Bone Nutrients for Vegetarians

Reed Mangels, PhD, RD, LDN, FADA

The Vegetarian Resource Group
Factors Affecting Risk of Osteoporosis:
- Heredity
- Gender
- Age
- Body Size
- Medications
- Diet
- Exercise
- Other
Nutrients Playing a Role in Bone Health

- Calcium
- Vitamin D
- Phosphorus
- Magnesium
- Zinc
- Copper
- Manganese
- Vitamin C
- Vitamin B$_{12}$
- Vitamin K
- Potassium
- Protein …
Factors Related to Vegetarianism that May Impact Bone Health

- Lower BMI
- Hormone levels
- Healthy lifestyle
- Exercise

Dietary factors

Dietary factors
Is a plant-based diet adequate for healthy bones?

Does a plant-based diet offer some advantages in terms of bone health?

What practical recommendations can be made to people following vegetarian diets?
Bone Mineral Density (BMD)
Nine studies of 2749 subjects (20-79 y; 68% F) included in the analysis

BMD was approximately 4% lower in vegetarians than in omnivores (95% CI: 2%, 7%) at both the femoral neck and the lumbar spine.

BMD was approximately 6% lower in vegans and 2% lower in LOVs than in omnivores (95% CI: 4%, 9% and 1%, 4%) at the femoral neck.
“In conclusion, the results of this meta-analysis suggest that there is a modest effect of vegetarian diets, particularly a vegan diet, on BMD, but the effect size is unlikely to result in a clinically important increase in fracture risk.”

Is a plant-based diet adequate for healthy bones?

The effect of a vegetarian diet on BMD appears to be modest and not of clinical significance.
Fracture Risk
ORIGINAL ARTICLE

Comparative fracture risk in vegetarians and nonvegetarians in EPIC-Oxford

P Appleby, A Roddam, N Allen and T Key
Fractures in Different Dietary Groups, EPIC-Oxford

<table>
<thead>
<tr>
<th>Diet Group</th>
<th>Fracture Incidence Rate Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat Eaters</td>
<td>1.00</td>
</tr>
<tr>
<td>Fish Eaters</td>
<td>1.05 (0.91-1.20)</td>
</tr>
<tr>
<td>Vegetarians</td>
<td>1.01 (0.89-1.13)</td>
</tr>
<tr>
<td>Vegans</td>
<td>1.37 (1.07-1.74)</td>
</tr>
</tbody>
</table>

Adjusted for age and sex only

<table>
<thead>
<tr>
<th>Diet Group</th>
<th>Fracture Incidence Rate Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat Eaters</td>
<td>1.00</td>
</tr>
<tr>
<td>Fish Eaters</td>
<td>1.01 (0.88-1.17)</td>
</tr>
<tr>
<td>Vegetarians</td>
<td>1.00 (0.89-1.13)</td>
</tr>
<tr>
<td>Vegans</td>
<td>1.30 (1.02-1.66)</td>
</tr>
</tbody>
</table>

Adjusted for age, sex, and non-dietary factors

<table>
<thead>
<tr>
<th>Diet Group</th>
<th>Fracture Incidence Rate Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat Eaters</td>
<td>1.00</td>
</tr>
<tr>
<td>Fish Eaters</td>
<td>1.05 (0.90-1.21)</td>
</tr>
<tr>
<td>Vegetarians</td>
<td>1.02 (0.90-1.15)</td>
</tr>
<tr>
<td>Vegans</td>
<td>1.00 (0.69-1.44)</td>
</tr>
</tbody>
</table>

Adjusted for age, sex, non-dietary factors, and only including subjects consuming at least 525 mg/day calcium

“the results [of this study] provide good evidence that omnivores and vegetarians do not differ with respect to bone fracture risk.”

181 Vietnamese postmenopausal women followed for 2 years; vertebral fracture incidence rate was NSD in vegans (5.7%) vs omnivores (5.4%) (Ho-Pham, 2012)
1857 peri- and postmenopausal women from AHS hazard risk (HR) for wrist fracture:
- Never ate meat, fish, poultry 1.00
- Meat, fish, poultry <1-4x/wk 0.87 (0.62-1.24)
- Meat, fish, poultry >4x/wk 0.44 (0.23–0.84)
- P for trend = 0.02
- Vegetarian women with the lowest vegetable protein intake were at highest risk for fracture.

Is a plant-based diet adequate for healthy bones?

Studies suggest that fracture rates are similar in vegetarians and nonvegetarians if calcium intake is adequate and diet contains good sources of protein.
Bone Nutrients for Vegetarians
Calcium
### Dietary Reference Intakes - Calcium

<table>
<thead>
<tr>
<th>Life Stage Group</th>
<th>Calcium EAR (mg/day)</th>
<th>Calcium RDA (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3 year olds</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>4-8 year olds</td>
<td>800</td>
<td>1000</td>
</tr>
<tr>
<td>9-18 year olds</td>
<td>1100</td>
<td>1300</td>
</tr>
<tr>
<td>19-50 year olds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>51-70 year old males</td>
<td>800</td>
<td>1000</td>
</tr>
<tr>
<td>51-70 year old females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;70 year olds</td>
<td>1000</td>
<td>1200</td>
</tr>
</tbody>
</table>
Range of Mean Calcium Intakes of Male Vegetarians and NVs

- LOV: Maximum 1000 mg, Minimum 800 mg
- VEG: Maximum 400 mg, Minimum 300 mg
- NV: Maximum 800 mg, Minimum 600 mg

Dietary Calcium (mg)
Range of Mean Calcium Intakes of Female Vegetarians and NVs

- LOV: Maximum = 600 mg, Minimum = 400 mg
- VEG: Maximum = 600 mg, Minimum = 400 mg
- NV: Maximum = 600 mg, Minimum = 400 mg
Foods Containing Approximately 150 mg of Calcium per Serving

- **1/2 cup** calcium-fortified plant milk, calcium-fortified orange juice, tempeh, soybeans, firm tofu made with calcium and nigari, calcium-fortified yogurt

- **1 c** cooked bok choy, collards, kale, mustard greens, okra, white beans

- **2 c** cooked broccoli

- **1/4 cup** calcium-fortified tofu, almonds

- **2 T** almond butter, tahini

- **2** navel oranges

- **10** dried figs

- **1/2** calcium-fortified energy bar
1 cup of cow’s milk has 96 mg absorbable calcium. So do these foods:

- ½ cup Chinese cabbage
- 0.6 - 1 cup calcium-fortified juice
- 1 cup bok choy
- 1-1/3 cups calcium-fortified soymilk
- 1-1/2 cups kale
- 5.4 ounces calcium-set tofu
- 2 cups white beans
- 2-1/4 cups broccoli

Sample Vegan Menu Providing >1200 mg of Calcium

<table>
<thead>
<tr>
<th></th>
<th>Calcium (mg)</th>
<th></th>
<th>Calcium (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breakfast</strong></td>
<td></td>
<td><strong>Lunch</strong></td>
<td></td>
</tr>
<tr>
<td>- 4 oz calcium-fortified orange juice</td>
<td>175</td>
<td>- ½ cup white bean hummus on pita</td>
<td>128</td>
</tr>
<tr>
<td>- 1 cup oatmeal</td>
<td>21</td>
<td>- Apple</td>
<td>11</td>
</tr>
<tr>
<td>- 4 oz soy yogurt</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dinner</strong></td>
<td></td>
<td><strong>Snack</strong></td>
<td></td>
</tr>
<tr>
<td>- Stir-fry with 4 oz calcium-set tofu and 1 cup kale</td>
<td>380</td>
<td>- 1 energy bar</td>
<td>425</td>
</tr>
</tbody>
</table>
Calcium Retention in the Adult Human Male as Affected by Protein Intake\textsuperscript{1}

RUTH M. WALKER\textsuperscript{2} AND HELLEN M. LINKSWILER
Department of Nutritional Sciences, University of Wisconsin, Madison, Wisconsin 53706

Urinary Calcium and Calcium Balance in Young Men as Affected by Level of Protein and Phosphorus Intake\textsuperscript{1}

MAREN HEGSTED,\textsuperscript{2} SALLY A. SCHUETTE, MICHAEL B. ZEMEL,\textsuperscript{2} AND HELLEN M. LINKSWILER
Department of Nutritional Sciences, University of Wisconsin, Madison, Wisconsin, WI 53706

Long-Term Effects of Level of Protein Intake on Calcium Metabolism in Young Adult Women\textsuperscript{1}

MAREN HEGSTED\textsuperscript{2} AND HELLEN M. LINKSWILER
Department of Nutritional Sciences, University of Wisconsin, Madison, WI 53706

Dietary Protein Increases Urinary Calcium

JANE E. KERSTETTER* AND LINDSAY H. ALLEN**
*School of Allied Health Professions and **Department of Nutritional Sciences, The University of Connecticut, Storrs, CT 06269-4017
### Hazard Ratio for Forearm Fracture by Vegetable Protein Intake

<table>
<thead>
<tr>
<th>Consumption Frequency</th>
<th>HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3 x/wk</td>
<td>1.00</td>
</tr>
<tr>
<td>3-7 x/wk</td>
<td>0.66 (0.32-1.39)</td>
</tr>
<tr>
<td>&gt;1 x/day</td>
<td>0.32 (0.13-0.76)</td>
</tr>
</tbody>
</table>

\( p \text{ for trend} = 0.04 \)

**Vegetable Protein = Beans, Nuts, Soy milk, Meat analogues**

More frequent consumption of each of these food groups was associated with a significant reduction in risk of fracture in vegetarian women:

- Beans
- Meat Analogues
- Cheese

### Positive Effects of Protein

- **Calcium absorption**
- **Muscle mass → improved bone health**
- **Growth factors such as insulin-like growth factor I (IGF-I)**

**Suppresses parathyroid hormone (PTH)**

**Maintains bone structure**

### Negative Effects of Protein

- **Urinary calcium losses**
- **Acid production → possible shift in the balance between osteoblastic and osteoclastic activity**
Most cross-sectional surveys and cohort studies found protein intake had a positive or no effect on BMD

Protein intake explained 1-2% of BMD

Protein intake either reduced or did not affect risk of hip fracture regardless of form of protein (animal vs vegetable)

Protein supplements had a positive effect on lumbar spine BMD although this was of questionable clinical importance

Protein supplements had no effect on risk of hip fracture
“... there is a small benefit of protein on bone health, but the benefit may not necessarily translate into reduced fracture risk in the long term.”

“...the effect of dietary protein on the skeleton appears to be favorable to a small extent or, at least, is not detrimental.”

How might we maintain the positive effects and avoid (or minimize) the negative effects?

**Positive Effects of Protein**

- **↑ Calcium absorption**
- **↑ Muscle mass → improved bone health**
- **↑ Growth factors such as insulin-like growth factor I (IGF-I)**

**Suppresses parathyroid hormone (PTH)**

**Maintains bone structure**

**More vegetables and fruits might:**

- **↓ Urinary calcium losses?**
Vitamin D
Basics of Vitamin D

- Vitamin D can be synthesized by humans in the skin upon exposure to ultraviolet-B (UVB) radiation from sunlight, or it can be obtained from the diet.

- Cutaneous vitamin D synthesis does not occur above 40° N and below 40° S, for 3-5 months per year.

- Sunscreen, dark-colored skin, clothing coverage, and other factors limit vitamin D synthesis.

- Many people require dietary/supplemental sources of vitamin D.
Vegetarian Vitamin D Intake

- Finland – premenopausal F: NV>LV; NV>VEG
- UK (EPIC – Oxford): NV>LOV/LV>VEG
- US and Canada (AHS-2): NSD between vegetarians and NV in total vitamin D; dietary vitamin D was lower in non-Hispanic white vegetarians
## Vitamin D Status – EPIC-Oxford

<table>
<thead>
<tr>
<th></th>
<th>Meat Eater</th>
<th>Vegetarian</th>
<th>Vegan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma 25(OH)D (nmol/L) - Geometric mean (95% CI)</td>
<td>77.0&lt;sup&gt;a&lt;/sup&gt; (75.4, 78.8)</td>
<td>66.0&lt;sup&gt;b&lt;/sup&gt; (63.3, 68.8)</td>
<td>55.8&lt;sup&gt;c&lt;/sup&gt; (51.0, 61.0)</td>
</tr>
</tbody>
</table>

- Mean values within a row with unlike superscript letters were significantly different (P<0.05).
- Geometric means were adjusted for multiple factors including season and year of blood sample collection, age, sex, BMI, smoking status, summer outdoor activity, vigorous exercise, current use of hormones.

% of study participants having plasma 25(OH)D concentrations ≤25 nmol/L when blood was collected in

<table>
<thead>
<tr>
<th></th>
<th>Winter and Spring</th>
<th>Summer and Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat eaters</td>
<td>&lt;1%</td>
<td>0%</td>
</tr>
<tr>
<td>Fish eaters</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Vegetarians</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Vegans</td>
<td>8%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Data from *Public Health Nutr*. 2010;14(2), 340–346
### Foods Containing Vitamin D$_2$

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving Size</th>
<th>Vitamin D (IU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fortified plant milk</td>
<td>8 ounces</td>
<td>40-120</td>
</tr>
<tr>
<td>Mushrooms, exposed to UV light</td>
<td>1 cup diced</td>
<td>384</td>
</tr>
<tr>
<td>Mushroom powder</td>
<td>1 teaspoon</td>
<td>600</td>
</tr>
<tr>
<td>Morel mushrooms</td>
<td>1 cup</td>
<td>136</td>
</tr>
<tr>
<td>Chanterelle mushrooms</td>
<td>1 cup</td>
<td>114</td>
</tr>
<tr>
<td>Brown, Crimini mushrooms</td>
<td>1 cup</td>
<td>2</td>
</tr>
<tr>
<td>White or portabella mushrooms</td>
<td>1 cup</td>
<td>3-9</td>
</tr>
</tbody>
</table>

*Data from USDA National Nutrient Database for Standard Reference, Release 25. 2012 and manufacturer’s information*
“At this time, firm conclusions about different effects of the two forms of vitamin D cannot be drawn; however, it would appear that at low doses, $D_2$ and $D_3$ are equivalent, but at high doses, $D_2$ is less effective than $D_3$. ”

*Dietary Reference Intakes for Calcium and Vitamin D (2011)*

Food and Nutrition Board (FNB)
Fruits and Vegetables
Fruits and vegetables provide nutrients and antioxidants that are involved in bone metabolism. These include:

- Magnesium
- Calcium
- Potassium
- Vitamin C
- Vitamin K
- Polyphenols
The lower dietary acid load seen in diets high in fruits and vegetables may promote calcium balance.

Phytochemicals and antioxidants could reduce bone resorption due to high oxidative stress.

Vegetable Intake and Risk of Forearm Fracture

Xu et al, Climacteric. 2009;12:222–229
Other Factors that may Impact Vegetarian Bone Health
Epidemiological studies indicate that women who have high soy food consumption have a lower risk of osteoporosis than women who consume a typical Western diet.

Epidemiological studies find a reduced risk of fracture in women with the highest soy intakes. Reduction in risk is similar to that reported for estrogen therapy.

Meta-analyses of RCTs of isoflavone supplements have mixed results.

Recent RCTs show positive effects of isoflavones on bone only in very high doses – considerably above typical intakes from soyfoods.
Potassium Intake and BMD

Lumbar Spine BMD

P<0.01

Femoral Neck BMD

P<0.01

Lumbar spine BMD (g/cm²)

Femoral neck BMD (g/cm²)

Quartiles of energy adjusted K intake

Quartiles of energy adjusted K intake

* P<0.05

** P<0.01

Range of Mean Potassium Intakes of Male Vegs & NVs

- **LOV**
  - Maximum: 3000 mg
  - Minimum: 1000 mg

- **VEG**
  - Maximum: 6000 mg
  - Minimum: 3000 mg

- **NV**
  - Maximum: 4000 mg
  - Minimum: 2000 mg

**ICVN**
International Congress on Vegetarian Nutrition
Range of Mean Potassium Intakes of Female Vegs & NVs

Dietary Potassium (mg)

- **LOV**
  - Maximum: 2500 mg
  - Minimum: 2000 mg

- **VEG**
  - Maximum: 5000 mg
  - Minimum: 4000 mg

- **NV**
  - Maximum: 3500 mg
  - Minimum: 3000 mg

**ICVN**
International Congress on Vegetarian Nutrition
Vitamin C and Fracture

- **Epidemiologic studies:**
  - low circulating vitamin B12 and high total homocysteine concentrations linked to low bone mineral density (BMD) and fractures

- **Observational study (Herrmann et al):**
  - Bone-turnover markers were significantly higher in vitamin B$_{12}$ deficient vegetarians and vegans
  - Mild to moderate vitamin B$_{12}$ deficiency appeared to increase bone turnover
  - Results were independent from vitamin D status.

Recommendations for Bone Health on a Plant-based Diet

- Adequate calcium and vitamin D
- Adequate protein from a variety of sources
- Generous amounts of a variety of fruits and vegetables
- Regular, reliable sources of vitamin B\textsubscript{12} to insure sufficiency
- Moderate to low sodium
- Weight-bearing exercise