

# The effectiveness of a short food frequency questionnaire in determining vitamin D intake in children

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**Abbreviations:** 25(OH)D, 25-hydroxyvitamin D; AAP, American Academy of Pediatrics; BMI, body mass index; cm, centimeter; EAR, estimated average requirement; FFQ, food frequency questionnaire; IOM, Institute of Medicine; IU, international units; kg, kilogram; LFFQ, long food frequency questionnaire; NHANES, National Health and Nutrition Examination Survey; NPV, negative predictive value; OJ, orange juice; PPV, positive predictive value; RCT, randomized controlled trial; RDA, recommended dietary allowance; SFFQ, short food frequency questionnaire; UPMC, University of Pittsburgh Medical Center; USDA, United States Department of Agriculture

Previous studies have found a high prevalence of vitamin D deficiency in children, yet few validated dietary vitamin D assessment tools are available for use in children. Our objective was to determine whether a short food frequency questionnaire (SFFQ) can effectively assess vitamin D intake in children. Vitamin D intake ascertained by a SFFQ was compared with assessments by a previously validated long food frequency questionnaire (LFFQ) in a population of 296 healthy 6- to 14-y-old children (54% male, 60% African American) from Pittsburgh, PA. The questionnaires were completed at two points 6 mo apart. Median reported daily vitamin D intake from the SFFQ (baseline: 380 IU, follow-up: 363 IU) was higher than the LFFQ (255 IU and 254 IU, respectively). Reported median dairy intake, including milk, cheese, and yogurt, was 3.7 cups/day, which meets the USDA recommendation for children. Vitamin D intake reported by the 2 questionnaires was modestly correlated at baseline and follow-up ( $r = 0.35$  and  $r = 0.37$ , respectively;  $p < 0.001$ ). These associations were stronger in Caucasians ( $r = 0.48$  and  $r = 0.49$ ,  $p < 0.001$ ) than in African Americans ( $r = 0.27$  and  $r = 0.31$ ;  $p = 0.001$ ). The sensitivity of the SFFQ for predicting daily vitamin D intake, defined as intake of  $\geq 400$  IU on both the SFFQ and LFFQ, was 65%. Specificity, defined as intake of  $< 400$  IU on both questionnaires, was 42%. Vitamin D requirements may not be met despite adequate consumption of dairy products. The SFFQ was found to be a modestly valid and sensitive tool for dietary assessment of vitamin D intake in children.

## Introduction

The primary role of vitamin D in humans is to maintain serum calcium and phosphorus concentrations at levels that support metabolic cellular function and bone mineralization.<sup>1,2</sup> When humans become deficient in vitamin D, calcium absorption is impaired, resulting in secondary hyperparathyroidism, with a potential for reduced peak bone mass in children and risk of osteoporosis and fragility fractures earlier in life.<sup>3</sup> Function of vitamin D also extend beyond calcium homeostasis; maintaining the adequacy of vitamin D status has the potential to improve immune function and cardiovascular health and reduce the risk of cancer and diabetes.<sup>2,4-6</sup> Vitamin D status is affected by dietary

intake, skin pigmentation, season, and latitude of residence.<sup>5,7</sup> Low serum 25-hydroxyvitamin D [25(OH)D], a marker of vitamin D status, is associated with African American race, obesity, inadequate sun exposure, topical sunblock lotions, and insufficient consumption of vitamin D-rich foods.<sup>8,9</sup>

Because vitamin D is found in few foods, fortified foods and beverages provide the US population with most of its dietary vitamin D. Fish liver oil, fatty fish, and mushrooms exposed to sunlight are natural sources of vitamin D.<sup>6,7</sup> Multiple studies have reported a high prevalence of hypovitaminosis D,<sup>8,10-19</sup> yet there are limited data on the validity of dietary assessment tools for children and adolescents.<sup>20-23</sup> The food frequency questionnaire (FFQ) has been shown to provide reasonable estimates of intake

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**Table 1.** Median anthropometric measures and obesity rate by visit and race

<b>Initial Visit</b>	<b>Total (n = 293)</b>	<b>African American (n = 178)</b>	<b>Caucasian (n = 115)</b>
Weight (kg)	37.8 (30.9, 49.1)	37.8 (30.4, 49.6)	37.8 (31.3, 48.9)
Height (cm)	140.1 (130.9, 150.8)	139.9 (130.6, 154.2)	141.0 (131.0, 149.3)
BMI (kg/m <sup>2</sup> )	19.1 (16.8, 22.5)	19.1 (16.9, 22.9)	19.1 (16.6, 22.1)
Obesity (BMI ≥ 95th percentile) Rate (%)	20	29.8	6.8
<b>6 Month Visit</b>	<b>Total (n = 252)</b>	<b>African American (n = 144)</b>	<b>Caucasian (n = 107)</b>
Weight (kg)	40.5 (32.2, 52.9)	41.2 (32.6, 54.5)	39.8 (31.9, 51.6)
Height (cm)	142.6 (134.0, 155.3)	142.5 (133.9, 157.3)	143.1 (134.0, 153.2)
BMI (kg/m <sup>2</sup> )	19.5 (16.9, 22.9)	19.8 (17.0, 23.5)	18.9 (16.9, 22.4)
Obesity (BMI ≥ 95th percentile) Rate (%)	19.5	28.1	6.8

Weight, height and BMI values are reported as median (25%, 75%).

in children when compared with food records,<sup>24,25</sup> 24-h dietary recalls,<sup>26</sup> and observed food intake.<sup>27</sup> Fumagalli et al.,<sup>28</sup> however, have reported that the FFQ appears to overestimate usual energy and nutrient intakes in children and portion sizes need to be adjusted before adoption of this instrument for children. Thus, there is a need to validate a FFQ for the assessment of vitamin D intake in children. Therefore, this study was designed to determine if a short food frequency questionnaire (SFFQ) can effectively assess vitamin D intake in children when compared with a previously validated long food frequency questionnaire (LFFQ).

## Results

Our sample comprised 296 healthy 6- to 14-y-old children (54% boys), with a median age of 10.0 y at baseline. The 6 mo follow-up dietary assessments were missing for 46 subjects (37 subjects were lost to follow-up and 9 subjects failed to complete the exit dietary assessments). Approximately 20% of the subjects were obese, and majority of them were African American (60%) and the remaining were Caucasian. There were no significant differences in median weight, height, or BMI values by race (Table 1).

While median intake of regular cow's milk was reported to be 2 cups/day (interquartile range, 1–2.5 cups/day), intake of other vitamin D-fortified dairy products (e.g., soy milk, Lactaid® and chocolate milk) or vitamin D-fortified orange juice was minimal (interquartile range 0–1 cup/day) at baseline and follow-up (Table 2). Median intake of cheese was reported at 1 ounce/day (interquartile range, 1–2 ounces/day), and intake of yogurt at 0.5 cup/day (interquartile range 0–1 cup/day). Median dairy intake, including all milk, cheese, and yogurt was 3.7 cups/day (interquartile range 2.2–5.3 cups/day). Few subjects reported consuming fish or dried mushrooms. Vitamin D intake as reported on the LFFQ was significantly lower than that reported on the SFFQ at both time points for the total population ( $p < 0.001$ ) and after stratification by race (Baseline:  $p < 0.001$  for both races; Follow-up: Caucasian  $p = 0.043$ , African American  $p < 0.001$ ). Vitamin D intake assessed by the SFFQ at the 6 mo visit differed significantly between racial groups ( $p = 0.003$ ). No racial differences in milk or dairy intake were observed.

Validity test statistics revealed that the degree of association between the two questionnaires (SFFQ and LFFQ) was modest

overall at baseline and follow-up ( $r = 0.35$  and  $r = 0.37$ , respectively;  $p < 0.001$ ), but was stronger in Caucasians ( $r = 0.48$  and  $r = 0.49$ , respectively;  $p < 0.001$ ) than the African American subgroups ( $r = 0.27$  and  $r = 0.31$ , respectively;  $p < 0.001$ ). Outliers did not affect the results. Therefore, only participants with missing observations at the 6 mo visit were removed from the validity analysis.

The SFFQ was tested against the gold standard LFFQ for sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) using daily intake of vitamin D reported by each participant at baseline ( $n = 294$  pairs). The sensitivity statistic evaluated whether the SFFQ was as likely as the LFFQ to identify a subject who met the AAP or IOM and Endocrine Society recommendations for vitamin D intake ( $\geq 400$  IU/day and  $\geq 600$  IU/day, respectively).<sup>29</sup> The SFFQ identified 65% of participants who met the AAP recommendation and 63% who met the IOM and Endocrine Society recommendation, as determined by the LFFQ. The specificity statistic evaluated whether the SFFQ was as likely as the LFFQ to identify a subject who did not meet the recommended intakes for vitamin D. Our SFFQ identified 42% of participants who did not meet the AAP guideline and 23% who did not meet the IOM and Endocrine Society guidelines, as determined by the LFFQ. The predictive value statistics examined the accuracy of the sensitivity and specificity predictions. The probabilities that subjects actually consumed  $\geq 400$  IU/day or  $\geq 600$  IU/day (PPV) were 0.37 and 0.15, respectively. Therefore, while the SFFQ appeared to be a very sensitive tool, the probability of accuracy of the result was modest at best. The probabilities that these participants did not actually consume  $< 400$  IU/day or  $< 600$  IU/day (NPV) were 0.82 and 0.97, respectively. Thus, among those who were identified as not consuming recommended levels, the likelihood that this result was true was very good.

## Discussion

We have demonstrated that an SFFQ is a valid and reproducible tool for assessing vitamin D intake in children as compared with a previously validated LFFQ. Adolescents' level of independence and their caretakers' unawareness of the foods they consume complicate assessment of dietary consumption.<sup>30</sup> The

**Table 2.** Dietary vitamin D intake by type of questionnaire, visit and race<sup>a</sup>

	<b>Total</b>	<b>African American</b>	<b>Caucasian</b>
<b>Initial Visit</b>	(n = 296)	(n = 178)	(n = 118)
Dietary vitamin D (IU)			
LFFQ	255 (150, 408)*	255 (152, 404)*	251 (144, 417)*
SFFQ	380 (236, 625)	408 (229, 662)	351 (236, 505)
<b>SFFQ Dietary data</b>			
Combined milk intake (cups/day) <sup>b</sup>	2 (1, 4)	2 (1, 4)	2 (1, 3.5)
Dairy intake (cups/day) <sup>c</sup>	3.7 (2.3, 5.3)	3.7 (2.2, 5.5)	3.6 (2.4, 5.0)
<b>6 Month Visit</b>	(n = 252)	(n = 144)	(n = 107)
Dietary Vitamin D (IU)			
LFFQ	254 (154, 420)*	252 (155, 439)*	287 (150, 414)**
SFFQ	363 (249, 558)	395 (290, 602)‡	315 (201, 464)
<b>SFFQ Dietary Data</b>			
Combined milk intake (cups/day) <sup>b</sup>	2 (1.5, 3.4)	2 (1.4, 3.6)	2 (1.5, 3.0)
Dairy intake (cups/day) <sup>c</sup>	3.7 (2.7, 5.3)	3.7 (2.7, 6.2)	3.7 (2.5, 5.3)

LFFQ, long food frequency questionnaire; SFFQ, short food frequency questionnaire. <sup>a</sup>Median (25%, 75%); <sup>b</sup>Combination of regular cow's milk, fortified soy milk, Lactaid<sup>®</sup> milk and chocolate milk; <sup>c</sup>All milk, cheese and yogurt. Comparison between LFFQ and SFFQ: \* $p < 0.001$ , \*\* $p = 0.043$ . Comparison by race: † $p = 0.003$ .

development of a valid and easy to administer tool that accurately measures vitamin D consumption in children is important in order to assess factors that optimize vitamin D status in this vulnerable subgroup.

In our sample, the daily median intake of vitamin D reported by the SFFQ was higher than the assessment by the LFFQ. This finding is not surprising because the primary focus of the SFFQ is on vitamin-D-rich foods, while the LFFQ assesses all foods eaten over a 1 y period. Despite these differences, associations between the short and long FFQs were modest to good. We found a weaker association between the LFFQ and SFFQ for African Americans. Kaaks et al.<sup>31</sup> have reported that obese adults usually underreport food intake regardless of dietary assessment technique used. Similarly, Bandini et al.<sup>32</sup> found that obese adolescents underreported food intake significantly more than non-obese adolescents. These findings may explain our results, as a high proportion of African American adolescents in our study were obese.

The USDA recommends an intake of 3 cups of dairy foods per day for girls and boys between 9 and 13 y of age.<sup>33</sup> One cup of dairy food is equivalent to 1 cup of milk or calcium fortified soy milk, 1 cup of yogurt, or 1.5 ounces of hard cheese. The reported median daily intake of dairy products in our sample was ~3.7 cups at both visits, which meets the USDA guideline. However, not all brands of cheese and yogurt are vitamin D-fortified. In our sample, consumption of vitamin D-fortified orange juice was minimal. Although the children in our sample reportedly consumed dairy servings in excess of the USDA daily recommendation, the amount of vitamin D consumed did not meet daily requirements. In November 2010, the IOM revised the Dietary Reference Intakes for vitamin D and set the estimated average requirement (EAR) as 400 IU/day for all age groups and the Recommended Dietary Allowance (RDA) as 600 IU for

persons aged 1–70 y.<sup>34,35</sup> In 2008, the AAP revised its recommended intake of vitamin D for infants, children, and adolescents upward, from 200 IU to 400 IU/day.<sup>29</sup> Using average daily vitamin D intake as determined by the LFFQ, only 27% of our population consumed  $\geq 400$  IU and only 6% consumed  $\geq 600$  IU/day. The Endocrine Society recently reported that children and adolescents at high risk for vitamin D deficiency may require as much as 1000 IU/day of vitamin D to raise the blood level of 25(OH)D consistently above  $> 30$  ng/ml, the level considered to be sufficient.<sup>35</sup> Only 1% of our sample consumed  $> 1000$  IU vitamin D/day.

To our knowledge, this study is one of only a few to evaluate a FFQ designed specifically to measure vitamin D consumption in youth. Taylor et al.<sup>36</sup> evaluated a 40-item FFQ for determining calcium and vitamin D intake in adolescent girls (12–18 y) with and without anorexia nervosa compared with 4-d food records. The researchers reported greater subject compliance with completion of the FFQ (99%) than the food record (71%). They found a strong correlation between the dietary assessment methods for calcium and vitamin D in girls with anorexia nervosa ( $r = 0.65$  and  $r = 0.78$ , respectively;  $P < 0.0001$ ). In controls, the relation was somewhat weaker for calcium ( $r = 0.45$ ,  $p = 0.004$ ) and vitamin D ( $r = 0.47$ ,  $p = 0.003$ ).

Using a 3-d diary as a reference, Marshall et al.<sup>24</sup> investigated the relative validities of the Iowa Fluoride Study questionnaire and the Block Kids' Food Questionnaire in assessing vitamin D intake. Associations between vitamin D intakes estimated from 3-d diaries and the 2 questionnaires were modest and virtually identical to our findings. The study authors concluded that a dietary assessment method that targets specific foods or nutrients can be as effective in estimating intake as a more comprehensive assessment tool. An earlier study by Marshall et al.,<sup>37</sup> which evaluated the validity of a beverage frequency questionnaire in

assessing calcium and vitamin D intake in young children, found that the questionnaire could provide a relative estimate of vitamin D intake. The authors noted that as beverage intake patterns change, with decreased milk intake and increased soft drink and energy drink intake, fewer beverages contribute vital nutrients such as calcium and vitamin D to the total diet; thus beverage intake is less useful in assessing vitamin D intake. Araujo et al.,<sup>25</sup> who examined the validity of dietary intake data from an FFQ designed for adolescents living in Brazil, concluded that their FFQ was a suitable tool for ranking adolescents' energy and nutrient intake. The authors stated that food models and photographs should be used to reduce bias when reporting food intake portions.

Recently, Diffey (2013) proposed a complex mathematical model for estimating serum 25(OH)D concentrations based on oral intake of vitamin D and sun exposure in British white adults.<sup>38</sup> Based on this model, it is reasonable to conclude that one could estimate the serum 25(OH)D concentrations given the availability of data on vitamin D intake and sun exposure. However, Diffey's (2013) model has several limitations. These include variabilities in endogenous production of vitamin D in the skin based on skin pigmentation within the individual and between 2 individuals, age (decreased production of vitamin D as person ages) and body composition (decreased synthesis of vitamin D with adiposity and bioavailability of oral vitamin D). Given these serious shortcomings, the use of Diffey's model has limited application in estimating circulating 25(OH)D concentrations.

Our study had a few limitations. We were unable to adjust our analyses for energy intake because energy intake could not be calculated from the SFFQ. However, no significant association was found between caloric intake and vitamin D intake with the LFFQ, and therefore, we don't anticipate energy to be a confounder. The LFFQ was validated with youth who were 9 y or older while our sample included youth as young as 6 y of age.<sup>39</sup> A small proportion of participants (15%) reported taking multivitamin supplements. If the supplement brand was not reported, a generic children's vitamin product with 400 IU vitamin D was used in the nutrient analysis. Given the variation in vitamin D content of multivitamin products, some with 800 or 1000 IU, the calculated vitamin D intake for those who took supplements may have been underestimated. Our questionnaire was designed to document intake of dried mushrooms. However, the vitamin D content of artificially dried mushrooms (10–100 IU/100 g) is considerably less than the vitamin D content of sun-dried mushrooms (350+ IU/100 g). Future versions of the questionnaire should therefore specify the method of drying. We also assumed that the soy milk consumed by participants was vitamin D-fortified. Future versions of the questionnaire should specify fortified soy milk in the question as unfortified varieties are still available. Also, the sunlight exposure questions should obtain information regarding timing of exposure (before 10 a.m.; between 10 a.m.–3 PM; after 3 p.m.) and incorporate chest and abdomen in the list of parts of the body that are usually exposed to sunlight under question #19. Although our sunlight exposure questions provide a surrogate estimate of the dose (duration and

area of exposure) and quality of sunlight (timing of exposure), which are relevant determinants of vitamin D photoproduction, variations in human skin color make it hard for these questions to estimate the amount of vitamin D photosynthesized in the skin.

## Subjects and Methods

**Participants.** Our study population comprised 296 healthy 6- to 14-y-old African American and Caucasian children residing in Pittsburgh, PA. Subjects were participants in Dr. Rajakumar's National Institutes of Health-funded (R03 and K23 grants) vitamin D clinical research protocols designed to assess the seasonal and racial differences in vitamin D status of African American and Caucasian children (short longitudinal observational study,  $n = 140$ ) and refine the serum 25(OH)D thresholds for defining vitamin D insufficiency in children [randomized controlled trial (RCT) of 1000 IU of vitamin D3 vs. placebo for 6 mo,  $n = 156$ ]. Subjects were enrolled between June 2006 and March 2011. Children with hepatic or renal disease, disorders of vitamin D or calcium metabolism, malabsorptive disorders, or cancer, and those on treatment with anticonvulsants or systemic glucocorticoids were excluded from participation in the observational study and the clinical trial. Children enrolled in the clinical trial were not taking oral contraceptives, depot medroxyprogesterone, vitamin D containing multivitamins, or vitamin D supplements. The University of Pittsburgh Institutional Review Board approved the vitamin D research protocols, and signed parental informed consent and participants' assent were obtained prior to enrollment. The Institutional Review Board at Georgia State University approved the dietary analysis done for the study reported here.

**Study measurements.** Subjects' height and weight were measured at baseline and at the 6 mo follow-up visit; BMI was calculated. Subjects were classified as obese if age and gender based BMI was  $\geq 95$ th percentile.<sup>40,41</sup> Dietary intake was recorded by participants at both time points using the SFFQ and the LFFQ. The SFFQ was adapted from a questionnaire developed by Dr. Michael Holick (Boston University Medical Center) for assessment of vitamin D intake and sunlight exposure in adults. The SFFQ has 21 questions and is designed for completion by the participant or the parent. Seventeen of the questions focus on vitamin D and calcium rich foods, since Dr. Rajakumar's initial study was designed to assess the intake of these nutrients (Supplemental Data). The LFFQ is a semi-quantitative FFQ designed by the Harvard Medical School (copyright ©1995 Brigham and Women's Hospital) that addresses intake of 7 food groups with 152 questions requesting information on dietary intake over the past year. Completed SFFQs were analyzed using the Food Processor SQL (version 10.4.0, ESHA Research). LFFQ data forms were analyzed at Brigham and Women's Hospital. Nutrient intake data comprised 17 nutrients, including total energy, dietary calcium, and dietary vitamin D.

**Statistical analysis.** The Mann-Whitney U test was used to determine if there was a significant difference between anthropometric and nutrition variables by race at each time point since



the distribution of these variables was skewed in our population. Internal validity was determined by comparing vitamin D intake reported on the LFFQ with that reported on the SFFQ at each time point using the Spearman rank correlation statistic. Correlations were interpreted using the following guidelines:  $r = 0.0-0.3$  weak,  $r = 0.3-0.6$  modest, and  $r = 0.6-1.0$  good. Using a 2 x 2 contingency table, external validity of the SFFQ was evaluated using sensitivity, specificity, PPV, and NPV equations. The table cell values were determined by whether or not subjects met the AAP recommendation for vitamin D of 400 IU/day (30) and the IOM and Endocrine Society Clinical Practice Guideline recommendation of 600 IU/day,<sup>34,35</sup> as reported by the LFFQ (x) and SFFQ (y). Statistical analyses were conducted using SPSS® (version 18, 2010, IBM Corp).

### Conclusion

The SFFQ is a reasonably valid and reliable tool that can be used to assess vitamin D intake in preadolescent and adolescent

children. The SFFQ can serve well as a tool for studies with large populations to monitor vitamin D intake in at risk populations because it is easy to administer, low cost, and takes little time to analyze. Additionally, validated FFQs can provide nutrient intake information more accurately for any micronutrient policy initiatives.

### Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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