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Vitamin D status in Oceania

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Introduction

Oceania is a geographical, often geopolitical, region consisting of numerous states, mostly islands in the Pacific Ocean and vicinity. It generally includes Australia and New Zealand, and is often taken to include New Guinea and Pacific Islands. Though there have been a number of published studies evaluating vitamin D status in Australia and New Zealand, data from the rest of Oceania are lacking.

Prevalence of vitamin D deficiency/insufficiency in Australia and New Zealand varies, but is considered to be much higher than previously thought. The magnitude of this problem has a broad expression across a wide latitudinal range (Table 1). Even in areas of low latitude, vitamin D insufficiency was identified in approximately one-third of the general community. The collective data (Table 1) suggests though vitamin D insufficiency decreases with decreasing latitude in the general community, this is not reflected in all subgroups, suggesting importance of other factors.

Currently, there is no standard definition of optimal vitamin D status. Several criteria have been used to define "sufficient" 25-hydroxyvitamin D (25-OH D) level, including the level associated with optimal suppression of parathyroid hormone (PTH) levels, greatest calcium absorption, highest bone mineral density, lowest rates of bone loss, lowest rates of falling and lowest fracture rates. Based on available evidence, it has been suggested that, although estimates of serum 25-OH D level needed for optimal suppression of PTH varied widely, optimal vitamin D status clusters in the 75 to 80nmol/L (30-32ng/ml) range [1]. The authors also suggested a low-

Table 1 Prevalence of vitamin D deficiency/insufficiency, as reported in the literature, stratified according to groups and latitudes of city of residence.

	"Medium" latitude (30° - 40°)		"High" latitude (>40°)	
	Vitamin D Deficiency* (%)	Vitamin D Insufficiency** (%)	Vitamin D Deficiency* (%)	Vitamin D Insufficiency** (%)
Elderly				
Residential care	63[4,12] (n=572)+	61[12](n=186)	-	-
Community	15[12] (n=70)	41[12,30](n=2054)+	17[11](n=52)	26[29](n=38)
Hip fractures	-	-	6[79](n=91)	-
Rehabilitation wards	-	-	67[11](n=109)	-
Immigrants	33[12](n=91)	68[12,13](n=181)+	-	-
Dark-skinned/ veiled	73[15,16](n=201)+	-	-	-
Pregnant women	15[23](n=971)	-	61[34](n=90)	87[34](n=90)
Mothers of infants with rickets	81[22](n=31)	-	-	-
People with disability	-	-	-	34[17](n=136)
General population in community#	7[25](n=861)	33[25,27](n=1422)+	-	55[17,27](n=1003)+

* *Vitamin D deficiency is variably defined as levels <23 to <30nmol/L (9.2 to 11.2ng/ml)*
** *Vitamin D insufficiency is variably defined as levels <37 to <50nmol/L (14.8 to 20.0ng/ml)*
\+ *Collective prevalence of vitamin D deficiency or insufficiency in stipulated studies*
\# *In areas of low latitude, prevalence of vitamin D insufficiency was 32%19,27 (n=792)*

er risk of fracture with serum 25-OH D levels higher than 75nmol/L (30ng/ml). Values of >75 to 80nmol/L (30-32ng/ml) have been suggested as sufficient, 25-OH D levels <25 to 30nmol/L (9.2 to 11.2ng/ml) as 'deficient' and levels <37 to 50nmol/L (14.8 to 20.0ng/ml) as 'insufficient'.

Australia

It has long been assumed that vitamin D deficiency is generally uncommon in countries with high sunlight exposure. Hence, in Australia, the National Health and Medical Research Council's recommended dietary intake for vitamin D assumes that most Australians receive sufficient sunlight to more than adequately meet their vitamin D requirements [2]. However, several studies have shown low vitamin D levels in a significant proportion of Australians and a large number of at risk groups within the community. The groups at greatest risk are:

- Older persons living in residential care,
- Dark-skinned and veiled women (particularly in pregnancy) and their infants,
- Those with skin conditions where avoidance of sunlight is required and
- Patients with malabsorption, eg coeliac disease [3]

In a prospective study evaluating prevalence of vitamin D deficiency in older people in residential aged-care facilities in the northern Sydney area, vitamin D deficiency (serum 25-OH D <28nmol/L [11.2ng/ml]) was present in 68% of men and 86% of women, with a mean serum 25-OH D level of 17nmol/L (6.8ng/ml) [4]. Marginal deficiency of 25-OH D (levels ranging from 25 to 50nmol/L [10.0 to 20.0ng/ml]) was reported in 76% of nursing home residents and 53% of hostel residents [5].

There is evidence of an association between low vitamin D levels and falls. A prospective cohort of older people (mean age 83.7 years) in residential care facilities across several states of Australia identified vitamin D deficiency (<25nmol/L [10.0ng/ml]) in 22% of women in low-level care and 45% in high-level care [6]. After adjusting for other variables, log serum 25-OH D level remained an independent predictor of time to first fall. Adjusted hazards ratio of 0.74 (0.59-0.94) implied a 20% reduction in the risk of falling with a doubling of the vitamin D level. A cross-sectional study of residents in an aged-care institution in Melbourne similarly reported those who fell had lower 25-OH D levels than other residents (median 22nmol/L[8.8ng/ml] vs 29nmol/L[11.6ng/ml], p=0.02) [7]. In addition, residents who fell had higher serum PTH levels (median 6.2 vs 4.8pmol/L, p<0.01). Serum PTH remained independently associated with falling in a multiple logistic regression analysis (odds ratio 5.6 [1.7-18.5]). Vitamin D deficiency (and insufficiency) may cause or worsen poor muscle strength and so increase risk of falling. A significant association between leg muscle strength and 25-OH D levels was observed in a cross-sectional study in females aged 60 years and older, with long-bone fractures in Western Australia [8]. In that study, leg muscle strength was most strongly associated with 25-OH D levels >50nmol/L [20ng/ml] (r=0.51, p<0.001).

Suboptimal vitamin D levels contribute to the development of osteoporosis, which is a major risk factor for hip fractures, one of the major causes of death and disability in the elderly. A case series of elderly patients (mean age 81.3 years) admitted with a hip fracture to Royal Hobart Hospital, Tasmania found vitamin D deficiency (<28nmol/L [11.2ng/ml]) in 67% [9]. In an observational, cross-sectional population-based study set in Geelong, involving 27,203 women >55 years, a fall in 25-OH D levels in winter was noted to be accompanied by increases in PTH levels, bone resorption, proportion of falls resulting in fracture and frequency of hip and wrist fractures [10].

With more than 72,500 nursing home residents and 60,000 hostel residents in Australia in 1997, these findings highlight vitamin D deficiency as a significant public health problem. Importantly community dwelling elderly are at risk as well. A cross-sectional study of older Tasmanian subjects (mean age 79 years) reported 17% of the community group to be vitamin D deficient (<28nmol/L [11.2ng/ml]) [11]. A significant predictor of vitamin D level in this study was poor physical function and activity.

Low vitamin D status has been reported to be highly prevalent among housebound elderly and among ethnic communities, especially Asians; including in Australia, which has a multicultural population. In a cross-sectional study involving elderly living in assisted care and the community in Sydney metropolitan area, elderly people of Middle Eastern origin were found to be at 4-fold risk and elderly of Vietnamese origin at 3-fold risk of vitamin D deficiency (defined as <25nmol/L [10ng/ml]) compared to their counterparts of European Caucasian origin [12]. The study included recently arrived young-middle-aged Chinese immigrants, of whom 28% were vitamin D deficient. In a further study evaluating 25-OH D levels in free-living elderly of Vietnamese and Australian/British origin, levels <37nmol/L (14.8ng/ml) were found in 63% and 37% respectively [13]. Cultural barriers to sun exposure, low vitamin D intake, reduced exercise levels and a high percentage of body fat levels in the immigrant groups were important potential contributors to vitamin D deficiency.

Women who wear a veil for cultural reasons have an increased prevalence of vitamin D deficiency. Skin pigmentation also affects ultraviolet light absorption, hence dark-skinned migrants from Africa are also at risk. In 2004 to 2005, 75% of the 7,000 refugees settling in Australia were from African countries and 20% were from the Middle East. Refugees may be exposed to less sunlight in Australia than in their country of origin because of an indoor lifestyle or an increased latitude. Fear of physical harm could be a contributing factor to refugees spending more time indoors. Refugee health centres across Australia confirmed vitamin D deficiency, defined as <50nmol/L (20ng/ml) in 40-80% of refugee patients [14]. This is usually asymptomatic. One study of veiled and dark skinned pregnant women in an antenatal clinic in Melbourne, Victoria, found that the majority (80%) were actually vitamin D deficient (<22.5nmol or 9ng/ml) [15]. A cross-sectional study of a random sample of Muslim women aged 20-65 years living in an urban community in south-western Sydney found vitamin D deficiency (defined as <30nmol/L [12ng/ml]) in 68%, hyperparathyroidism in 39% and high bone turnover in 46% [16]. The aetiology of vitamin D deficiency was multi-factorial beyond a lack of ultraviolet light exposure, with dietary differences and skin pigmentation being other possible factors.

There is a strong association between disability, sun exposure and vitamin D status. Greater disability and associated reduced exposure to sun may contribute to the high prevalence of vitamin D insufficiency reported in a population-based multiple sclerosis (MS) case sample[17]. Amongst 136 prevalent cases with MS in Tasmania, those individuals with greater disability were more likely to have vitamin D insufficiency than controls with OR of 3.07 (1.37-6.90) for 25-OH D levels <40nmol/L (16ng/ml). There was no such increased risk in those with lesser disability [OR=0.87 (0.41-1.86)]. Overall, 34% of people with MS had 25-OH D levels <40nmol/L versus 23% of community controls.

Vitamin D deficiency has major health implications for young women, particularly during the child-bearing years; however, there are few studies involving healthy, young adults. In a large hospital-based survey, involving 2,690 women, with differing age and ethnic backgrounds, residing in suburbs across inner West and North Melbourne, vitamin D insufficiency (<50nmol/L [20ng/ml]) was reported in 80% of all referrals. Mean age of this group was 29 years, suggesting that vitamin D insufficiency is more prevalent in younger women than anticipated [18]. Even in a subtropical climate like southeast Queensland, 23% of younger adults (mean age 42 years) had 25-OH D levels <50nmol/L (20ng/ml) [19].

An assumption in Australia has been that all young athletes have good vitamin D levels. However, a survey of 18 females in an elite gymnastics program found 83% to have levels less than 75nmol/L (30ng/ml), the current recommended optimal 25-OH D level [20]. One-third had levels below 50nmol/L (20ng/ml). Incidentally 72% had dietary calcium intakes below the recommended daily intake for their age. Although, the sample size is small, this study emphasises the need to carefully review indoor athletes for vitamin D and calcium status.

Vitamin D deficiency has re-emerged as a significant paediatric health issue in Australia, with complications including hypocalcaemic seizures, rickets, limb pain and fracture. A major risk factor for infants is maternal vitamin D deficiency. For older infants and children, risk factors include dark skin colour, cultural practices, prolonged breastfeeding, restricted sun exposure and certain medical conditions, such as small bowel disorders, pancreatic insufficiency, biliary obstruction, chronic liver or renal disease [21]. A retrospective audit of medical records of children diagnosed with vitamin D deficiency rickets in Melbourne identified 25-OH D levels <25nmol/L (10ng/ml) in 81% of the mothers [22]. Ninety percent had levels <40nmol/L (16ng/ml) or less. Fifty-four of the 55 children were born to mothers with ethnocultural risk factors (including veiling) for vitamin D deficiency. A population-based study of pregnant women and their neonates from South Eastern Sydney, identified vitamin D deficiency (<25nmol/L [10ng/ml]) in 15% of women and 11% of neonates [23]. Median 25-OH D level was 52nmol/L (21 ng/ml) in mothers and 60nmol/L (24 ng/ml) in neonates. Factors associated with maternal vitamin D deficiency in this study were: maternal birthplace outside Australia, dark skin, wearing a veil and younger maternal age. Birth weight was noted to be lower among infants of vitamin D deficient versus sufficient mothers: mean birth weight 3245g versus 3453g ($p<0.001$). These findings are consistnet with the presumption that maternal vitamin D deficiency increases the risk of neonatal vitamin D deficiency. This realationship has other implications as in another study, low maternal 25-OH D levels (<28nmol/L) in late pregnancy (28 to 32 week) were associated with reduced intrauterine long bone growth [24].

The main source of vitamin D is exposure to sunlight. Thus, levels of serum 25-hydroxyvitamin D (25-OH D), the indicator of vitamin D status, vary according to season. Levels tend to be lower at the end of winter compared to the end of summer. In a cross-sectional study of a population-based, random sample of women aged 20-92 years in Geelong, 25-OH D levels were less than 28nmol/L (11.2ng/ml) in 7% overall and 11% in winter [25]. Levels were less than 50nmol/L (20ng/ml) in 30% overall and 43% in winter. A cross-sectional audit of patients admitted to general medical units at the Royal Melbourne Hospital, Victoria similarly reported lower 25-OH D levels in winter, with average 25-OH D of 35nmol/L (14ng/ml) at the end of winter versus 43nmol/L (17 ng/ml) at the end of summer [26]. Overall, two-thirds of the general medical patients were vitamin D insufficient (<50nmol/L [20ng/ml]) and 23% had moderate to severe deficiency (<25nmol/L [10ng/ml]).

A comparison of vitamin D status in people <60years of age using data from cross-sectional studies of three regions across Australia [southeast Queensland (27oS), Geelong region (38oS), and Tasmania (43oS)] confirmed vitamin D insufficiency (<50nmol/L [20ng/ml]) to be common over a wide latitude range in Australia [27]. Prevalence of vitamin D insufficiency in women in winter/spring was 41% in southeast Queensland, 37% in the Geelong region, and 67% in Tasmania. Season appeared to be more important than latitude in determining serum 25-OH D levels according to this study. Although latitude explained only 3.9% of the variation in 25-OH D levels, a decrease in average 25-OH D of 1.0nmol/L (0.7-1.3) for every degree increase in latitude might be clinically relevant. However, vitamin D insufficiency in the Geelong region was lower than expected, on the basis of its latitude. As the three populations were recruited with their own eligibility criteria, selection bias might be a limitation. Simulated maximum daily duration of vitamin D synthesis and effective daily dose of vitamin D were also important predictors of serum 25-OH D levels.

New Zealand

Data from New Zealand are similar to that reported from Australia, with evidence that vitamin D deficiency/insufficiency is a growing problem. Serum 25-OH D levels in New Zealand reveal much more insufficiency than expected, especially for those of Pacific Islander and Maori origin. In a national sample of New Zealanders aged 15 years and over, mean serum 25-OH D levels were 47nmol/L (19 ng/ml) in women and 52nmol/L (21 ng/ml) in men [28]. Mean concentrations in those of Maori and Pacific Islander origin were 42 and 37nmol/L [16.8 and 14.8ng/ml], respectively versus 51nmol/L (20.4ng/ml) in those of European and other ethnic group (NZEO) origin. The NZEO group included Asians and Indians. Three percent of the total sample had serum 25-OH D concentrations <17.5nmol/L (7ng/ml); 48% and 84% were insufficient based on cut-offs of <50nmol/L (20ng/ml) and 80nmol/L (32.1ng/ml), respectively. Determinants of serum 25-OH D levels in women were age, ethnicity, obesity, latitude and season; determinants in men were ethnicity and season. Women living in the South Island of New Zealand had a mean serum 25-OH D that was 6(3-9)nmol/L [2.4(1.2-3.6)ng/ml) lower than women living in the North Island.

Vitamin D deficiency is common among elderly women with a high risk of fracture living in southern New Zealand. This is most marked in the winter months. In a study involving elderly women living independently in Dunedin, 26% had 25-OH D levels below the reference range for healthy adults (<40nmol/L [16ng/ml]). In winter, 69% had levels below the reference range [29].

A cross-sectional study conducted in Auckland also concluded seasonal variation significantly affected the prevalence of vitamin D insufficiency [30-32]. Also gender differences have been suggested in 25-OH D levels, with men having higher levels of 25-OH D throughout the year than women, a finding that persisted after adjusting for potential confounding factors. Predicted duration of 25-OH D concentrations less than 50nmol/L (20ng/ml) was 250 days per year in women and 165 days per year in men [30]. Levels of 25-OH D, in men, peaked in early autumn at 103nmol/L (41.3ng/ml) with a nadir in early spring at 59nmol/L (23.6ng/ml) [31]. Major determinants of 25-OH D were month of blood sampling, fat percentage, physical activity, and serum albumin [32]. In Christchurch, 88% of healthy volunteers (median age 45years) had 25-OH D levels below 75nmol/L (30.0ng/ml) in February (spring), increasing to 100% in June and July (winter) [33].

Vitamin D deficiency is reported as common in pregnant women in New Zealand, with re-emergence of childhood rickets. In a study of women presenting to a general practice for antenatal care in Wellington, 87% had 25-OH D levels <50nmol/L (20ng/ml) and 61% <25nmol/L (10ng/ml) [34]. Only 22% of the women were veiled, and the group included a diverse ethnic population, including African and Middle Eastern as well as, Maori, European, and Polynesian women.

A National Children's Nutritional Survey in New Zealand reported that there is a high prevalence of vitamin D insufficiency in New Zealand children [35]. Ethnicity was a major determinant of serum 25-OH D. Serum 25-OH D concentration in children of Maori origin was 43nmol/L (17.2ng/ml), in those of Pacific Islander ancestry 36nmol/L (14.4ng/ml), and in those of European or other ancestry, 53nmol/L (21.2ng/ml). The prevalence of very low 25-OH D levels (≤17.5nmol/L [7.0ng/ml]) was 5%, 8% and 3% respectively and low 25-OH D levels (<37.5nmol/L [15.0ng/ml]) was 41%, 59% and 25% respectively. In a clinical review of children less than 5 years of age with radiological evidence of rickets and low serum 25-OH D levels in Auckland, the majority were of Indian ethnic origin [36].

Rest of Oceania

Studies evaluating vitamin D status in Asia have been published, however, a medline search failed to return any articles evaluating vitamin D status in Singapore. A review article from Singapore documented an increase in hip fracture rates in several Asian countries including Singapore [37]. Compared to Caucasian populations, it was suggested that there was a relatively greater impact of dietary factors on osteoporosis and fractures demonstrated in Asian populations, possibly related to generally lower calcium intake throughout life in Asians. Though there was no mention of vitamin D status, the author suggested better response to vitamin D analogs in Asians versus Caucasians.

An extensive literature search returned a paucity of studies emanating from the rest of Oceania. Considering the wide extent of vitamin D deficiency/insufficiency, it would be important to evaluate vitamin D status in this population group. It has been postulated that the amount of vitamin D intake needed to maintain a sufficient 25-OH D level for pigmented, veiled, or sun protected persons is >50micrograms/day ie 2,000 IU/day [38]. Adequate levels of vitamin D are unlikely to be achieved through normal dietary intake, particularly in the groups at greatest risk, although vitamin D-fortified foods may assist in maintaining vitamin D status in the general population.

Conclusion

In conclusion, vitamin D deficiency/insufficiency is a growing problem. Low vitamin D levels are associated with increased morbidity, including an increased risk of fractures, requiring detailed studies especially in at risk cohorts. In the general community, those at high risk include older persons living in residential care, dark-skinned and veiled women (particularly in pregnancy) and their infants, in addition to any with medical conditions that limit sun exposure or absorption of food.

Recent evidence suggests optimal serum 25-OH D levels may be higher than the commonly used criterion of >50nmol/L (20ng/ml). Readjustment of the lower limit of vitamin D sufficiency to >75nmol/L (30ng/ml) would indicate vitamin D insufficiency is even more common. A consensus is growing regarding the biochemical definition of vitamin D insufficiency and standardisation of assays used to measure 25-OH D levels. Even without these changes, existing data stress the need for strategies to detect vitamin D insufficiency and to supplement accordingly.

For further information, the reader is referred to:

A. Mithal, D.A. Wahl, J-P. Bonjour et al. on behalf of the IOF Committee of Scientific Advisors (CSA) Nutrition Working Group. Global vitamin D status and determinants of hypovitaminosis D (2009) *Osteoporosis International, In press*

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