Current vitamin D status in Korea

Dongguk University Ilsan Hospital
Han Seok Choi
Overview

- Introduction: vitamin D
- Definition of vitamin D status
- Vitamin D status in Korea and other countries
- Determinants of vitamin D status
- Strategies to improve vitamin D status
- Conclusion
Introduction: vitamin D
Vitamin D metabolism

UV spectrum (290-310 nm)

- Sunlight
- Skin
- 7-Dehydrocholesterol
- Cholecalciferol (vitamin D₃)
- Liver
- 25-hydroxyvitamin D₃
- Kidney
- 1,25-dihydroxyvitamin D₃

The best indicator of overall vitamin D status

Maintains calcium balance in the body

Vitamin D₂ (supplements)
Vitamin D action on bone and mineral metabolism

Vitamin D deficiency

Vitamin D deficiency, falls and fractures

- low sunshine exposure
- low serum 25 (OH)D
- low serum 1,25 (OH)₂D
- decreased Ca absorption
- muscle weakness
- mineral deficit hyperosteooidosis
- high turnover bone resorption

- higher PTH
- decreased renal function

- low vitamin D intake

- falls
- osteomalacia
- osteoporosis

(hip) fractures
Non-skeletal action of vitamin D

Vitamin D deficiency
- Cardiovascular disease
- Diabetes mellitus
- Cancer
- Autoimmune diseases
- Infection

Definition of vitamin D status
25(OH)D continuum controversy

Deficiency Insufficiency Optimal

Serum 25(OH)D (nmol/L)

Deficiency Insufficiency

0 25 50 75 100

0 10 20 30 40

ng/mL

100

nmol/L
Guidelines from professional societies

- International workshop on vitamin D (2007)
  - Minimum desirable 25(OH)D is 50 nmol/l

- Osteoporosis Canada (2010)
  - 25(OH) level should be at least 75 nmol/l

- International Osteoporosis Foundation (IOF) (2010)
  - A target level of 25(OH)D of 75 nmol/l

- Institute of Medicine (IOM) (2011)
  - 25(OH)D above the 50 nmol/l is needed for good bone health for practically all individuals
Serum 25(OH)D and PTH

Study design: Multicenter, epidemiologic study of serum 25(OH)D distribution in 1569 healthy men and women in France

Adapted from Chapuy M-C, et al. Osteoporos Int. 1997;7:439-443

\[ \text{Serum } 25\text{(OH)D and PTH} \]

\[ P < 0.01 \]

\[ 31 \text{ = 77. 5nmol/l} \]
Calcium absorption plateaus at serum 25(OH)D levels ≥ 80 nmol/l

Calcium absorption rises as 25(OH)D increases within the range of 25(OH)D values commonly encountered

Adapted from Heaney RP. Am J Clin Nutr. 2004;80(suppl):1706S–1709S.
Serum 25(OH)D and BMD

- The association between serum 25(OH)D and hip BMD among 13,432 subjects
- The third National Health and Nutrition Examination Survey (NHANES III)

Higher 25(OH)D was associated with higher BMD throughout the reference range of 22.5 to 94 nmol/L. In younger whites and younger Mexican Americans, higher 25(OH)D was associated with higher BMD, even that >100 nmol/L

Bone Mineralization Defects and Vitamin D Deficiency

Histomorphometric Analysis of Iliac Crest Bone Biopsies and Circulating 25(OH)D in 675 autopsies

Mineralized bone is stained blue
Unmineralized osteoid is stained red

- No case of osteomalacia with 25(OH)D above 75 nmol/L
- About 96.5% of osteomalacia cases occurred at a 25(OH)D level of less than 50 nmol/L

JBMR 2010;25:305-312
Serum 25(OH)D and BMD

- The Longitudinal Aging Study Amsterdam (LASA)
- A total of 1319 subjects (643 men and 676 women)

A threshold appeared to exist around the serum 25(OH)D level of 50 nmol/L.
Serum 25(OH)D and BTM

- The Longitudinal Aging Study Amsterdam (LASA)
- A total of 1319 subjects (643 men and 676 women)

A steep decrease up to the serum 25(OH)D level of about 40 nmol/L, followed by a plateau.
## Serum 25(OH)D and BMD in Korea

### The Korea National Health and Nutrition Examination Survey (KNHANES) 2008-2009

#### Serum 25(OH)D\(^a\) (nmol/L) in Women

<table>
<thead>
<tr>
<th>Serum 25(OH)D(^a) (nmol/L) in Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25 (n=119)</td>
</tr>
<tr>
<td>Lumbar spine</td>
</tr>
<tr>
<td>Femur trochanter</td>
</tr>
<tr>
<td>Femoral neck</td>
</tr>
<tr>
<td>Total hip</td>
</tr>
</tbody>
</table>

#### Serum 25(OH)D\(^a\) (nmol/L) in Men

<table>
<thead>
<tr>
<th>Serum 25(OH)D(^a) (nmol/L) in Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25 (n=393)</td>
</tr>
<tr>
<td>Lumbar spine</td>
</tr>
<tr>
<td>Femur trochanter</td>
</tr>
<tr>
<td>Femoral neck</td>
</tr>
<tr>
<td>Total hip</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard error.

\(^a\) Adjusted by age, BMI, regular walking, regular exercise, current smoking, and season of vitamin D determination

\(^b\) Overall results of covariance analysis.

\(* p < 0.05, ** p < 0.01, *** p < 0.001,\) as compared to the reference group (20~30 ng/mL).
### Serum 25(OH)D and femur geometry

The Korea National Health and Nutrition Examination Survey (KNHANES) 2008-2009

<table>
<thead>
<tr>
<th>Serum 25(OH)D&lt;sup&gt;a&lt;/sup&gt; (nmol/L) in Women</th>
<th>&lt;25 (n=214)</th>
<th>25~50 (n=1995)</th>
<th>50~75 (n=1182)</th>
<th>&gt;75 (n=270)</th>
<th>( P ) value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN cortical thickness (mm)</td>
<td>1·62±0·00**</td>
<td>1·66±0·00</td>
<td>1·69±0·00</td>
<td>1·67±0·00</td>
<td>0·005</td>
</tr>
<tr>
<td>FN CSA(cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>2·52±0·03***</td>
<td>2·62±0·01</td>
<td>2·65±0·01</td>
<td>2·62±0·03</td>
<td>&lt;0·001</td>
</tr>
<tr>
<td>FN CSMI (cm&lt;sup&gt;4&lt;/sup&gt;)</td>
<td>2·16±0·04***</td>
<td>2·30±0·01</td>
<td>2·34±0·02</td>
<td>2·32±0·04</td>
<td>&lt;0·001</td>
</tr>
<tr>
<td>FN buckling ratio</td>
<td>11·8 ±0·19**</td>
<td>11·34±0·06</td>
<td>11·20±0·08</td>
<td>11·19±0·18</td>
<td>0·013</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Serum 25(OH)D&lt;sup&gt;a&lt;/sup&gt; (nmol/L) in Men</th>
<th>&lt;25 (n=50)</th>
<th>25~50 (n=995)</th>
<th>50~75 (n=1088)</th>
<th>&gt;75 (n=361)</th>
<th>( P ) value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN cortical thickness (mm)</td>
<td>1·76±0·00</td>
<td>1·83±0·00</td>
<td>1·86±0·00</td>
<td>1·86±0·00</td>
<td>0·020</td>
</tr>
<tr>
<td>FN CSA(cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>3·18±0·06</td>
<td>3·27±0·01*</td>
<td>3·34±0·01</td>
<td>3·35±0·02</td>
<td>0·002</td>
</tr>
<tr>
<td>FN CSMI (cm&lt;sup&gt;4&lt;/sup&gt;)</td>
<td>3·68±0·11</td>
<td>3·76±0·02**</td>
<td>3·87±0·02</td>
<td>3·93±0·04</td>
<td>&lt;0·001</td>
</tr>
<tr>
<td>FN buckling ratio</td>
<td>12·10±0·29</td>
<td>11·56±0·07</td>
<td>11·33±0·06</td>
<td>11·38±0·10</td>
<td>0·020</td>
</tr>
</tbody>
</table>

FN, femur neck; CSA, cross-sectional area; CSMI, cross-sectional moment of inertia

Unpublished data
Association between serum 25(OH)D and PTH

![Graph showing the association between serum 25(OH)D and PTH](image)

- Difference in PTH (pg/mL) on the y-axis.
- Serum 25(OH)D, nmol/L on the x-axis.

Unpublished data
Serum 25(OH)D level and all-cause mortality

- Cohort studies
- U-shaped or reverse J-shaped pattern

Visser et al., 2006; Jia et al., 2007
Serum 25(OH)D level and all-cause mortality

- The Uppsala Longitudinal Study of Adult Men
- A community-based cohort of elderly men (mean age: 71 yr, n= 1,194)
- Follow up: 12.7 yr
- U-shaped or reverse J-shaped pattern

An approximately 50% higher total mortality rate was observed among men in the lowest 10% (<46 nmol/L) and the highest 5% (>98 nmol/L) of plasma 25(OH)D concentrations compared with intermediate concentrations.
Relation between baseline vitamin D status and incident cardiovascular events

- The Framingham Offspring cohort
- 1739 participants (mean age 59 years) without prior cardiovascular disease

A nonlinear relation between 25(OH)D levels and cardiovascular risk, with increased risk for cardiovascular events at 25(OH)D levels below 37.5 to 50 nmol/L
Vitamin D and colorectal cancer

- Previous studies found an inverse association of vitamin D intake with colon or rectal cancer.

- A lower risk of colorectal cancer associated with higher 25(OH)D levels was reported. (P for trend = 0.02)

<The Nurses’ Health Study>
Vitamin D and pancreatic cancer

- The Cohort Consortium Vitamin D Pooling Project of Rarer Cancers
- Involving 10 cohorts that are members of the National Cancer Institute Cohort Consortium

→ An increased risk at very high levels (above 100 nmol/L) was noted
Vitamin D and prostate cancer

- A longitudinal nested case-control study in the Nordic countries

Both high and low levels of blood vitamin D are associated with a higher prostate cancer risk

Definition of vitamin D status

Serum 25(OH)D, nmol/L

- **25(OH)D < 50 nmol/L**: insufficient for skeletal health
- **25(OH)D ≥ 50 nmol/L**: generally appropriate and safe for public health
- **25(OH)D ≥ 75 nmol/L**: needed for vulnerable people (osteoporotic, elderly)
- **25(OH)D ≥ 375 nmol/L**: intoxication can occur
- **25(OH)D between 100~150 nmol/L**: consider potential risk and benefit. Further research is needed

Potential benefit
- Further benefit in skeletal health
- Potential benefit in extra-skeletal health

Potential risk
- Cardiovascular events, Cancer risk
- All-cause mortality
Vitamin D status in Korea and other countries
Cholecalciferol (vitamin D₃) is converted to 7-dehydrocholesterol by sunlight on the skin. It is then converted to 25-hydroxyvitamin D₃ in the liver and further to 1,25-dihydroxyvitamin D₃ in the kidney. This maintains the calcium balance in the body. Dietary intake includes Vitamin D₃ (fish, meat) and Vitamin D₂ (supplements).
Demographic Differences and Trends of Vitamin D Insufficiency in the US Population, 1988-2004

Adit A. Ginde, MD, MPH; Mark C. Liu, MD; Carlos A. Camargo Jr, MD, DrPH

![Table 1. Description of Demographics and Serum 25(OH)D Levels in NHANES III and NHANES 2001-2004](image)

Demographic Differences and Trends of Vitamin D Insufficiency in the US Population, 1988-2004

Adit A. Ginde, MD, MPH; Mark C. Liu, MD; Carlos A. Camargo Jr, MD, DrPH

Figure 1. Mean serum 25-hydroxyvitamin D (25[OH]D) levels in the Third National Health and Nutrition Examination Survey (NHANES III) (1988-1994) and in NHANES 2001-2004, stratified by demographic characteristics. NH indicates non-Hispanic. To convert 25(OH)D levels to nanomoles per liter, multiply by 2.496.
Vitamin D status in Korea

Mean 25(OH)D (ng/mL) by country and descending latitude (North to South)

(n = 2589) postmenopausal osteoporotic women

101 Koreans

17.6 ng/mL

Switzerland - 48N

France - 46.5N

Spain - 40.5N

Turkey - 39.5N

South Korea - 38N

Japan - 35.5N

Lebanon - 34N

Mexico - 19N

Thailand - 13N

Malaysia - 4N

Brazil - 19S

Chile - 34S

Australia - 34S

Overall

Vitamin D status in Korea

25(OH)D < 75nmol/l

The Fourth Korean National Health and Nutrition Examination Survey

- The KNHANES has been conducted periodically since 1998 to assess the health and nutritional status of the civilian, non-institutionalized population of the Korea
- A cross-sectional and nationally representative survey conducted by the Division of Chronic Disease Surveillance, Korea Centers for Disease Control and Prevention
- **Duration:** February, 2008 – December, 2008
- **Participants:** Total 6,925 (Male- 3,047, Female- 3,878)
- **Age:** ≥10 yr
- **25-hydroxyvitamin D assay:** RIA (DiaSorin)
Age-related change of serum 25(OH)D levels

Mean serum 25(OH)D level: **53 nmol/L** (21.2 ng/dL) for men, and **45.5 nmol/L** (18.2 ng/dL) for women
Prevalence of vitamin D insufficiency by 10-year age categories

The Korea National Health and Nutrition Examination Survey (KNHANES) 2008

**Male**

<table>
<thead>
<tr>
<th>Serum 25(OH)D Level, ng/mL</th>
<th>10-19</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>≥80</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 to &lt;20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 to &lt;30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Female**

<table>
<thead>
<tr>
<th>Serum 25(OH)D Level, ng/mL</th>
<th>10-19</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>≥80</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 to &lt;20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 to &lt;30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Vitamin D insufficiency**

- < 50 nmol/L: 47.3% in men and 64.5% in women
- < 75 nmol/L: 86.8% in men and 93.3% in women

Serum 25(OH)D Level, ng/mL
- <10
- 10 to <20
- 20 to <30
- ≥30 (75 nmol/l)
Female

Spring

Summer

Fall

Winter

Age, yr

Percentage

10-19 20-29 30-39 40-49 50-59 60-69 70-79 ≥80

Age, yr

Percentage

10-19 20-29 30-39 40-49 50-59 60-69 70-79 ≥80

Serum 25(OH)D Level, ng/mL

<10 10 to <20 20 to <30 ≥30 (75 nmol/l)
Prevalence of vitamin D insufficiency by occupation in adults aged 20 yrs or older

The Korea National Health and Nutrition Examination Survey (KNHANES) 2008

A. Agriculture, forestry, and fishery
B. Manual labor
C. Engineering, assembling, and technical work
D. Sales, and service
E. Administration, clerical work, and specialists
F. Students
G. N/A

 Serum 25(OH)D Level, ng/mL
- <10
- 10 to 20
- 20 to 30
- ≥30

Prevalence of vitamin D insufficiency by school in participants younger than 20 yrs

Serum 25(OH)D Level, ng/mL  
- <10
- 10 to <20
- 20 to <30
- ≥30 (75 nmol/l)
## Mean 25(OH)D level and the prevalence of vitamin D insufficiency based on nationwide surveys in Korea, the US, and Canada

<table>
<thead>
<tr>
<th>Country</th>
<th>Survey</th>
<th>Sample size</th>
<th>Age (yr)</th>
<th>Assay</th>
<th>Mean 25(OH)D (nmol/l)</th>
<th>25(OH)D (nmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(n)</td>
<td></td>
<td></td>
<td>&lt;50</td>
<td>&lt;75</td>
</tr>
<tr>
<td>Korea</td>
<td>KNHANES 2008</td>
<td>6,925</td>
<td>10-93</td>
<td>RIA (DiaSorin)</td>
<td>48.7</td>
<td>56.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(M:3,047, F:3,878)</td>
<td></td>
<td></td>
<td>(M:52.9, F:45.4)</td>
<td>(M:47.3%, F:64.5%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90.5%</td>
<td>90.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(M:86.8%, F:93.3%)</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>NHANES 1988-1994</td>
<td>18,641</td>
<td>≥12</td>
<td>RIA (DiaSorin)</td>
<td>60.7</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(M:8,759, F:9,882)</td>
<td></td>
<td></td>
<td>(M:22%, F:35%)</td>
<td>69%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69%</td>
<td>(M:64%, F:74%)</td>
</tr>
<tr>
<td>US</td>
<td>NHANES 2001-2006</td>
<td>23,424</td>
<td>≥2</td>
<td>RIA (DiaSorin)</td>
<td>55.2</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(M:11,443, F:11,981)</td>
<td></td>
<td></td>
<td>(M:29%, F:34%)</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76%</td>
<td>(M:76%, F:76%)</td>
</tr>
<tr>
<td>Canada</td>
<td>CHMS 2007-2009</td>
<td>5,306</td>
<td>6-79</td>
<td>CLIA-LIAISON (DiaSorin)</td>
<td>67.7</td>
<td>64.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(M:2,566, F:2,740)</td>
<td></td>
<td></td>
<td>(M:65.7, F:69.7)</td>
<td>(M:67.0%, F:62.2%)</td>
</tr>
</tbody>
</table>

Comparison between the RIA and LIAISON methods showed an average bias of 4.8±16 nmol/L with the LIAISON method giving higher values.
Higher rate of vitamin D insufficiency in younger generation

Is it a unique finding in Korea or recent worldwide trend in the modern epidemic of vitamin D insufficiency?
# Canadian Health Measures Survey 2007-2009

<table>
<thead>
<tr>
<th>Age group and sex</th>
<th>Mean nmol/L</th>
<th>95% confidence interval from</th>
<th>to</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total 6 to 79 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>65.7</td>
<td>62.5</td>
<td>68.9</td>
</tr>
<tr>
<td>Female</td>
<td>69.7</td>
<td>67.8</td>
<td>71.7</td>
</tr>
<tr>
<td><strong>6 to 11 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>75.0</td>
<td>70.3</td>
<td>79.7</td>
</tr>
<tr>
<td>Female</td>
<td>73.1</td>
<td>67.0</td>
<td>79.1</td>
</tr>
<tr>
<td><strong>12 to 19 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>68.1</td>
<td>63.8</td>
<td>72.4</td>
</tr>
<tr>
<td>Female</td>
<td>70.8</td>
<td>65.8</td>
<td>75.9</td>
</tr>
<tr>
<td><strong>20 to 39 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>65.0</td>
<td>61.0</td>
<td>69.0</td>
</tr>
<tr>
<td>Female</td>
<td>69.5</td>
<td>65.8</td>
<td>73.2</td>
</tr>
<tr>
<td><strong>40 to 59 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>66.5</td>
<td>63.8</td>
<td>69.2</td>
</tr>
<tr>
<td>Female</td>
<td>67.1</td>
<td>65.0</td>
<td>69.2</td>
</tr>
<tr>
<td><strong>60 to 79 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>72.0</td>
<td>69.4</td>
<td>74.5</td>
</tr>
<tr>
<td>Female</td>
<td>73.3</td>
<td>70.3</td>
<td>76.4</td>
</tr>
</tbody>
</table>

Health Reports, Vol. 21, no. 1, March 2010 • Statistics Canada, Catalogue no. 82-003-XPE
Determinants of vitamin D status
Risk factors for vitamin D insufficiency

- Older age*
- Female sex
- Lower latitude
- Winter season
- Darker skin pigmentation
- Factors that determine sunlight exposure: clothing and cultural practises, dietary habits, national policies of vitamin D fortification

*The cutaneous production of vitamin D3 declines with age

Mithal et al. Osteoporos Int 20: 1807, 2009
Independent predictors for vitamin D insufficiency in Koreans

Male

Age group (20-29)
Age group (30-39)
Age group (40-49)
Age group (≥80)
Season (spring)
Season (winter)
Region (urban)
Occupation (A) Agriculture, forestry, and fishery
Occupation (B) Manual labor
Occupation (C) Engineering, assembling, and technical work
Occupation (D) Sales, and service
Occupation (E) Administration, clerical work, and specialists
Occupation (F) Students
Occupation (G) NA

Occupation

Regular exercise (no)

Odds ratio (95% CI)

1.42 (1.16-1.75)
2.75 (1.89-4.01)
3.80 (1.88-7.66)
2.26 (1.52-3.38)
2.44 (1.58-3.77)
1.74 (1.17-2.60)
1.90 (1.22-2.96)
1.93 (1.58-2.36)
4.19 (3.14-5.60)
4.90 (3.86-6.23)
2.03 (1.06-3.89)
1.64 (1.17-2.29)
2.14 (1.52-3.01)
3.48 (2.37-5.12)

Independent predictors for vitamin D insufficiency in Koreans

Female

Age group (20-29)
Age group (30-39)
Age group (40-49)
BMI (<23)
Season (spring)
Season (winter)
Region (urban)
Occupation (B)
Occupation (C)
Occupation (D)
Occupation (E)
Occupation (F)
Occupation (G)
Regular walking (no)
Regular exercise (no)

A. Agriculture, forestry, and fishery
B. Manual labor
C. Engineering, assembling, and technical work
D. Sales, and service
E. Administration, clerical work, and specialists
F. Students
G. NA

Odds ratio (95% CI)
Independent predictors for vitamin D insufficiency in Koreans

- After adjusting for confounders, young age groups were independent predictors for vitamin D insufficiency in our study.

- Although the cause of this finding is not clear, it might be due to other behavioral factors of young age groups (indoor lifestyle, sunscreen use, or dietary habits).
Strategies to improve vitamin D status
Sunlight and vitamin D

- Whole body exposure to 10~15 minutes of midday sun in summer [1 MED (minimal erythemal dose)], or the amount of sun exposure which produces a faint redness of skin
  - $\rightarrow$ 15,000 ~ 20,000 IU of vitamin D

- Exposure of hand, face and arms (15% of body surface) to around 1/3 MED
  - $\rightarrow$ 1000 IU of vitamin D

- Holick’s rule: ¼ of body to ¼ MED of sunlight
  - $\rightarrow$ 1000 IU of vitamin D
Sunlight and vitamin D

- 120 white Caucasians, aged 20–60 years, from UK (53.51N)
- A simulated summer’s sunlight exposures, specifically 1.3 SED (= summer’s 13 minutes sunlight exposures), three times weekly for 6 weeks, while wearing T-shirt and shorts (35%)

![Graph showing the variation of 25(OH)D levels over weeks](chart.png)

- 17.6 ng/ml = 44 nmol/l
- 28.0 ng/ml = 70 nmol/l
- 32 ng/ml

10.4 ng/ml = 26 nmol/l

Journal of Investigative Dermatology (2010) 130, 1411–1418
Sunlight and vitamin D

- 120 white Caucasians, aged 20–60 years, from UK (53.51N)
- A simulated summer’s sunlight exposures, specifically 1.3 SED (= summer's 13 minutes sunlight exposures), three times weekly for 6 weeks, while wearing T-shirt and shorts (35%)
**Table 4. Estimated time taken to acquire the same vitamin D-weighted dose as used in this study, at different North American and European locations at local noon on June 21 and December 21**

<table>
<thead>
<tr>
<th>City</th>
<th>Latitude¹ (deg, min)</th>
<th>Summer² (minutes)</th>
<th>Winter² (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Orleans</td>
<td>29, 57</td>
<td>9</td>
<td>39</td>
</tr>
<tr>
<td>San Diego</td>
<td>32, 42</td>
<td>9</td>
<td>49</td>
</tr>
<tr>
<td>Athens</td>
<td>37, 58</td>
<td>9</td>
<td>—</td>
</tr>
<tr>
<td>Washington</td>
<td>38, 53</td>
<td>9</td>
<td>—</td>
</tr>
<tr>
<td>Boston</td>
<td>42, 21</td>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td>Vancouver</td>
<td>49, 13</td>
<td>11</td>
<td>—</td>
</tr>
<tr>
<td>Brussels</td>
<td>50, 52</td>
<td>12</td>
<td>—</td>
</tr>
<tr>
<td>Manchester</td>
<td>53, 30</td>
<td>13</td>
<td>—</td>
</tr>
<tr>
<td>Oslo</td>
<td>58, 57</td>
<td>16</td>
<td>—</td>
</tr>
</tbody>
</table>

¹ Latitude is given in degrees and minutes.
² Times are given to the nearest minute; times > 1 h are not shown.
Participants who received exposures 1.95 SEDs (equivalent to 45 min unshaded sunlight) attained a mean (6SD) 25(OH)D of 39.25 nmol/l.

Sunlight and vitamin D

Dietary sources

• Fatty fish species
  ➢ Catfish, 85 g provides 425 IU (5 IU/g)
  ➢ Salmon, cooked, 100 g provides 360 IU (3.6 IU/g)
  ➢ Mackerel, cooked, 100 g, 345 IU (3.45 IU/g)
  ➢ Sardines, canned in oil, drained, 50 g, 250 IU (5 IU/g)
  ➢ Tuna, canned in oil, 100 g, 235 IU (2.35 IU/g)
  ➢ Eel, cooked, 100 g, 200 IU (2.00 IU/g)

• A whole egg provides 20 IU (0.33 IU/g)

• Beef liver, cooked, 100 g provides 15 IU (0.15 IU/g)

• Fish liver oils, such as cod liver oil, 15 ml provides 1360 IU (90.6 IU/ml)
Vitamin D Supplementation on Serum 25-Hydroxyvitamin D

- Meta-analysis of changes in circulating 25-hydroxyvitamin D level associated with vitamin D supplementation in Caucasian subjects over 50 yr old
- Seventy-six trials published from 1984 to March 2011 included 6207 subjects

The average increase in serum 25(OH)D was 0.78 ng/ml (1.95 nmol/liter) per microgram of vitamin D3 supplement (40IU) per day.
Fracture risk correlated with achieved 25(OH)D levels in RCTs

**Hip Fracture**

Relative Risk (95% CI) vs. 25(OH)D Level, nmol/L

Vitamin D Dose
- 400 IU/day
- 700–800 IU/day

RR 0.74 (0.61–0.88)

**Nonvertebral Fracture**

Relative Risk (95% CI) vs. 25(OH)D Level, nmol/L

Vitamin D Dose
- 400 IU/day
- 700–800 IU/day

RR 0.77 (0.68–0.87)

Fracture risk correlated with achieved 25(OH)D levels in RCTs.

Bischoff-Ferrari et al. JAMA. 2005; 293:2257–226
Fall prevention by dose and achieved 25(OH)D concentrations

Markers:

- 700-1000 IU: RR 0.81 (0.71-0.92)
- ≥60 nmol/l: RR 0.77 (0.65-0.9)

Graphs showing the relative risk of fall prevention with different doses and concentrations of vitamin D.
Dose of vitamin D and achieved 25(OH)D levels based on RCTs with a duration of at least 4 weeks

## Dietary Reference Intakes for Calcium and Vitamin D

### Table: Dietary Reference Intakes for Calcium and Vitamin D

<table>
<thead>
<tr>
<th>Life Stage Group</th>
<th>Calcium</th>
<th>Vitamin D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated</td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Dietary</td>
</tr>
<tr>
<td></td>
<td>Requirement</td>
<td>Allowance</td>
</tr>
<tr>
<td><strong>Infants 0 to 6 months</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Infants 6 to 12 months</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>1-3 years old</strong></td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td><strong>4-8 years old</strong></td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>9-13 years old</strong></td>
<td>1,100</td>
<td>1,300</td>
</tr>
<tr>
<td><strong>14-18 years old</strong></td>
<td>1,100</td>
<td>1,300</td>
</tr>
<tr>
<td><strong>19-30 years old</strong></td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>31-50 years old</strong></td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>51-70 year old males</strong></td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>51-70 year old females</strong></td>
<td>1,000</td>
<td>1,200</td>
</tr>
<tr>
<td><strong>&gt;70 years old</strong></td>
<td>1,000</td>
<td>1,200</td>
</tr>
<tr>
<td><strong>14-18 years old, pregnant/lactating</strong></td>
<td>1,100</td>
<td>1,300</td>
</tr>
<tr>
<td><strong>19-50 years old, pregnant/lactating</strong></td>
<td>800</td>
<td>1,000</td>
</tr>
</tbody>
</table>
NOF recommendations for vitamin D

- The National Osteoporosis Foundation (NOF) recommends that
  - Adults under age 50 get 400 - 800 IU of vitamin D every day
  - Adults age 50 and older get 800 - 1,000 IU of vitamin D every day
  - Some people may need more vitamin D
<table>
<thead>
<tr>
<th>연령</th>
<th>남자</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>평균 필요량</td>
<td>권장 섭취량</td>
<td>충분 섭취량</td>
<td>상한 섭취량</td>
<td>평균 필요량</td>
<td>권장 섭취량</td>
<td>충분 섭취량</td>
</tr>
<tr>
<td>0~5개월</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>1,000</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>1,000</td>
</tr>
<tr>
<td>6~11개월</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>1,000</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>1,000</td>
</tr>
<tr>
<td>1~2세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>3~5세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>6~8세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>9~11세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>12~14세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>15~18세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>19~29세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>30~49세</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>2,400</td>
</tr>
<tr>
<td>50~64세</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>2,400</td>
</tr>
<tr>
<td>65~74세</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>2,400</td>
</tr>
<tr>
<td>75세 이상</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>2,400</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>2,400</td>
</tr>
<tr>
<td>임신부</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>수유부</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

한국영양학회, 한국인 영양섭취기준 개정판, 2010
Conclusions

- The prevalence of vitamin D insufficiency, defined as a serum 25-hydroxyvitamin D [25(OH)D] level below 50 nmol/L, was 47.3% in males and 64.5% in females.

- Only 13.2% of males and 6.7% of females had a serum 25(OH)D level of greater than 75 nmol/L.

- In Korea, vitamin D insufficiency was more prevalent in young adults than in elderly people, likely due to the indoor lifestyle of younger people.
Conclusions

- Compared with the United States and Canada, Korea has a lower mean 25(OH)D level and a higher prevalence of vitamin D insufficiency.

- To improve the vitamin D status of the Korean population, more aggressive policies on food fortification and vitamin D supplementation are needed.