Vitamin D Status of Australian Adults

Prevalence of Vitamin D Deficiency and Its Determinants in Australian Adults

Robin M. Daly  PhD  FASMF
Professor | Chair of Exercise and Ageing
Centre for Physical Activity and Nutrition Research (C-PAN)
Deakin University, Burwood,
Melbourne, Australia

Email: rmdaly@deakin.edu.au
The half-life of circulating 25(OH)D is reported to be about 3 weeks. 1,25(OH)2D is generally not a good indicator of vitamin D status because it has a short half-life of 15 hours and serum concentrations are closely regulated by PTH, hormone, calcium and phosphate.

## Defining Optimal Vitamin D Status

<table>
<thead>
<tr>
<th>Serum 25OHD levels</th>
<th>Status</th>
<th>Physiological / Clinical Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥60-75 nmol/L</td>
<td>New Sufficiency?</td>
<td>- Maintain healthy strong bones&lt;br&gt;- Maintain muscle function, prevent falls</td>
</tr>
<tr>
<td>25 – 50 nmol/L</td>
<td>Mildly deficient</td>
<td>- ↑ PTH secretion&lt;br&gt;- ↑ bone turnover</td>
</tr>
<tr>
<td>12.5 – 25 nmol/L</td>
<td>Moderately deficient</td>
<td>- ↓ bone density&lt;br&gt;- ↑ bone turnover&lt;br&gt;- ↑ risk of fracture</td>
</tr>
<tr>
<td>&lt; 12.5 nmol/L</td>
<td>Severely deficient</td>
<td>- Osteomalacia (adults)&lt;br&gt;- Rickets (children)</td>
</tr>
</tbody>
</table>

The half-life of circulating 25(OH)D is reported to be about 3 weeks. 1,25(OH)2D is generally not a good indicator of vitamin D status because it has a short half-life of 15 hours and serum concentrations are closely regulated by PTH, hormone, calcium and phosphate.

Defining Optimal Vitamin D Status

The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know

A. Catharine Ross, JoAnn E. Manson, Steven A. Abrams, John F. Aloia, Patsy M. Brannan, Steven K. Clinton, Ramon A. Durazo-Arvizu, J. Christopher Gallagher, Richard L. Gallo, Gemelle Jones, Christopher S. Kovač, Susan T. Mayne, Clifford J. Rosen, and Sue A. Shapses

Department of Nutritional Sciences (C.A.R.J.), Pennsylvania State University, University Park, Pennsylvania 16802; Department of Medicine (S.I.M.), Brigham and Women’s Hospital, Harvard Medical School, Boston, Massachusetts 02115; Department of Pediatrics (D.A.A.) and Baylor College of Medicine, Houston, Texas 77030; Department of Medicine (U.F.A.), State University of New York at Stony Brook, Stony Brook, New York 11794; Wadsworth University Hospital (U.F.A.) Medical Center, New York 10016. Division of Endocrinology, Internal Medicine, Albert Einstein College of Medicine, Bronx, New York 10461.

This article summarizes the new 2011 report on dietary requirements for calcium and vitamin D from the Institute of Medicine (IOM). An IOM Committee charged with determining the population needs for these nutrients in North America conducted a comprehensive review of the evidence for both skeletal and extraskelletal outcomes. The Committee concluded that available scientific evidence supports a key role of calcium and vitamin D in skeletal health, with a causal effect relationship and providing a sound basis for determination of intake requirements. For extraskelletal outcomes, including cancer, cardiovascular disease, diabetes, and autoimmune disorders, the evidence was inconsistent, inconclusive as to causality, and insufficient to inform nutritional requirements. Randomized clinical trials evidence for extraskelletal outcomes was limited and generally uninformative. Based on bone health, the Committee recommended Dietary Allowances (RDAs) covering requirements of >97.5% of the population for calcium range from 700 to 1300 mg/d for life-stage groups at least 1 yr of age. For vitamin D, RDA of 600 IU/d for ages 1-7 yr and 800 IU/d for ages 8 yr and older, corresponding to a serum 25-hydroxyvitamin D level of at least 20 nmol/L (50 nmol/L) in adults, meet the requirements of at least 97.5% of the population. RDAs for vitamin D were derived based on conditions of minimal sun exposure due to wide variability in vitamin D synthesis from ultraviolet light and the risks of skin cancer. Higher values were not consistently associated with greater benefit, and for some outcomes U-shaped associations were observed, with risks at both low and high levels. The Committee concluded that the prevalence of vitamin D inadequacy in North America has been overestimated. Urgent research and clinical priorities were identified, including reassessment of laboratory ranges for 25-hydroxyvitamin D, to avoid problems of both undertreatment and overtreatment.

Evaluation, Treatment, and Prevention of Vitamin D Deficiency: an Endocrine Society Clinical Practice Guideline

Michael F. Holick, Neil C. Binkley, Heike A. Biscoff-Fenari, Catherine M. Gordon, David A. Hanley, Robert P. Heaney, M. Hassan Murad, and Connie M. Weaver

Boston University School of Medicine (M.F.H., J.A.T.), Boston, Massachusetts 02118; University of Wisconsin (M.C.H.), Madison, Wisconsin 53706; University Hospital Zurich (K.B.-F.), CH-8091, Zurich, Switzerland; Children’s Hospital Boston (C.M.W.), Boston, Massachusetts 02115; University of Calgary Faculty of Medicine (D.A.H.), Calgary, Alberta, Canada T2N 4N1; Creighton University (H.A.B.), Omaha, Nebraska 68178; Mayo Clinic (H.A.B.), Rochester, Minnesota 55905; and Purdue University (M.C.H.), West Lafayette, Indiana 47907.

Summary of Recommendations

1. Diagnostic procedure
   1.1. We recommend screening for vitamin D deficiency in individuals who are at risk for vitamin D deficiency. We do not recommend population screening for vitamin D deficiency in individuals who are not at risk (1D/2D).
   1.2. We recommend using the serum circulating 25-hydroxyvitamin D [25(OH)D] level, measured by a reliable assay, to evaluate vitamin D status in patients who are at risk for vitamin D deficiency. Vitamin D deficiency is defined as a 25(OH)D level below 20 ng/mL (50 nmol/L). We recommend against using the serum 1,25-dihydroxyvitamin D (1,25(OH)2D) assay for this purpose and are in favor of using it only in monitoring certain conditions, such as acquired and inherited disorders of vitamin D and phosphate metabolism.

Recommendation 
≥50 nmol/L

Recommendation 
≥75 nmol/L
Groups at Risk for Vitamin D Deficiency

- Elderly people
- Housebound or chronically ill
- Dark-skinned, veiled
- Babies of vitamin D deficient mothers
- Obese individuals
- People with secondary medical disorders (renal or coeliac disease)
- People living at a latitude >35° S
- Those that limit sun exposure (incl. indoor athletes, office workers, taxi drivers, night shift workers)
- People who use overzealous amounts of sunscreen (SF30+ reduces vitamin D synthesis by 95%+)
# Prevalence of Vitamin D Deficiency

## Prevalence in “High Risk” Groups in Australia

<table>
<thead>
<tr>
<th>High Risk Groups</th>
<th>Prevalence of Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential care elderly in high level care</td>
<td>55%</td>
</tr>
<tr>
<td>Residential care elderly in high and low level care</td>
<td>68–86%</td>
</tr>
<tr>
<td>Residential care elderly in low level care</td>
<td>22%</td>
</tr>
<tr>
<td>Geriatric admissions to hospital</td>
<td>67%</td>
</tr>
<tr>
<td>Patients with hip fracture</td>
<td>61%</td>
</tr>
<tr>
<td>Dark skinned women (particularly veiled)</td>
<td>63%**</td>
</tr>
<tr>
<td>Mothers of infants with rickets</td>
<td>&gt;80%**</td>
</tr>
<tr>
<td>(particularly dark skinned and veiled)</td>
<td>80%</td>
</tr>
</tbody>
</table>

* Deficiency defined as either <25 or 28 nmol/L

** Deficiency defined as <50 nmol/L

Flicker et al. 2003
Sambrook et al. 2002
Flicker et al. 2003
Inderjeeth et al. 2000
Crone et al. 2002
Diamond et al. 1998
Grover et al. 2001; Diamond et al 2002
Nozza et al. 2001

Pasco et al. Australian Family Physician 33(3), 2004
Prevalence of Vitamin D Deficiency


Vitamin D ≤ 25 nmol/L
- 7% SE Qld
- 8% Geelong
- 13% Tasmania

Vitamin D ≤ 50 nmol/L
- 41% SE Qld
- 37% Geelong
- 67% Tasmania

Prevalence of Vitamin D Deficiency

**Vitamin D deficiency in Athletes**

16 ballet dancers (Australian ballet school)
- <25 nmol/L 12.5%
- 25-50 nmol/L 44%  
  
18 gymnasts (Australian Institute of Sport)
- <50 nmol/L 33%
- <75 nmol/L 83%  
  
*Vu et al. Photochem Photobiol 2011*

**Vitamin D deficiency in Office Workers**

Officer workers (Brisbane, n=304)
- End of summer: 14% <50 nmol/L; 54% <75 nmol/L
- End of winter: 34% <50 nmol/L; 81% <75 nmol/L

*Vu et al. Photochem Photobiol 2011*

*Centre for Physical Activity and Nutrition Research*
Serum Vitamin D Levels in Office Workers in a Subtropical Climate

Lan H. Vu¹, David C. Whiteman², Jolieke C. van der Pols², Michael G. Kimlin¹ and Rachel E. Neale²¹

Queensland University of Technology, Brisbane, Australia
²Queensland Institute of Medical Research, Herston, Australia
Received 17 October 2010, accepted 13 January 2011, DOI: 10.1111/j.1751-1097.2011.00899.x

ABSTRACT

Vitamin D is necessary to maintain healthy bones, and may also have beneficial effects on a variety of other health outcomes. Vitamin D levels lower than 50 nmol L⁻¹ are “insufficient.” However, it has been suggested that 75 nmol L⁻¹, or even 100 nmol L⁻¹, should be the target level in human populations (2,10–12).

High 25(OH)D levels in summer were associated with time spent outdoors in nonpeak UV periods, while in winter high levels were associated with intake of vitamin D from food or supplements.

Month prior to blood collection. Summer and winter mean serum 25(OH)D was 74 (95% CI 70–77) nmol L⁻¹ and 54 (95% CI 51–57) nmol L⁻¹, respectively. In summer, 14% of participants were classed as “insufficient,” compared with 51% in winter. High 25(OH)D levels in summer were associated with time spent outdoors in nonpeak UV periods, while in winter high levels were associated with intake of vitamin D from food or supplements. The high prevalence of vitamin D insufficiency observed in this population highlights the need for further examination of the relation between sunlight and vitamin D production to enable more accurate sun exposure recommendations.

shown to influence individual 25(OH)D levels, including both environmental and personal characteristics and behaviors (9), but these are likely to vary depending on the population under study.

There is a paucity of information about 25(OH)D levels in people who work mainly indoors and who are presumably at risk of vitamin D deficiency due to limited opportunity for exposure to solar UV radiation. We therefore conducted this study in a population residing at low latitude with very high levels of ambient ultraviolet radiation, aiming to ascertain the 25(OH)D status in summer and winter of indoor office workers and to examine factors that independently determine
Australian Diabetes, Obesity and Lifestyle (AusDiab) Study

11,218 Men and Women $\geq$ 25 years

Original AusDiab study conducted in 1999/00

42 randomly selected urban and nonurban Census Collector Districts; 6 testing sites in each state.

N = 17,129
Eligible households

N = 20,347
Adults $\geq$ 25 years Completed Interview

N = 11,247
Attended Biomedical Examination

N = 11,218
Blood specimens available
Prevalence of Vitamin D Deficiency and Insufficiency in Australia (1999/00)

National, Population-based Study in 11,247 Adults

Vitamin D Moderate Deficiency
- <25 nmol/L: 4%

Vitamin D Deficiency
- <50 nmol/L: 31%

Vitamin D Insufficiency
- <75 nmol/L: 73%

11,247 men and women aged 25+ years

42 randomly selected urban and nonurban Census Collector Districts; 6 testing sites in each state.

Daly R et al. Clin Endocrinol (Oxf). 2011 Dec 15
Global Prevalence of Vitamin D Deficiency

- **Canada**: 1995–97, 20% classified as 'low' (Greene-Finestone et al. 2010)
- **USA**: 2001–04, 36% (Ginde et al. 2009)
- **New Zealand**: 1996/97, 48% (Rockell et al. 2006)
- **Korea**: 2008, 56% (Choi et al. 2011)
- **Australia**: 1999/00, 31% (Rockell et al. 2006)
- **Worldwide**: 63% (Lips et al. 2006)

Serum 25(OH)D level:
- <50 nmol/L
- <75 nmol/L

* <80 nmol/L
Distribution of Serum 25(OH)D in 11,218 Australian Adults aged ≥25 years

**Males**
- N=5040
- Mean: 67.7 nmol/L
- Median: 65 nmol/L

**Females**
- N=6178
- Mean: 57.9 nmol/L
- Median: 55 nmol/L

Centre for Physical Activity and Nutrition Research
Vitamin D Status by Age and Gender in 11,218 Australians Aged ≥25 years

Serum 25-hydroxyvitamin D

Daly R et al. Clin Endocrinol 2011 Dec 15 [Epub ahead of print]
Seasonal Variability in Vitamin D

Daly R et al. Clin Endocrinol 2011 Dec 15 [Epub ahead of print]
Seasonal Variation in 25(OH)D levels
Season more important than latitude (both accounted for <20% variability)

Max. Daily Duration of VD synthesis
Time in which UVR exceeds the threshold required to produce vitamin D

Vitamin D Effective Daily Dose
Daily dose of UVR wavelengths relevant to the conversion of 7-dehydrocholesterol into previtamin D in the skin
Vitamin D Status by Season and Latitude

**Serum 25OHD Level**
- ≥75 nmol/L
- 50 to <75 nmol/L
- <50 nmol/L

**Prevalence (%)**

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Male</th>
<th>Summer-Autumn</th>
<th>Female</th>
<th>Winter-Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30° S</td>
<td>15.4</td>
<td>24.5</td>
<td>27.6</td>
<td>33.5</td>
</tr>
<tr>
<td>30-35° S</td>
<td>63.5</td>
<td>44.9</td>
<td>41.0</td>
<td>40.5</td>
</tr>
<tr>
<td>&gt;35° S</td>
<td>23.1</td>
<td>35.3</td>
<td>41.4</td>
<td>57.9</td>
</tr>
</tbody>
</table>

Daly R et al. Clin Endocrinol 2011 Dec 15 [Epub ahead of print]
Prevalence of Deficiency in Tasmania (43°S)
Prevalence across the lifespan: five cross-sectional studies (primary school to old age)

Winter/Spring

Estimated Prevalence on Minimum Day
(‘Worst case scenario’)

Summer/Autumn

Estimated Prevalence on Maximum Day
(‘Best case scenario’)

Van der Mei et al. Int Med J 2012 Apr 5 (Epub ahead of print)
## Prevalence of Deficiency in Tasmania

Percentage of people in Tasmania with a serum 25(OH)D levels <50 nmol/L who reported >4 hours per day

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Serum 25(OH)D &lt; 50 nmol/L (%)</th>
<th>Winter/Spring</th>
<th>Summer/Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adolescents</td>
<td>44 – 68%</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>Young to middle aged adults</td>
<td>45%</td>
<td></td>
<td>29%</td>
</tr>
<tr>
<td>Older adults</td>
<td>44%</td>
<td>14%</td>
<td></td>
</tr>
</tbody>
</table>

Self reported sun exposure was measured by a validated questionnaire that asked about the amount of time participants would normally spend in the sun; no data on the time of the day that the people spent outdoors.

Van der Mei et al. Int Med J 2012 Apr 5 (Epub ahead of print)
# Risk Factors for Deficiency (AusDiab)

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio (95% CI)</th>
<th>Men (n=5,040)</th>
<th>Women (n=6,178)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europids</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>Non-Europids</td>
<td>4.7 (3.1, 6.9) ***</td>
<td>3.5 (2.6, 4.7) ***</td>
<td></td>
</tr>
<tr>
<td>Latitude</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;30° S</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>30 – 35° S</td>
<td>1.4 (0.8, 2.2)</td>
<td>1.3 (0.9, 1.9)</td>
<td></td>
</tr>
<tr>
<td>&gt;35° S</td>
<td>2.6 (1.5, 4.6) **</td>
<td>2.2 (1.4, 3.4) ***</td>
<td></td>
</tr>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer (Dec-Feb)</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>Autumn (Mar-May)</td>
<td>2.7 (1.6, 4.7) **</td>
<td>1.4 (0.9, 2.2)</td>
<td></td>
</tr>
<tr>
<td>Winter (Jun-Aug)</td>
<td>4.1 (2.5, 6.7) ***</td>
<td>2.7 (2.1, 3.5) **</td>
<td></td>
</tr>
<tr>
<td>Spring (Sept-Nov)</td>
<td>3.3 (2.2, 5.0) ***</td>
<td>1.8 (1.4, 2.4) ***</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy weight</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>Overweight</td>
<td>0.9 (0.7, 1.3)</td>
<td>1.4 (1.2, 1.7) ***</td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>1.7 (1.1, 2.6) **</td>
<td>2.0 (1.6, 2.6) ***</td>
<td></td>
</tr>
<tr>
<td>Physical Activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sufficient (≥150 min/wk)</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>Insufficient (&lt;150 min/wk)</td>
<td>1.7 (1.3, 2.4) **</td>
<td>1.6 (1.4, 1.9) **</td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>1.9 (1.4, 2.5) ***</td>
<td>1.8 (1.5, 2.1) ***</td>
<td></td>
</tr>
</tbody>
</table>

Vitamin D deficiency: < 50 nmol/L; Odds ratio adjusted for all variables shown + age, TV time, location of residence, smoking and education

Daly R et al. Clin Endocrinol 2011 Dec 15 [Epub ahead of print]
Prevalence of Vitamin D Deficiency in 2008-10

NSW (latitude 28-37 S): Ambulatory and Inpatient Samples

- 24,819 ambulatory (diagnostic referral, outpatient, private outpatient and emergency) and inpatient (inpatient private, public hospital and private hospital) samples taken from the largest reference laboratory in NSW.
- All testing conducted between 1st July 2008 and 30th July 2010.
- Latitude range 28 S to 37 S.
Vitamin D Status by Season in 2008-10

NSW (latitude 28-37° S): Ambulatory Samples vs AusDiab (99/00)

**Male**
- Summer and Autumn: 46% <50 nmol/L, 32% 50 to <75 nmol/L, 22% ≥75 nmol/L
- Winter and Spring: 26% <50 nmol/L, 43% 50 to <75 nmol/L, 27% ≥75 nmol/L

**Females**
- Summer and Autumn: 33% <50 nmol/L, 31% 50 to <75 nmol/L, 18% ≥75 nmol/L
- Winter and Spring: 18% <50 nmol/L, 54% 50 to <75 nmol/L, 19% ≥75 nmol/L

Serum 25-hydroxyvitamin D

Boyages and Bilinski Clin Endocrinol (Oxf). 2012 Apr 3 [Epub ahead of print]
Daly R et al. Clin Endocrinol 2011 Dec 15 [Epub ahead of print]
## Prevalence of Vitamin D Deficiency in 2008-10

NSW (latitude 28-37 S): 13,979 Ambulatory Samples

<table>
<thead>
<tr>
<th></th>
<th>2008-10 NSW (28-37 S)</th>
<th>1999-00 AusDiab (28-37 S)</th>
<th>Difference over 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moderate-Severe Deficiency: 25(OH)D &lt;25 nmol/L</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>8%</td>
<td>2.3%</td>
<td>▲ ~5%</td>
</tr>
<tr>
<td>Female</td>
<td>14%</td>
<td>5.3%</td>
<td>▲ ~8%</td>
</tr>
<tr>
<td><strong>Vitamin D Deficiency: 25(OH)D &lt;50 nmol/L</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>31%</td>
<td>21%</td>
<td>▲ ~10%</td>
</tr>
<tr>
<td>Female</td>
<td>43%</td>
<td>38%</td>
<td>▲ ~5%</td>
</tr>
<tr>
<td><strong>Vitamin D Insufficiency: 25(OH)D &lt;75 nmol/L</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>63%</td>
<td>66%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>75%</td>
<td>78%</td>
<td></td>
</tr>
</tbody>
</table>

Boyages and Bilinski Clin Endocrinol (Oxf). 2012 Apr 3 [Epub ahead of print]
Daly R et al. Clin Endocrinol 2011 Dec 15 [Epub ahead of print]
Take Home Message

- In Australia, nearly **one-third of community-dwelling healthy adults** aged 25 years had vitamin D deficiency (<50 nmol/L)
  - 42% of women and 27% of men in southern Australia during **summer/autumn** were **deficient**
  - Increased to 58% of women and 35% of men during **winter/spring**.

- Those at greatest risk included: **women, the elderly, obese, those not meeting the current PA guidelines (≥2.5 hr/wk), those with a higher level of education (men) and those of non-Europid descent**.

- Based on the current evidence, there is an urgent need to identify safe and effective strategies at the population level to improve the vitamin D status of all Australians.
Acknowledgements

• Research Team
  – Dr Dianna Magliano
  – Dr Claudia Gagnon
  – A/Prof. David Dunstan
  – Prof. Paul Zimmet
  – Prof. Peter Ebeling
  – A/Prof. Jonathan Shaw

• Melbourne Pathology
  – Dr Zhong Lu
  – Dr Ken Sikaris
  – Warren Louey
  – DiaSorin for subsidizing the Liaison 25OHD reagents

  ▸ Prof. Daly and A/Prof Shaw are supported by NHMRC Fellowships.
  ▸ A/Prof. David Dunstan is supported by an Australian Research Council Future Fellowship
  ▸ Dr Magliano is supported by a Victorian Cancer Agency Public Health Fellowship.

  ▸ AusDiab was supported by NHMRC
  ▸ AusDiab field team