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Nutrition & Bone Health Across the Lifespan

March 31, 2021

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Osteoporosis is a pediatric disease with geriatric consequences

USDairy.com

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Today's Speaker



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Dr. Taylor
AMERICA'S FAVORITE
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f t i @DrTaylorWallace

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Nutrition and Bone Health Across the Lifespan



Taylor C. Wallace, PhD
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George Mason University

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Agenda

Today we will cover:

1. Bone Biology
2. Bone Development and Maintenance
3. Bone Building Nutrients
4. Dietary Patterns and Food Groups
5. Other Lifestyle Factors
6. Concluding Remarks



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Disclosures

It's always important to be transparent and declare perceived conflicts of interest:

<p>Employment: Think Healthy Group George Mason University</p> <p>Journal Editorships (paid): Journal of Dietary Supplements Journal of the American College of Nutrition Annals of Medicine</p>	<p>Research Funding (past 3-years): National Dairy Council National Institutes of Health (NIH) National Osteoporosis Foundation (NOF) National Cattlemen's Beef Association Pfizer Consumer Healthcare Produce for Better Health Foundation U.S. Department of Agriculture (USDA)</p> <p><i>*These conflicts of interest are those that could be perceived as relating to this presentation. All research grants and disclosures can be found at: www.drtylorwallace.com</i></p>
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Disclosures

This presentation was developed, and continuing education credits provided through an educational grant from National Dairy Council.

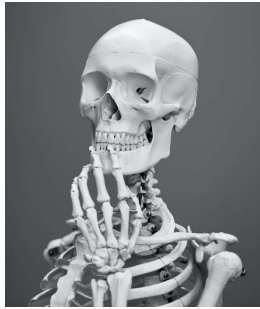
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The funder was completely "hands off" and had **no influence** over the content of today's lecture. I always adhere to best practices for minimizing bias, as published by the American Society for Nutrition. Documentation of these best practices are available upon request (drtylorwallace@gmail.com).



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1. Bone Biology



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1. Bone Biology

Bone Cells:

- 🟡 **Osteoblasts:** Responsible for **bone formation** (lifespan is about 3-months).
- 🔴 **Osteoclasts:** Responsible for **bone resorption** (lifespan is about 2- to 3-weeks).
- 🌸 **Osteocytes:** Mechanosensory cells that control the activity of osteoblasts and osteoclasts.



Osteoblast



Osteoclast



Osteocyte

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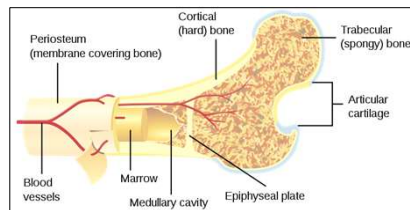
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1. Bone Biology

Bones are Comprised of Two Types of Tissues:

- 🟡 **Cortical bone** (i.e., compact bone): this hard-outer layer is strong and dense.
- 🟡 **Trabecular bone** (i.e., cancellous bone): this spongy inner layer network of trabeculae is lighter and less dense than cortical bone.



[International Osteoporosis Foundation \(IOF\)](#)

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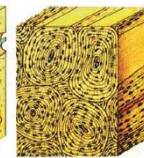
1. Bone Biology

Two Types of Bone:

- 🟡 **Woven Bone:** Characterized by haphazard organization of collagen fibers and is mechanically weak. Produced when initially in fetal bones but replaced by remodeling and deposition of more resilient lamellar bone. In adults, woven bone is formed when there is a need for rapid repair of a fracture. Woven bone is then remodeled, and lamellar bone is deposited. Virtually all bone in a healthy mature adult is lamellar bone.
- 🟡 **Lamellar Bone:** Characterized by a regular parallel alignment of collagen into sheets (lamellae) and is mechanically strong.



Woven Bone



Lamellar Bone

[International Osteoporosis Foundation \(IOF\)](#)

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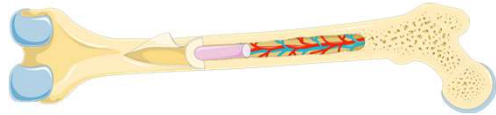
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1. Bone Biology

The Bone Matrix:

- Bone is ~25% organic matrix (2-5% of which are cells), ~5% water, and ~70% mineral.
- Organic matrix is comprised of **mostly type-I collagen (~94%)** and other non-collagen proteins.
- Hardness and rigidity due to the **crystalline complex of calcium and phosphate** (i.e., hydroxyapatite).



International Osteoporosis Foundation (IOF)

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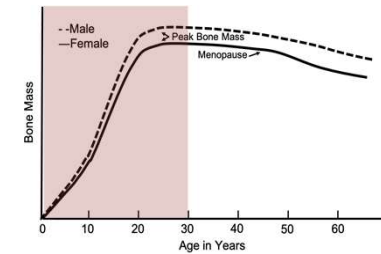
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1. Bone Biology

Bone Modeling Process:

- **Bone modeling:** when bone resorption and bone formation occur on separate surfaces (i.e., formation and resorption are not coupled). This occurs during birth to young adulthood and is responsible for gain in skeletal mass and changes in skeletal form.



International Osteoporosis Foundation (IOF)
Osteoporos Int. 2016;27:1281.

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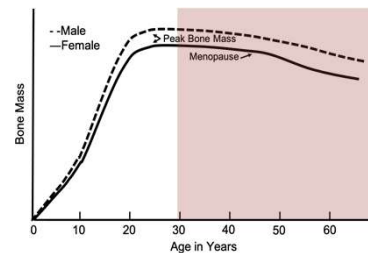
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1. Bone Biology

Bone Remodeling:

- **Bone remodeling:** the process of coupling between bone resorption and formation that maintains bone mass in adult life.
- Replacement of old tissue by new bone tissue and continues throughout life so that most of the adult skeleton is replaced about every 10-years.



International Osteoporosis Foundation (IOF)

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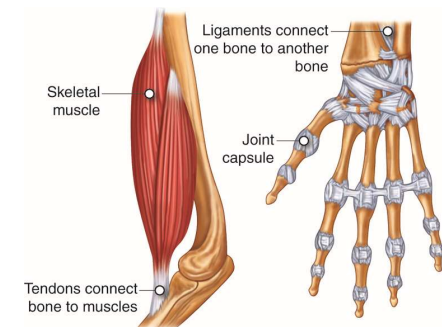
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1. Bone Biology

Musculoskeletal System:

- Bones, muscles and joints are an integral part of the body's musculoskeletal system.
- Problems with any one component of this system can affect the other components. For example, weakness of the muscles can lead to loss of bone and joint damage.



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2. Bone Development & Maintenance




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2. Bone Development & Maintenance

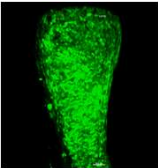
Longitudinal Growth of Bones and the Epiphyseal Plate:

- During growth and development, skeletal growth proceeds through the coordinated action of bone deposition and resorption to allow bones to **expand** (i.e., periosteal apposition of cortical bone) and **lengthen** (i.e., endochondral ossification) into their adult form.
- Epiphyseal plate:** Area of elongation of long bone.
- This process of bone modeling begins during fetal growth and continues until epiphyseal fusion, usually by the end of the second decade of life.



Epiphyseal Plates
(Growth Plates)

Epiphyseal Fusion



Li et al. 2015

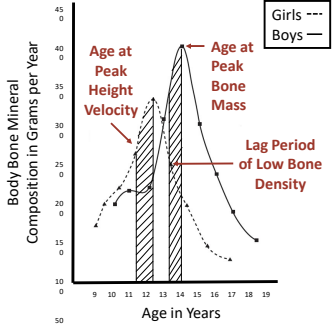
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2. Bone Development & Maintenance

Peak Bone Mass:

- Peak Bone Mass:** The amount of bone gained by the time a stable skeletal state has been attained during young adulthood.
- This definition more broadly captures **peak bone strength**, which is characterized by mass, density, microarchitecture, micro-repair mechanisms, and geometric properties that provide structural strength.
- Peak bone mass is attained when age-related changes in a bone outcome are no longer positive and plateau.




Osteoporos Int. 2016;27:1281. 2
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2. Bone Development & Maintenance

Why Attaining Maximal Peak Bone Mass within One's Genetic Potential Important:

- Once peak bone mass is attained, you cannot increase bone mass later in life.
- Peak bone mass is predictive of fracture risk later in life. Just a 5 – 10% difference in peak bone mass may result in a 25 – 50% reduction in hip fractures later in life.



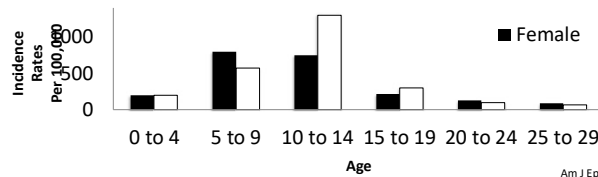
Osteoporos Int. 2016;27:1281.
Osteoporos Int. 2000;11:985. 2
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2. Bone Development & Maintenance

Bone Mass Matters in Childhood and Adolescence:

- 30 to 50% of children have at least one fracture by the end of their teenage years.
- 89% increase in childhood fracture risk per one standard deviation below the age and sex specific median BMD.



Am J Epidemiol. 1992;135:477.
Figure Adapted from JAMA. 2003;290:1479.

2. Bone Development & Maintenance

Genetics of Peak Bone Mass:

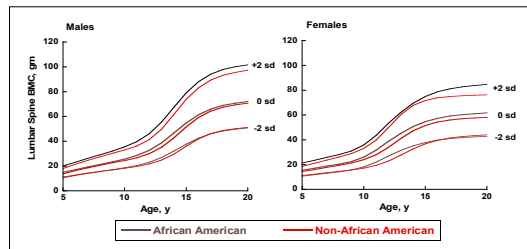
- Twin studies: heritability of peak bone mass is up to 80%... With 20% being influenced by lifestyle factors and sex hormone levels during puberty.
- Areal BMD (aBMD) is lower among daughters of women with osteoporosis and familial resemblance is expressed prior to puberty.
- Genome-wide association studies have identified >70 loci associated with adult bone density and/or fractures.



Osteoporos Int. 2016;27:1281.
Adapted from JAMA. 2003;290:1479.

2. Bone Development & Maintenance

Genetics of Peak Bone Mass (Population Ancestry):

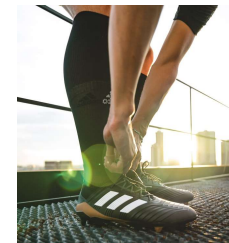


J Clin Endocrin Metab. 2011;96(10):3160.

2. Bone Development & Maintenance

Genetics of Peak Bone Mass:

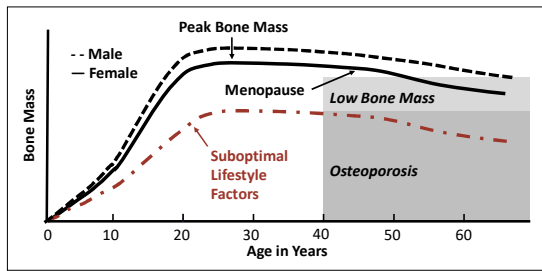
- Timing of plateau in bone accretion differs by sex and skeletal site. For example, the lumbar spine plateau occurs in one's 30's but bone loss in the hip occurs beginning in the late teens to early 20's.
- Trabecular bone loss at most sites is already occurring in the early 20's.
- Girls who enter puberty earlier have greater bone mass.



J Bone Min Res. 2008;23:205.
J Bone Min Res. 2010;25(9):1948.
J Clin Endocrinol Metab. 2009;94:3424.

2. Bone Development & Maintenance

Lifestyle Factors Influence Peak Bone Mass:



Osteoporosis Int. 2016;27:1281.

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2. Bone Development & Maintenance

Lifestyle Factors Influencing Peak Bone Mass:

Lifestyle Factor	Grade	Lifestyle Factor	Grade
Macronutrients		Infant Nutrition	
Fat	D	Duration of Breastfeeding	D
Protein	C	Breast vs. Formula Feeding	D
Micronutrients		Enriched Formula Feeding	
Calcium	A	Adolescent Special Issues	
Vitamin D	B	Detriment of Oral Contraceptives	D
Other micronutrients	D	Detriment of DMPA Injections	B
Food Patterns		Detriment of Alcohol	
Dairy	B	Detriment of Smoking	
Fiber	C	Physical Activity	
Fruits and Vegetables	C	Effect on bone mass and density	A
Detriment of soda and caffeinated beverages	C	Effect on bone structural outcomes	B

A: Strong
B: Moderate
C: Limited
D: Inadequate

Osteoporosis Int. 2016;27:1281.

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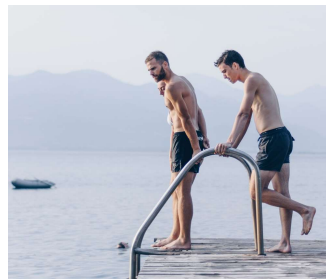
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2. Bone Development & Maintenance

Young to Middle Adulthood Bone

- Bones are continuously remodeled throughout life to regulate mineral homeostasis and repair micro-damaged bones (from everyday stress).
- Modeling and remodeling continue so that about 10% of the adult skeleton is replaced every year. Breakdown (resorption) and formation occur in balance.
- There is a "calcium balance," where intake is equal to the amount excreted.



Am J Med. 1993;94(6):646.

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2. Bone Development & Maintenance

Wolff's Law

- A healthy person will adapt to the load under which it is placed. If loading on a particular bone increases, the bone will remodel itself to provide the strength needed for resistance.
- The opposite is also true. Rapid weight loss (particularly through restrictive dieting) can result in rapid bone loss.
- This can impact bone later in life.



Am J Med. 1993;94(6):646.

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2. Bone Development & Maintenance

Older Adults

- As people age, the rate of bone resorption far exceeds the rate of bone formation.
- The hormone estrogen, which protects bones, sharply decreases when women reach menopause. This is why the chance of developing osteoporosis increases as women reach menopause.
- The **menopause transition may be a critical timepoint** during which lifestyle factors (e.g., calcium intake) have a more pronounced effect on bone loss – *our new research*.



J Bone Min Res Plus. 2020;4(1):e10246.

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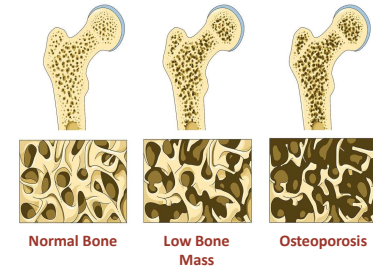
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2. Bone Development & Maintenance

Osteoporosis and Low Bone Mass:

- Osteoporosis:** A systemic skeletal disease characterized by low mineral bone mass and micro-architectural deterioration of bone tissue, more specifically a decrease in the number of trabeculae coupled to trabecular thinning and loss of connectivity, as well as a decrease in cortical thickness and increase in its porosity. This increases bone fragility and susceptibility to fracture.
- Low bone mass** (i.e., osteopenia): A risk factor for osteoporosis.



Am J Med. 1993;94(6):646.

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2. Bone Development & Maintenance

Clinical Diagnosis of Osteoporosis

- Osteoporosis has been traditionally diagnosed as having a **T-score of -2.5 or lower** at the spine or hip by bone mineral density testing (BMD) using dual-energy X-ray absorptiometry (DXA).
- Postmenopausal women and men aged 50 years should be diagnosed with **osteoporosis if they have a demonstrable elevated risk for future fractures**, including:
 - Finding of a T-score ≤ -2.5 at the spine or hip.
 - Low trauma hip fracture..
 - Low bone mass (T-score ≤ -1.0) by BMD who sustain a low trauma vertebral, proximal humerus, pelvis, or in some cases, distal forearm fracture.
 - Elevated fracture risk based on the World Health Organization Fracture Risk Algorithm (FRAX).

Am J Med. 1993;94(6):646.
Osteoporos Int. 2014;25(5):1439.

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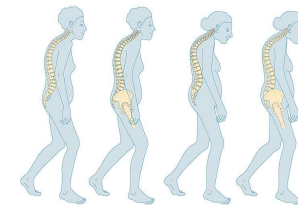
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2. Bone Development & Maintenance

Osteoporosis and Low Bone Mass in the USA:

- 16% of men and 29.9% of women** 50+ years have osteoporosis.
- 46.3% of men and 77.1% of women** 80+ years have osteoporosis.
- Estimated annual costs exceed **\$19B to the U.S healthcare system**.
- 1/2 of women and 1/3 of men** will experience an osteoporotic-related fracture in their lifetime.



Osteoporos Int. 2017;28(4):1225.
J Bone Min Res. 2007;22(3):465.
National Osteoporosis Foundation

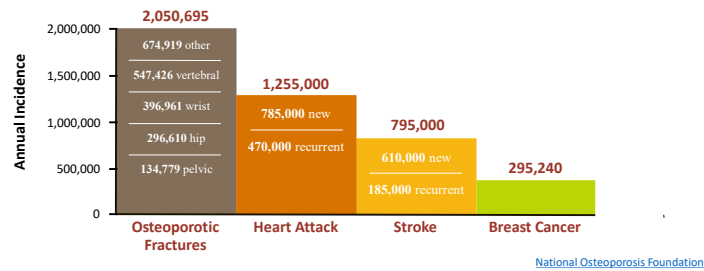
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Significance of Osteoporosis:



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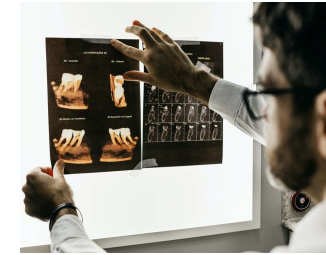
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2. Bone Development & Maintenance

Risk Factors for Osteoporosis:

- Genetics
- Excessive thinness
- Inadequate calcium intake
- Vitamin D deficiency or insufficiency
- Smoking and excessive alcohol intake
- Lack of physical activity and immobility
- High salt (sodium) intake
- Comorbid conditions
- Medication use (e.g., steroids, proton pump inhibitors, etc)



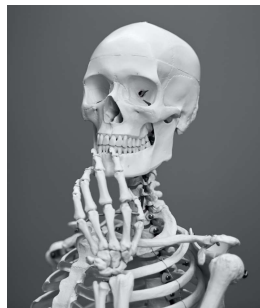
National Osteoporosis Foundation

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3. Bone Building Nutrients



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3. Bone Building Nutrients

Nutrients – Good Scientific Evidence

- Calcium
- Vitamin D
- Magnesium
- Phosphorus
- Potassium
- Vitamin A
- Protein



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3. Bone Building Nutrients

Calcium

- Calcium is the principal mineral that makes your bones strong.
- 99% of calcium in the body is stored in the bones and teeth. The rest circulates in the blood and is used for processes such as muscle contraction, nerve transmission, and blood clotting.
- If you don't get enough calcium from food the body takes it from the bones to ensure normal cell function.
- The body also pulls minerals like calcium from the bone to buffer changes in pH.



3. Bone Building Nutrients

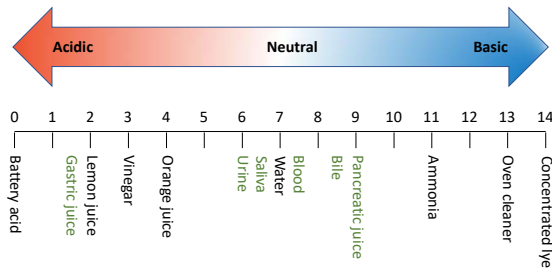
Calcium Absorption from Food:

Food	Serving size	Average Calcium Content (mg)	Estimated Absorption (%)	Calcium Absorbed (mg)	Servings Required to Equal 1-Cup of Milk
Milk	1-cup	310	32.1	99.5	1
Yogurt	¾-cup	272	32.1	87.3	1
Spinach	½-cup	129	5.1	6.6	15.25
Broccoli	½-cup	33	61.3	20.2	5
Almonds	¼-cup	97	21.2	20.6	4.75
White Beans	¼-cup	85	21.8	18.5	5.5
Whole Wheat Bread	35 g (1-slice)	26	82	21.3	4.75
Orange Juice (fortified)	¼-cup	155	36.3	56.3	1.75
Soy Milk (fortified)	1-cup	319	24	76.6	1.25
Tofu (fortified)	85 g	171	31	53	2

Am J Clin Nutr. 1999;70:51238.

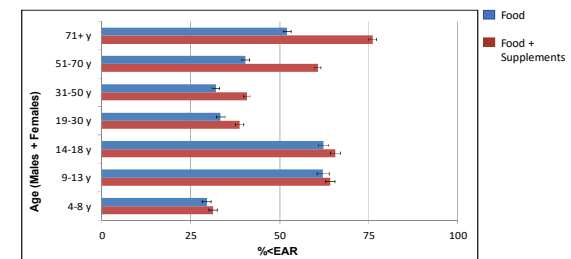
3. Bone Building Nutrients

Calcium and Body pH:



3. Bone Building Nutrients

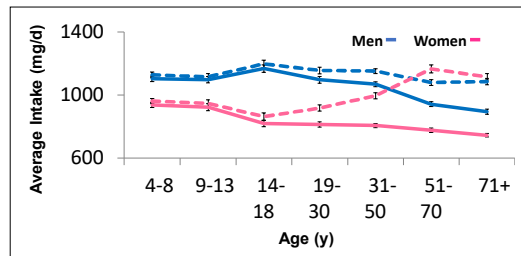
Calcium Shortfalls in the USA:



J Am Coll Nutr. 2013; 32(5):321.

3. Bone Building Nutrients

How Calcium Supplements Affect Intake:



J Am Coll Nutr. 2013; 32(5):321.

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3. Bone Building Nutrients

Vitamin D:

- Adequate vitamin D status is needed for calcium absorption in the intestine. The two nutrients do not need to be co-ingested simultaneously.
- Vitamin D also puts calcium into the bones.
- Deficiency is common.
 - Breastfed infants – at risk group for deficiency since breast milk only provides small amounts.
 - Older adults – at risk group since the skin's ability to synthesize vitamin D declines with age and older adults tend to spend more time indoors.
- Although vitamin D can be synthesized by the skin when exposed to sunshine, the sun is not a reliable source of vitamin D for most people in the U.S.



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3. Bone Building Nutrients

Vitamin D:

- The National Academy of Medicine recommends 15 – 20 mcg (600 – 800 IU) per day; however, societies such as the Endocrine Society, the National Osteoporosis Foundation, and American Bone Health recommend more.
- The Endocrine Society recommends 50 mcg (2000 IU) per day for individuals with osteoporosis.
- There are few food sources of vitamin D – so most people need to take a supplement. Foods containing vitamin D include fatty fish (e.g., salmon), egg yolks, fortified dairy products and other fortified foods (e.g., orange juice).



NIH Office of Dietary Supplements
Endocrine Society

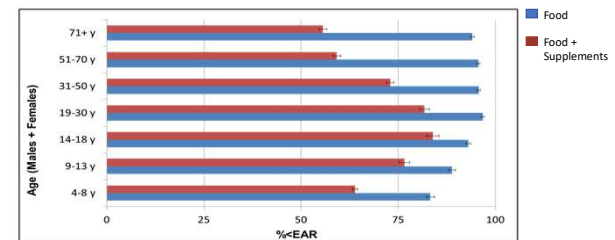
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3. Bone Building Nutrients

Vitamin D Shortfalls in the USA:



J Am Coll Nutr. 2013; 32(5):321.

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3. Bone Building Nutrients

Calcium Homeostasis:

The flowchart illustrates the process of calcium homeostasis. It starts with 'Low Calcium Intake' and 'Low Vitamin D Status' leading to 'Insufficient Calcium Absorbed'. This results in a 'Fall in Extracellular Ca²⁺', which triggers 'Increased PTH' and 'Increased 1,25(OH)₂D'. These hormones then lead to 'Increased Bone Turnover'. Feedback loops show 'Decrease Urinary Calcium' and 'Increased Intestinal Calcium Absorption' as responses to the fall in extracellular calcium.

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3. Bone Building Nutrients

Calcium with Vitamin D Supplements:

- Calcium carbonate needs stomach acid to be absorbed, so its best to take it with a meal. Calcium citrate isn't as dependent on stomach acid, so it can be taken any time, and is best for people using proton-pump inhibitors or H2 blockers.
- Your body only absorbs 500 to 600 mg of calcium at a given time.
- Studies have consistently shown that people with high calcium intake and lots of dairy products in the diet are less likely to get colon cancer.
- Do not exceed the UL (more is not better).

NIH Office of Dietary Supplements

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3. Bone Building Nutrients

Calcium with Vitamin D Supplements:

- It is better to take calcium supplements (any form) with a meal, since calcium can bind oxalates, which may contribute kidney stone formation.
- 1 in 273 women taking calcium supplements vs. placebo developed a urinary stone in the Women's Health Initiative (WHI) Clinical Trial. However, WHI participants who took personal calcium supplements on top of the treatment showed no increased risk of urinary stones. This suggests that there is likely no increased risk in the general healthy population.
- Calcium citrate is the more soluble form and should be recommended to those with concerns over urinary stones.

N Engl J Med. 2006;354(7):669. Osteoporos int. 2013;24:567.

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3. Bone Building Nutrients

Magnesium:

- Involved in over 600 enzymatic reactions in the body.
- About 60% of total body magnesium is stored in the bone. 1/3 of skeletal magnesium resides on cortical bone either on the surface of the hydroxyapatite or in the hydration shell around the crystal.
- As with calcium, the skeleton serves as a reservoir of exchangeable magnesium useful to maintain physiological extracellular concentrations of the cation.
- Magnesium insufficiency promotes oxidative stress, partly due to reduced antioxidant defenses that occur when an individual has low magnesium status. The increased amounts of free radicals potentiate the activity of osteoclasts and depress that of osteoblasts.

Nutrients. 2013;5(8):3022.

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3. Bone Building Nutrients

Phosphorus:

- Phosphorus (along with calcium) is a major component of hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$).
- It is an important nutrient for bone health, but **intakes in the U.S. well exceed the human requirement.**
- Inorganic phosphate additives, which are absorbed at a high rate, account for a substantial and likely underestimated portion of intake.
- Phosphate additives may have negative effects on bone metabolism when consumed in high quantities.



Curr Osteoporos Rep. 2017;15(5):473

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3. Bone Building Nutrients

Potassium:

- Potassium (like magnesium) contributes to the acid-base balance in the body, preventing bone loss. As previously stated, a low extracellular pH favors the resorption of the mineralized matrix that provides hydroxyl groups for opposing acid loading.
- High fruits and vegetables have been associated with a benefit to bone health. **Potassium levels in fruits and vegetables have been the leading candidate for this benefit.**
- Potassium bicarbonate and citrate, but not sodium bicarbonate or citrate, reduces urinary calcium excretion.



Adv Nutr. 2013;4(3):368S.

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3. Bone Building Nutrients

Vitamin A:

- Vitamin A plays an essential role in the development of osteoblasts.
- Too much or little vitamin A is linked to bone loss.
- Adverse effects may occur at a level of retinol intake that is only about twice the current recommendation.
- Provitamin A precursors (alpha carotene, beta-carotene, and beta-cryptoxanthin) from plants associated with improved bone health but may just be a biomarker that reflects a generally healthy lifestyle.



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3. Bone Building Nutrients

Protein:

- Protein provides the glue for bone mineral.
- There is a beneficial relationship between high protein intake and bone density for nearly all bone sites.
- A recent review and position statement by the International Osteoporosis Foundation (IOF) found no adverse effects of higher protein intakes.
- Calcium and protein have synergistic effects on bone density, particularly when combined with physical activity.
- Older individuals and adolescents likely need more protein.



Nutr Today. 2019;54(3):107.

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3. Bone Building Nutrients

Nutrients – Potential Relationship to Bone Health:

- Zinc
- Iron
- Vitamin B12
- Vitamin C
- Vitamin K
- Trace minerals



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3. Bone Building Nutrients

Zinc:

- Alkaline phosphatase uses zinc as a co-factor during the bone mineralization process.
- About 29% of zinc preferentially localizes in bone. When dietary zinc is limited, serum levels appear to be maintained by mobilization from bone.
- Zinc has also been suggested to promote osteoblast proliferation.



Materials. 2020;13(10):2211.

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3. Bone Building Nutrients

Iron:

- Iron overload and deficiency both associated with weakened bones, suggesting that balanced bone homeostasis requires optimal iron levels.
- Emerging evidence suggests both high and low iron influence differentiation and activity of osteoclasts and osteoblasts in a way that promotes bone loss.



Pharmaceuticals. 2018;11(4):107

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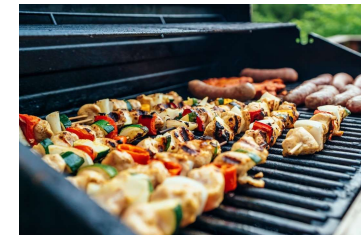
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3. Bone Building Nutrients

Vitamin B12:

- Suggested to influence the quality (or micro-architecture) of bone. The mechanism is not well characterized but seems to be due to its effects on the formation of collagen or ability to alter the metabolism of osteoblasts.
- Study findings are mixed.
- Older individuals lose the ability to adequately absorb vitamin B12, and thus may need more.



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3. Bone Building Nutrients

Vitamin C:

- Essential for collagen formation and increases absorption of plant-based iron.
- Vitamin C is an important antioxidant and cofactor, which is involved in the regulation of, development, function and maintenance of several cell types in the body. It influences expression of bone matrix genes in osteoblasts.



J Bone Min Res. 2015;30(11):1945.

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3. Bone Building Nutrients

Vitamin K:

- Vitamin K is essential for the carboxylation of many bone-related proteins, regulating transcription of osteoblastic markers and in regulating bone resorption.
- Low dietary intake of vitamin K1 and K2 is associated with decreased bone density.
- MK-4, a form of phyloquinone is used at doses of 45mg/d for the treatment of osteoporosis in Japan. However, whilst there is good evidence that MK-4 promotes bone turnover, recent trials have failed to show any protective effect in terms of bone density of the hip.
- Those using blood thinners (e.g., Warfarin) should beware of supplements containing vitamin K.



[American Bone Health](#)

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3. Bone Building Nutrients

Trace Minerals:

- You may hear of trace minerals like boron, copper, silicon and strontium being promoted for bone health.
- Deficiency in these nutrients is rare unless you have intestinal absorption issues.



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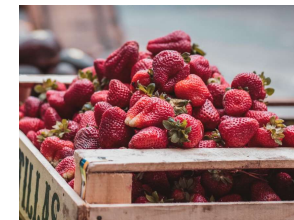
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3. Bone Building Nutrients

Dietary Bioactive Compounds:

- The NIH Office of Dietary Supplements has defined dietary bioactives as "compounds that are constituents in foods and dietary supplements, other than those needed to meet basic human nutritional needs, which are responsible for changes in health status.
- Flavonoids, found in a wide variety of plant foods have the most potential of the dietary bioactives for promotion of bone health.
 - Anti-inflammatory actions.
 - Enhancement of bone formation and inhibition of bone resorption through action on cell signaling pathways.



J Nutr Gerontol Geriatr. 2012;31(3):239.

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3. Bone Building Nutrients

Dietary Bioactive Compounds:

- Dietary soluble corn fiber has recently been shown to exhibit dose-response relationships with calcium retention.
- May be due to significant increases in bone-specific alkaline phosphatase, which is a bone-formation marker.



Am J Clin Nutr. 2017;105(3):772.

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3. Bone Building Nutrients

Lactoferrin:

- Lactoferrin is an iron-binding glycoprotein that belongs to the transferrin family.
- Recently shown to promote bone growth by stimulating proliferation and differentiation of osteoblasts. It has been suggested to have a physiological role in bone growth and healing, and a potential therapeutic role as an anabolic factor in osteoporosis.
- A small clinical trial showed that supplementation with milk ribonuclease enriched lactoferrin resulted in a significant reduction in bone resorption and increase in osteoblastic bone formation in postmenopausal women.



Osteoporos Int. 2009;20(9):1603.
Clin Med Res. 2005;3(2):93.

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3. Bone Building Nutrients

Alcohol:

- Moderate alcohol consumption may protect bone.
- Heavy alcohol use, particularly during adolescence and young adulthood can dramatically compromise bone quality and increase the risk for osteoporosis.
- Moderate consumption of beer containing higher amounts of dietary silicon (in the soluble form of orthosilicic acid) has been suggested to promote bone density and type-1 collagen synthesis (i.e., bone connective tissue).
- Grains like granola and oat bran are also sources of silicon.



J Sci Food Agric. 2010;90:784.

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3. Bone Building Nutrients

Caffeine:

- If you have good calcium and vitamin D intake and partake in regular exercise, there is little reason for concern about moderate caffeine intake (i.e., less than 300 mg per day).
- Caffeine may modestly reduce calcium absorption (by about 4 mg per cup of coffee), but this is offset completely by adding 1-2 tablespoons of low- or non-fat milk to your coffee.
- Excessive caffeine intake can increase loss of calcium in the urine.
- Some studies indicate moderate coffee consumption may have protective effects on bone due to the dietary bioactive compounds present.



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3. Bone Building Nutrients

Salt (Sodium):

- High salt intake is a well-recognized risk factor for osteoporosis because it increases urinary calcium excretion.
- A recent stable isotope labeling study found high salt intake (11 grams per day) increased urinary calcium excretion and affected bone calcium balance, with a high calcium diet.
- Salt (i.e., sodium chloride) contributes to the acid load and results in the body pulling minerals from bone.



American Bone Health
J Bone Miner Res. 2008;23(9):1477.

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4. Dietary Patterns and Food Groups



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4. Dietary Patterns and Food Groups

Dietary Guidelines for Americans:

- Published every 5-years the *Dietary Guidelines for Americans* provide advice on what to eat and drink to build a healthy diet that can promote healthy growth and development, help prevent diet-related chronic disease, and meet nutrient needs. It is developed and written for a professional audience, including policymakers, healthcare providers, nutrition educators, and Federal nutrition program operators. Each edition of the Dietary Guidelines reflects the current body of nutrition science.
- The Dietary Guidelines are used by professionals to: 1) form the basis of Federal nutrition policy and programs, 2) support nutrition education efforts, 3) guide local, state, and national health promotion and disease prevention initiatives, and 4) inform various organizations and industries.



www.dietaryguidelines.gov

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4. Dietary Patterns and Food Groups

Dietary Guidelines for Americans:

- More recent iterations of the Dietary Guidelines for Americans focus on dietary patterns, since it is acknowledged that people do not consume nutrients or foods in isolation but in various combinations over time. It also reflects growing evidence that components of a dietary pattern may have interactive, synergistic, and potentially cumulative relationships that can predict overall health status and disease risk more fully than can individual foods or nutrients.



Dietary Guidelines Advisory Committee

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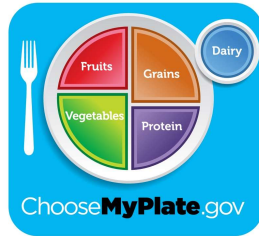
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4. Dietary Patterns and Food Groups

MyPlate and Food Groups:

- MyPlate is the consumer-facing graphic based on the Dietary Guidelines for Americans. It is divided into 5 basic food groups: fruits, vegetables, grains, protein foods, and dairy.
- On the MyPlate website (www.ChooseMyPlate.gov) you can find recipes and tools to help you and your patients make healthier choices.
- Information on food groups are based on life stage, physical activity levels and other important attributes.



www.ChooseMyPlate.gov

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4. Dietary Patterns and Food Groups

Dietary Patterns and Bone Health:

- Moderate evidence indicates that a dietary pattern higher in fruits, vegetables, legumes, nuts, low-fat dairy, whole grains, and fish, and lower in meats (particularly processed meats), sugar-sweetened beverages, and sweets is associated with favorable bone health outcomes in adults, primarily decreased risk of hip fracture.
- Moderate evidence suggests a beneficial effect of dairy intake on bone health in middle- to older-aged adults.



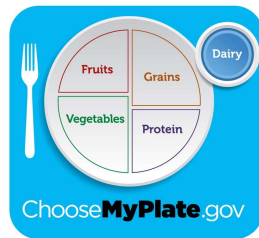
Dietary Guidelines Advisory Committee
Crit Rev Food Sci Nutr. 2020. 14:1.

71

4. Dietary Patterns and Food Groups

Dairy:

- Move to low-fat or fat-free milk or yogurt (or lactose-free dairy or fortified soy versions).
- 90% of Americans do not get enough dairy.
- The amount each person needs can vary between 1½ to 3-cups per day. 1½ ounces of cheese can be considered 1-cup of dairy.
- The dairy group provides more bone-building nutrients than any other food group, including calcium, phosphorus, vitamin A, vitamin D (fortified products), riboflavin, vitamin B12, protein, potassium, zinc, choline, magnesium, and selenium.
- Consuming dairy products provides health benefits – especially building and maintaining strong bones.

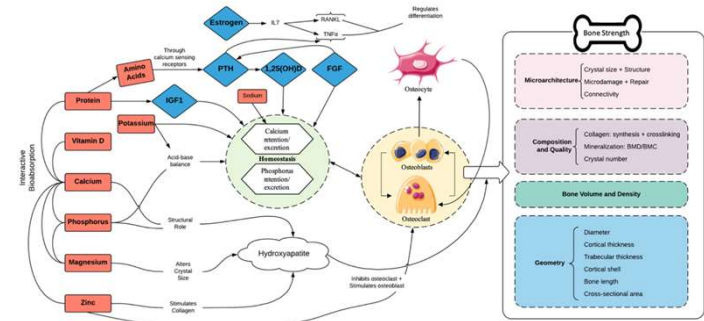


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4. Dietary Patterns and Food Groups

Dairy Nutrients Bone Strength:

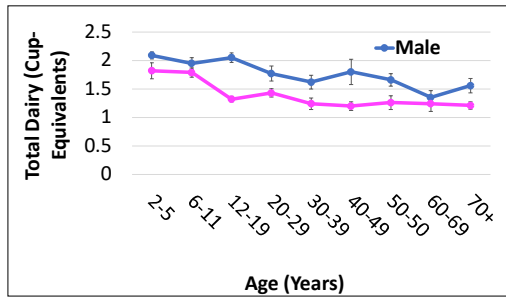


Crit Rev Food Sci Nutr. 2020. 14:1.

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4. Dietary Patterns and Food Groups

Dairy Intake:



USDA Food Patterns Equivalents Database (FPED) 2017-2018.

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4. Dietary Patterns and Food Groups

Lactose Intolerance:

- Many people develop lactose intolerance with age. These individuals often avoid dairy products and often do not get enough calcium (and potentially other nutrients) from the diet.
- To reduce the symptoms of lactose intolerance:
 - Lactose-free milk.** It is real milk and contains the same nutrient package, just without the lactose.
 - Think **hard cheese** as most of the lactose is removed in the cheesemaking process.
 - Enjoy **yogurts with live and active cultures**, which help ferment the lactose.
 - Reduce the amount of lactose per serving.** Most individuals can tolerate some lactose.
 - Plant-based milks, fortified foods, and supplements – **remember to read the label!**
- Lactose intolerance is not a food allergy. **Allergic individuals should completely avoid dairy.**

American Bone Health

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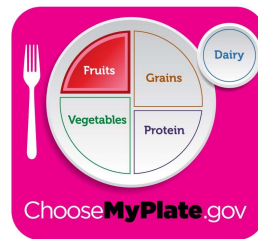
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4. Dietary Patterns and Food Groups

Fruits:

- Focus on whole fruits.
- The amount each person needs can vary between 1- to 2-cups per day.
- Fruits are sources of many essential nutrients that are under-consumed, including potassium, dietary fiber, vitamin C and folate.
- Fruits are key for **maintaining acid/base balance** and keeping calcium in the bones.



www.ChooseMyPlate.gov

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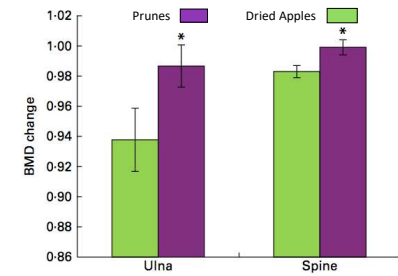
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4. Dietary Patterns and Food Groups

Fruits:

- Several clinical trials have shown that 50- to 100-grams of dried plums (i.e., prunes) compared to the control prevents loss of bone density, particularly at the ulna, hip and spine.
- Daily consumption of dried plums seemed to also prevent bone density loss when compared to dried apples.
- Likely due to dietary fiber and bioactive content.



Brit J Nutr. 2014;112:55. Nutrients. 2017;9:401.

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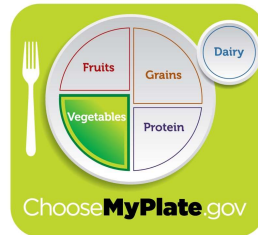
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4. Dietary Patterns and Food Groups

Vegetables:

- Vary your veggies.
- The amount each person needs can vary between 1- to 3-cups per day.
- Based on their nutrient content, vegetables are organized into 5-subgroups: 1) dark green, 2) red and orange, 3) peas and lentils, 4) starchy, and 5) other vegetables.
- Vegetables are important sources of many nutrients, including potassium, dietary fiber, folate (folic acid), vitamin A, and vitamin C.
- Vegetables are also key for maintaining acid/base balance and keeping calcium in the bones.



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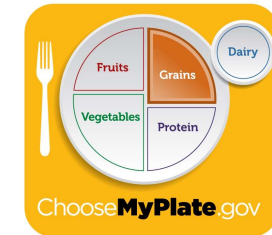
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4. Dietary Patterns and Food Groups

Grains:

- Make at least **half your grains whole grains**.
- The amount each person needs can vary between 3 to 8-ounces per day.
- Grains are divided into 2-subgroups: 1) whole grains and 2) refined grains.
- Grains are important sources of many nutrients including complex carbohydrates, dietary fiber, several B vitamins (thiamin, riboflavin, niacin, and folate), and minerals (iron, magnesium, and selenium).
- Grains provide the most dietary fiber, which can increase calcium absorption and thus bone mineralization.



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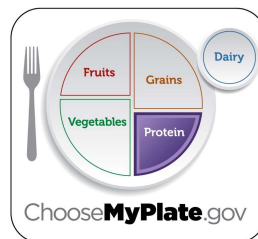
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4. Dietary Patterns and Food Groups

Protein:

- Vary your protein routine. **Include at least 8-ounces of cooked seafood per week.**
- The amount each person needs varies between 2- and 6½ ounce-equivalents each day. ¼ cup of beans, 1-egg, 1-tablespoon of peanut butter, or ½ ounce of nuts or seeds can be considered as 1-ounce-equivalent.
- Meat, poultry, fish, dry beans, peas, lentils, eggs, nuts, and seeds supply many nutrients including B vitamins (niacin, thiamin, riboflavin, and vitamin B6), vitamin E, iron, zinc, and magnesium.
- Older adults, vegetarians, and vegans sometimes don't get enough protein.



www.ChooseMyPlate.gov

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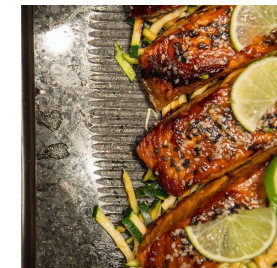
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4. Dietary Patterns and Food Groups

Protein:

- Because cross-linking of collagen molecules in bone involves modification of certain amino acids, many collagen fragments released during bone remodeling cannot be reutilized to build new bone. Accordingly, a daily supply of dietary protein is necessary for continual bone accretion prior to peak bone mass and maintenance thereafter.
- There is a trend towards decreased protein intake with age. Protein needs depend on age, body weight, and activity level.
- Substitution of animal protein with that from plants may be detrimental to bone, due to lower intakes of nutrients such as calcium, phosphorus and vitamin D.



Nutr Today. 2019;54(3):107.
J Nutr. 2021;151(1):7.

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4. Dietary Patterns and Food Groups

Vegetarian and Vegan Diets:

- A systematic review of 20-studies and >37,000 subjects found that **compared to omnivores, vegetarians and vegans had lower bone density** at the femoral neck (i.e., hip) and lumbar spine.
- **Vegans also had higher fracture rates.**
- Individuals who are vegetarian or vegan need to work extra hard to get enough protein, iron, zinc, calcium, vitamin D, riboflavin, vitamin B12, vitamin A, choline, omega-3 fats, and iodine. Consumption of fortified foods and use of dietary supplements may be appropriate to help fill gaps.



Nutr Rev. 2019;77(1):1.
J Acad Nutr Diet. 2003;103(6):748.

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4. Dietary Patterns and Food Groups

Dietary Supplements:

- Dietary supplements are **NOT** designed to replace food.
- Some people including vegans, vegetarians, and those who suffer from malabsorption problems (e.g., Celiac or Crohn's disease) may need supplements.
- No healthy dietary pattern within the Dietary Guidelines for Americans supplies enough vitamin D. Most individuals who **don't have full arm and leg sun exposure 3 times per week (30-minutes each)** need **supplemental vitamin D.**
- It is best to look for trusted national brands and those that have been tested and certified by an independent testing laboratory such as USP or NSF International vs. an unrecognized brand online.
- For each absent serving of dairy, supplement with 300 mg of calcium.

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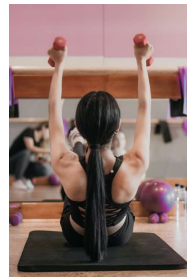
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4. Dietary Patterns and Food Groups

Dieting and Rapid Weight Loss:

- Rapid weight loss is often associated with loss of bone density.
- Low-carb (e.g., keto) and other restrictive diets are known for causing bone density loss.
- Slower weight loss is much less apt to adversely affect bone density, especially when exercise training (heavy resistance training or high impact loading) and adequate calcium and vitamin D intake are involved.
- Recall Wolff's law from the prior section.



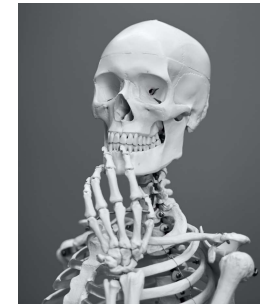
Curr Opin Endocrinol Diabetes Obes. 2014;21(5):358.

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5. Other Lifestyle Factors



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5. Other Lifestyle Factors

Physical Activity – Children and Adolescents:

- Periods of growth are thought to be the best time to strengthen bone through increased loading (i.e., impact exercise).
- Strong evidence supports that physical activity improves bone mass and density. Moderate evidence supports that physical activity improves bone structural outcomes (e.g., geometry).

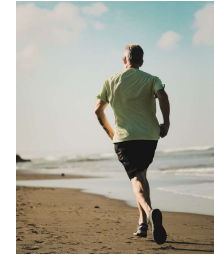
Dimension	Amount
Intensity	≥ 3.5 Times Body Weight
Session Duration	100 Impacts
Frequency	3 Days Per Week
Long-term Duration	≥ 7 Months

Osteoporos Int. 2016;27:1281.

5. Other Lifestyle Factors

Physical Activity – Middle Aged and Older Adults:

- **Weight-bearing and resistance exercises are best.**
- Weight-bearing exercises like jogging, climbing stairs, playing tennis, and dancing force you to work against gravity.
- Resistance or muscle-strengthening exercises like lifting weights can also strengthen bones.
- Other exercises like swimming and bicycling can help build and maintain strong muscles and have excellent cardiovascular benefits, but they are not the best way to exercise your bones.
- The Surgeon General recommends **30 minutes of physical activity** on most days, preferably daily.



National Institutes of Health

5. Other Lifestyle Factors

Medications that Can Harm Bones:

- Steroid-like medications, such as prednisone
- Thyroid medications
- Drugs that reduce estrogen or androgen levels (e.g., contraceptives)
- Certain diabetes medications
- Proton pump inhibitors and antacids that contain aluminum
- Selective serotonin uptake inhibitors (SSRIs)
- Loop diuretics
- Some anticonvulsive medications
- Some blood thinners and anticoagulants



American Bone Health

5. Other Lifestyle Factors

Smoking:

- There is a direct relationship between tobacco use and decreased bone density.
- Observational studies suggest **smoking increases the risk of fracture.**
- Smoking as been shown to have a negative impact on bone healing after fracture.



National Institutes of Health

5. Other Lifestyle Factors

Health Conditions – Chronic Kidney Disease:

- Chronic kidney disease (CKD) patients with osteoporosis is common.
- Bisphosphonates can be problematic.
- Serum calcium concentrations should be monitored carefully to prevent the development of hypocalcemia and vitamin D should be administered concomitantly.
- Minimal vitamin D3 supplementation (particularly in those on denosumab therapy) can help prevent hypocalcemia.
- Diet high in fruits and vegetables (focus on potassium) is likely the best nutrition strategy.



Intern Med. 2017;56(24):3271.

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5. Other Lifestyle Factors

Health Conditions – Diabetes:

- People with diabetes, particularly type-1 diabetes, often have poorer bone quality and an increased risk of fractures. Those with long-standing disease and poor blood sugar control, and who take insulin have the highest fracture risk.
- The onset of type-1 diabetes typically occurs at a young age and it is possible that these individuals achieve lower peak bone mass.
- Some of the complications of diabetes, such as nerve damage, muscle weakness, episodes of low blood sugar, and vision problems can increase the risk of falls and fractures.
- Low-fat and low-sugar calcium foods (e.g., dairy) and low-glycemic index fruits and vegetables are particularly important dietary strategies.

National Institutes of Health

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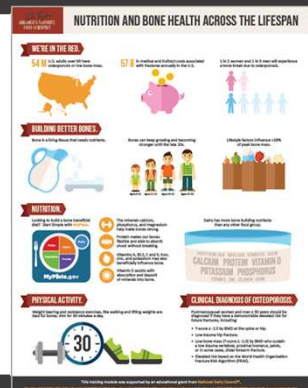
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Additional Resources

Resources for Health Professionals:

- 2-hour Bone Health course on <https://drtaylorwallace.com/education/>
- Course Infographic at www.DrTaylorWallace.com
- American Bone Health's [Fracture Risk Calculator™](#)
- American Bone Health's [Nutrition Website](#)
- National Osteoporosis Foundation's [Clinician's Guide to Prevention and Treatment of Osteoporosis](#)
- National Osteoporosis Foundation's [Position Statement on Peak Bone Mass Development](#)
- Dairy Intake and Bone Health Across the Lifespan [Systematic Review](#)
- International Osteoporosis Foundation [Resources for Health Professionals](#)



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Thank You!



Dr. Taylor
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Dr. Taylor Wallace

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Host of Resources and Recipes on USDairy.com

Recipes




Dinner

Gilled Pizzas Made With No-Yeast Greek Yogurt Pizza Dough



Dessert


Cottage Cheese and Fruit Blender Ice Cream




Side Dish / Appetizer

Gilled Jicama, Watermelon and Avocado Salad With Cotija Cheese


Science Summaries



Science Summary: Dairy and Cardiovascular Disease




Science Summary: Dairy and Inflammation

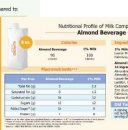


Science Summary: Dairy and Bone Health


Resources



Nutritional Profile of Milk Compared to Soy Beverage



Nutritional Profile of Milk Compared to Almond Beverage




Nutritional Profile of Milk Compared to Unsweetened Almond Beverage

USDairy.com | @NIDairyCouncil | #DairyNourishesLife

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COMPLIMENTARY WEBINAR | APRIL 29 | 12:00-1:00 PM CST





Save the Date

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Reinford Farms
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Alise Sjostrom
Redhead Creamery
Brooten, MN



Adam Wylie
Leprino Foods
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Questions?

Please enter your questions into the Q&A window.

Continuing education certificates are available upon completion of the survey

The full webinar recording will be available next week on USDairy.com.



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