± 3	87 ± 3	0.30

EAR: estimated average requirement; AI: adequate intake; UL: tolerable upper intake level

1 P-value for difference between age groups

2 The estimated mineral intake was calculated by multiplying the self-reported

consumption (in mg or µg/1,000 Kcal) by the estimated energy requirement.
3 % of children was calculated by comparing the recommended with the estimated mineral consumption per for the respective age and gender group.

Besides vitamin D, all children and 78 ± 3% of children did not meet the recommendations for legume and whole grain consumption, respectively (Table 2). In response, 70 ± 3% of children consumed less fiber than recommended (Table 4). Besides fiber, legume consumption is associated with increased intake of potassium, phosphorus, magnesium, and folate (Papanikolaou, & Fulgoni, 2008). Nearly all children (99 ± 0.6% and 89 ± 2%, respectively) consumed less potassium and more sodium than recommended (Table 3). Targeting legume and whole-grain consumption together may improve nutrient intakes of children.

Table 4.

Self-Reported Daily Macronutrient Consumption of Elementary School Children in a Highly Educated Community in the Pacific Northwest

Macronutrients	**5-8 years old (n = 75)**	**9-11 years old (n = 100)**	***P*-value[1]**
Energy (kcal)	**Mean ± SEM2**		
Reported Intake	1,074 ± 27	1,227 ± 39	0.003
Consumption/Content (g/1,000 Kcal)			
Proteins	43.7 ± 0.7	42.5 ± 0.6	0.19
Carbohydrates	123.4 ± 1.6	129.0 ± 1.5	0.01
Sugar	81.8 ± 1.9	87.5 ± 2.0	0.05
Sugar in Foods/Beverages	64.7 ± 1.6	69.5 ± 1.6	0.03
Added Sugar	17.1 ± 0.7	17.9 ± 1.0	0.51
Sugar from Sodas	1.58 ± 0.44	3.80 ± 0.66	0.01
Starch	30.7 ± 1.1	30.3 ± 1.3	0.83
Fiber	10.96 ± 0.30	11.24 ± 0.28	0.48
Total Fat	36.8 ± 0.6	34.9 ± 0.5	0.02
Saturated Fat	13.43 ± 0.29	12.77 ± 0.23	0.07
Linoleic Acid (mg/1,000 Kcal)	4.78 ± 0.08	4.71 ± 0.09	0.58
Linolenic Acid (mg/1,000 Kcal)	0.527 ± 0.010	0.522 ± 0.009	0.74

Cholesterol (mg/1,000 Kcal)	137.9 ±5.1	120.8 ± 3.9	0.008
Consumption (% of calories)			
Total Fat (% of calories)	33.2 ± 0.5	31.4 ± 0.5	0.02
Saturated Fat (% of calories)	12.09 ± 0.26	11.49 ± 0.21	0.07
Not Meeting Recommendations	**% of Children ± SEM3**		
Protein (<RDA)	0 ± 0	0 ± 0	1
Carbohydrate (<RDA)	0 ± 0	0 ± 0	1
Fiber (<IOM)	60 ± 6	78 ± 4	0.01
Total Fat (>AMDR)	35 ± 6	20 ± 4	0.03
Saturated Fat (>DG)	83 ± 4	80 ± 4	0.66
Linoleic Acid (<AI)	99 ± 1	93 ± 3	0.11
Linolenic Acid (<AI)	71 ± 5	84 ± 4	0.04
Cholesterol (>DG)	13 ± 4	8 ± 3	0.26

RDA: recommended dietary allowance; IOM: Institute of Medicine; AMDR: acceptable macronutrient distribution range; DG: dietary guidelines; AI: adequate intake

1 P-value for difference between age groups

2 The estimated macronutrient intake was calculated by multiplying the self-reported consumption (in g or mg/1,000 Kcal or % calories) by the estimated energy requirement.

3 % of children was calculated by comparing the recommended with the estimated macronutrient consumption per 1,000 Kcal or % calories for the respective age and gender group.

We also observed inadequate intakes of lipids and fat soluble vitamins. Only one child met the intake guidelines for vitamin E, and 22 ± 3% of children consumed less vitamin K than recommended (Table 5). Furthermore, 95 ± 2% of children did not meet the guidelines for linoleic acid and 78 ± 3% for linolenic acid (Table 4). Conversely, 81 ± 3% of children exceeded the guidelines of getting less than 10% of calories from saturated fat, and 26 ± 3% and 10 ± 2% of children, respectively, consumed more total fat (>35% of calories) and cholesterol (>300 g/day) than recommended (Table 4).

Table 5.

Self-Reported Daily Vitamin Consumption of Elementary School Children in a Highly Educated Community in the Pacific Northwest

	5-8 years old	**9-11 years old**	

Vitamins	**(n = 75)**	**(n = 100)**	***P*-value[1]**
Consumption/Content	**Mean ± SEM[2]**		
Vitamin A (µg RAE/1,000 Kcal)	494 ± 16	499 ± 14	0.82
Vitamin C (mg/1,000 Kcal)	62.8 ± 2.8	76.6 ± 2.9	0.001
Vitamin E (mg/1,000 Kcal)	2.76 ± 0.05	2.96 ± 0.05	0.005
Thiamin (mg/1,000 Kcal)	0.877 ± 0.016	0.866 ± 0.015	0.60
Riboflavin (mg/1,000 Kcal)	1.40 ± 0.03	1.32 ± 0.03	0.08
Niacin (mg/1,000 Kcal)	10.19 ± 0.22	10.2 ± 0.21	0.94
Vitamin B6 (mg/1,000 Kcal)	1.084 ± 0.022	1.106 ± 0.020	0.46
Folate (µg DFE/1,000 Kcal)	320 ± 11	314 ± 10	0.73
Vitamin B12 (µg/1,000 Kcal)	3.37 ± 0.11	3.11 ± 0.09	0.06
Vitamin K (µg/1,000 Kcal)	60.6 ± 4.7	77.7 ± 5.7	0.03
Not Meeting Guidelines	**% of Children ± SEM[3]**		
Vitamin A (RAE; <EAR)	0 ± 0	1 ± 1	1
Vitamin C (<EAR)	0 ± 0	0 ± 0	1
Vitamin E (<EAR)	99 ± 1	100 ± 0	0.43
Thiamin (<EAR)	0 ± 0	0 ± 0	1
Riboflavin (<EAR)	0 ± 0	0 ± 0	1
Niacin (<EAR)	0 ± 0	0 ± 0	1
Vitamin B6 (<EAR)	0 ± 0	0 ± 0	1
Folate (DFE; <EAR)	0 ± 0	0 ± 0	1
Vitamin B12 (<EAR)	0 ± 0	0 ± 0	1
Vitamin K (<AI)	32 ± 5	15 ± 4	0.01

RAE: retinol activity equivalents; DFE: dietary folate equivalents; EAR: estimated average requirement; AI: adequate intake

1 P-value for difference between age groups

2 The estimated vitamin intake was calculated by multiplying the self-reported consumption (in mg or µg/1,000 Kcal) by the estimated energy requirement.

3 % of children was calculated by comparing the recommended with the estimated vitamin consumption per for the respective age and gender group.

Implications for Extension

Adequate nutrient status in childhood is critical for optimum development and function of mind and body throughout life. Our Extension project data indicate that, even in a highly educated community, low vitamin D status and inadequate nutrient intake (insufficient in fiber, essential fatty acids, potassium, and vitamin E while excessive in saturated fatty acids and sodium) are prevalent in elementary school children and worse in older children. Therefore, nutrition programs should be inclusive for all youth populations, not just the low-income and other under-served groups that we are often encouraged to focus on. Based on our results and input from elementary school-aged children and their parents, we developed inclusive Extension educational programs with hands-on activities for the youth and their families. These include family and youth gardening and cooking programs, grocery store tours for healthful meals on a budget, kid-friendly cookbooks, and healthful recipes for food that is commonly available in food banks. These programs are currently under evaluation.

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