**Diet and Bone Health**

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**Outline**

- Diet and lifelong bone health
- Shortfall nutrients
- Function of shortfall nutrients
- Relation to bone health

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**Bone Mass Throughout the Lifespan**

![Graph showing bone mass throughout the lifespan with factors affecting bone mass such as environment, peak bone mass, genetics, fracture zone, and menopause.]

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**Strategies to Prevent Fracture**

![Graph illustrating strategies to prevent fracture with adequate calcium intake, fracture zone, and factors such as heredity, exercise/loading, and structural errors.]

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**Total Body Bone Mineral Content**

![Graph showing total body bone mineral content with % Total Body BMC at different ages (1-7 years).]

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**10 % increase** in peak bone mass, this could delay onset of **osteoporosis** by **13 years** and decrease risk of **fracture** in postmenopausal women by **50 %**
2010 Dietary Guidelines

Shortfall nutrients for children and adults

- Vitamin D
- Calcium
- Potassium
- Dietary Fiber

Possibly: vitamin A, C, and E, magnesium

2010 Dietary Guidelines

Shortfall food groups for children and adults

- Vegetables
- Fruits
- Whole grains
- Fluid milk and milk products
- Oils

Calcium

Half of women over age 50 will have a fracture.
World wide cost of hip fracture - $131 billion
Maximizing Bone Mineral Content
Reduces Risk of Fracture

RDAs for calcium with age (line) compared to mean intakes of calcium for men and women in the U.S. (bars). Mean intakes for calcium are from the NHANES 2003-2006 data.

Calcium storage in bone is a functional reserve

http://www.ohsuhealth.com/vich/health/orthopaedics
Adolescence: Period of Rapid Bone Accretion

Camp Calcium
Metabolic Studies in Adolescents
How much Calcium?

Camp Calcium Studies
- 10 metabolic balance studies, 1990 to 2007
- Adolescent boys and girls
- Controlled diets for 3 week metabolic balance periods
- Urine and fecal collections pooled by 24h
- Calcium retention (mg/d) = Ca intake (mg/d) – Urinary Ca* (mg/d) – Fecal Ca (mg/d)

Study Design

Maximal Calcium Retention as a Function

Over 1 year represents gain of 4% skeleton

Jackman et al., AJCN, 1997

Bailey et al., JBMR 14:711, 1999
Boys have higher bone accretion than girls

Camp Calcium tested whether boys require more calcium for their larger skeletons

Girls and Boys matched for Tanner Stage to girls ~3.6

Bailey, et al., JBMR 14:711, 1999

Calcium retention was greater in white boys compared to white girls but the intake for maximal retention was not different from girls (1140 mg/d vs 1300 mg/d)

Calcium intake and IGF-1 predicted 33.2% of calcium retention.

Camp Calcium and AJCN, 84:4142006; Hill et al., 93:4743, 2008

Role of Race?

Calcium intake and IGF-1 explained 12.3% and Race explained 13.7% Ca retention in adolescent girls

Camp Calcium

Dietary calcium mainly comes from dairy

Braun et al. AJCN. 85:1657-63, 2007
**Ca absorbed/serving**

<table>
<thead>
<tr>
<th>Food</th>
<th>Ca absorbed/serving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk or Drummer</td>
<td>100</td>
</tr>
<tr>
<td>Yogurt*</td>
<td>120</td>
</tr>
<tr>
<td>Cheddar Cheese</td>
<td>80</td>
</tr>
<tr>
<td>Red Beans</td>
<td>80</td>
</tr>
<tr>
<td>Kale</td>
<td>60</td>
</tr>
<tr>
<td>Spinach</td>
<td>60</td>
</tr>
<tr>
<td>Whole wheat bread</td>
<td>40</td>
</tr>
<tr>
<td>Bran cereal</td>
<td>40</td>
</tr>
<tr>
<td>Split wheat bread</td>
<td>20</td>
</tr>
<tr>
<td>Tofu**</td>
<td>20</td>
</tr>
<tr>
<td>OJ**</td>
<td>20</td>
</tr>
<tr>
<td>Soy milk**</td>
<td>20</td>
</tr>
</tbody>
</table>

**Milk Products and Health**

US 2010 Dietary Guidelines recommend 3 cups milk products per day (871/mg Ca)

- Go low-fat or fat-free
- If you don’t or can’t consume milk, choose lactose-free products or other calcium sources

http://www.mypyramid.gov

**Analysis of NHANES 2001-2002**

It is impossible to meet Ca recommendations while meeting other nutrient recommendations with a dairy-free diet within the current US dietary pattern

Gao et al. JADA 105:1759, 2006

**Benefit of milk products vs. supplements rarely been studied head-to-head**

Power calculations determined n=50 rats/group

Weaver et al. JBMR 24:1411-1419, 2009

**Objectives**

1. To directly compare NFDM and CaCO₃ for bone acquisition in growing female rats.
2. To determine any protection of early feeding of NFDM and CaCO₃ on bone maintenance in mature rats.
Experimental Design

Mature Rats

Benefit of NDFM over CaCO₃ in Growing Rats

Advantages to femur of early feeding NDFM over CaCO₃ switched to low CaCO₃ diets

Milk during growth confers substantial benefits to bone over nutritionally adequate diets that help protect against Ca deficits later in life.

Low milk intake during childhood 2 x risk fracture in 3251 Caucasian women from NHANES III

Lactose Intolerance & Fracture in Finnish Women 38-57 y

N=11,619
N=1,299 fracture 1980-1989
N=896 Lactose intolerant

<table>
<thead>
<tr>
<th>Lactose Intolerant</th>
<th>Lactose Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Ca (mg/d)</td>
<td>570</td>
</tr>
<tr>
<td>Fracture OR</td>
<td>1.33 (1.09-1.62)</td>
</tr>
<tr>
<td>Lower body excluding ankle OR</td>
<td>2.15 (1.53-3.04)</td>
</tr>
</tbody>
</table>


Protein

• Bone is 22% protein by weight
• Bone is 50% protein by volume

Role of Salt

Dietary salt varied

Low Na diet → 1.3 g/d
High Na diet → 4 g/d

Significant Ca x protein interaction (p=0.044) on 3-y change in total body BMD in 342 men and women (aged>65 yr)

Calcium (500 mg/d) + vitamin D (700 IU/d)

Protein as % energy

Effect of dietary salt in calcium retention

• Metabolic balance study
  - Randomized order high/low salt
• Adolescent black and white subjects matched for size and sexual maturity
Urinary sodium excretion (Mean±SEM)

Palacios, et al. JCEM 89(4):1858-1863, 2004

Urinary calcium excretion (Mean ± SEM)

Palacios, et al. JCEM 89(4):1858-1863, 2004

Calcium retention (Mean ± SEM)

* p<0.05 for diet and race

Vitamin D

Hot nutrient, more hormone than nutrient

How are we doing?
Vitamin D Intake From 2003-2006 NHANES Compared With 2010 RDAs (Includes Food Plus Supplements)

[Bar chart showing vitamin D intake by age group and sex]

Sources of Vitamin D

[Diagram showing sources of vitamin D, including fortified foods and sunlight]
Vitamin D status affected by BMI, sun protection, milk consumption – NHANES III and 2000-2004

Why expect vitamin D input to come from diet?

- the elderly
- individuals with dark skin
- individuals living at temperate latitudes and higher
- invalids & shut-ins
- others who are not exposed to UVB radiation

Calcium and vitamin D and age related bone loss

Calcium and vitamin D and age related bone loss

Vitamin D status did not affect Ca absorption in Black or White girls

Effect of Vitamin D Supplementation on Ca Absorption and Retention in Adolescent Girls: Study Design

Results
- Vitamin D status improved with supplementation
- No impact on functional outcome measures
**Bone healthy diet**
Calcium rich foods, dairy
Fruits/Vegetables
Whole grains

**Benefits of Diet:**
Maximize peak bone mass
Minimize bone loss
Promote overall health

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Adolescent Studies
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