Vitamin D status of older South Africans

K. E. Charlton, D. Labadarios, C. J. Lombard, M. E. J. Louw

Objective. To determine the vitamin D status of older 'coloured' South Africans who had not sustained a fracture.

Design. Cross-sectional analytic study.

Methods. A random sample of 200 non-institutionalised subjects in Cape Town aged ⩾ 65 years was drawn using a two-stage cluster design. Trained fieldworkers interviewed subjects to obtain demographic, dietary and lifestyle data, to draw fasting blood samples for the analysis of serum 25-hydroxyvitamin D (25(OH)D) and other biochemical parameters, and to take anthropometric measurements.

Results. Seventeen per cent of the subjects (95% CI: 11.4 - 22.6%) had serum 25(OH)D levels in the deficient range for the elderly (< 10 ng/ml); 7.5% (95% CI: 3.6 - 11.4%) had concentrations in the moderately severe range of deficiency (< 8 ng/ml). Sixty-three per cent of the subjects had raised serum alkaline phosphatase concentrations. Regression modelling showed neither a sex difference in 25(OH)D levels nor a sex-age interaction; however, a negative association with age was found ($r = -0.18$; $P < 0.05$). Mean oral vitamin D intake was low (3.6 (SD = 2.7) µg and 2.8 (SD = 1.7) µg for men and women, respectively), but no association between dietary vitamin D intake and serum 25(OH)D was found.

Conclusions. The prevalence of suboptimal vitamin D status was high. However, the interpretation of the data, with regard to bone health, is limited by the cross-sectional design of the study. Further investigation is required to determine the potential benefits of intervention in this age group.

S Afr Med J 1996; **86:** 1406-1410.

In South Africa, 1.7 million people are aged 65 years and over, a figure projected to rise to more than 7 million by the year 2035.[1] Bone health is a major determinant of quality of life in the elderly[2] and certainly a major financial drain on health care resources.[3] In this regard, it has been estimated that more than 1.5 million Americans sustain fractures relating to osteoporosis at an annual cost of $10 billion,[4] an expenditure which, it is projected, will more than double in the next 30 years.[3]

Decreased bone mass is an important factor predisposing to bone fragility. Apart from nutrition, bone mass is also influenced by age, genetics, gonadal hormone status, physical activity, lifestyle and pharmacological agents.[5] Bone health throughout life is primarily dependent on the complex interrelationship between parathyroid hormone (PTH), vitamin D and its metabolites (25-hydroxy (25(OH)D) and 1.25-dihydroxy vitamin D ($1.25(OH)_2D$)), as well as calcium;[6] other important nutrients associated with bone health include vitamin C, protein, trace elements and vitamin K.

Vitamin D[7,8] and calcium[9-12] status is known to be adversely affected by age. Although marginal status of these nutrients has frequently been reported in the elderly,[13] the populations studied tend to be biased towards institutionalised elderly, hospitalised patients, or patients who present with specific medical conditions such as osteoporosis and fractures. Such information has, however, not been documented in non-institutionalised elderly 'coloured' (mixed ancestry) South Africans who have not sustained a fracture.

Methods

A sample of 200 non-institutionalised coloured subjects (104 women; 96 men) aged 65 years and older and resident in Cape Town was recruited for a cross-sectional analytic study using a two-stage cluster sampling technique. The study area consisted of suburbs in Cape Town, spanning four magisterial districts, Bellville, Goodwood, Cape Town and Wynberg. Approximately 18 500 coloured elderly lived in this area, which was subdivided into 21 sub-areas, according to the enumeration areas of the 1991 Population Census data.[14] A random sample of 10 of the sub-areas was selected, proportional to the number of elderly living there. At the second sampling stage ten random starting points were selected in each sub-area. The fieldworker started at each point and systematically screened the households in a prescribed way until an elderly man or woman was found. Exclusion criteria included institutionalisation and mental confusion, assessed on the basis of a subject's inability to answer three questions relating to his/her name, address and the current year. The study formed part of the International Union of Nutritional Sciences Committee on Nutrition and Ageing's cross-cultural studies on food habits and health in later life.[15] Written informed consent was obtained from all participants and the study was approved by the Ethics and Research Committee of the University of Cape Town and Allied Teaching Hospitals.

Trained fieldworkers interviewed subjects in their homes to obtain demographic, dietary and lifestyle data, to draw blood samples and to take anthropometric measurements. Physical activity levels were assessed by asking the subjects to estimate the duration of time spent performing five common activities (walking, light and heavy housework, gardening and participating in a sport) during the week prior to the interview. Dietary intake was assessed using a

HSRC/UCT Centre for Gerontology, University of Cape Town

K. E. Charlton, M.SC., PG. DIP. DIET.

Department of Human Nutrition, University of Stellenbosch, Tygerberg, W. Cape

D. Labadarios, M.B. CH.B, PH.D., F.A.C.N.

M. E. J. Louw, M.SC.

Centre for Epidemiological Research in Southern Africa, Medical Research Council, Parowvallei, W. Cape

C. J. Lombard, PH.D.

validated quantified food frequency questionnaire, using the past month as the reference period; the dietary methods are described elsewhere.[16]

Height and weight were recorded and body mass index (BMI) was calculated as weight (kg)/height squared (m^2). Fasting blood samples were drawn from all consenting subjects (N = 191) for the determination of serum albumin, calcium, alkaline phosphatase, phosphate, urea, creatinine and electrolytes (Hitachi 747 auto-analyser) and serum 25-hydroxyvitamin D (25(OH)D) values.[17]

Differences between the variables according to sex were tested using the Wilcoxon 2-sample test. Regression modelling was used to investigate the association between 25(OH)D concentrations and sex and age. The associations between 25(OH)D and oral vitamin D intake, BMI, serum calcium and serum alkaline phosphatase levels by sex were investigated using Spearman correlation coefficients.

Results

The mean age of the subjects was 73.7 years (SD = 5.9; range 65 - 92 years). The age distribution of the sample was similar to that of the national coloured population aged 65 years and older,[14] for both sexes. The mean serum values and percentile distribution for the measured biochemical parameters relating to bone health (serum calcium, phosphate, alkaline phosphatase and 25(OH)D) are shown in Table I. All mean values were within the normal laboratory ranges except for alkaline phosphatase, which was marginally above the upper limit of normal (> 70 IU/l). Hypocalcaemia (< 2.1 mmol/l) was not seen in any of the subjects, whereas marginal hypophosphataemia (> 0.63 - < 0.80 mmol/l) was recorded in 5 men and hypercalcaemia (> 2.6 mmol/l) in 2 women. In contrast, 63% of the subjects had raised serum alkaline phosphatase concentrations; 22% had serum alkaline phosphatase levels which exceeded 100 IU/l, and 2% had levels exceeding 200 IU/l. Alkaline phosphatase levels were not associated with age in either sex, and were negatively correlated with 25(OH)D levels in men ($r = -0.28$; $P < 0.05$) and women ($r = -0.40$; $P < 0.0001$). Serum electrolyte, urea and creatinine concentrations were within the laboratory normal range in all subjects. Mean serum gamma-glutamyl transferase (GGT) concentrations fell within the normal range for both men and women (32 (49) and 23 (24) IU/l, respectively); however, GGT was raised (> 40 IU/l) in 13 (14%) men and 7 (7%) women tested. In 3 of the men with this derangement, the mean corpuscular volume of red cells was increased, suggesting excessive alcohol intake even though these subjects also had marginal increases of serum alkaline phosphatase activity. In most cases, the derangement of GGT was accompanied by mild derangements in serum alkaline phosphatase activity. Reported alcohol intake was low for both men and women (3.0 (7.4) and 0.3 (1.4) g/day, respectively).

The percentages of men and women with nutrient intakes of less than 100% and 67% of the RDA[18] are shown in Fig. 1. Mean dietary vitamin D intake fell below the RDA[18] of 5 µg/day (3.6 (SD = 2.7) µg and 2.8 (SD = 1.7) µg for men and women, respectively; $P < 0.05$). Mean dietary calcium intake, which did not differ between the sexes, was 490 mg/day (i.e. 61% of the RDA). Mean daily protein intakes of 1.1 (0.5) g/kg body weight for men and 1.0 (0.4) g/kg for women were assumed to indicate an adequate dietary intake.[19] No association was found between dietary vitamin D intake and serum 25(OH)D.

Seventeen per cent of the subjects (95% CI: 11.4 - 22.6%) had serum 25(OH)D levels in the deficient range for the elderly (i.e. < 10 ng/ml) (19.3% and 15.6% for men and women, respectively);[7] 7.5% (95% CI: 3.6 - 11.4%) had serum levels which were in the moderately severe range of deficiency (< 8 ng/ml).[20] Regression modelling showed no sex difference or sex-age interaction in 25(OH)D levels; however, an age effect was found ($P < 0.05$). A combined correlation for both sexes was therefore performed for age and 25(OH)D, which yielded a weak negative association

Table I. Summary statistics for serum albumin, calcium, 25(OH)D, phosphate and alkaline phosphatase

Parameter	No.	Reference range	Mean	SD	Q_1	Median	Q_3	$Q_3 - Q_1$
Albumin (g/l)								
Men	93	35 - 60	45	3.9	43	45	47	4
Women	97		44	3.7	42	44	47	5
Total	190		44	3.8	42	45	47	5
Calcium (mmol/l)								
Men	93	2.10 - 2.60	2.38	0.09	2.31	2.38	2.44	0.13
Women	97		2.39	0.12	2.30	2.38	2.47	0.17
Total	190		2.38	0.11	2.30	2.38	2.45	0.15
Phosphate (mmol/l)								
Men	92	0.80 - 1.40	1.04	0.17	0.92	1.04	1.17	0.25
Women	95		1.14	0.15	1.03	1.14	1.24	0.21
Total	187		1.09	0.16	0.97	1.08	1.21	0.24
25(OH)D (ng/ml)								
Men	83	> 10	14.5	4.7	10.4	14.2	18.0	7.6
Women	90		15.1	5.1	11.5	15.6	18.2	6.7
Total	173		14.8	4.9	10.9	14.9	18.1	7.2
Alkaline phosphatase (IU/l)								
Men	93	30 - 70	87	52	61	77	96	35
Women	97		93	65	65	79	98	33
Total	190		90	59	64	78	98	34

Q_1 = 25th percentile; Q_3 = 75th percentile; $Q_3 - Q_1$ = interquartile range.

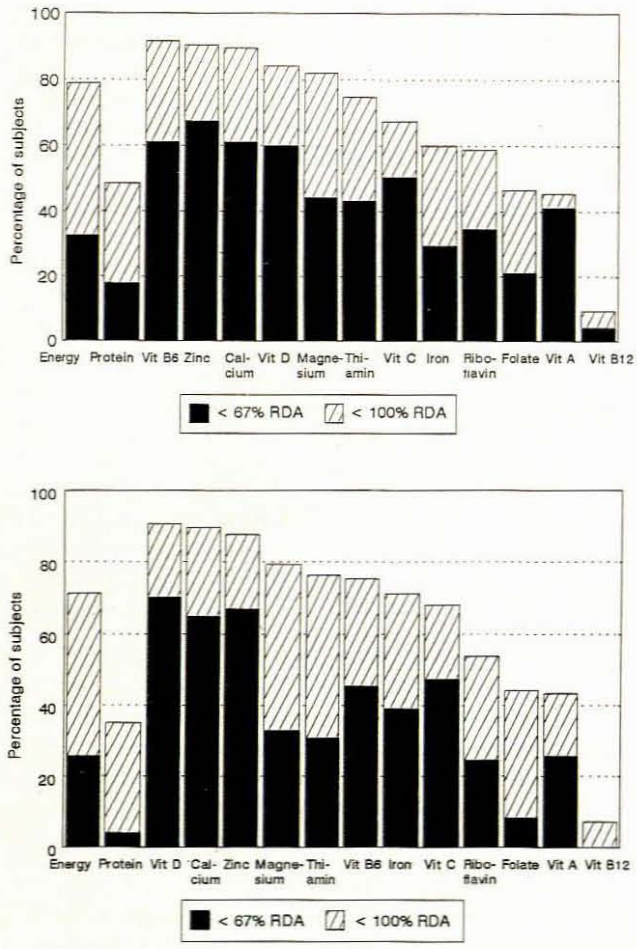

Fig. 1. Percentage of subjects with nutrient intakes below 100% and 67% of the RDA — men (above) **and women** (below).

($r = -0.18$; $P < 0.05$) (Fig. 2). Mean 25(OH)D levels, according to the age categories 65 - 74 years and 75+ years, were 15.0 (4.8) ng/ml and 13.6 (0.6) ng/ml for men and 16.1 (5.2) ng/ml and 13.4 (4.6) ng/ml for women, respectively.

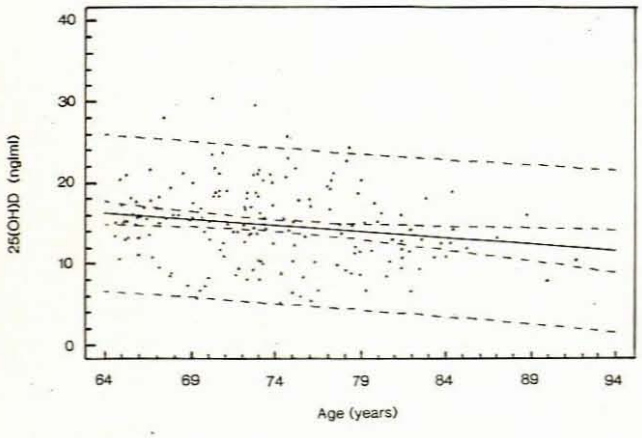

Fig. 2. Association between age and serum 25(OH)D.

Serum 25(OH)D was found to be positively associated with BMI in men ($r = 0.39$; $P < 0.0005$); however, no association was found for women. BMI decreased significantly with age in women ($r = -0.25$; $P < 0.05$), but no age effect was found for men. The reported time spent performing outdoor physical activities was low. In most cases, subjects spent less than an hour a week either walking, gardening or participating in a sport.

Discussion

This study found, for the first time, that the elderly coloured population of Cape Town has a high prevalence of suboptimal vitamin D status, as determined by serum 25(OH)D levels. In addition, the prevalence of raised serum alkaline phosphatase concentrations (> 100 IU/l) was found to be 22% and was not associated with gender.

The low serum 25(OH)D levels found in this sample of elderly subjects are consistent with findings from studies of elderly populations in other countries. In North America and Scandinavia, nearly 25% of healthy elderly subjects have low values in the winter but fewer than 5% have low levels throughout the remainder of the year.[21-26] In the UK, 7% of 925 elderly subjects studied[8] were found to have very low serum 25(OH)D levels (< 5 ng/ml); similarly, in New Mexico, USA, 15% of healthy, free-living elderly subjects had low serum 25(OH)D concentrations (< 8 ng/ml);[23] the greatest frequency of low levels occurred during the late winter and early spring. In the present study in Cape Town (latitude 35°S), blood samples were collected during the late winter months of August and September.

Seasonal variations in plasma concentrations of 25(OH)D have been well documented.[8,27-29] In South Africa, these seasonal variations in plasma levels in the elderly have been associated with the prevalence of fractures of the femoral neck, in spite of an abundance of sunlight in the country.[30] In this regard, a recent *in vitro* study demonstrated a significant seasonal variation in the production of vitamin D from its precursor in the skin, 7-dehydrocholesterol, through sunlight exposure in Cape Town; minimal vitamin D was formed during the winter months of May to September inclusive.[31] It may therefore be assumed that the distribution of serum 25(OH)D levels found in the present study probably represents lower values than those expected in the summer months of the year and implies a greater reliance on dietary sources of vitamin D in winter months. A decrease in the seasonal variation of 25(OH)D concentrations in older British subjects with age has been demonstrated and has been attributed to an accompanying decrease in outdoor physical activity levels.[8] Although the majority of the subjects in the present study reported high levels of mobility and an absence of physical disability,[16] the time spent performing outdoor physical activities was very low. However, the questions relating to physical activity levels lacked sensitivity in assessing habitual exposure to ultraviolet light and further analyses in this regard were not warranted.

Obesity has been shown to be associated with lower 25(OH)D levels.[32] The mechanism for this remains unknown; it is hypothesised that there is a greater uptake of vitamin D by adipose tissue or that its metabolic clearance is increased. In contrast to the findings of previous studies,

BMI was positively associated with 25(OH)D levels in men in the present study; no association was found in women. Age appears to be a confounding factor in this association since BMI decreased significantly with age in women but not in men.

Dietary intake of vitamin D in this study was low, consistent with the dietary trends reported for other elderly populations.[5,33,34] However, in contrast to these studies, no association was found between oral vitamin D intake and serum 25(OH)D concentrations. In the elderly vitamin D status may be compromised not only by an inadequate dietary vitamin D intake but also by the age-related decline in the absorption of the vitamin,[35] by gastro-intestinal surgery and malabsorption, as well as by impaired hepatic metabolism associated with liver disease or anticonvulsant therapy.[36]

Vitamin D has complex effects on bone metabolism and the exact role and implications of various serum levels across the normal range are uncertain in elderly populations. In the elderly, hypovitaminosis D is associated with an elevation in serum alkaline phosphatase levels.[34,37,38] Although the concentration of the latter is known to increase with age[37] and with hepatic dysfunction,[38] the concomitant high prevalence of suboptimal serum 25(OH)D levels in this study may be indicative of early underlying bone disease. It may be argued that the hypophosphataemia seen in a small number of the subjects supports this interpretation, since serum calcium and phosphate alterations vary, depending on the stage of severity of osteomalacia, and do not significantly decrease until serum 25(OH)D concentrations decrease to below 2 ng/ml.[39] Certainly in this regard, mean serum calcium, although within the given normal range, was nevertheless significantly ($P < 0.01$) lower in the group of subjects with serum 25(OH)D concentrations of < 8 ng/ml. The interpretation of these findings is, however, severely hampered by the lack of serum PTH measurements in this study. With regard to other causes of raised alkaline phosphatase concentrations, it is noteworthy that the level of GGT, a sensitive but somewhat nonspecific marker of hepatocyte dysfunction, was increased in 10% of subjects, which is likely to be related to an excessive alcohol consumption. Although reported alcohol intake was low, the analyses of GGT, together with high identified prevalences of macrocytosis, raised serum ferritin levels and folate deficiency in the men,[16] suggest that habitual alcohol intake was probably under-reported.

The role of vitamin D deficiency in the aetiology of osteoporosis is not well established; however, the available evidence indicates that an adequate vitamin D status (as determined by dietary intake or vitamin D supplementation) is inversely related to age-related bone loss, its prevention and the prevalence of fractures.[40,41] Whether the beneficial preventive effect of the vitamin is because it facilitates adaptation to marginal dietary calcium intake, or because of direct extra-intestinal effects of the vitamin and its metabolites, is not clear at present. A consensus seems to be emerging that the prevention of vitamin D deficiency in the elderly, who are unable or unwilling to obtain adequate sunlight exposure, requires oral vitamin D supplementation.[42] The lower seasonal fluctuation in serum 25(OH)D shown in the elderly in the USA versus older adults in European countries provides further evidence that dietary factors are important in the maintenance of optimal vitamin D status. Both older and younger adults in the USA have a higher vitamin D intake than in Europe due, in part, to the vitamin D fortification of dairy products and higher oral supplementation.[42] This is of particular relevance to the population studied since, although the prevalence of osteoporosis and the incidence of fracture rates are unknown, the appendicular bone mass of coloured South Africans has been shown to be significantly lower than that of sex- and age-matched Caucasians.[43]

In conclusion, although the cross-sectional design of the present study limits the interpretation of the data on vitamin D status in respect of bone health, the relative health risks of low serum 25(OH)D concentrations in the elderly are well documented in the literature. Randomised controlled trials are required to evaluate the potential benefits of any intervention in this age group. The importance of genetics to bone mineral density is undisputed; however, preventive measures such as physical exercise, moderate alcohol and caffeine consumption, smoking cessation, and eating sufficient calcium- and vitamin D-rich foods are known to influence the attainment of peak bone mass, the onset of bone loss and the rate of bone loss and its consequences, as manifested in fractures.

Financial assistance from the South African Sugar Association, the Zerilda Steyn Memorial Trust and the Medical Research Council (D. Labadarios) is acknowledged.

REFERENCES

1. Hofmeyr BE, Mostert WP. *Demographic Ageing of the South African Population.* Pretoria: Human Sciences Research Council, 1989.
2. Marottoli RA, Berkman LF, Cooney LM. Decline in physical function following hip fracture. *J Am Geriatr Soc* 1992; **40:** 861-866.
3. Cummings SR, Rubin SM, Black D. The future of hip fractures in the United States: numbers, costs and potential effects of postmenopausal estrogen. *Clin Orthop* 1990; **252:** 163-166.
4. Riggs BL, Melton LJ III. Involutional osteoporosis. *N Engl J Med* 1986; **314:** 1676-1686.
5. Heaney RP. Nutritional factors in osteoporosis. *Ann Rev Nutr* 1993; **13:** 287-316.
6. Holick MF. McCollum Award Lecture 1994: Vitamin D — new horizons for the 21st century. *Am J Clin Nutr* 1994; **60:** 619-630.
7. Baker MR, Peacock M, Nordin BEC. The decline in vitamin D status with age. *Age Ageing* 1980; **9:** 249-252.
8. Dattani JT, Exton-Smith AN, Stephen JML. Vitamin D status of the elderly in relation to age and exposure to sunlight. *Hum Nutr Clin Nutr* 1984; **38C:** 131-137.
9. Heaney RP, Recker RR, Saville PD. Menopausal changes in calcium balance performance. *J Lab Clin Med* 1978; **92:** 953-963.
10. Gallagher JC, Riggs BL, Eisman J, Hamstra A, Arnaud SB, DeLuca HF. Intestinal calcium absorption and serum vitamin D metabolites in normal and osteoporotic patients: effects of age and dietary calcium. *J Clin Invest* 1979; **64:** 729-736.
11. Recker RR, Saville PD, Heaney RP. Effect of estrogens and calcium carbonate on bone loss in postmenopausal women. *Ann Intern Med* 1977; **87:** 647-655.
12. Tsai K-S, Heath H III, Kumar R, Riggs BL. Impaired vitamin D metabolism with aging in women: possible role in pathogenesis of senile osteoporosis. *J Clin Invest* 1984; **73:** 1668-1672.
13. Cummings SR, Kelsey JL, Nevvitt MC, O'Dowd KJ. Epidemiology of osteoporosis and osteoporotic fractures. *Epidemiol Rev* 1985; **7:** 178-208.
14. Central Statistical Service. *Population Census, 1991. Summarised Results after Adjustment for Undercount.* Pretoria: CSS, 1992.
15. Wahlqvist ML, Kouris-Blazos A, Hage B, *et al.* Food habits in later life: a cross-cultural study. International Union of Nutritional Sciences Committee on Nutrition and Ageing. Preliminary results from communities in Australia, Greece, China and Sweden. *Age Nutr* 1992; **3:** 151-154.
16. Charlton KE, Wolmarans P, eds. *Dietary Intake, Food Habits and Health of Older Coloured South Africans.* Cape Town: HSRC/UCT Centre for Gerontology, 1995.
17. Shephard GS, Carlini SM, Hanekom C, Labadarios D. Analysis of 25-hydroxyvitamin D in plasma using solid phase extraction. *Clin Chim Acta* 1987; **167:** 231-236.
18. Subcommittee on the Tenth Edition of the RDAs (Food and Nutrition Board, Commission on Life Sciences, National Research Council). *Recommended Dietary Allowances.* 10th ed. Washington, DC: National Academy Press, 1989: 1-285.
19. Young VR, Pellet PL. Protein intake and requirements with reference to diet and health. *Am J Clin Nutr* 1987; **45:** 1323-1343.
20. Asknes L, Rødland O, Aarskog D. Serum levels of vitamin D_3 and 25-hydroxyvitamin D_3 in elderly and young adults. *Bone Miner* 1988; **3:** 351-357.
21. Delvin EE, Imbach A, Copti M. Vitamin D nutritional status and related biochemical indices in an autonomous elderly population. *Am J Clin Nutr* 1988; **48:** 373-378.
22. Von Knorring J, Slatis P, Weber TH, Helenius T. Serum levels of 25-hydroxyvitamin D, 24,25 hydroxyvitamin D and parathyroid hormone in patients with femoral neck fracture in Southern Finland. *Clin Endocrinol* 1982; **17:** 189-194.
23. Omdahl JL, Garry PJ, Hunsaker LA, Hunt WC, Goodwin JS. Nutritional status in a healthy elderly population: vitamin D. *Am J Clin Nutr* 1982; **36:** 1125-1133.

24. Clemens TL, Zhou X-Y, Myles M, Endres D, Lindsay R. Serum vitamin D_3 and serum vitamin D_3 metabolite concentrations and absorption of vitamin D_3 in elderly subjects. *J Clin Endocrinol Metab* 1986: **63:** 656-660.
25. Lukert BP, Carey M, McCarty B, *et al.* Influence of nutritional factors on calcium-regulating hormones and bone loss. *Calcif Tissue Int* 1987; **40:** 119-125.
26. Rudman D, Rudman IW, Mattson DE, *et al.* Fractures in the men of a Veterans' Administration nursing home: relation to 1,25-dihydroxyvitamin D. *J Am Coll Nutr* 1989; **43:** 199-201.
27. Stamp TCB, Round JM. Seasonal changes in human plasma levels of 25-hydroxyvitamin D. *Nature* 1974; **247:** 563-565.
28. McLaughlin M, Fairney A, Lester E, Raggatt PR, Brown DJ, Wills MR. Seasonal changes in serum 25-hydroxycholecalciferol in healthy people. *Lancet* 1974; **1:** 536-538.
29. Stryd RP, Gilbertson TJ, Brunden MN. A seasonal variation study of 25-hydroxyvitamin D_3 serum levels in normal humans. *J Clin Endocrin Metab* 1979; **48:** 771-775.
30. Pettifor JM, Ross FP, Solomon L. Seasonal variation in serum 25-hydroxy-cholecalciferol concentrations in elderly South African patients with fractures of femoral neck. *BMJ* 1978; **1:** 826-827.
31. Pettifor JM, Moodley GP, Hough FS, *et al.* The effect of season and latitude on *in vitro* vitamin D formation by sunlight in South Africa. *S Afr Med J* 1996; **86:** 1270-1272.
32. Bell NH, Epstein S, Greene A, *et al.* Evidence for alteration of the vitamin D endocrine system in obese subjects. *J Clin Invest* 1985; **76:** 370-373.
33. Parfitt AM, Gallagher JC, Heaney RP, Johnston CC, Neer R, Whedon GD. Vitamin D and bone health in the elderly. *Am J Clin Nutr* 1982; **36:** 1014-1031.
34. McKenna MJ, Freaney R, Meade A, Muldowney FP. Hypovitaminosis D and elevated serum alkaline phosphatase in elderly people. *Am J Clin Nutr* 1985; **41:** 101-109.
35. Montgomery RD, Heaney MR, Ross IN, *et al.* The aging gut: a study of intestinal absorption in relation to nutrition in the elderly. *Q J Med* 1978; **47:** 197-211.
36. Francis RM. The pathogenesis of osteoporosis. In: Francis R, ed. *Osteoporosis: Pathogenesis and Management.* Lancaster: Kluwer Academic, 1990: 51-80.
37. Leask RGS, Andrews GR, Caird FI. Normal values for sixteen blood constituents in the elderly. *Age Ageing* 1973; **2:** 14-23.
38. McKenna MJ, Freaney R, Casey OM, *et al.* Osteomalacia and osteoporosis: evaluation of a diagnostic index. *J Clin Pathol* 1983; **36:** 245-252.
39. McKenna MJ. Vitamin D and bone disease in Ireland (Thesis). Dublin: University College, 1984.
40. Lukert B, Higgins J, Stoskopf M. Menopausal bone loss is partially regulated by dietary intake of vitamin D. *Calcif Tissue Int* 1992; **51:** 173-179.
41. Heikinheimo RJ, Inkovaara JA, Harju EJ, *et al.* Annual injection of vitamin D and fractures of aged bones. *Calcif Tissue Int* 1992; **51:** 195-210.
42. McKenna MJ. Differences in vitamin D status between countries in young adults and the elderly. *Am J Med* 1992; **93:** 69-77.
43. Wagener GW, Hough FS. Metacarpal bone mass in the white and coloured populations of the Cape. *S Afr Med J* 1987; **72:** 205-208.

Accepted 9 Sep 1996.