

Vitamin D and adult bone health in Australia and New Zealand: a position statement

Working Group of the Australian and New Zealand Bone and Mineral Society,
Endocrine Society of Australia and Osteoporosis Australia*

A significant number of Australians are deficient in vitamin D. Indeed, it is a fallacy that Australians receive adequate vitamin D from casual exposure to sunlight. Here, we outline the causes and outcomes of vitamin D deficiency, the people who are at risk, and recommendations for management of deficiency.

Vitamin D

The term "vitamin D" encompasses two molecules:

- Cholecalciferol (vitamin D₃), formed in the skin through the action of ultraviolet (UV) light on 7-dehydrocholesterol to produce cholecalciferol.
- Ergocalciferol (vitamin D₂), produced by UV irradiation of the plant steroid ergosterol. Ergosterol is the major form of supplemental vitamin D currently available in Australia.

1,25-Dihydroxyvitamin D

Vitamin D₃ and D₂, made in the skin or ingested, are transported to the liver and metabolised to 25-hydroxyvitamin D (25-OHD), the major circulating form. Further hydroxylation occurs in the kidney to form the highly biologically active 1,25-dihydroxyvitamin D (1,25-(OH)₂D). This compound promotes:

- absorption of calcium and phosphate from the small intestine;¹
- extracellular calcium homeostasis, directly and through its interaction with parathyroid hormone;¹ and
- mineralisation of the skeleton.¹

* MEMBERS OF THE WORKING GROUP WERE:

University of New South Wales, Sydney, NSW.

Terrence H Diamond, MRCP, FRACP, Associate Professor of Medicine, Department of Endocrinology.

Garvan Institute of Medical Research, St Vincent's Hospital and University of New South Wales, Sydney, NSW.

John A Eisman, PhD, FRACP, Professor and Director, Bone and Mineral Research Program.

University of Sydney, NSW.

Rebecca S Mason, MB BS, PhD, Associate Professor, Department of Physiology and Institute for Biomedical Research.

Deakin University, Melbourne, VIC.

Caryl A Nowson, PhD, DipNutDiet, Associate Professor, School of Exercise and Nutrition Sciences.

The University of Melbourne, Geelong, VIC.

Julie A Pasco, BSc(Hons), PhD, DipEd, Senior Research Fellow, Department of Clinical and Biomedical Sciences, Barwon Health.

University of Sydney and Royal North Shore Hospital, NSW.

Philip N Sambrook, MD, LLB, FRACP, Professor of Rheumatology.

The University of Melbourne and Royal Melbourne Hospital, VIC.

John D Wark, PhD, FRACP, Professor of Medicine.

Reprints will not be available from the authors. Correspondence: Dr Julie A Pasco, Department of Clinical and Biomedical Sciences, Barwon Health, The University of Melbourne, PO Box 281, Geelong, VIC 3220. juliep@barwonhealth.org.au

ABSTRACT

- A significant number of Australians are deficient in vitamin D — it is a fallacy that Australians receive adequate vitamin D from casual exposure to sunlight.
- People at high risk of vitamin D deficiency include elderly people (particularly those in residential care), people with skin conditions where avoidance of sunlight is advised, those with dark skin (particularly if veiled), and those with malabsorption.
- Exposure of hands, face and arms to one-third of a minimal erythemal dose (MED) of sunlight (the amount that produces a faint redness of skin) most days is recommended for adequate endogenous vitamin D synthesis. However, deliberate sun exposure between 10:00 and 14:00 in summer (11:00–15:00 daylight saving time) is not advised.
- If this sun exposure is not possible, then a vitamin D supplement of at least 400 IU (10 µg) per day is recommended.
- In vitamin D deficiency, supplementation with 3000–5000 IU ergocalciferol per day (Ostelin [Boots]; 3–5 capsules per day) for 6–12 weeks is recommended.
- Larger-dose preparations of ergocalciferol or cholecalciferol are available in New Zealand, Asia and the United States and would be useful in Australia to treat moderate to severe vitamin D deficiency states in the elderly and those with poor absorption; one or two annual intramuscular doses of 300 000 IU of cholecalciferol have been shown to reverse vitamin D deficiency states.

MJA 2005; 182: 281–285

Sources of vitamin D

Exposure to sunlight: For people living in Australia and New Zealand, the main source of vitamin D is through exposure to sunlight. It has been shown that whole body exposure to 10–15 minutes of midday sun in summer (about 1 minimal erythemal dose [MED], or the amount of sun exposure which just produces a faint redness of skin) is comparable to taking 15 000 IU (375 µg) of vitamin D (cholecalciferol) orally.² On this basis, exposure of hands, face and arms (around 15% of body surface) to around 1/3 MED should produce around 1000 IU of vitamin D (cholecalciferol). The amount of sun exposure to produce 1/3 MED varies with latitude, season, time of day and skin type (Box 1).

Less vitamin D is synthesised in winter, in those who have dark skin or are older, and in those who dress with little potential for skin exposure to sunlight for cultural reasons or for sun protection. Therefore, serum vitamin D levels are lower in winter than in summer.⁵ Short exposures may be more efficient at producing vitamin D. Once previtamin D₃ (a chemical precursor of vitamin D₃) and vitamin D₃ (cholecalciferol) have been formed, continued exposure to UV results in their degradation to relatively inert over-irradiation products.²

1 Recommended sun exposure times (minutes) which result in 1/3 MED for people with moderately fair skin* at different times of day

Region†	December–January		July–August	
	At 10:00 or 14:00‡		At 10:00	At 12:00
Northern Australia				
Cairns	6–7		9–12	7
Townsville	5–7		9–13	7
Central Australia				
Brisbane	6–7		15–19	11
Perth	5–6		20–28	15
Southern Australia				
Sydney	6–8		26–28	16
Adelaide	5–7		25–38	19
Melbourne	6–8		32–52	25
Hobart	7–9		40–47	29
New Zealand				
Auckland	6–8		30–47	24
Christchurch	6–9		49–97	40

MED = minimal erythemal dose.

* Exposure times for people with highly pigmented skin would be 3–4 times greater.³

† Based on the relationship 1 MED = 200 J/m² effective or 2 standard erythemal doses for people with type I or II (sensitive) skin.

Data for Australian cities were obtained from Gies et al,⁴ using measured averages of MED/h over the 2 months listed, for a minimum of 5 years in the period 1996–2003, except Hobart, which used data from 1 year.

Times for New Zealand were calculated from ultraviolet data averaged over 2 years provided by the National Institute of Water and Atmospheric Research.

‡ 11:00 or 15:00 daylight saving time, respectively.

It is therefore prudent to expose hands, face and arms to 1/3 MED of sunlight most days. Box 1 shows approximate exposure times for various regions, months and skin types. But there is a caveat: deliberate exposure to sunlight between 10:00 and 14:00 (or 11:00 and 15:00 daylight saving time) in the summer months is not advised. If adequate sunlight exposure to generate sufficient endogenous cholecalciferol is not possible, then a vitamin D supplement of at least 400 IU (10 µg) per day is recommended.

Diet: Vitamin D₃ is found in small quantities in a few foods, such as fatty fish (North Sea salmon, herring and mackerel). Liver, eggs and fortified foods, such as margarine and some low-fat milks, also contain very small amounts of vitamin D.

For most Australians, adequate vitamin D is unlikely to be achieved through diet alone. Intake is estimated as 2–3 µg/day (<100 IU). Recommended dietary intakes are currently under review in Australia. Daily reference intakes for vitamin D devised by the Food and Nutrition Board of the Institute of Medicine of the United States National Academy of Science⁶ are shown in Box 2. These are similar to the recommendations of the Food and Agriculture Organization of the United Nations (FAO).⁷

Sunscreens

Broad-spectrum sunscreens protect the skin against UVA and UVB radiation (wavelengths, 320–400 nm and 290–320 nm, respec-

tively). Radiation in the UVB range is responsible for skin carcinogenesis as well as the conversion of 7-dehydrocholesterol into previtamin D₃.² Glass blocks UVB rays required for previtamin D₃ synthesis. Concerns were raised that sunscreen use may cause vitamin D deficiency, especially among older people.² Yet sunscreens are essential to prevent skin damage with longer periods of sun exposure. For incidental sun exposures (< 1/2 MED), it may be reasonable to omit the sunscreen for the time required.

Groups at risk of vitamin D deficiency

Older people who are institutionalised or housebound are at a particularly high risk of vitamin D deficiency. For example, up to 80% of women and 70% of men living in hostels or nursing homes in Victoria, New South Wales and Western Australia were frankly deficient in vitamin D, and 97% had a 25-OHD level below the median value of the healthy reference range.^{8,9} There also appears to be a significant prevalence of mild vitamin D deficiency in younger adults, particularly during winter.⁵

Groups for whom low vitamin D levels have been documented include:

- older people in low- and high-level residential care;⁸⁻¹⁰
- older people admitted to hospital;¹¹
- patients with hip fracture;^{12,13}
- dark-skinned women (particularly if veiled);¹⁴⁻¹⁶ and
- mothers of infants with rickets (particularly if dark-skinned and veiled).¹⁷

Vitamin D deficiency and bone

Circulating 25-OHD and 1,25-(OH)₂D levels decrease with age. This may be a result of age-related factors, such as reduced capacity to produce vitamin D, diminished sunlight exposure,² reduced intake, decline in renal function, disorders associated with abnormal gut function, or reduced synthesis or enhanced degradation of 25-OHD (Box 3).

Mild vitamin D deficiency: Defined as serum 25-OHD levels in the range 25–50 nmol/L, mild deficiency leads to increased parathyroid hormone secretion and high bone turnover.

Moderate vitamin D deficiency: Defined as serum 25-OHD levels of 12.5–25 nmol/L,¹⁸ moderate deficiency has been associated with reduced bone density,¹⁹ high bone turnover²⁰ and increased risk of hip fracture in older people.^{13,21}

Severe vitamin D deficiency: Serum 25-OHD levels of < 12.5 nmol/L, resulting in osteomalacia, are rare in Australia and New Zealand. Patients with severe deficiency may present with bone and muscle pains, weakness and pseudofractures. Bone

2 Recommended adequate intake (AI) for vitamin D from the US Food and Nutrition Board^{6*}

Age (years)	Daily intake	
	(IU)	(µg)
0–50	200	5
51–70	400	10
71 +	600	15

* AIs are recommended levels of dietary intake when there are limited data on the relationship between intake and deficiency. AIs cover the needs of adults regardless of sunlight exposure.

histomorphometry shows classic findings of thickened unmineralised seams, increased osteoclast surfaces, smearing of tetracycline labels and prolonged mineralisation lag times. Cortical thinning occurs because of secondary hyperparathyroidism.

Vitamin D deficiency, muscle function and falls

Vitamin D deficiency is an independent predictor of falls in older women in residential care in Australia.⁸ It is also linked with falls and fragility fractures in both women and older men.^{22,23} In Australia, a randomised clinical trial of vitamin D supplementation in non-institutionalised people is required to determine whether falls and fracture can be prevented in this group.

Vitamin D supplementation

- Some calcium supplements and multivitamin preparations contain vitamin D, but the levels of 32–200 IU per tablet are too low to treat vitamin D deficiency.
- Halibut or cod liver oil capsules contain 400 IU of cholecalciferol (vitamin D₃) per capsule. However, although these are cheap (0.08 cents each), they also contain vitamin A (4000 IU), which may not be beneficial (epidemiological studies suggest that vitamin A excess may be associated with an increased fracture risk²⁴).
- The single pure vitamin D preparation in Australia is Ostelin 1000 (Boots), which contains ergocalciferol (vitamin D₂) (1000 IU or 25 µg) and costs about 24 cents per capsule.
- A larger dose (50 000 IU) of cholecalciferol is available in New Zealand.
- Some commercial 25-OHD assays do not measure 25-OHD₂ (the vitamin D₂ form) as well as they measure 25-OHD₃ (the vitamin D₃ form) and may not be optimal for monitoring replacement therapy.

Dosages required to treat moderate to severe vitamin D deficiency

Vitamin D is stored in fat and muscle and slowly released, particularly during winter.²⁵ In vitamin D-deficient patients, it is necessary to replete the vitamin D stores. While the daily requirement for vitamin D is 400–600 IU, a larger dose is needed to treat patients with deficiency. As vitamin D is distributed in the body fat compartment, which is larger than the plasma and extracellular fluid compartment, large doses are needed before changes in serum 25-OHD are seen. This may explain the lag time seen with vitamin D supplements before normalisation of serum 25-OHD levels. Vitamin D status should be assessed 3–4 months after commencing treatment. Recommendations for management of vitamin D deficiency states are summarised in Box 4.

- High dosages of Ostelin (3000–5000 IU daily for 6–12 weeks) can be used to replete body stores. Indeed, oral doses of 10 000 IU per day have been given without adverse effects for at least 90 days in postmenopausal women.²⁶ Oral dosing can be effective in individuals with malabsorption, unless it is very severe, but higher doses are required.
- Higher single doses of 50 000–500 000 IU orally or 300 000–600 000 IU vitamin D₃ intramuscularly can effectively treat vitamin D deficiency.¹⁸ One or two annual intramuscular doses of 300 000 IU of cholecalciferol have been shown to reverse vitamin D deficiency states.¹⁸ Intramuscular preparations are preferable for malabsorption. However, these formulations are not currently

3 Causes of vitamin D deficiency

Reduced intake or synthesis of cholecalciferol

- Reduced sunlight exposure: ageing, veiling, illness, immobility
- Reduced synthesis from a given ultraviolet exposure: ageing, dark skin
- Combined with low consumption of foods with high vitamin D content

Disorders associated with abnormal gut function and malabsorption

- Small bowel disorders: coeliac disease, sprue, inflammatory bowel disorders, infiltrative disorders (eg, lymphoma, granuloma, amyloid disease), small bowel resection
- Pancreatic insufficiency: chronic pancreatitis, cystic fibrosis
- Biliary obstruction: primary biliary cirrhosis, external biliary drainage (eg, treatment for obstructive jaundice or after surgical resection of the common bile duct)

Reduced synthesis or enhanced degradation of 25-OHD

- Chronic hepatic disorders: hepatitis, cirrhosis
- Drugs: rifampicin, perhaps multiple anticonvulsant drug therapy

available in Australia, and there is concern about inducing hypercalcaemia or hypercalciuria if excessive doses are used. Vitamin D₃ appears more effective than D₂ in raising serum 25-OHD level.²⁷

- Calcitriol (1,25-(OH)₂D₃) is not appropriate for treating patients with deprivational vitamin D deficiency as it has a narrow therapeutic window, may result in hypercalcaemia or hypercalciuria and does not increase serum 25-OHD levels.

Toxicity

Vitamin D intoxication produces hypercalcaemia (with anorexia, nausea, polyuria, constipation, weakness, weight loss, headache, depression, vague aches, stiffness, soft tissue calcification, nephrocalcinosis, hypertension and anaemia). In severe cases, hypercalcaemia may lead to irreversible renal and heart failure²⁸ or coma and death.

- Vitamin D toxicity can be caused by excess oral intake through supplementation,²⁹ but not by prolonged exposure of the skin to UV light.
- No clinical or biochemical evidence of toxicity has been noted with doses up to 4 000 IU (100 µg) daily.³⁰ Although there is little evidence for toxicity with high-dose injections (300 000 IU) at intervals of not less than 3–6 months,¹⁸ the safety of such supraphysiological doses is yet to be established.
- The contraindication for administration of vitamin D is hypercalcaemia.
- Cod liver oil also contains vitamin A, which can be toxic at high doses.

Vitamin D supplementation and fractures

The greatest benefits of vitamin D supplementation are seen in high-risk vitamin D-deficient individuals with demonstrated decreases in bone density. Increases in bone density from 0–4% in vitamin D-insufficient patients and from 10%–40% in vitamin D-deficient patients with osteomalacia have been reported after optimal treatment with vitamin D.^{31,32} It is unlikely that vitamin D supplementation has any role in vitamin D-replete individuals. However, the optimal level of serum 25-OHD is unknown;

4 Recommendations for management of vitamin D deficiency states

High-risk groups

- Elderly people, particularly in residential care
- People with skin cancers or skin-related conditions where avoidance of sunlight is required
- Dark-skinned people, particularly veiled women
- Patients with malabsorption syndromes

Optimal blood test

- 25-hydroxyvitamin D (25-OHD) (note that not all commercially-available assays detect 25-OHD₂ [vitamin D₂ form] optimally)

Dietary sources of vitamin D

- Fatty fish, such as mackerel and herring
- Liver
- Foods fortified with vitamin D (margarine and some milks)

Minimum sun exposure to prevent deficiency

- For most people, exposure of hands, face and arms to 1/3 minimal erythemal dose (MED) most days
- Older people require more frequent exposure

Dietary vitamin D required to prevent deficiency

- At least 200 IU (5 µg) (age < 50 years) or 600 IU (15 µg) (age > 70 years) per day
- Those with substantial sun avoidance may require higher doses

Vitamin D supplementation required to reduce fracture risk in the elderly

- About 1000 IU (25 µg) per day

Vitamin D required to treat moderate to severe deficiency

- 3000–5000 IU (75–125 µg) per day for at least 6–12 weeks; this will usually return serum 25-hydroxyvitamin D levels to the reference range, and allow ongoing treatment with a lower dose (eg, 1000 IU per day).
- For example, Ostelin (1000 IU ergocalciferol; Boots), 3–5 capsules per day for 6–12 weeks, followed by 1 capsule per day.
- An alternative is Calciferol Strong (50 000 IU cholecalciferol; PSM Healthcare), 1 tablet once per month for 3–6 months (available in New Zealand only).
- Most patients will need ongoing treatment with a lower dose (eg, 1000 IU per day).

threshold values ranging from 50 nmol/L to as high as 110 nmol/L have been suggested.^{33,34} Some of the benefit of vitamin D supplementation may relate to improved muscle function and lesser likelihood of falling.

- In randomised controlled trials, vitamin D plus calcium reduced the risk of hip and other non-vertebral fractures in older people living in institutions or at home.^{35,36}
- A comprehensive meta-analysis suggests that vitamin D reduces the risk of vertebral fractures by 37% with no significant reduction in non-vertebral fractures.³⁷
- A recent double-blind randomised placebo-controlled trial of oral cholecalciferol (100 000 IU 4-monthly over 5 years) showed that it reduced the risk of first hip, wrist, forearm or vertebral fracture by 33% in people over the age of 65 years living in the community.³⁸
- Adequate dietary calcium is likely to be required together with adequate vitamin D to reduce fracture rates, as most studies have used a combination of vitamin D and calcium supplementation.

Acknowledgements

We thank the many members of the Australian and New Zealand Bone and Mineral Society (ANZBMS), Osteoporosis Australia (OA), the Endocrine Society of Australia (ESA) and the Cancer Councils of Australia for their suggestions and critical comments; the Australian Radiation Protection and Nuclear Safety Agency for calculating the data and providing information on sun exposure times; and Dr Richard McKenzie (National Institute of Water and Atmospheric Research) for providing the New Zealand data. We also thank Professor BEC Nordin for critical appraisal of the final draft of the position statement and Professor GC Nicholson (Chair, Medical and Scientific Affairs Committee, ANZBMS) for commissioning the project on behalf of ANZBMS.

Consensus process: This position statement was developed by a working group commissioned by the ANZBMS and OA. The first draft was developed by the seven members of the working group with expertise in bone health and osteoporosis. Drafts were circulated to other experts in the area and also to the Cancer Council of Victoria for advice on sun exposure recommendations. The subsequent draft was posted on the ANZBMS website for widespread comment and feedback. Suggested revisions were incorporated with consensus from each member of the working party. Further advice about sun exposure was provided by the Australian Radiation Protection and Nuclear Safety Agency. The final manuscript was reviewed by Councils of the ANZBMS, ESA and OA scientific affairs committees.

Competing interests

None identified.

References

- 1 DeLuca HF, Zierold C. Mechanisms and functions of vitamin D. *Nutr Rev* 1998; 56: S4-S10.
- 2 Holick MF. McCollum Award Lecture, 1994: vitamin D — new horizons for the 21st century. *Am J Clin Nutr* 1994; 60: 619-630.
- 3 Pathak MA, Nghiem P, Fitzpatrick TB. Acute and chronic effects of the sun. In: Freedberg I, Eisen A, Wolff K, et al, editors. *Fitzpatrick's dermatology in general medicine*. 5th ed. Vol 1. New York: McGraw-Hill, 1999: 1598-1607.
- 4 Gies P, Roy C, Javorniczky J, et al. Global Solar UV Index: Australian measurements, forecasts and comparison with the UK. *Photochem Photobiol* 2004; 79: 32-39.
- 5 Pasco JA, Henry MJ, Nicholson GC, et al. Vitamin D status of women in the Geelong Osteoporosis Study: association with diet and casual exposure to sunlight. *Med J Aust* 2001; 175: 401-405.
- 6 Food and Nutrition Board: Institute of Medicine. Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. Washington, DC: National Academy Press, 1997.
- 7 Human vitamin and mineral requirements. Report of a joint FAO/WHO expert consultation. Bangkok, Thailand. Rome: World Health Organization, Food and Agriculture Organization of the United Nations, 2002.
- 8 Flicker L, Mead K, MacInnis RJ, et al. Serum vitamin D and falls in older women in residential care in Australia. *J Am Geriatr Soc* 2003; 51: 1533-1538.
- 9 Sambrook PN, Cameron ID, Cumming RG, et al. Vitamin D deficiency is common in frail institutionalised older people in northern Sydney [letter]. *Med J Aust* 2002; 176: 560.
- 10 Stein M, Scherer S, Walton S, et al. Risk factors for secondary hyperparathyroidism in a nursing home population. *Clin Endocrinol* 1996; 44: 375-383.
- 11 Inderjeeth CA, Nicklason F, Al-Lahham Y, et al. Vitamin D deficiency and secondary hyperparathyroidism: clinical and biochemical associations in older non-institutionalised Southern Tasmanians. *Aust N Z J Med* 2000; 30: 209-214.
- 12 Morris HA, Morrison GW, Burr M, et al. Vitamin D and femoral neck fractures in elderly South Australian women. *Med J Aust* 1984; 140: 519-521.
- 13 Diamond T, Smerdely P, Kormas N, et al. Hip fracture in elderly men: the importance of subclinical vitamin D deficiency and hypogonadism. *Med J Aust* 1998; 169: 138-141.
- 14 Grover SR, Morley R. Vitamin D deficiency in veiled or dark-skinned pregnant women. *Med J Aust* 2001; 175: 251-252.
- 15 Diamond TH, Levy S, Smith A, Day P. High bone turnover in Muslim women with vitamin D deficiency. *Med J Aust* 2002; 177: 139-141.
- 16 Skull SA, Ngeow JY, Biggs BA, et al. Vitamin D deficiency is common and unrecognized among recently arrived adult immigrants from The Horn of Africa. *Intern Med J* 2003; 33: 47-51.
- 17 Nozza JM, Rodda CP. Vitamin D deficiency in mothers of infants with rickets. *Med J Aust* 2001; 175: 253-255.

POSITION STATEMENT

- 18 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.
- 19 Dawson-Hughes B, Dallal GE, Krall EA, et al. Effect of vitamin D supplementation on wintertime and overall bone loss in healthy postmenopausal women. *Ann Intern Med* 1991; 115: 505-512.
- 20 Kipen E, Helme RD, Wark JD, Flicker L. Bone density, vitamin D nutrition, and parathyroid hormone levels in women with dementia. *J Am Geriatr Soc* 1995; 43: 1088-1091.
- 21 Weatherall M. A meta-analysis of 25 hydroxyvitamin D in older people with fracture of the proximal femur. *N Z Med J* 2000; 113: 137-140.
- 22 Pfeifer M, Begerow B, Minne HW, et al. Effects of short-term vitamin D and calcium supplementation on body sway and secondary hyperparathyroidism in elderly women. *J Bone Miner Res* 2000; 15: 1113-1118.
- 23 Bischoff HA, Stahelin HB, Dick W, et al. Effects of vitamin D and calcium supplementation on falls: a randomised controlled trial. *J Bone Miner Res* 2003; 18: 343-351.
- 24 Feskanich D, Singh V, Willett WC, Colditz GA. Vitamin A intake and hip fractures among postmenopausal women. *JAMA* 2002; 287: 47-54.
- 25 Mawer EB, Backhouse J, Holman CA, et al. The distribution and storage of vitamin D and its metabolites in human tissues. *Clin Sci* 1972; 43: 413-431.
- 26 Mastaglia S, Oliveri B, Parisi MS, et al. 10,000 IU of oral vitamin D per day are required to rapidly (3 months) reach adequate 25OHD in osteoporotic women. *J Bone Miner Res* 2003; 18 (Suppl 2): S55.
- 27 Tjellesen L, Hummer L, Christiansen C, Rodbro P. Serum concentration of vitamin D metabolites during treatment with vitamin D2 and D3 in normal premenopausal women. *Bone Miner* 1986; 1: 407-413.
- 28 Swain R, Kaplan B. Vitamins as therapy in the 1990's. *J Am Board Fam Pract* 1995; 8: 206-216.
- 29 Koutkia P, Chen TC, Holick MF. Vitamin D intoxication associated with an over-the-counter supplement. *N Engl J Med* 2001; 345: 66-67.
- 30 Vieth R, Chan PC, MacFarlane GD. Efficacy and safety of vitamin D3 intake exceeding the lowest observed adverse level. *Am J Clin Nutr* 2001; 73: 288-294.
- 31 Parfitt AM. Osteomalacia and related disorders. In: Avioli LV, Krane SM, editors. *Metabolic bone disease and related disorders*. Philadelphia: WB Saunders, 1990.
- 32 Mithal A, Sen I, Naik V, Ravishakar U. Spectacular recovery of bone mineral density following treatment of osteomalacia [abstract]. *J Bone Miner Res* 2000; 15: S577.
- 33 Freaney R, McBrinn Y, McKenna MJ. Secondary hyperparathyroidism in elderly people: combined effect of renal insufficiency and vitamin D deficiency. *Am J Clin Nutr* 1993; 58: 187-191.
- 34 Dawson-Hughes B, Harris SS, Dallal GE. Plasma calcidiol, season, and serum parathyroid hormone concentrations in healthy elderly men and women. *Am J Clin Nutr* 1997; 65: 67-71.
- 35 Chapuy MC, Arlot ME, Duboeuf F, et al. Vitamin D3 and calcium to prevent hip fractures in the elderly women. *N Engl J Med* 1992; 327: 1637-1642.
- 36 Dawson-Hughes B, Harris SS, Krall EA, Dallal GE. Effect of calcium and vitamin D supplementation on bone density in men and women 65 years of age or older. *N Engl J Med* 1997; 337: 670-676.
- 37 Papadimitropoulos E, Wells G, Shea B, et al. Meta analyses of therapies for postmenopausal osteoporosis. VIII Meta analysis of the efficacy of vitamin D treatment in preventing osteoporosis in postmenopausal women. *Endocr Rev* 2002; 23: 560-569.
- 38 Trivedi DP, Doll R, Khaw KT. Effect of four monthly oral vitamin D3 (cholecalciferol) supplementation on fractures and mortality in men and women living in the community: randomised double blind controlled trial. *BMJ* 2003; 326: 469-475.

(Received 26 Nov 2004, accepted 24 Dec 2004)

□