High prevalence of hypovitaminosis D in young healthy adults from the western part of India

Vyankatesh K Shivane, Vijaya Sarathi, Tushar Bandgar, Padmavathy Menon, Nalini S Shah

Department of Endocrinology, Seth G S Medical College, Parel, Mumbai, Maharashtra, India

Correspondence to
Dr Vijaya Sarathi, Department of Endocrinology, Seth G S Medical College, Parel, Mumbai 400012, Maharashtra, India; drvijayasarathi@gmail.com

Received 1 November 2010
Accepted 21 March 2011
Published Online First
20 April 2011

ABSTRACT

Objective Data on the prevalence of hypovitaminosis D in Indians living in the western part of the country are limited. The authors aimed to study the vitamin D status and dietary intake of calcium and phytates in healthy adult volunteers from a city in the western part of India.

Methods This cross-sectional study was conducted at a tertiary care centre in western India. A total of 1137 young (age: 25–35 years), healthy volunteers of both sexes were included in the study. All subjects were assessed for sun exposure, dietary intake of energy, protein, fat, calcium and phytates. Biochemical investigations included calcium, inorganic phosphorus, alkaline phosphatase, 25-hydroxyvitamin D (25(OH)D), intact parathyroid hormone (iPTH), total proteins, albumin and creatinine in serum and spot urinary calcium to creatinine ratio.

Results The serum 25(OH)D concentration for the whole study population was low (17.4±9.1 ng/ml), and that for men and women were 18.9±8.9 ng/ml and 15.8±9.1 ng/ml, respectively. Seventy per cent of the study population had hypovitaminosis D (25(OH)D <20 ng/ml) with a slightly higher prevalence in women (76%). Mean dietary calcium intake of the study population was 322.92±135.17 mg/day and was very low when compared with the recommended dietary allowance (400 mg/day for adults of both sexes) issued by the Indian Council of Medical Research. Dietary phytate was much higher than calcium intake with a dietary phytate to calcium ratio of 2.25±0.76. Serum iPTH had significant negative correlation with 25(OH)D ($r=-0.23$, $p<0.001$).

Conclusion Hypovitaminosis D, low dietary calcium and high phytate consumption are highly prevalent among young healthy adults in the western part of India.

INTRODUCTION

Vitamin D and calcium are the important factors that affect bone homeostasis. Vitamin D, 'the sunshine vitamin' is a unique vitamin with hormonal properties. It has a profound effect on the growth and development of children in whom the deficiency of the vitamin causes rickets and interferes with the realisation of optimal peak bone mass. In adults, hypovitaminosis D can cause osteomalacia or exacerbate osteopenia. Vitamin D has also been linked to many non-skeletal disorders like glucose intolerance, hypertension, autoimmune disorders, cancers, depression and Alzheimer's dementia.[1] The accurate indicator of optimal vitamin D status of a person is still unclear. Currently, the best method for determining vitamin D adequacy is to measure the serum 25-hydroxyvitamin D (25(OH)D) concentration.[2]

Theoretically, the Indian subcontinent, located between 8.41°N and 37.61°N, gets plenty of sunlight throughout the year and therefore people in India should not experience poor vitamin D status. Nonetheless, there are many reports of widespread vitamin D deficiency/insufficiency in India. Few large-scale studies have reported a high prevalence of hypovitaminosis D in southern India.[3–5] Similar reports have also been published from different parts of northern India with documentation of high prevalence of hypovitaminosis D even among soldiers who are likely to have good nutrition and sun exposure.[6 7]

Coexisting calcium deficiency further worsens the effects of hypovitaminosis D on bone parameters. Studies from Delhi have reported adequate (≥400 mg/day) dietary calcium intake while studies from the rest of India have reported lower dietary calcium intake.[6] A recent large-scale study has shown low dietary calcium, high phytate consumption and hypovitaminosis D among healthy Indians from the southern part of the country.[3]

However, no such data are available from the western part of India, which differs significantly from other parts of India with respect to dietary habits, zenith angle, skin type of subjects and other factors that significantly affect sunlight-mediated vitamin D synthesis. Hence, we studied the vitamin D status and dietary intake of calcium and phytates among healthy adult volunteers from an urban area (Mumbai, Maharashtra) in western India.

METHODS

Subjects

This cross-sectional study was conducted at Mumbai city in the western part of India during May–June 2008. The study was approved by the institutional ethics committee and written informed consent was obtained from all participants. A total of 1137 young (age: 25–35 years), healthy volunteers of both sexes were recruited for the study from Mumbai city by organising community awareness camps. Pregnant and lactating women, those with medical disorders that could affect bone mineral density, those who had received steroids, antituberculous or antiepileptic medication within the last 2 years, those who had a bone fracture within the last 2 years and those who were on calcium and vitamin D supplements for more than 3 months were excluded from the study.

Estimation of sun exposure, physical activity, dietary intake

Sunlight exposure was calculated in terms of the length of usual weekly outdoor activity, sunscreen

use and usual outdoor attire. The 'rule of nine' was adapted to estimate the fraction of body surface area (BSA) exposed to sunlight based on each subject's usual outdoor attire.[8] The sun index was calculated as the product of hours of sun exposure per week and the fraction of BSA exposed to sunlight. Mumbai is located at 18°56′N latitude and all of the study population were from areas below 37°N latitude. Sunlight exposure was measured only between 08:00 to 17:00 in summer and 09:00 to 15:00 in winter. All our patients belonged to the same ethnicity and were of skin type V. Physical activity was assessed using the Global Physical Activity Questionnaire developed by WHO (http://www.who.int/chp/steps/).

Detailed dietary history was recorded by an experienced dietician and average daily dietary intake of total energy, carbohydrate, protein, fat, calcium, phytate, vitamin D, magnesium and salt were calculated. In addition, all subjects were tested for areal bone mineral density and urinary dihydroxy pyridinoline. However, these parameters are not discussed in this article.

Assays

Blood samples were collected after overnight fasting for estimation of serum calcium, inorganic phosphorus, alkaline phosphatase, 25(OH)D, serum intact parathyroid hormone (iPTH), total proteins, albumin and creatinine. Serum calcium, inorganic phosphorus, alkaline phosphatase, total proteins, albumin and creatinine were measured on the same day with an autoanalyser (Biosystems SA, Barcelona, Spain). Serum iPTH estimation was done using an immunochemiluminescence assay (Immulite 1000 Diagnostic Products Corp, Los Angeles, CA, USA), with an intra-assay coefficient of variation (CV) of 5.5%–6.3% and inter-assay CV of 7.9%–8.6%. Serum 25(OH)D estimation was done using a radioimmunoassay (DiaSorin Inc., Stillwater, Minnesota, USA), with an intra-assay and inter-assay CV of 0.141% and 6.49%, respectively. The urine sample collected on the first morning was examined for calcium to creatinine ratio. Urinary calcium and urinary creatinine were estimated by an auto-analyser by using the same reagent that was used for serum calcium and creatinine estimation.

Data analysis

Vitamin D status was classified into severe vitamin D deficiency (<5 ng/ml), moderate vitamin D deficiency (5–10 ng/ml), mild vitamin D deficiency (10–20 ng/ml), vitamin D sufficiency (>20 ng/ml) and optimal vitamin D status (>30 ng/ml). Distribution of vitamin D status was reported in percentages. The rest of the results were expressed as mean±SD. The statistical significance for difference between males and females was calculated using Student t test. Correlation of serum 25 (OH)D and dietary calcium with other factors was calculated using Pearson's correlation coefficient (r). A p value of <0.05 was considered statistically significant. Data analysis was done using SPSS version 14.0.

RESULTS

A total of 1137 young adult subjects (age range: 25–35 years) including 558 men and 579 women were studied. Baseline characteristics of the study group are shown in table 1. There were no significant differences between men and women with respect to anthropometric parameters, physical activity, sun exposure, dietary parameters and biochemical parameters including serum 25(OH)D levels.

Vitamin D status

The 25(OH)D of the whole study population was low (17.4±9.1 ng/ml); the status for men and women were 18.9±8.9 ng/ml and 15.8±9.1 ng/ml, respectively. The serum calcium, serum phosphorus and serum alkaline concentrations of both men and women were within the normal range (table 1). Hypovitaminosis D is classified according to Lip's classification.[9]

Prevalence of various degrees of hypovitaminosis D and vitamin D sufficiency in the study population is shown in

Table 1 Baseline characteristics of total study population

	Whole study population (n=1137)	Males (n=558)	Females (n=579)	p Value*
Age (years)	30.38±3.55	30.11±3.53	30.52±3.57	0.86
Height (cm)	159.9±9.62	166.59±8.69	154.35±6.74	0.56
Weight (kg)	58.53±12.74	62.62±12.67	54.43±11.34	0.87
Body mass index (kg/m^2)	22.76±4.18	22.71±3.91	22.85±4.36	0.94
Waist circumference (cm)	74.96±10.26	78.32±9.78	71.61±9.67	0.94
Waist to hip ratio	0.94±0.05	0.95±0.04	0.92±0.06	0.95
Sun index	2.40±2.75	2.92±2.82	1.95±2.63	0.19
Physical activity (MET min/week)	4236.3±997	6464.3±896	3125.1±706	0.08
Total energy intake (kcal/day)	1948.9±603.1	2198.3±643.53	1696.9±452.21	0.31
Dietary carbohydrate intake (g/day)	286.70±108.75	336.93±115.97	237.95±74.76	0.39
Dietary protein intake (g/day)	59.19±23.29	67.7±25.01	50.92±18.12	0.17
Dietary fat intake (g/day)	64.24±22.19	66.48±21.95	61.82±22.21	0.95
Dietary calcium intake (mg/day)	322.92±135.17	353.68±140.91	293.84±123.34	0.99
Dietary phytate intake (mg/day)	704.03±343.48	839.86±377.38	571.47±246.11	0.29
Dietary phytate to calcium ratio	2.25±0.76	2.45±0.78	2.05±0.68	0.59
Serum calcium (mg/dl)	9.54±0.51	9.56±0.51	9.53±0.51	0.86
Serum phosphorous (mg/dl)	3.69±0.6	3.69±0.62	3.67±0.61	0.53
Serum alkaline phosphatase (IU/l)	79.72±23.97	79.12±24.89	80.48±23.27	0.47
Serum iPTH (pg/ml)	48.31±25.64	43.24±22.19	53.15±27.84	0.82
Urinary calcium to creatinine ratio	0.06±0.07	0.06±0.07	0.06±0.07	0.53
Serum 25(OH)D (ng/ml)	17.4±9.1	18.9±8.9	15.8±9.1	0.81

*p Value is for the comparison of males and females.
iPTH, intact parathyroid hormone; 25(OH)D, 25-hydroxyvitamin D.

Table 2 Prevalence of various degrees of hypovitaminosis D and vitamin D sufficiency in the study population

Serum 25(OH)D	Whole study population, n=1137 (%)	Men, n=558 (%)	Women, n=579 (%)
Severe vitamin D deficiency (<5 ng/ml)	33 (2.9)	6 (1.1)	27 (4.67)
Moderate vitamin D deficiency (5–10 ng/ml)	187 (16.45)	61 (10.9)	126 (21.76)
Mild vitamin D deficiency (10–20 ng/ml)	585 (51.45)	279 (50)	288 (49.7)
Vitamin D sufficiency (>20 ng/ml)	350 (30.78)	212 (38)	138 (23.83)
Optimal vitamin D status (>30 ng/ml)	82 (7.2)	54 (9.68)	28 (4.83)

25(OH)D, 25-hydroxyvitamin D.

table 2. Only 30.78% of subjects had sufficient 25(OH)D levels while only 7.2% had 25(OH)D level >30 ng/ml. Serum 25(OH)D had significant negative correlation with serum iPTH in the whole study population (r=−0.23, p<0.001), men (r=−0.24, p<0.001) and women (r=−0.18, p<0.001). Serum iPTH level attained a plateau at a 25(OH)D level of 25–30 ng/ml (figure 1). Serum 25(OH)D had no significant correlation with serum calcium, serum phosphorus and serum alkaline phosphatase in any group. Serum 25(OH)D had significant correlation with sun index (r=0.18, p<0.001).

Dietary composition

The mean energy consumption of the study group was 1948.4±603.1 kcal/day, and that of men and women were 2058.9 and 1810.2 kcal/day, respectively. The carbohydrate source was primarily cereals with wheat and rice providing 75% and 25% of total carbohydrates, respectively. Vegetable sources included amaranth leaves, cauliflower, carrots, okra, other seasonal vegetables and tubers. Animal sources of protein were consumed once a week. Carbohydrates, proteins and fats contributed 69.75%, 14.4% and 15.6% of the total energy intake of the whole study population, respectively. In men, carbohydrates, proteins and fats contributed 71.64%, 14.28% and 14.1% of the total energy intake, respectively, while in women, they contributed 67.78%, 14.57% and 17.42% of the total energy intake, respectively. The mean dietary calcium intake of the study population was 322.92±135.17 mg/day, and that of men and women were 353.68±140.91 and 293.84±123.34 mg/day, respectively, which was very low when compared with the recommended dietary allowance (RDA) of 400 mg/day for adults (both sexes) issued by the Indian Council of Medical Research (ICMR).[6]

Dietary calcium intake had significant positive correlation with total energy, protein, carbohydrate and fat intake in the diet (table 3). Similar observations were also found when males and females were analysed separately. Overall dietary calcium intake had significant negative correlation with iPTH (r=−0.085, p=0.004). However, when analysed separately, this finding was observed only in males (r=−0.43, p<0.001) and not in females (r=0.005, p=0.94).

Dietary phytate was much higher than the dietary calcium intake with a dietary phytate to calcium ratio of 2.25±0.76. Dietary phytate had significant positive correlation with dietary calcium in the study population (r=0.61, p<0.001). Similar findings were observed both in men (r=0.61, p<0.001) and in women (r=0.58, p<0.001). There was no correlation between dietary calcium intake and dietary phytate to calcium ratio in any group. The dietary phytate to calcium ratio had no significant correlation with iPTH.

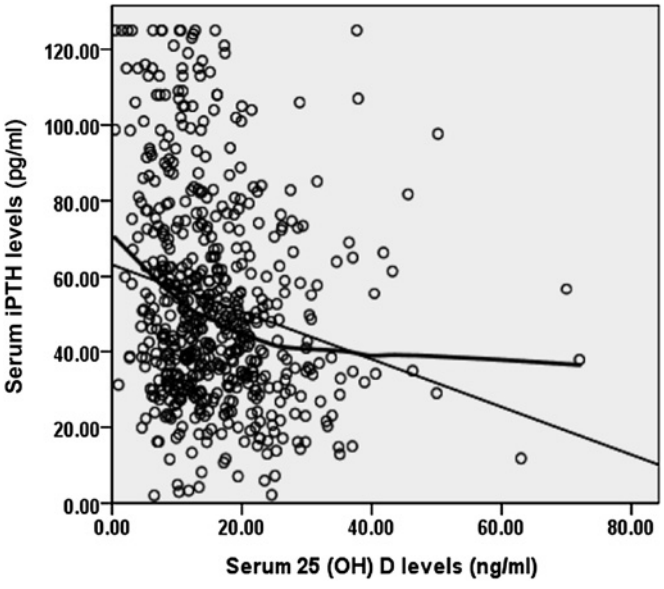

Figure 1 Linear and locally weighted scatterplot smoothing model curve showing relation of serum 25-hydroxyvitamin D (25(OH)D) and intact parathyroid hormone (iPTH) levels.

DISCUSSION

Our study reports high prevalence of hypovitaminosis D among Indians living in the western part of the country. Seventy per cent of the study population was vitamin D insufficient with a slightly higher prevalence (79.28%) in women. The study also reports high prevalence of low calcium intake and high phytate intake in the diet of the study population. Our study is one of the largest studies on vitamin D status from India and is the first large-scale study from the western part of the country.

Table 3 Correlation of dietary calcium intake with other dietary and biochemical parameters

	Whole study population	Men	Women
Total energy intake (kcal/day)	0.698**	0.697**	0.669**
Dietary carbohydrate (g/day)	0.643**	0.636**	0.603**
Dietary protein (g/day)	0.716**	0.731**	0.696**
Dietary fat (g/day)	0.374**	0.398**	0.376**
Dietary phytate (mg/day)	0.613**	0.611**	0.583**
Dietary phytate to calcium ratio	−0.087	−0.079	−0.093
Serum calcium (mg/dl)	0.045	0.042	−0.040
Serum phosphorous (mg/dl)	0.007	0.041	−0.015
Serum alkaline phosphatase (U/L)	−0.006	0.008	−0.009
Serum 25(OH)D (ng/ml)	0.022	0.077**	−0.004
Serum iPTH (pg/ml)	−0.085**	−0.143**	0.005
Urinary calcium to creatinine ratio	0.024	0.068*	−0.016

*p<0.05; **p<0.001.
iPTH, intact parathyroid hormone; 25(OH)D, 25-hydroxyvitamin D.

Vitamin D status

Vitamin D insufficiency is highly prevalent among Indian men and women with relatively higher prevalence in the latter.[6] It is also highly prevalent across all age groups ranging from newborns to postmenopausal women. A large-scale study conducted in South India reported 25(OH)D levels of <20 ng/ml, 20–30 ng/ml and >30 ng/ml in 62%, 26% and 12% of the men and 75%, 19% and 6% of the women, respectively.[3] Our study also found a similar prevalence of 25(OH)D levels <20 ng/ml, 20–30 ng/ml and >30 ng/ml in 62%, 28% and 10% of the men and 76%, 19% and 5% of the women, respectively. However, a recent study has shown a much lesser prevalence of hypovitaminosis D among healthy young men and women from North India. The study reports a prevalence of 25(OH)D levels of <20 ng/ml, 20–30 ng/ml and >30 ng/ml in 18.3%, 9.2% and 72.5%, respectively.[10] This difference may be due to the relatively more favourable skin type (type IV) and zenith angle at Chandigarh than Mumbai.

Previous reports on vitamin D status from the western part of India are few. Mumbai and Pune are the two cities in this region from where data on vitamin D status have been previously reported. We have previously reported a high prevalence (87.5%) of hypovitaminosis D among resident doctors in Mumbai with a higher prevalence among female resident doctors (97%).[11] We have also observed poor vitamin D status (serum 25(OH)D: 17 ng/ml) among a small number of diabetic subjects from our centre.[12] A study from Pune has reported hypovitaminosis D (25(OH)D <12.5 ng/ml) among 70% of adolescent girls.[13] Bhalala *et al* reported a mean 25(OH)D level of 22.99±10.93 ng/ml among pregnant women from Mumbai and 19.36±9.57 ng/ml in their neonates.[14]

Studies from other developing countries have also reported a high prevalence of hypovitaminosis D.[15] Several surveys have shown a very poor vitamin D status in the Middle East.[16] In an international study of women with osteoporosis, the highest prevalence of hypovitaminosis D was reported in the Middle East.[17] People from most developed countries have better vitamin D status.[16] However, Australians have a higher prevalence (37.4%–67.3%) of hypovitaminosis D.[18]

The sun exposure was inadequate in our study cohort and had significant positive correlation, suggesting inadequate sun exposure as an important cause of hypovitaminosis D. In addition, unfavourable zenith angle and environmental pollution in Mumbai could impede effective sun exposure. The unfavourable skin type (skin type V) of Indians demands longer periods of sun exposure to ensure adequate vitamin D synthesis.

Correlation of vitamin D and iPTH

Serum 25(OH)D had significant negative correlation with iPTH (r=−0.23). This observation has consistently been reported in most of the previous studies, usually with a correlation coefficient between 0.20 and 0.30.[9] The 25(OH)D threshold for elevation of PTH which is commonly used to define adequacy of vitamin D status is not well studied in Indians. It may be different from that of people in Western countries. The present study shows that PTH level plateaus at a 25(OH)D value of 25–30 ng/ml, substantiating the use of the same cut-offs in our population. However, two other Indian studies have shown that PTH starts rising at a 25(OH)D level of 20–25 ng/ml in school children and young healthy adults.[10 19]

Some patients have shown low iPTH levels despite low 25(OH)D levels, suggesting a state of functional hypoparathyroidism. This finding is not uncommon and has been previously reported by others.[20–23] The reason for this failure of parathyroid glands to mount an adequate parathyroid hormone response is not clear. Coexisting magnesium deficiency (possibly due to phytate-induced impaired absorption of magnesium) may be responsible for some of these cases. However, serum magnesium levels were not assessed in our cohort.

Dietary calcium and phytate

Calcium absorption through the gut is highly dependent on 25(OH)D status.[24 25] Low 25(OH)D concentrations impair calcium absorption in the gut.[24 25] It has been demonstrated that low dietary calcium converts the 25(OH)D to polar metabolites in the liver and leads to secondary 25(OH)D deficiency.[26] In addition, low dietary calcium increases PTH leading to increased conversion of 25(OH)D to 1,25-dihydroxyvitamin D. 1,25-Dihydroxyvitamin D induces its own destruction by increasing 24-hydroxylase. Overall calcium deficiency induces secondary vitamin D deficiency or worsens existing vitamin D deficiency.

Our study has also shown a high prevalence of low dietary calcium and high dietary phytate intake in Indians living in the western part of the country. The dietary calcium to phytate ratio was low. The RDA for calcium in India as recommended by the ICMR is lower than the revised dietary reference intake of calcium.[6] The dietary calcium intake of our study group did not even meet the minimum RDA recommended by the ICMR. A previous study from South India has also shown low calcium and high phytate consumption in the diet of healthy adults.[3] We have previously reported adequate calcium intake among resident doctors from Mumbai with dietary calcium intakes of 971.06±338.32 and 822.56±326.86 mg/day in male and female resident doctors, respectively.[11] However, the calcium to phosphorus ratio in their diet was unfavourable for optimal calcium absorption. Another study from Pune, in the western part of India, has reported a median (range) dietary calcium intake of 449 (356–538) mg/day in adolescent girls which is lower than that recommended by the ICMR for the adolescent age group (600 mg/day).[13]

Dietary calcium intake had significant positive correlation with total energy, protein, carbohydrate and fat intake in the diet. The lower the total energy intake, the lower was the dietary calcium intake. Hence, reduced calories in the diet may be one of the significant contributors for low calcium intake in the diet.

Dietary phytate correlated positively with dietary calcium in the study population. This finding implies that an attempt to increase the dietary calcium intake with the available fixed dietary pattern of people in the western part of India will simultaneously increase the dietary phytate intake. The absorption of calcium decreases with increasing dietary calcium in the diet.[27] Simultaneously, increasing dietary phytate may further decrease the absorption of calcium leading to decreased bioavailable calcium. Hence, there may be a need for the change of dietary pattern or calcium supplementation among these people. Since the study was specifically designed to recruit participants in a short period of 2 months (May–June 2008) when the sunshine is abundant in this region, we could not study the seasonal variation in 25(OH)D levels. A recent study from Australia has shown season as the most significant predictor of vitamin D status.[18] Another recent Indian study has also demonstrated significant seasonal variation of vitamin D.[10]

Various studies from India indicate that widely prevalent hypovitaminosis D is functionally relevant to skeletal health including osteomalacia and rickets. A recent Indian study has also reported that a large chunk of hypovitaminosis D is subclinical, characterised by non-specific musculoskeletal symptoms as the only manifestation. The same study also concludes that

Main messages

- There is a high prevalence of hypovitaminosis D and low dietary calcium intake in Indians living in the western part of India.
- There is a need to focus on improving vitamin D status and increasing the intake of bioavailable calcium in people living in India.

Current research questions

- Comparison of the safety and efficacy of increased sun exposure with that food fortification would be required to identify the appropriate method of improving vitamin D status.

hypovitaminosis D affects individuals in the prime of their life and affects the quality of life and the productivity of those suffering from it.[28] Another limitation of our study was not assessing the functional relevance of hypovitaminosis D.

Inadequate sun exposure in our cohort may suggest a role for lifestyle modification with increased sun exposure for improvement of the vitamin D status. However, studies from rural areas of India, that too in the southern Indian states with almost perennial sunshine, also report a high prevalence of hypovitaminosis D, which suggests that increased sun exposure may not be the best option for increasing vitamin D status in people in India. This may be predominantly due to skin pigmentation. In such a scenario, active intervention is required in the form of a national policy for a vitamin D food fortification programme in our country. It would also be interesting to compare the efficacy of increased sun exposure with food fortification so that the appropriate method of improving vitamin D status can be implemented.

In summary, our study reports a high prevalence of hypovitaminosis D in Indians in the western part of the country. It also reports a high prevalence of low calcium and high phytate consumption in the diet of these people. There is a need to focus on the improvement of vitamin D status and the increase of the intake of bioavailable calcium among people living in India.

Competing interests None.

Ethics approval This study was conducted with the approval of the Ethics Committee, Seth G S Medical College and KEM Hospital.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Holick MF.** The vitamin D deficiency pandemic and consequences for nonskeletal health: mechanisms of action. *Mol Aspects Med* 2008;**29**:361—8.
2. **Millen AE,** Bodnar LM. Vitamin D assessment in population-based studies: a review of the issues. *Am J Clin Nutr* 2008;**87**:1102S—5.
3. **Harinarayan CV,** Ramalakshmi T, Prasad UV, *et al*. High prevalence of low dietary calcium, high phytate consumption, and vitamin D deficiency in healthy south Indians. *Am J Clin Nutr* 2007;**85**:1062—7.
4. **Harinarayan CV,** Ramalakshmi T, Venkataprasad U. High prevalence of low dietary calcium and low vitamin D status in healthy south Indians. *Asia Pac J Clin Nutr* 2004;**13**:359—64.
5. **Paul TV,** Thomas N, Seshadri MS, *et al*. Prevalence of osteoporosis in ambulatory postmenopausal women from a semiurban region in Southern India: relationship to calcium nutrition and vitamin D status. *Endocr Pract* 2008;**14**:665—71.
6. **Harinarayan CV,** Joshi SR. Vitamin D status in India—its implications and remedial measures. *J Assoc Physicians India* 2009;**57**:40—8.
7. **Goswami R,** Gupta N, Goswami D, *et al*. Prevalence and significance of low 25-hydroxyvitamin D concentrations in healthy subjects in Delhi. *Am J Clin Nutr* 2000;**72**:472—5.
8. **Barger-Lux MJ,** Heaney RP. Effects of above average summer sun exposure on serum 25-hydroxyvitamin D and calcium absorption. *J Clin Endocrinol Metab* 2002;**87**:4952—6.
9. **Lips P.** Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. *Endocr Rev* 2001;**22**:477—501.
10. **Ramakrishnan S,** Bhansali A, Bhadada SK, *et al*. Vitamin D status and its seasonal variability in young healthy adults in an Asian Indian urban population. *Endocr Pract* 2010;**14**:1—26.
11. **Multani SK,** Sarathi V, Shivane V, *et al*. Study of bone mineral density in resident doctors working at a teaching hospital. *J Postgrad Med* 2010;**56**:65—70.
12. **Parekh D,** Sarathi V, Shivane VK, *et al*. Pilot study to evaluate the effect of short-term improvement in vitamin D status on glucose tolerance in patients with type 2 diabetes mellitus. *Endocr Pract* 2010;**16**:600—8.
13. **Khadilkar A,** Das G, Sayyad M, *et al*. Low calcium intake and hypovitaminosis D in adolescent girls. *Arch Dis Child* 2007;**92**:1045.
14. **Bhalala U,** Desai M, Parekh P, *et al*. Subclinical hypovitaminosis D among exclusively breastfed young infants. *Indian Pediatr* 2007;**44**:897—901.
15. **Arabi A,** El Rassi R, El-Hajj Fuleihan G. Hypovitaminosis D in developing countries—prevalence, risk factors and outcomes. *Nat Rev Endocrinol* 2010;**6**:550—61.
16. **Lips P.** Worldwide status of vitamin D nutrition. *J Steroid Biochem Mol Biol* 2010;**121**:297—300.
17. **Lips P,** Hosking D, Lippuner K, *et al*. The prevalence of vitamin D inadequacy amongst women with osteoporosis: an international epidemiological investigation. *J Intern Med* 2006;**260**:245—54.
18. **van der Mei IA,** Ponsonby AL, Engelsen O, *et al*. The high prevalence of vitamin D insufficiency across Australian populations is only partly explained by season and latitude. *Environ Health Perspect* 2007;**115**:1132—9.
19. **Marwaha RK,** Tandon N, Reddy DR, *et al*. Vitamin D and bone mineral density status of healthy schoolchildren in northern India. *Am J Clin Nutr* 2005;**82**:477—82.
20. **Chapuy MC,** Preziosi P, Maamer M, *et al*. Prevalence of vitamin D insufficiency in an adult normal population. *Osteoporos Int* 1997;**7**:439—43.
21. **Melin AL,** Wilske J, Ringertz H, *et al*. Vitamin D status, parathyroid function and femoral bone density in an elderly Swedish population living at home. *Aging (Milano)* 1999;**11**:200—7.
22. **Guillemant J,** Taupin P, Le HT, *et al*. Vitamin D status during puberty in French healthy male adolescents. *Osteoporos Int* 1999;**10**:222—5.
23. **Sahota O,** Gaynor K, Harwood RH, *et al*. Hypovitaminosis D and "functional hypoparathyroidism"—the NoNoF (Nottingham Neck of Femur Study). *Age Ageing* 2003;**32**:465—6.
24. **Heaney RP,** Dowell MS, Hale CA, *et al*. Calcium absorption varies within the reference range for serum 25-hydroxyvitamin D. *J Am Coll Nutr* 2003;**22**:142—6.
25. **Heaney RP.** Vitamin D depletion and effective calcium absorption. *J Bone Miner Res* 2003;**18**:1342.
26. **Clements MR,** Johnson L, Fraser DR. A new mechanism for induced vitamin D deficiency in calcium deprivation. *Nature* 1987;**325**:62—5.
27. **Thakker RV,** Bringhurst FR, Puppner H. Calcium regulation, calcium homeostasis and genetic disorders of calcium metabolism. In: Jameson JL, DeGroot JL, eds. Endocrinology. Philadelphia, PA: Saunders, Elsevier 2010:1136—59.
28. **Kanekar A,** Sharma M, Joshi VR. Vitamin D deficiency—a clinical spectrum: is there a symptomatic nonosteomalacic state? *Int J Endocrinol* 2010;**2010**:521457.

High prevalence of hypovitaminosis D in young healthy adults from the western part of India

Vyankatesh K Shivane, Vijaya Sarathi, Tushar Bandgar, Padmavathy Menon and Nalini S Shah

Postgrad Med J 2011 87: 514-518 originally published online April 20, 2011
doi: 10.1136/pgmj.2010.113092