Nutritional Approaches to Maintaining Bone Health: Current Focus and Future Perspectives

Osteoporosis Master Class: University of Exeter
Friday 17th May 2019

Professor Susan Lanham-New FAfN, FRSB
Head of Department of Nutritional Sciences
• What is a healthy diet? Comments & discussion around what our diet should look like.

• Importance of vitamin D to health
  • Mechanisms of action of vitamin D metabolism
  • Vitamin D through sunlight exposure and dietary intake
  • New UK Vitamin D requirements – 400IU per day / 10µg per day
  • Sources of vitamin D2 (plant source) and vitamin D3 (animal source)

• Criticality of dietary calcium to bone health. How to achieve 700mg per day.

• Dietary protein and skeletal integrity. Importance of acid-base balance to bone. Other nutrients critical to bone

• Summary and take home messages
What is a Healthy Diet?
Eatwell Guide

Use the Eatwell Guide to help you get a balance of healthier and more sustainable food. It shows how much of what you eat overall should come from each food group.

- **Choose wholegrain or higher fibre versions with less salt, added fat, oil and sugars.**
- **Choose unsaturated oils and use in small amounts.**
- **Eat at least 5 portions of a variety of fruit and vegetables every day.**
- **Choose foods lower in fat, salt and sugars.**
- **Eat less often and in small amounts.**
- **Dairy and alternatives.**
- **Legumes, pulses, fish, eggs, meat and other proteins.**
- **Plain nuts.**
- **Whole and cereal grains.**
- **Frozen peas.**

Per day 

<table>
<thead>
<tr>
<th>2000kcal</th>
<th>2500kcal</th>
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<tbody>
<tr>
<td>ALL FOOD + ALL DRINKS</td>
<td></td>
</tr>
</tbody>
</table>

**6 a day**

Water, lower fat milk, sugar-free drinks including tea and coffee, all count.

Limit fruit juice and/or smoothies to a total of 160ml a day.
Beware of cutting out specific food groups
Dairy-free diets warning over risk to bone health

Prof Susan Lanham-New, head of nutritional sciences at the University of Surrey and clinical advisor to the National Osteoporosis Society, said: "Diet in early adulthood is so important because by the time we get into our late 20s it is too late to reverse the damage caused by poor diet and nutrient deficiencies and the opportunity to build strong bones has passed."
Vegan sources of Calcium

You can achieve a calcium rich diet on a vegan or vegetarian diet

- Dairy alternatives e.g. milk, yoghurts and puddings
- Fortified white bread
- Firm tofu
- Dark green leafy vegetables e.g. Kale, broccoli, Brussel sprouts and watercress
- Fortified orange juice
- Fortified breakfast cereals
Veganism and Bone Health

Knurick et al 2015

Young, non-obese adults consuming meat-based (n = 27), lacto-ovo vegetarian (n = 27), or vegan (n = 28) diets for ≥1 year

24-hour diet recall, whole body DXA scan, 24-hour urine specimen, and fasting blood samples collected

BMD was non-significantly lower in non-meat eaters in comparison to omnivores. Protein intake was reduced ~30% in individuals consuming lacto-ovo and vegan diets as compared to those consuming meat-based diets (68 ± 24, 69 ± 29, and 97 ± 47 g/day respectively, p = 0.006)

Urinary pH was more alkaline in the lacto-ovo and vegan groups versus omnivores (6.5 ± 0.4, 6.7 ± 0.4, and 6.2 ± 0.4 respectively, p = 0.003), while calcium excretion was significantly higher in omnivores compared to vegetarians (p = 0.045)

Data suggest that plant-based diets are not detrimental to bone in young adults
Vitamin D Research
Vitamin D – Introductory Comments

Vitamin D is not a ‘vitamer’ (vitamine)

The term ‘vitamin D’ is a confusing; it is not a ‘vital amine’ in the true sense of the word. It is a pro-hormone.

Only nutrient where main source is not one of diet but UV exposure

UVB exposure must be at 290-315nm
Vitamin D converting enzymes

Manbir S. Sandhu, MD,* and Thomas B. Casale, MD**

The role of vitamin D in asthma


Active Hormone
### Why is vitamin D so important?

Vitamin D is absolutely critical to health

<table>
<thead>
<tr>
<th>Children Rickets</th>
<th>Adults Osteomalacia; osteoporosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Disease</td>
<td>Diabetes</td>
</tr>
<tr>
<td></td>
<td>Cancer</td>
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<tr>
<td></td>
<td>TB</td>
</tr>
<tr>
<td></td>
<td>The Common Cold!</td>
</tr>
</tbody>
</table>

In the UK, we can only make vitamin D between April to September

British Winter is a huge challenge for vitamin D health!
Why is vitamin D so important?

New meta-analysis linking low vitamin D status to the common cold

Daily vitamin D dose would prevent millions of colds

Vitamin D supplements 'the key to beating colds and flu', study finds

New research finds taking on additional nutrients protects against acute respiratory infections

Ella Pickover | Thursday 16 February 2017 07:34 GMT
Innovations – Public health policy

Vitamin D

Scientific Advisory Committee on Nutrition

The Scientific Advisory Committee on Nutrition (SACN) advises Public Health England and other government agencies and departments on nutrition and related health issues.

SACN advises on:

- nutrient content of individual foods, and on diet as a whole including the definition of a balanced diet, and the nutritional status of people
- nutritional status of people in the UK and how it may be monitored
- nutritional issues which affect wider public health policy issues including conditions where nutritional status is one of a number of risk factors (e.g. cardiovascular disease, cancer, osteoporosis and/or obesity)
- nutrition of vulnerable groups (e.g. infants and the elderly) and health inequality issues
- research requirements for the above
Worldwide Vitamin D Recommendations

Slide Courtesy of Dr Taryn Smith
Defining Vitamin D Deficiency

Institute of Medicine (North America)

Scientific Advisory Committee on Nutrition (UK)

European Food Safety Authority

Endocrine Society

25OHD levels (nmol/l) 20 30 40 50 60 70 80 90

Slide Courtesy of Dr Taryn Smith
UK Recommendations

1991

Nutrition and Bone Health: Dietary Reference Values for Food Energy and Nutrients for the United Kingdom

1998

Dietary Reference Values for Food Energy and Nutrients for the United Kingdom

2007

Update on Vitamin D

2016

Vitamin D and Health

0 µg/day recommendation

10 µg/day recommendation

Slide Courtesy of Dr Taryn Smith
### Vitamin D

#### Innovations – Public health policy

<table>
<thead>
<tr>
<th>Age group</th>
<th>DRI NEW (Institute of Medicine, 2010)</th>
<th>RNI (Department of Health, 1991)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6 months</td>
<td>15 µg (600 IU)</td>
<td>8.5 µg (340 IU)</td>
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<tr>
<td>7 mo - 3 y</td>
<td>15 µg (600 IU)</td>
<td>7 µg (280 IU)</td>
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<tr>
<td>4 - 50 years</td>
<td>15 µg (600 IU)</td>
<td>10 µg</td>
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<tr>
<td>51 - 64 years</td>
<td>15 µg (600 IU)</td>
<td>10 µg</td>
</tr>
<tr>
<td>65 – 70 years</td>
<td>20 µg (800 IU)</td>
<td>10 µg (400 IU)</td>
</tr>
<tr>
<td>71 + years</td>
<td>25 µg (1000 IU)</td>
<td>10 µg (400 IU)</td>
</tr>
</tbody>
</table>

**New vitamin D requirements is 10 µg/400IU per day**

This represents a significant challenge to the UK population since we would achieve no more than 3.5 µg/140IU per day
Controversy – where to set the cut-point for total 250HD status
SACN – achievement of >25nmol/l (at the individual level)

Slide courtesy of Professor R Francis
Estimation of the dietary requirement for vitamin D in adolescents aged 14–18 y: a dose-response, double-blind, randomized placebo-controlled trial\textsuperscript{1,2}

Taryn J Smith,\textsuperscript{3,\#} Laura Tripkovic,\textsuperscript{3} Camilla T Damsaard,\textsuperscript{4} Christian Mølgaard,\textsuperscript{4} Christian Ritz,\textsuperscript{4} Saskia L. Wilson-Barnes,\textsuperscript{3} Kirsten G Dowling,\textsuperscript{5} Aine Hennessy,\textsuperscript{5} Kevin D Cashman,\textsuperscript{5,6} Mairead Kiely,\textsuperscript{5,7} Susan A Lanham-New\textsuperscript{5} and Kathryn H Hart\textsuperscript{4}

Estimation of the dietary requirement for vitamin D in white children aged 4–8 y: a randomized, controlled, dose-response trial\textsuperscript{1,2}

Charlotte Mortensen,\textsuperscript{3,4,9,\#} Camilla T Damsaard,\textsuperscript{3,9} Hanne Hauger,\textsuperscript{3} Christian Ritz,\textsuperscript{3} Susan A Lanham-New,\textsuperscript{5} Taryn J Smith,\textsuperscript{5} Aine Hennessy,\textsuperscript{6} Kirsten Dowling,\textsuperscript{6} Kevin D Cashman,\textsuperscript{6,7} Mairead Kiely,\textsuperscript{6,8} and Christian Mølgaard\textsuperscript{3}
What does it mean to target specific serum 25-hydroxyvitamin D concentrations in children and adolescents?

Steven A Abrams*

Mathematical Modelling of the Distribution of Vitamin D Intakes in Relation to 25(OH)D Status

Figure 2. The relation between post-intervention serum 25(OH)D concentrations and total vitamin D intake (diet plus supplemental) in 14-18 year old adolescents (n = 102) living in the UK (51°N). Mean response (central line) and its 95% prediction intervals (outer lines). Horizontal hashed lines represent serum 25(OH)D thresholds of 25, 30 and 50 nmol/l.

\[ y = 19.0 + (70.1 - 19.0) \times (1 - \exp(-x/12.5)) \quad (R^2 = 0.6170) \]

Smith et al. Out in November issue of AJCN with Editorial and second paper with the Copenhagen Group

Figure 2. The relation between post-intervention serum 25(OH)D concentrations and total vitamin D intake (diet plus supplemental) in 14-18 year old adolescents (n = 102) living in the UK (51°N). Mean response (central line) and its 95% prediction intervals (outer lines). Horizontal hashed lines represent serum 25(OH)D thresholds of 25, 30 and 50 nmol/l.
## Mathematical Modelling of the Distribution of Vitamin D Intakes in Relation to 25(OH)D Status

Table 3. Estimated dietary requirements for vitamin D (presented at selected percentiles) to maintain serum 25(OH)D concentrations above selected cut-offs during the winter-time in male and female adolescents aged 14-18 years (n = 102)\(^1\)

<table>
<thead>
<tr>
<th>Serum 25(OH)D concentration</th>
<th>50(^{th}) percentile(^2)</th>
<th>90(^{th}) percentile</th>
<th>95(^{th}) percentile</th>
<th>97.5(^{th}) percentile(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 25 nmol/l</td>
<td>1.6 (0.2, 2.7)</td>
<td>6.4 (5.2, 8.6)</td>
<td>8.2 (6.6, 10.9)</td>
<td>10.1 (8.0, 12.8)</td>
</tr>
<tr>
<td>&gt; 30 nmol/l</td>
<td>3.0 (1.3, 4.0)</td>
<td>8.7 (7.0, 11.0)</td>
<td>10.9 (8.7, 13.7)</td>
<td>13.1 (10.5, 16.6)</td>
</tr>
<tr>
<td>&gt; 40 nmol/l</td>
<td>6.6 (5.3, 8.1)</td>
<td>14.8 (12.2, 18.0)</td>
<td>18.6 (15.4, 24.0)</td>
<td>23.3 (18.0, 38.3)</td>
</tr>
<tr>
<td>&gt; 50 nmol/l</td>
<td>11.6 (9.2, 13.9)</td>
<td>27.8 (22.1, 62.2)</td>
<td>N/A(^4)</td>
<td>N/A(^4)</td>
</tr>
</tbody>
</table>

1 Estimates based on a non-linear model of serum 25(OH)D concentration as a function of vitamin D intake (y = b2 + b0 * (1 – exp(-b1 * x)). 95% CIs for the lower prediction limits were obtained using bias-corrected bootstrap based on 1000 replications.

2 The vitamin D intake required to maintain serum 25(OH)D in 50% of the population above the selected cut-off representing an EAR.

3 The vitamin D intake required to maintain serum 25(OH)D in 97.5% of the population above the selected cut-off representing an RDA.

4 N/A; not applicable as the plateau in 25(OH)D response at 46 nmol/l using the non-linear regression model means the 95% prediction line does not cross the 50 nmol/l threshold.
Vitamin D

Innovations – D-FINES Study (£0.7M, FSA funded)

**Aim:**
Effect of diet and sunlight on vitamin D status.

**Outcome:**
Extensive vitamin D issues in white Caucasian and South Asian populations.

**Impact:**
Informed DoH, PHE; Led to new significant funding from BBSRC.
Key Findings from D-FINES Study

Caucasian women consistently higher 25OHD, with seasonal change
Considerable vitamin D ‘insufficiency’ in Caucasian women in late autumn and winter.
Asian women extremely deficient throughout the year

Darling et al OI 2011, 2012)
Vitamin D

Innovations – D2 v D3 Study (£0.75M, BBSRC DRINC I)

Aim:
Does it matter if you give vitamin D2 (plant source) or vitamin D3 (animal sources)?

Outcome:
Vitamin D3 was 50% better at raising vitamin D levels in white Caucasian and South Asian populations.

Impact:
Key information for DoH, PHE and the food industry...
Led to exciting bid for further significant funding from BBSRC DRINC II.
Vitamin D –

generic term for two molecules:

1) Ergocalciferol (Vitamin D2) – derived from UV irradiation of ergosterol that is widely distributed in plants and other fungi

2) Cholecalciferol (Vitamin D3) – formed from the action of UV irradiation on the skin: form that is found in fish, eggs etc.
## Participant Characteristics

<table>
<thead>
<tr>
<th>Baseline anthropometrics</th>
<th>Groups</th>
<th>Groups</th>
<th>Groups</th>
<th>Groups</th>
<th>Groups</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Placebo</td>
<td>$D_2$ - juice</td>
<td>$D_2$ - biscuit</td>
<td>$D_3$ - juice</td>
<td>$D_3$ - biscuit</td>
<td></td>
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<tr>
<td></td>
<td>CA $n_{48}$ SA $n_{17}$</td>
<td>CA $n_{49}$ SA $n_{18}$</td>
<td>CA $n_{49}$ SA $n_{17}$</td>
<td>CA $n_{51}$ SA $n_{19}$</td>
<td>CA $n_{48}$ SA $n_{19}$</td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>44.1±11.48</td>
<td>44.3±11.18</td>
<td>43.2±13.23</td>
<td>43.0±12.73</td>
<td>43.7±12.84</td>
<td>0.965</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.64±0.07</td>
<td>1.64±0.07</td>
<td>1.64±0.06</td>
<td>1.65±0.06</td>
<td>1.64±0.07</td>
<td>0.834</td>
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<tr>
<td>Weight (kg)</td>
<td>65.8±10.12</td>
<td>64.4±8.30</td>
<td>64.8±11.79</td>
<td>64.4±10.28</td>
<td>63.6±10.90</td>
<td>0.794</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.4±3.62</td>
<td>24.2±3.42</td>
<td>24.1±4.45</td>
<td>23.8±3.65</td>
<td>23.8±3.82</td>
<td>0.848</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>82.9±10.76</td>
<td>81.9±9.93</td>
<td>81.9±11.83</td>
<td>81.0±11.68</td>
<td>82.1±11.86</td>
<td>0.912</td>
</tr>
<tr>
<td>WHR (cm)</td>
<td>0.81±0.08</td>
<td>0.81±0.07</td>
<td>0.81±0.07</td>
<td>0.79±0.08</td>
<td>0.81±0.08</td>
<td>0.645</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>30.1±6.87</td>
<td>30.1±5.54</td>
<td>30.5±6.36</td>
<td>29.9±6.75</td>
<td>29.3±7.81</td>
<td>0.897</td>
</tr>
<tr>
<td>Sys BP (mmHg)</td>
<td>118.9±15.09</td>
<td>116.8±14.78</td>
<td>120.0±15.46</td>
<td>118.1±12.69</td>
<td>117.4±15.49</td>
<td>0.749</td>
</tr>
<tr>
<td>Dias BP (mmHg)</td>
<td>78.7±9.69</td>
<td>77.5±9.51</td>
<td>79.3±9.48</td>
<td>77.9±9.83</td>
<td>77.2±10.27</td>
<td>0.707</td>
</tr>
</tbody>
</table>

**Key:**  
CA – Caucasian; SA – South Asian; BMI – Body Mass Index;  
WC – Waist Circumference; WHR – Waist:Hip Ratio;  
Sys BP – Systolic Blood Pressure; Dias BP – Diastolic Blood Pressure;
Serum total 25OHD levels per visit, taking into account the type of vitamin D consumed and the food matrix.
Daily supplementation with 15 μg vitamin D₂ compared with vitamin D₃ to increase wintertime 25-hydroxyvitamin D status in healthy South Asian and white European women: a 12-wk randomized, placebo-controlled food-fortification trial

Laura Tripkovic,¹ Louise R Wilson,¹ Kathryn Hart,¹ Sig Johnsen,² Simon de Lusignan,³ Colin P Smith,⁴ Giselda Bucca,⁴ Simon Penson,⁵ Gemma Chope,⁵ Ruan Elliott,¹ Elina Hyppönen,⁶ Jacqueline L Berry,⁷ and Susan A Lanham-New¹

¹Department of Nutritional Sciences, ²Surrey Clinical Research Centre, and ³Department of Clinical and Experimental Medicine, School of Biosciences and Medicine, Faculty of Health and Medical Sciences, University of Surrey, Guildford, United Kingdom; ⁴School of Pharmacy and Biomolecular Sciences, University of Brighton, Brighton, United Kingdom; ⁵Campden BRI, Chipping Campden, Gloucestershire, United Kingdom; ⁶Division of Health Sciences, School of Population Health, University of South Australia, Adelaide, South Australia, Australia; and ⁷Vitamin D Research Group, Department of Medicine, University of Manchester, Manchester, United Kingdom

Received May 25, 2016. Accepted for publication June 5, 2017.
doi: https://doi.org/10.3945/ajcn.116.138693.
Sources of vitamin D

You can buy vitamin D supplements in all chemists and supermarkets.

Slide Courtesy of Marcela Mendes & Saskia Wilson-Barnes
Sources of vitamin D

Slide Courtesy of Marcela Mendes & Saskia Wilson-Barnes
Vitamin D

When your shadow is *longer* than your height . . . .

You make **no** vitamin D
Hypothesis that cycles of rising and falling 25(OH)D concentrations are bad for health.

Humans “designed” through natural selection to have steady, levels around 150 nmol/L

Modern humans in the North suffer annual cycles of 25(OH)D fluctuation that our species was never designed to experience.

Modern Humans often have 25(OH)D levels around 50 nmol/L
Greater seasonal fluctuation or ‘cycling’ of 25-hydroxyvitamin D is associated with increased bone resorption

A.L.Darling (Surrey), F. Gossiel (Sheffield), F. Robertson (Surrey), K.Hart (Surrey), T.Hill (Newcastle), J.L.Berry (Manchester) S.Johnsen (Surrey), R.Eastell (Sheffield), S.A. Lanham-New (Surrey)

Young Investigator Award for AD, NOS Conference 2014. Published BONE in 2017
Vitamin D

Innovations – HM Submarines (£0.5M):
In collaboration with Professor Joanne Fallowfield (PI: Institute of Naval Medicine, Gosport)

Aim: To provide evidence of the nutritional issues in the health of British Submariners. Focus on vitamin D.

Outcome: Largest study ever conducted in the world on submarines. Involves 300 Submariners on 4 boats.

Low serum 25-hydroxyvitamin D is associated with increased risk of stress fracture during Royal Marine recruit training

T. Davey, S. A. Lanham-New, A. M. Shaw, B. Hale, R. Cobley, J. L. Berry, M. Roch, A. J. Allsopp & J. L. Fallowfield
Vitamin D

Innovations – Royal Marines Commando (£1.2M)
In collaboration with Professor Fallowfield Joanne (PI: Institute of Naval Medicine, Gosport)

Aim:
To undertake a vitamin D supplementation study in 5000 RM Marines for stress fracture prevention.

Outcome:
Largest study ever conducted in the world on vitamin D in Military Personnel. Funded until 2020.

Impact:
Will change MoD Policy - all British Military Personnel will be offered vitamin D if proves successful. Potential Impact Case for REF 2021.
Dietary Calcium and Bone Health
<table>
<thead>
<tr>
<th>Age</th>
<th>0-6 m</th>
<th>6-12 m</th>
<th>1-3 y</th>
<th>4-8 y</th>
<th>9-18 y</th>
<th>19-50 y</th>
<th>51-70 y</th>
<th>&gt;70 y</th>
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<tr>
<td>All</td>
<td>1000mg^U</td>
<td>1500mg^U</td>
<td>700mg</td>
<td>1000mg</td>
<td>1300mg</td>
<td>1000mg</td>
<td>1000mg</td>
<td>1200mg</td>
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<tr>
<td>Female*</td>
<td>1200mg</td>
<td>1200mg</td>
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**Department of Health (UK) RNI**

<table>
<thead>
<tr>
<th>Age</th>
<th>0-12 m</th>
<th>1-3 y</th>
<th>4-6 y</th>
<th>7-10 y</th>
<th>11-18 y</th>
<th>19-50 y</th>
<th>&gt;50 y</th>
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<tbody>
<tr>
<td>All</td>
<td>525mg</td>
<td>350mg</td>
<td>450mg</td>
<td>550mg</td>
<td>1000mg</td>
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<td>700mg</td>
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<td>Female*</td>
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RDA Recommended Dietary Allowance; RNI Reference Nutrient Intake; m months; y years; ^U Upper Level Intake; *where different from recommendation for males.
### Calcium Requirements

<table>
<thead>
<tr>
<th>Institute of Medicine (USA) RDA</th>
<th>Department of Health (UK) RNI</th>
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<tbody>
<tr>
<td><strong>Age</strong></td>
<td>0-6 m</td>
</tr>
<tr>
<td>All</td>
<td>1000mg&lt;sup&gt;U&lt;/sup&gt;</td>
</tr>
<tr>
<td>Female*</td>
<td>1200mg</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>0-12 m</td>
</tr>
<tr>
<td>All</td>
<td>525mg</td>
</tr>
<tr>
<td>Female*</td>
<td>800mg</td>
</tr>
</tbody>
</table>

RDA Recommended Dietary Allowance; RNI Reference Nutrient Intake; m months; y years; <sup>U</sup> Upper Level Intake; *where different from recommendation for males.

IOM based recommendations on varying outcomes relevant to the age of focus such as bone density in childhood and fracture risk in the elderly.

DoH based recommendations on a factorial approach which combined calculations of skeletal accretion and turnover rates with calcium absorption and excretion.
Calcium Intakes & Supplementation: During Growth

• In the latest NDNS data (2016) the percentages of boys and girls aged 11-18yrs with calcium intakes below the LRNI was 12% and 19% respectively.

• Low calcium intakes during growth will affect peak bone mass attainment, and consequently have an effect on osteoporosis and fracture risk later in life.

• Clinical trials with calcium supplements in both children and teenagers have shown an overall positive effect of calcium on bone mass accrual, although a meta-analysis of RCTs found that calcium had no effect on BMD, and only a small positive effect on bone mineral content (Wizenburg et al. 2006).
Calcium Intakes & Supplementation: Prevention of Osteoporosis & Fracture

- In the latest NDNS data (2016) the percentages of men and women aged 65+yrs with calcium intakes below the LRNI was 3% and 8% respectively.

- Good data from RCTs, reviews and meta-analyses have shown that calcium supplements are effective in reducing bone loss in late menopausal women, especially those with low habitual calcium intakes (Heaney 2000, Dawson-Hughes et al 1997, Shea et al 2002).

- However, the role of calcium supplementation in the prevention of osteoporosis and fracture has recently been the subject of considerable debate...
Dietary calcium intake is not associated with risk of fracture, and there is no clinical trial evidence that increasing calcium intake from dietary sources prevents fractures. Evidence that calcium supplements prevent fractures is weak and inconsistent.

This meta-analysis of RCTs supports the use of calcium plus vitamin D supplements as an intervention for fracture risk reduction in both community-dwelling and institutionalized middle-aged to older adults.
Dietary calcium intake is not associated with risk of fracture, and there is no clinical trial evidence that increasing calcium intake from dietary sources prevents fractures. Evidence that calcium supplements prevent fractures is weak and inconsistent. This meta-analysis of RCTs supports the use of calcium plus vitamin D supplements as an intervention for fracture risk reduction in both community-dwelling and institutionalized middle-aged to older adults.
Dietary calcium intake is not associated with risk of fracture, and there is no clinical trial evidence that increasing calcium intake from dietary sources prevents fractures. Evidence that calcium supplements prevent fractures is weak and inconsistent.

This meta-analysis of RCTs supports the use of calcium plus vitamin D supplements as an intervention for fracture risk reduction in both community-dwelling and institutionalized middle-aged to older adults.

Further research required to establish risk-benefit ratio; to date there has not been an RCT with cardiovascular health as the primary aim.
Dietary calcium intake is not associated with risk of fracture, and there is no clinical trial evidence that increasing calcium intake from dietary sources prevents fractures. Evidence that calcium supplements prevent fractures is weak and inconsistent.

This meta-analysis of RCTs supports the use of calcium plus vitamin D supplements as an intervention for fracture risk reduction in both community-dwelling and institutionalized middle-aged to older adults. The current consensus across professional bodies (National Osteoporosis Society, UK; International Osteoporosis Foundation, USA) is that calcium supplements should only be used on an individual basis to bring total calcium intake to the recommended level in healthy adults.
Dietary Protein and Bone Health
Higher dietary protein may also increase calcium absorption

(Dawson-Hughes (2003), Proc Nut Soc 62(2) 505-509)
Dietary Protein and Catabolic Effects on Bone

Arnett (2003) Proc Nutr Soc. 62(2) 511-20
### Table 4
Estimation of daily renal net acid excretion (NAE) for a woman\(^a\) consuming a fictitious diet with a relatively high (diet A) or low (diet B) potential renal acid load (PRAL)

<table>
<thead>
<tr>
<th>Food</th>
<th>Intake (g/d)</th>
<th>Energy (kcal/d)</th>
<th>Protein (g/d)</th>
<th>PRAL(^b) (mEq/100 g)</th>
<th>PRAL(^b) (mEq/d)</th>
<th>PRAL(^a) (mEq/d)</th>
<th>Food</th>
<th>Intake (g/d)</th>
<th>Energy (kcal/d)</th>
<th>Protein (g/d)</th>
<th>PRAL(^b) (mEq/100 g)</th>
<th>PRAL(^b) (mEq/d)</th>
<th>PRAL(^a) (mEq/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread, wheat flour</td>
<td>200</td>
<td>466</td>
<td>12.4</td>
<td>3.8</td>
<td>7.6</td>
<td>7.0</td>
<td>Bread, wheat flour</td>
<td>200</td>
<td>466</td>
<td>12.4</td>
<td>3.8</td>
<td>7.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>350</td>
<td>343</td>
<td>48.3</td>
<td>8.7</td>
<td>30.5</td>
<td>28.0</td>
<td>Tomatoes</td>
<td>300</td>
<td>51</td>
<td>2.1</td>
<td>–3.1</td>
<td>–9.3</td>
<td>–8.4</td>
</tr>
<tr>
<td>Turkey</td>
<td>200</td>
<td>214</td>
<td>43.8</td>
<td>9.9</td>
<td>19.8</td>
<td>19.0</td>
<td>Turkey</td>
<td>200</td>
<td>214</td>
<td>43.8</td>
<td>9.9</td>
<td>19.8</td>
<td>19.0</td>
</tr>
<tr>
<td>Cucumber</td>
<td>200</td>
<td>20</td>
<td>1.4</td>
<td>–0.8</td>
<td>–1.6</td>
<td>–5.8</td>
<td>Carrots</td>
<td>300</td>
<td>90</td>
<td>2.1</td>
<td>–4.9</td>
<td>–14.7</td>
<td>–8.4</td>
</tr>
<tr>
<td>Spaghetti</td>
<td>120</td>
<td>410</td>
<td>14.4</td>
<td>6.5</td>
<td>7.8</td>
<td>8.0</td>
<td>Potatoes</td>
<td>400</td>
<td>300</td>
<td>8.4</td>
<td>–4.0</td>
<td>–16.0</td>
<td>–11.2</td>
</tr>
<tr>
<td>Butter, margarine</td>
<td>102</td>
<td>753</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>Butter, margarine</td>
<td>147</td>
<td>1,065</td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Daily urinary excretion of organic acids\(^a\) = 39.8\(^d\) + 41.6\(^e\)

Daily NAE (estimated) = 103.9 + 98.0

\(^a\)An adult female 63 kg in weight and 163 cm in height.

\(^b\)PRAL values taken from Table 2.

\(^c\)Calculated from the average PRAL values listed in Table 3.

\(^d\)Estimation of daily excretion of organic acids (OA):

OA (mEq/d) = body surface area (m\(^2\)) \times 41 (mEq/d/1.73 m\(^2\))

\(^e\)Simplified estimation of daily excretion of OA using individual body weight (BW) (9): OA (mEq/d) = BW \times 0.66.
Dietary protein and bone health: a systematic review and meta-analysis\textsuperscript{1–3}

Andrea L Darling, D Joe Millward, David J Torgerson, Catherine E Hewitt, and Susan A Lanham-New
Conclusions

• A small positive effect of protein supplementation on lumbar spine BMD in RCTs supports the positive association between protein intake and bone health found in cross-sectional surveys.

• However these results were not supported by cohort study findings for fracture risk. Any effects found were small and close to zero.

• Therefore, this review showed a small positive benefit of dietary protein on bone health, but the benefit may not necessarily translate into reduced fracture risk in the long term.
LATEST NEWS

• New and updated systematic review and meta-analysis of over 120 studies shows no association between dietary protein and fracture risk, and no detrimental effect of protein supplementation on BMD

• (Darling et al, 2018- manuscript just out in Osteoporosis Review.)
Implications for clinical practice

- No detrimental effect of protein supplementation on bone health seen in healthy adults habitually consuming protein above the recommended dietary intake level.

- No evidence for differences between protein types on bone health (e.g. animal, vegetable, soy protein devoid of isoflavones).

- There may be a beneficial effect of increased protein intake in persons with very protein low intakes (e.g. frail elderly, malnourished for other reasons), but research evidence in these groups is lacking.

- The whole diet needs to be considered, adequate calcium intake is likely to be important in offsetting any protein-induced physiological acidity.
Other Nutrients & Dietary Patterns and Bone Health
Sodium high intakes

eat less SALT!
Sodium

- Osteoclast proliferation
- Neurological symptoms/unsteady gait
- Hyponatraemia
- High intakes

↑ osteoporosis
↑ falls & fractures

1 Verbalis et al, 2010; 2 Hoorn et al, 2010

eat less SALT!
Sodium

**Increased urinary calcium excretion**

- **Osteoclast proliferation**
- **Hyponatraemia**
- **Neurological symptoms/unsteady gait**
- **↑ osteoporosis**
- **↑ falls & fractures**

**Increased urinary Na excretion**

- **Post-menopausal women**
- **↓ BMD**
- **↑ Bone resorption**
- **↑ Osteoporosis risk**

• Monitor those at risk for hyponatraemia for osteoporosis

• Encourage adherence to salt reduction targets
• Achieve ‘balance’ (potassium, bicarbonate, calcium)

Practical advice

eat less SALT!
Vitamin K

$K_1$
phylloquinone

- Green leafy vegetables & brassicas

$K_2$
menaquinone

- MK-4: egg yolk, butter, liver, meat
- MK-7: fermented foods
- MK-10: colonic bacteria
Vitamin K

\[ K_1 \] phylloquinone

Green leafy vegetables & brassicas

\[ K_2 \] menaquinone

MK-4: egg yolk, butter, liver, meat

MK-7: fermented foods

MK-10: colonic bacteria

↑ number and activity of osteoblasts

Activation of osteocalcin

Apoptosis of osteoclasts

↑ Lumbar spine

BMD\(^1\)

↓ fractures\(^2\)

Post-menopausal women + Osteoporosis

\(^1\) Fang et al, 2012; \(^2\) Huang et al, 2014
Vitamin K

K₁ phylloquinone
Green leafy vegetables & brassicas

K₂ menaquinone
MK-4: egg yolk, butter, liver, meat
MK-7: fermented foods
MK-10: colonic bacteria

Carboxylation of osteocalcin

Δ bone geometry & ↑ quality

↑ BMD³  ↓ fractures⁴

↑ number and activity of osteoblasts

Post-menopausal women
Osteoporosis

Apoptosis of osteoclasts

↑ Lumbar spine BMD  ↓ fractures

³ Kanellakis et al, 2012; ⁴ Cheung et al, 2008
**Vitamin K**

- **$K_1$** phylloquinone
- **$K_2$** menaquinone

- Significant –ve correlation with under-carboxylated osteocalcin
- No significant effect on BMD at any site
- Insufficient data for fracture risk or bone resorption

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**Wadsworth et al., 2010**

Andrea’s Forest plots???

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- Significant –ve correlation with under-carboxylated osteocalcin
- Effect of supplementation on BMD and fracture risk
Vitamin K

**K₁**
phylloquinone

Studies:
10mg/d

Rich dietary sources/
vegetables
and legumes

**K₂**
menaquinone

Studies:
45mg/d

Varied diet
+ supplementation
for post-menopausal
women/ those
with osteoporosis?

Practical advice

AI: 90-120µg/d

Not supported by National Osteoporosis Foundation
But...are single nutrients the answer?

“Suboptimal single nutrient intake does not occur in isolation but rather reflects a poor diet quality.”

And...are all contemporary diets ‘bad’ for bone health?

“Such (Western) diets .... cause...chronic progressively worsening, pathologically significant, low grade, hyperchloremic metabolic acidosis”

Frassetto et al, 2008
CHARACTERISTICS OF THE MODERN DIET COMPARED TO THE HUMAN ANCESTRAL DIET – AND PATHOPHYSIOLOGICAL CONSEQUENCES

↑Added NaCl Intake
  ↓K⁺ intake
  ↓Plasma [K⁺] & ↓Body Potassium Content
  ↓Arteriolar Vasoconstriction
  Hypertension, CVD, Stroke

↓Fruits/Vegetables Intake
  ↓HCO₃⁻ Precursors Intake
  ↓Plasma [HCO₃⁻] & ↓Body Carbonate Content
  ↓Urine Citrate Excretion
  Kidney Stones

↑Cereal Grain Products Intake
  ↑endogenous H⁺ generation
  ↑Bone Formation & ↑Bone Resorption
  ↑Urinary Calcium Excretion
  Osteopenia / Osteoporosis
  Muscle Protein Catabolism / Sarcopenia

Metabolic Acidosis
CHARACTERISTICS OF THE MODERN DIET COMPARED TO THE HUMAN ANCESTRAL DIET – AND PATHOPHYSIOLOGICAL CONSEQUENCES

- **↑Added NaCl Intake**
  - **↓K⁺ Intake**
  - **↓HCO₃⁻ Precursors Intake**
  - **↑Cereal Grain Products Intake**
  - **↑endogenous H⁺ generation**

  **→ Metabolic Acidosis**

  **↓Body Potassium Content**
  - **↓Plasma [K⁺]**
  - **↓Urine Citrate Excretion**
  - **↑Urine Calcium Excretion**
  - **↓Bone Formation & ↑Bone Resorption**

  **→ Osteopenia / Osteoporosis**

  **↓Arteriolar Vasoconstriction**

  **Hypertension, CVD, Stroke**

  **↓Plasma [CH] & ↑ECFV**

  **Kidney Stones**

  **Muscle Protein Catabolism / Sarcopenia**
American diet acidosis = ‘bicarbonate deficiency’ acidosis + ‘NaCl-induced dilutional’ acidosis + ‘renal’ acidosis
Forget five a day, eat 10 portions of fruit and veg to cut risk of early death

Scientists say even just 2.5 portions daily can lower chance of heart disease, stroke, cancer and premature death.

Eating loads of fruit and vegetables - 10 portions a day - may give us longer lives, say researchers.

The study, by Imperial College London, calculated such eating habits could prevent 7.8 million premature deaths each year.
• Eating a well balanced diet (following the Eatwell Guide) is key for health. Eat a wide variety of foods and ensure no less that 5 portions of fruit & veg per day.

• Take a vitamin D supplement to ensure that you are reaching the new UK Vitamin D requirements. Consider winter-time vitamin D supplementation only if you are able to be out April-Sept.

• When outside - remember your shadow must be shorter than your height to make vitamin D!

• Consume an adequate amount of dairy/dairy alternatives to ensure an adequate calcium supply (e.g of 3 portions - 200ml glass of milk, a 150g yoghurt, match box size of cheddar cheese).

• Dietary protein from a mixed diet is key for bone health. Ensure consumption of an alkaline-rich diet and minimum salt intake.
Food and Nutrition for Health
Fifty years of distinguished teaching and research in food and nutrition – benefiting public health and educating future practitioners
Questions