If Low Calcium Is Not the Cause of Osteoporosis . . .

What Is?
Rethinking the Nature and Causes of Osteoporosis

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Osteoporosis Statistics

54 million American adults over the age of 50 are affected by osteoporosis and osteopenia:

- 10+ million with osteoporosis
- 43.4 million with osteopenia

By 2030:
- 71.2 million is projected

The real “proof of the pudding” diagnosis of osteoporosis (fragile bones) is the occurrence of a low-trauma fracture.

1 in 2 women and up to 1 in 4 men over age 50 will break a bone due to osteoporosis.
## Defining Osteoporosis

<table>
<thead>
<tr>
<th>Classification</th>
<th>T-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>-1.00 or greater</td>
</tr>
<tr>
<td>Osteopenia</td>
<td>Between -1.00 and -2.50</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>-2.50 or less</td>
</tr>
<tr>
<td>Severe/Established Osteoporosis</td>
<td>-2.50 or less and fragility fracture</td>
</tr>
</tbody>
</table>
Bone Mineral Density Does Not Predict Fracture Risk

- The US Study of Osteoporotic Fractures (SOF) looked at 8,065 women 65 and older.
- They reported that only 10 to 44% of osteoporotic fractures occurred in those women with an “osteoporotic bone density.”
- European trials report that only 18% of all fractures occur in women with “osteoporotic” bone density.

— Stone et al. 2003; Seeman et al. 2008
So What Is a Better Definition of Osteoporosis?

In 1993, a U.S. Consensus Development Conference defined osteoporosis as:

“A systemic skeletal disease characterized by low bone mass and architectural deterioration of bone tissue with a consequent increase in bone fragility and susceptibility to fractures”

– Consensus Development Conference 1993
RETHINKING THE NATURE OF OSTEOSPOROSIS
Osteoporosis is not just . . .

- Thin bone or low bone density
- A disorder of the elderly
- A disorder of women
- Something “gone wrong” in the body
- Peak bone mass is achieved in our late 20s or early 30s.
- Bone loss begins shortly after that.
- There are various reasons for low bone mass in young folks.
Osteoporosis Is Not Something “Gone Wrong” with Your Bones
- Osteoporosis is our magical body’s intelligent response to long-term imbalances and stressors.
- Bone is a gigantic reservoir of essential nutrients that can be made available to the body instantly.
- Osteoporosis is best seen as a positive coping mechanism by an intelligent biological system that is under stress.
- Osteoporosis is really just the end product “disorder” of our body’s lifelong attempt to maintain a crucial internal “order.”

- It is a positive, life-supporting coping mechanism which allows the body to maintain internal balance.
Osteoporosis Is a Complicated Disorder . . .

. . . that everyday medicine presents as simple.
Osteoporosis Does Not Stand Alone

- The body is one whole, interconnected unit.
- Fragile bones are not an isolated disorder.
Muscle and Bone

- As we lose muscle mass over time, we also lose bone mass.
- Back muscle strength has been shown to decrease 50% in women as they age from 50 to 80.
- The average woman loses 47% of her spinal bone mass during her lifetime, while most men lose 30%.

– Riggs et al. 1986; Sinaki 2003; Sinaki et al. 2002
Aging and Muscle

- Back muscle strength has been shown to decrease 50% in women and 64% in men as they age from 50 to 80.
- Reduction in height with aging has also been reported.

– Sinaki et al. 2002
RETHINKING THE CAUSES OF OSTEOPOROSIS
Total Load
Annual Risk of Hip Fracture According to the Number of Risk Factors and the Age-Specific Calcaneal Bone Density

– Cummings et al. 1995
The Importance of Multiple Risk Factors

Hip fracture risk was **17 times greater** among the **15 percent of the women** who had **five or more risk factors** (exclusive of bone density) than the 47 percent of the women with **two or fewer risk factors**.

– Cummings et al. 1995
Muscle and bone wasters include:

- Sugar and sugar substitutes
- Refined carbs
- Processed vegetable oils
- Soda
- Excessive caffeine
- Smoking
- Medications
- Transfats
- Preservatives
- Excessive alcohol
Stress-Induced Muscle and Bone Loss
How Many Hours Did You Sleep Last Night?
Older women who are satisfied with their lives have higher bone density and are less likely to develop osteoporosis than their unsatisfied peers, according to a study in Finland.
Highlights of Bone Depleting Factors

- Low Levels of Any of the 20 Key Bone Nutrients
- Chronic Low-Grade Metabolic Acidosis — Acid-Base Balance
- Contemporary Life Style:
  - physical inactivity
  - emotional over-activity
  - medication use
  - medical disorders
To Protect Your Bones, You Need at Least 20 Key Nutrients, Not Just Calcium
Nutrient Repletion: The Key Bone Nutrients

- Chromium
- Vitamin D
- Vitamin C
- Vitamin A
- Vitamin B₆
- Vitamin B₁₂
- Folate
- Vitamins K₁ and K₂
- Essential Fats
- Protein

- Calcium
- Phosphorus
- Magnesium
- Silicon
- Zinc
- Manganese
- Copper
- Boron
- Potassium
- Strontium
# The 20 Key Bone Building Nutrients

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Description</th>
<th>Adequate Daily Intake</th>
<th>Deficiency Symptoms</th>
<th>Important Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Essential for bone health and muscle function</td>
<td>1000-1200 mg/day</td>
<td>Bone pain, increased bone density</td>
<td>Vitamin D enhances absorption;晒太阳有助于维生素D的吸收</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Essential for calcium absorption and immune function</td>
<td>600-800 IU/day</td>
<td>Weak bones, immune dysfunction</td>
<td>Exposure to sunlight or oral supplements recommended; 维生素D的吸收需要阳光的照射</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Important for muscle function and bone health</td>
<td>400-420 mg/day</td>
<td>Muscle cramping, bone pain</td>
<td>Good sources include leafy greens, nuts, and seeds; 镁对于肌肉和骨骼健康都很重要</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Essential for bone health and energy production</td>
<td>700 mg/day</td>
<td>Weak bones, muscle weakness</td>
<td>Phosphorus is often co-supplemented with vitamin D; 磷酸盐是钙和维生素D的良好搭档</td>
</tr>
<tr>
<td>Zinc</td>
<td>Important for immune function and wound healing</td>
<td>8-11 mg/day</td>
<td>Weak immune system, delayed wound healing</td>
<td>Good sources include red meat, nuts, and seafood; 锌对于免疫系统和伤口愈合至关重要</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Essential for bone health and blood clotting</td>
<td>90-120 mg/day</td>
<td>Bone pain, increased bone density</td>
<td>Good sources include leafy greens and fermented foods; 维生素K对于骨质疏松和凝血都至关重要</td>
</tr>
<tr>
<td>Copper</td>
<td>Important for bone health and immune function</td>
<td>900 mcg/day</td>
<td>Weak bone, immune dysfunction</td>
<td>Good sources include red meat and nuts; 铜对于骨质疏松和免疫系统都重要</td>
</tr>
<tr>
<td>Iodine</td>
<td>Essential for thyroid function and bone health</td>
<td>150-230 mcg/day</td>
<td>Goiter, bone pain</td>
<td>Good sources include seafood and dairy products; 碘对于甲状腺和骨质疏松都很重要</td>
</tr>
<tr>
<td>Manganese</td>
<td>Important for bone health and antioxidant function</td>
<td>2-3 mg/day</td>
<td>Bone pain, decreased bone density</td>
<td>Good sources include whole grains, nuts, and seeds; 锰对于骨质疏松和抗氧化都很重要</td>
</tr>
<tr>
<td>Silicon</td>
<td>Essential for bone health and connective tissue function</td>
<td>200-300 mg/day</td>
<td>Bone pain, decreased bone density</td>
<td>Good sources include leafy greens and tofu; 硅酸盐对于骨质疏松和结缔组织都很重要</td>
</tr>
<tr>
<td>Boron</td>
<td>Important for bone health and hormone balance</td>
<td>1-3 mg/day</td>
<td>Bone pain, decreased bone density</td>
<td>Good sources include oranges and broccoli; 硼对于骨质疏松和荷尔蒙平衡都很重要</td>
</tr>
<tr>
<td>Selenium</td>
<td>Essential for immune function and bone health</td>
<td>55-250 mcg/day</td>
<td>Immune dysfunction, bone pain</td>
<td>Good sources include seafood, Brazil nuts, and brown rice; 硒对于免疫系统和骨质疏松都很重要</td>
</tr>
</tbody>
</table>

*Note: Adequate Daily Intake and Deficiency Symptoms are based on general recommendations and may vary depending on individual health conditions.*
Sub-Optimal Nutrient Intake Is the Norm, Not the Exception

- **Magnesium**: all ages, sexes, and classes (except those under 5) fail to consume even the RDA
- **Zinc**: average intake is 46 to 63% the RDA
- **Potassium**: average intake is around 50% RDA
- **Copper**: 75% of diets fail to contain the RDA
- **Vitamin D**: Low serum levels are common
- **Calcium**: Average intake is 500 to 600 mg

## Nutrient Losses in Food (from 1950 to 1999)

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Calcium</th>
<th>Iron</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli</td>
<td>↓63%</td>
<td>↓32%</td>
<td>↓13%</td>
</tr>
<tr>
<td>Carrots</td>
<td>↓31%</td>
<td>↓37%</td>
<td>↓19%</td>
</tr>
<tr>
<td>Kale</td>
<td>↓40%</td>
<td>↓23%</td>
<td>↓10%</td>
</tr>
<tr>
<td>Onions</td>
<td>↓37%</td>
<td>↓56%</td>
<td>↓25%</td>
</tr>
<tr>
<td>Potatoes</td>
<td>↓36%</td>
<td>↓8%</td>
<td>↓18%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Calcium</th>
<th>Iron</th>
<th>Vit. A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>None</td>
<td>↓40%</td>
<td>↓41.1%</td>
</tr>
<tr>
<td>Lemons</td>
<td>↓57%</td>
<td>↓14.3%</td>
<td>↑3.3%</td>
</tr>
<tr>
<td>Oranges</td>
<td>↓2.4%</td>
<td>↓75%</td>
<td>↑2.5%</td>
</tr>
<tr>
<td>Strawberries</td>
<td>↓33.3%</td>
<td>↓62%</td>
<td>↓67.1%</td>
</tr>
<tr>
<td>Tangerines</td>
<td>↓65%</td>
<td>↓75%</td>
<td>↑119%</td>
</tr>
</tbody>
</table>

– Davis et al. 2004
Repair Deficit

What keeps you from having perfect health?
Are you in repair deficit?
How do we stimulate repair?
Are There Nutrients More Important Than Calcium?
Vitamin D
Relation between Serum 25(OH)D and Calcium Absorption in Vitamin D Insufficiency

Calcium absorption fraction as a function of serum 25(OH)D3 concentrations (combined results of 3 studies)


Error bars indicate ± 1 SEM
From Heaney RP Am J Clin Nutr 2005; 80: 1706S-9S.
Vitamin D Inadequacy Is Widespread

- 1 billion people worldwide are deficient in vitamin D, especially among the elderly and dark-skinned individuals.
- Half of adults in US, Europe, and up to two-thirds of post-menopausal women are deficient in vitamin D.
- 30 to 40% of children in many cultures are deficient in vitamin D.
- 80% of school children in New Delhi are deficient in vitamin D.
- 97% of hip fracture patients in UK are deficient in vitamin D.
- Half the population of Tasmania is deficient in vitamin D.
Meta-Analysis Trials Using 700–800 IU Vitamin D$_3$ and Calcium

In a 1992 18-month study (n=3270), mean age 84, ambulatory elderly, using 1.2g calcium, 800 IU vitamin D$_3$ . . .

- 32% fewer non-vertebral fractures
- 43% fewer hip fractures

– Chapuy et al. 1992
Vitamin D and Fracture Reduction

The Better Bones Foundation estimates that supplementation with therapeutic levels of vitamin D could result in an overall 50- to 60-percent reduction in low-trauma osteoporotic fractures.

Other vitamin D researchers who agree with this statement include:

- William Grant, PhD
- Cedric Garland, DrPH
- Michael Holick, MD, PhD

— Brown 2008
Vitamin K
Vitamin K and Bone

Vitamin K is essential for the carboxylation of osteocalcin, the bone protein which attracts calcium to the crystallization site.

— Hart et al. 1985
Vitamin K and Fracture Risk

Work with elderly French patients shows that ucOC, but not conventional calcium metabolism parameters, predicts the subsequent risk of hip fracture.

– Szulc et al. 1993

European EPIDOS Study found ucOC to be major independent risk factor for hip fracture among healthy elderly women. The women with low BMD and high ucOC had a 5.5x increased risk of hip fracture as compared to those with only low BMD or high ucOC levels.

– Vergnaud et al. 1997
Dietary Vitamin K and Fracture

Data from the Framingham Heart Study revealed that those women and men in the highest quintile of vitamin K intake (250 mcg/d) had one-third the risk of hip fracture as those in the lowest quintile (75 mcg/d).

– Booth et al. 2000

The Nurses Health Study (N=72,732) also reported that the women in the lowest quintile of vitamin K intake had an increased risk of hip fracture.

– Feskanich et al. 1999
Meta-Analysis of Vitamin K and Fracture Reduction

7 RCTs using MK-4 (menatetrenone) (6 using 45 mg and 1 using 15 mg)
- 77% Reduction in Hip Fractures
- 60% Reduction in Vertebral Fractures
- 81% Reduction in all Non-Vertebral Fractures

– Cockayne et al. 2006
Ascorbate: The Best Form of Vitamin C
According to new research on the effects of vitamin C on bone health, moderate amounts of vitamin C led to a nearly 44% reduction in risk of fracture.

Vitamin C Is Essential for Healthy Bones

- As an antioxidant to protect bone from free radical damage
- As an electron donor to energize bone cells
- A key nutrient for healthy collagen

According to new research on the effects of vitamin C on bone health, moderate amounts of vitamin C led to a nearly 44% reduction in risk of fracture.

– Sahni 2015
Trace Minerals

**Magnesium, Zinc, Manganese, Copper, Boron, Silica, Iron**

Inadequacy Is Common !!

Actual intake levels and therapeutic levels are outlined on the 20 Key Bone Building Nutrients Chart Handout
Sub-Optimal Nutrient Intake Is the Norm

**Magnesium:** All ages, sexes, and classes (except those under 5) fail to consume even the RDA.

**Zinc:** Average intake is 46 to 63% the RDA.

**Potassium:** Average intake is around 50% RDA.

**Copper:** 75% of diets fail to contain the RDA.

**Vitamin D:** Low serum levels are common.

**Calcium:** Average intake is 500 to 600 mg.

Bone Protein Matrix Minerals: Manganese, Zinc, Copper, and Iron

- Copper and iron act as cofactors in the cross-linking of collagen and elastins.
- Manganese participates in the biosynthesis of mucopolysaccharides.
- Zinc deficiency causes a reduction in osteoblastic activity, collagen and chondroitin sulfate synthesis, and alkaline phosphatase activity.

— Strause et al. 1994
Magnesium Depletion and Osteoporosis — Experimental Animal Models

- Universal observation is decreased growth of whole body and skeleton
- Reduced osteoblast formation
- Decreased collagen formation
- Impaired mineralization
- Production of brittle and fragile bone

– Rude 2001
Magnesium Builds Bone in Girls

RCT of 120 girls (8 to 14 yrs) with magnesium intakes less than 220 mg/day and a 1-year intervention with 300 mg magnesium:

- Significant improvement in hip BMD.
- Slight increase in spinal BMD.

– Carpenter et al. 2006
Magnesium Builds Bone in Postmenopausal Women

Magnesium, Zinc, Copper, Magnesium, and Selenium Levels in Postmenopausal Women with Osteoporosis. Can Magnesium Play a Key Role in Osteoporosis? A Postmenopausal Women with Osteoporosis. Can Magnesium Play a Key Role in Osteoporosis?

Magnesium Intake from Food and Supplements Is Associated with Bone Mineral Density in Healthy Older White Subjects

Kathryn M. Ryder, MD, MS,* Ronald I. Shore, MD, MS,† Andrew J. Buah, PhD,‡ Stephen B. Ketchum, PhD,§ Tamarra Harris, MD, MPH,∥ Katie Stone, PhD,∥ Jane Cauley, DrPH,∥ and Frances A. Tyasvysy, DrPH

OBJECTIVES: To determine whether magnesium intake from supplemental and dietary sources is associated with bone mineral density (BMD) in older men and women.

DESIGN: Cross-sectional.


PARTICIPANTS: Two thousand thirty-eight black and white men and women aged 70 to 79 at baseline enrolled in the Health, Aging, and Body Composition Study.

MEASUREMENTS: Dietary intake of magnesium was assessed using a semiquantitative food frequency questionnaire, and supplement data were collected based on a medication inventory. BMD of the whole body was obtained using a fan-beam densitometer. Additional covariates included age, body mass index (BMI), smoking status, alcohol use, physical activity, estrogen use, and supplement use.

CONCLUSION: Greater magnesium intake was significantly related to higher BMD in white women and men. The lack of association observed in black women and men may be related to differences in Ca regulation or in nutrient reporting. J Am Geriatr Soc 53:1873-1880, 2005. Key words: bone mineral density; nutrition; magnesium; osteoporosis; elderly.

Osteoporotic fractures are a significant health problem in older adults, and the burden of osteoporosis is expected to increase as the population ages. White women have a lifetime risk of any clinical fracture approaching 75% and a lifetime risk of hip fracture of 60%. White men have a lifetime risk of any clinical fracture approaching 50% and a lifetime risk of hip fracture of 20%.
Zinc Is Essential for Bone Health

- Zinc stimulates osteoblast bone-building formation and mineralization.
- It facilitates bone collagen synthesis.
- It inhibits osteoclastic bone breakdown.
- Studies show women with osteoporosis have lower than normal levels of zinc.
Multiple Intervention Strategies

2-year multi-nutrient blinded, controlled study, N59 healthy postmenopausal women:

**Intervention:**
- Placebo
- Just Ca citrate malate (1,000 mg)
- Ca citrate malate (1,000 mg), zinc (15 mg), manganese (5 mg), and copper (2.5 mg).

**BMD Changes:**
The only significant change from placebo was **calcium plus trace minerals. This was the only group to halt loss and gain bone.**

— Strause et al. 1994
Multi-Nutrient Intake and Fracture Risk

In a Swedish observational study of 65,000 women aged 48 to 80, when highest quartile of intake was compared to lowest:

- Intakes of iron, magnesium, and vitamin C were found to be independent risk factors for hip fracture (or 3.3; 2.7; 1.9).

- High calcium intake did not protect against hip fracture.

— Michaëlsson et al. 1995
Potassium: The Unexpected Bone Builder

The RDA for potassium at 4,700 mg is nearly four times that of calcium (at 1,200 mg).

Potassium Protects Bone
Metabolic Functions of Bone

- Serum Calcium Homeostasis
- Systemic Acid-Base Balance

Bone Sacrifices Structural Functions for Metabolic Functions
Obligatory pH Balance and Chronic Low Grade Metabolic Acidosis

pH homeostatic mechanisms are central to our discussion of toxic metals and bone health.
Our skeleton serves as a gigantic reserve of alkaline mineral compounds ready for transfer into the blood for maintenance of an obligatory, precise pH level.

– Brown and Jaffe 2000
Bone and the hydration shell around it contain:

- 80% of body carbonate
- 80% of body citrate
- 35% of body sodium
- 53 to 80% of body magnesium
- 0.1 to 0.2% of body potassium

– Brown and Jaffe 2000; Green and Kleeman 1991a
If we do not maintain adequate alkaline-mineral reserves from our diet, our skeleton willingly sacrifices itself for survival of the whole.
Chronic Metabolic Acidosis

- Dietary changes over the last two centuries have resulted in a mismatch between genetically determined nutritional requirements and actual nutrient intake.
- This has resulted in *chronic metabolic acidosis* being the norm rather than the exception:
  - Deficiency of potassium, magnesium, and other essential minerals from alkaline-forming foods
  - Excess dietary intake of acid-forming foods
  - Excess sodium chloride
Cell Net Acid Excess (NAE)

NAE is a key determinant of bone health because of its role in:

- Regulating the efficiency of protein synthesis
- Controlling bone alkaline mineral reserves
- Regulating the efficiency of our elective protective and anti-toxic mechanisms

— Brown and Jaffe 2000
Metabolic Acidosis Is the Norm and It Endangers Bone

- Bone loss can be re-thought of and understood more fundamentally as a “hidden tax of high-tech living.”
- People with high-tech diets and lifestyles usually acquire chronic metabolic cellular acidosis and become progressively more deficient in cell mineral reserves that proportionately impair efforts to rebuild bone matrix and detoxify.

– Frassetto et al. 2005; Jehle et al. 2013
Chronic Low-Grade Metabolic Acidosis Damages Bone

These acid-forming excesses are not mediated by dietary bicarbonates and lead to chronic low-grade metabolic acidosis with ensuing damage to bone. Among other effects you see:

- Urinary loss of calcium
- Increased bone resorption
- Kidney function decline
- Reduction in growth hormone
- Nitrogen and muscle losses

— Frassetto et al. 2001; Frassetto and Sebastian 1996; Green and Kleeman 1991b
Remember . . .

Chronic Low-Grade Metabolic Acidosis = Low Mineral Status
The Acid-Alkaline Food Guide
Become a Nutrition Detective