# Changes in Skeletal Systems over the Lifespan

Connie M. Weaver, Ph.D.
Purdue University

# *Disclosures*

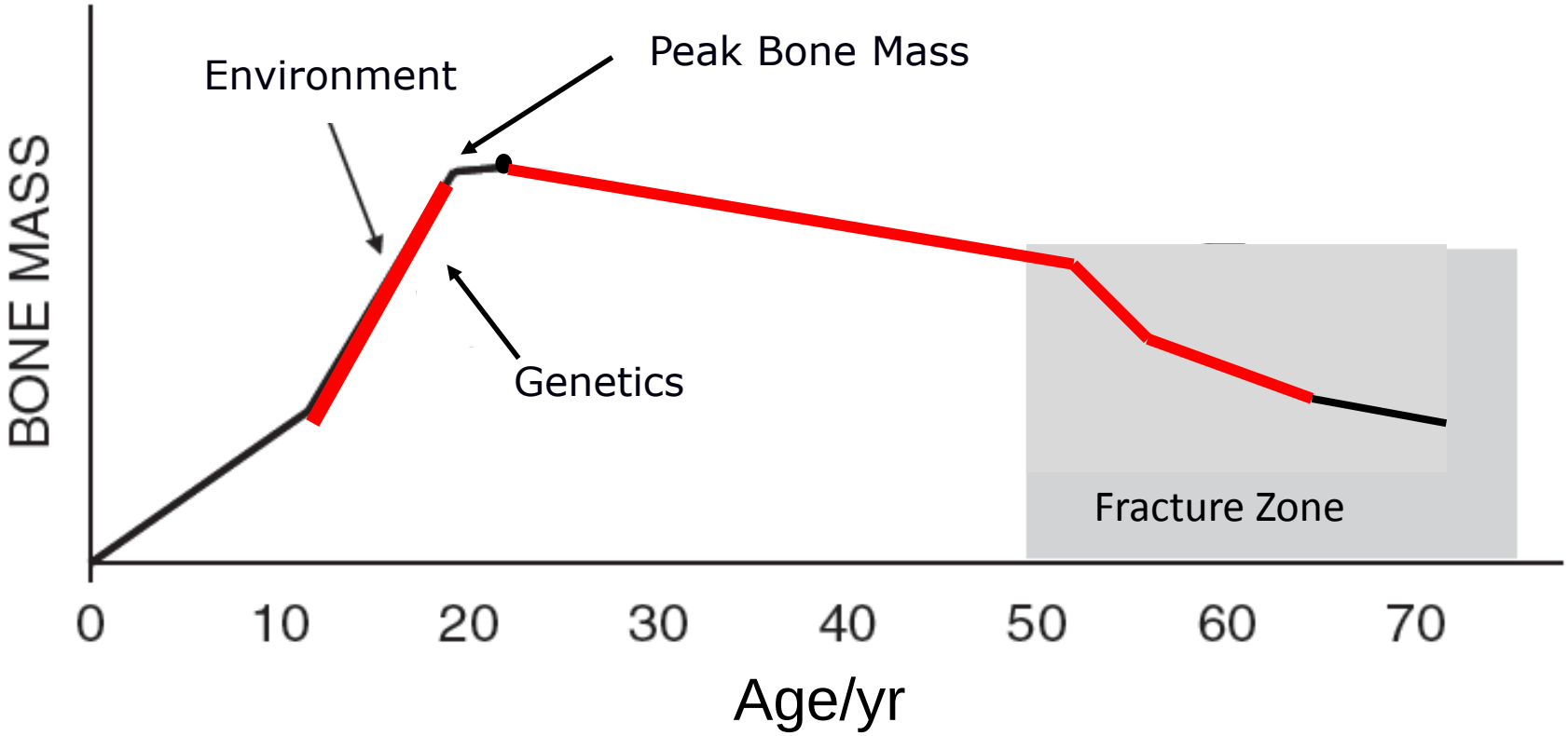
**Boards/Scientific Advisory Committees –**

- **ILSI**
- **Showalter**
- **Pharmavite**

**Grants –**

- **NIH**
- **Dairy Research Institute**
- **Nestle**
- **Tate and Lyle**
- **Fonterra**
- **Kraft**
- **Dairy Australia**
- **Pharmavite**

# Bone Mass throughout the LifeSpan

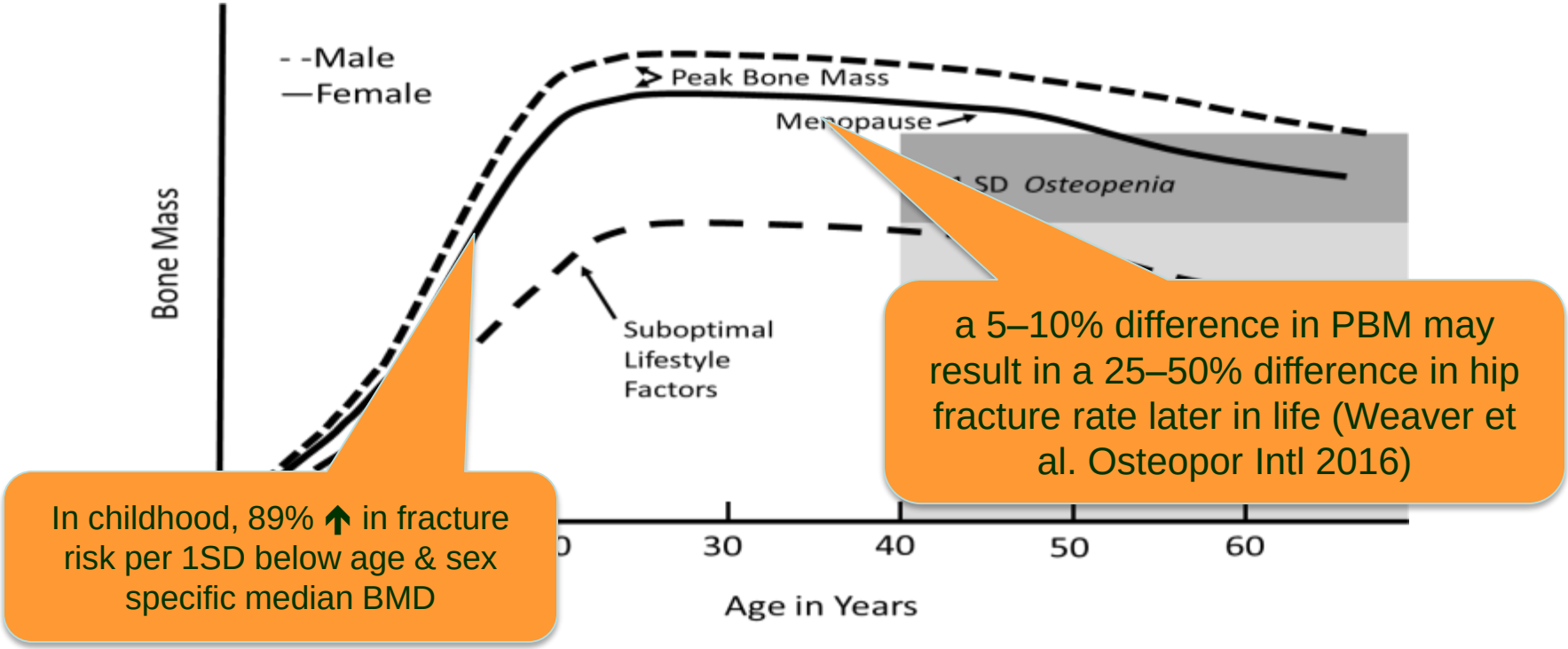



- Strategies to prevent fracture are to build peak bone mass early in life and to reduce bone loss later in life

# Why is peak bone mass important?

- 30 to 50% of children have at least one fracture by the end of teenage years
- 50% of women and 20% of men over 50y will experience an osteoporotic fracture
- Estimated annual costs exceed $18 billion

# Bone Mass Across the Lifespan

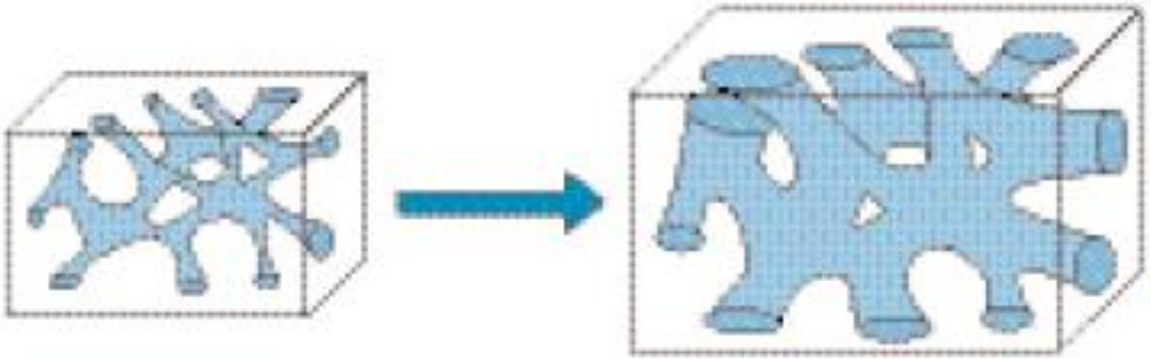



Adapted from Heaney et al. Osteoporos Int (2000) 11:985–1009

# How Bones Grow

Spine

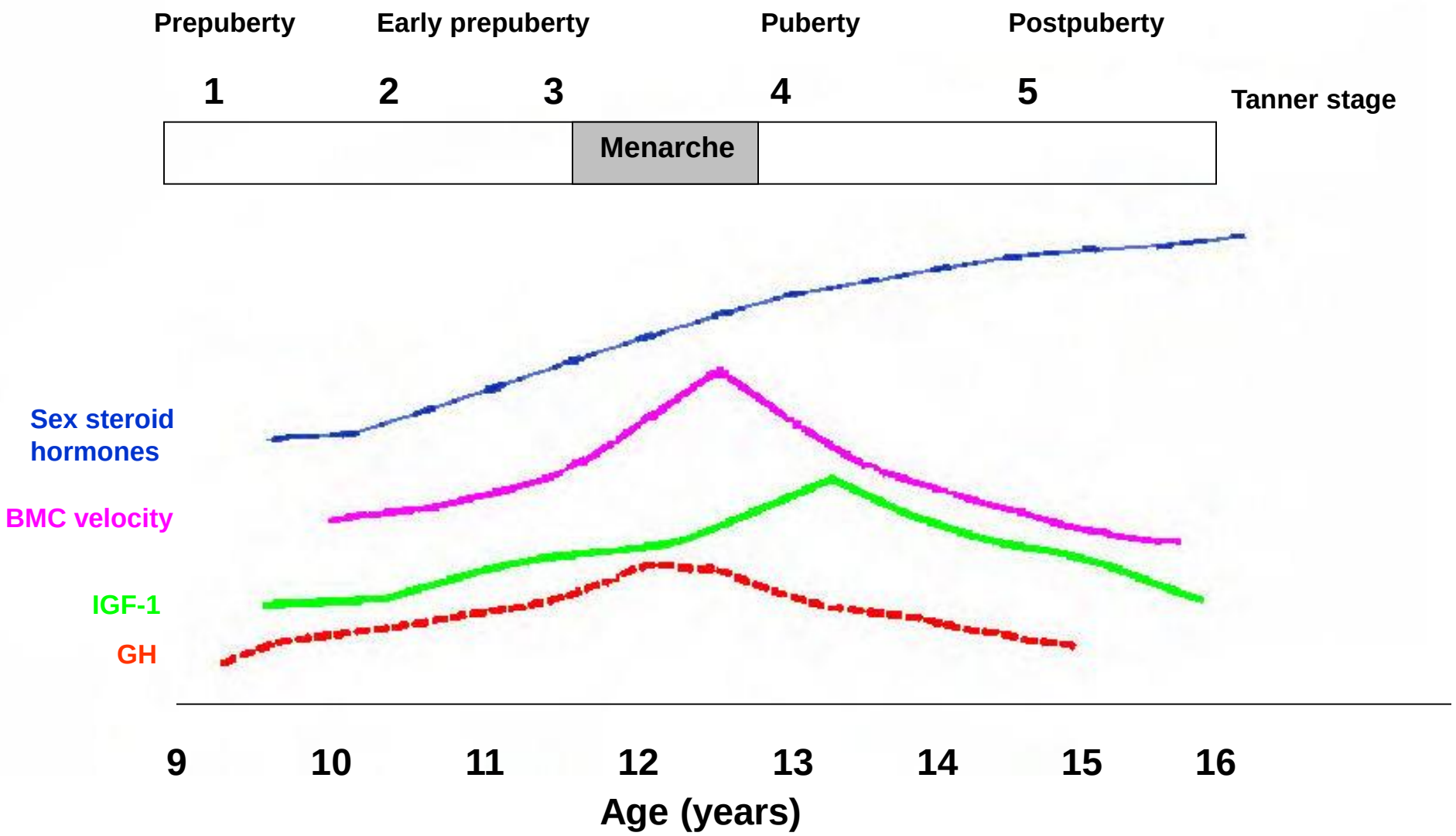
Increased size and trabecular thickness



Long bones

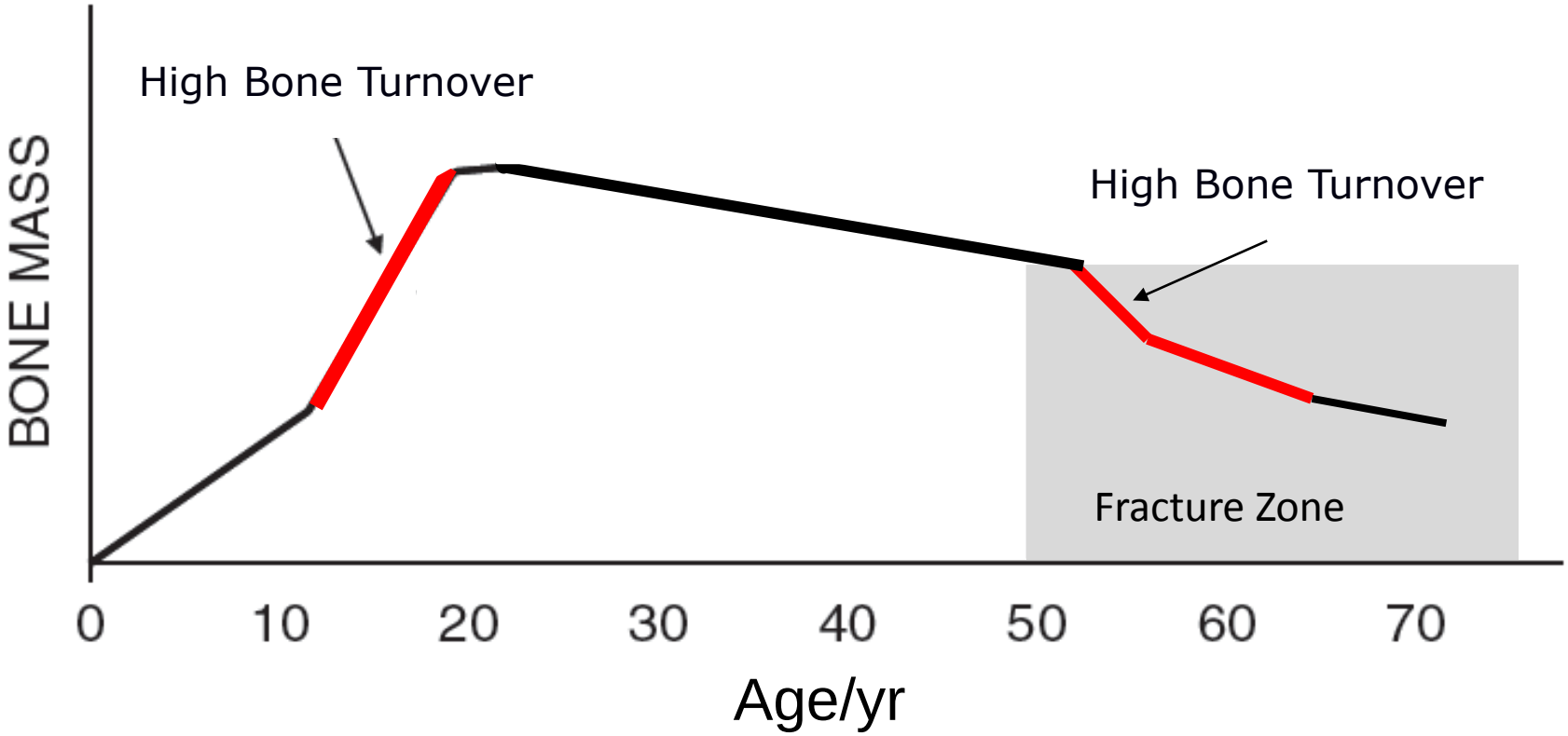
Increased length and diameter


- 1st year of life-birth weight triples
- Outer bone expands as bone redistributes from endocortical to periosteal surface. ↓ BMD but bone strength ↑




- Increases in sex-steroid hormones triggers growth hormone and IGF-1 production to initiate the growth spurt
- IGF-1 predicts skeletal calcium accretion
- When estrogen levels rise in late puberty, epiphases close and linear growth ceases
- Testosterone stimulates periosteal expansion at cortical sites → large bone size in males
- Estrogen limits periosteal expansion in females

# Interventions may by more effective when Bone Turnover is Rapid



# NOF Position Statement on Peak Bone Mass Development and Lifestyle Factors

## Writing Team

Connie M. Weaver, lead; Catherine Gordon, Kathleen Janz, Heidi Kalkwarf, Joan Lappe, Richard Lewis, Megan O'Karma, Taylor Wallace, Babette Zemel

*Osteoporosis International 27:1281-1386, 2016*

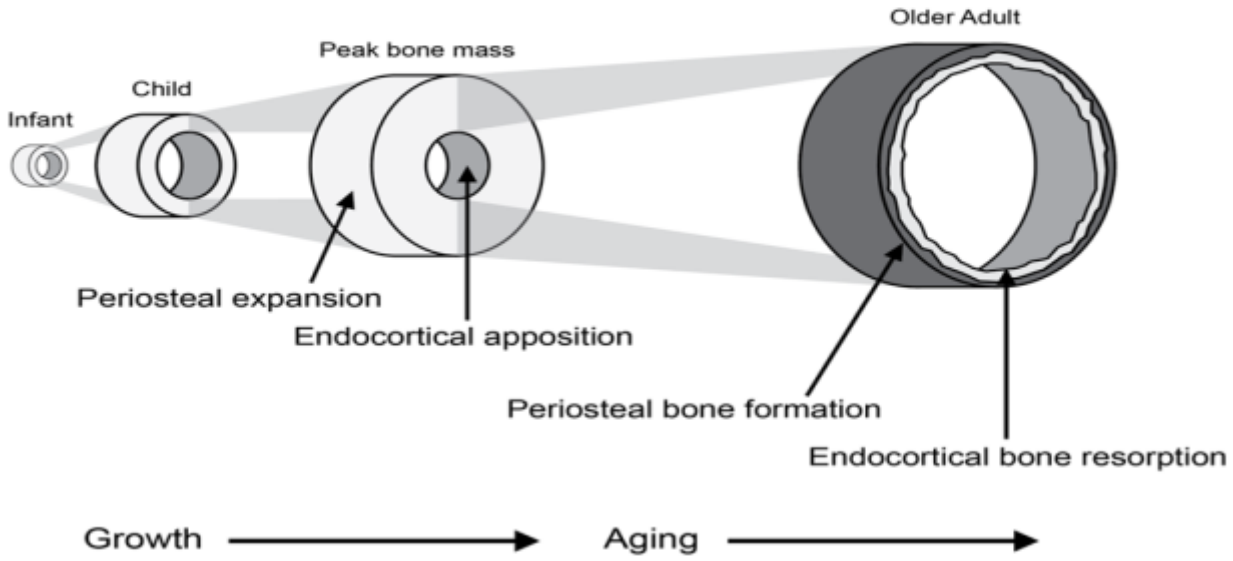
# Search Results

| Term | #RCTs | #Prospective | #Observational | Grade |
|---|---|---|---|---|
| Macronutrients | | | | |
| Fat | 1 | 1 | 1 | D |
| Protein | 1 | 5 | 6 | C |
| Micronutrients | | | | |
| Calcium | 16 | 4 | 4 | A |
| Vitamin D | 7 | 1 | 4 | B |
| Vitamin C | | | 2 | D |
| Magnesium | 1 | | | D |
| Zinc | | | 1 | D |
| Iron | | | 1 | D |
| Sodium (-) | | | 1 | D |
| Phosphorus (-) | | | 1 | D |
| Vitamin K | | | 1 | D |
| Fluoride | | 2 | 3 | D |

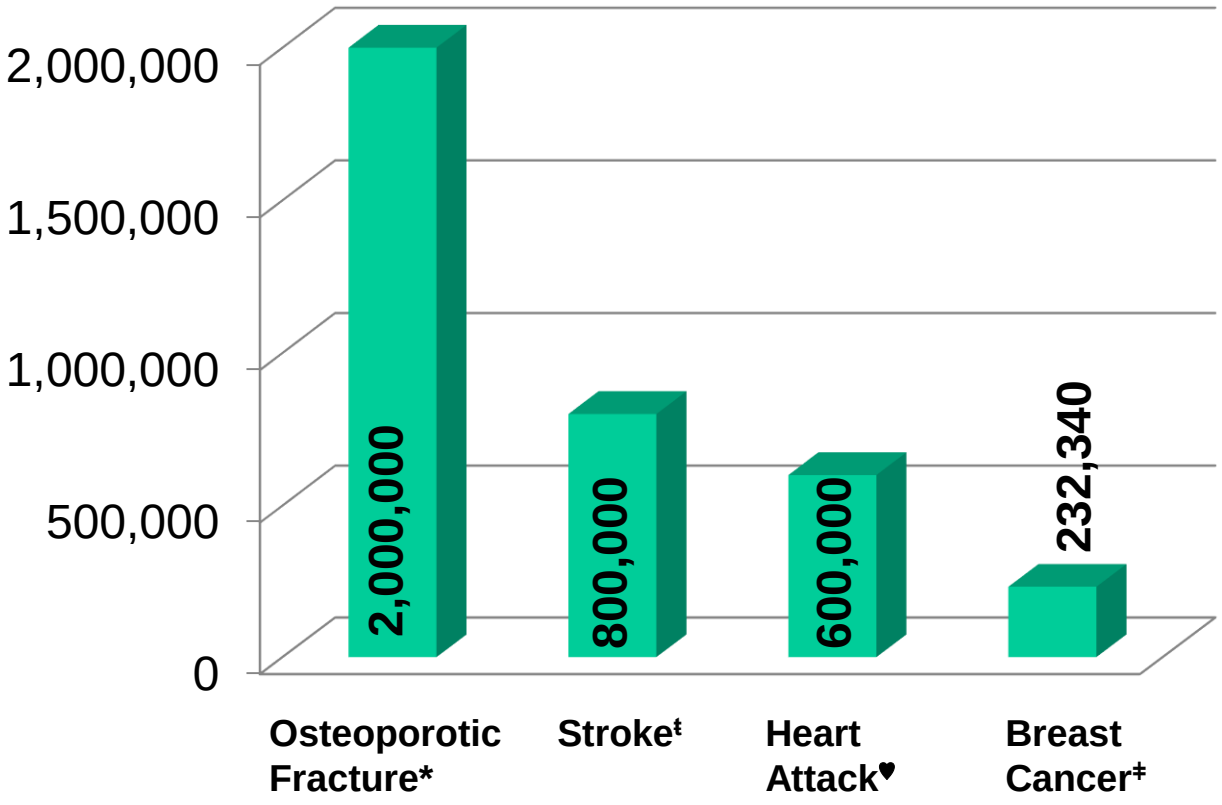
# Search Results

| Term | #RCTs | #Prospective | #Observational | Grade |
|---|---|---|---|---|
| Food Pattern | | | | |
| Dairy | 3 | | 1 | B |
| Fibers | 1 | | | C |
| Selected Cola/Caffeine/ Carbonated beverage | | | 11 | C |
| Infant Nutrition – source/duration | 1 | | 11 | D |
| Alcohol (adverse) | | 3 | 5 | D |
| Smoking (adverse) | | | 11 | C |
| Physical Activity | | | | |
| Bone mass and density | 38 | 19 | | A |
| Bone structure | 18 | 8 | | B |

# Structural Strength Across the Life Span



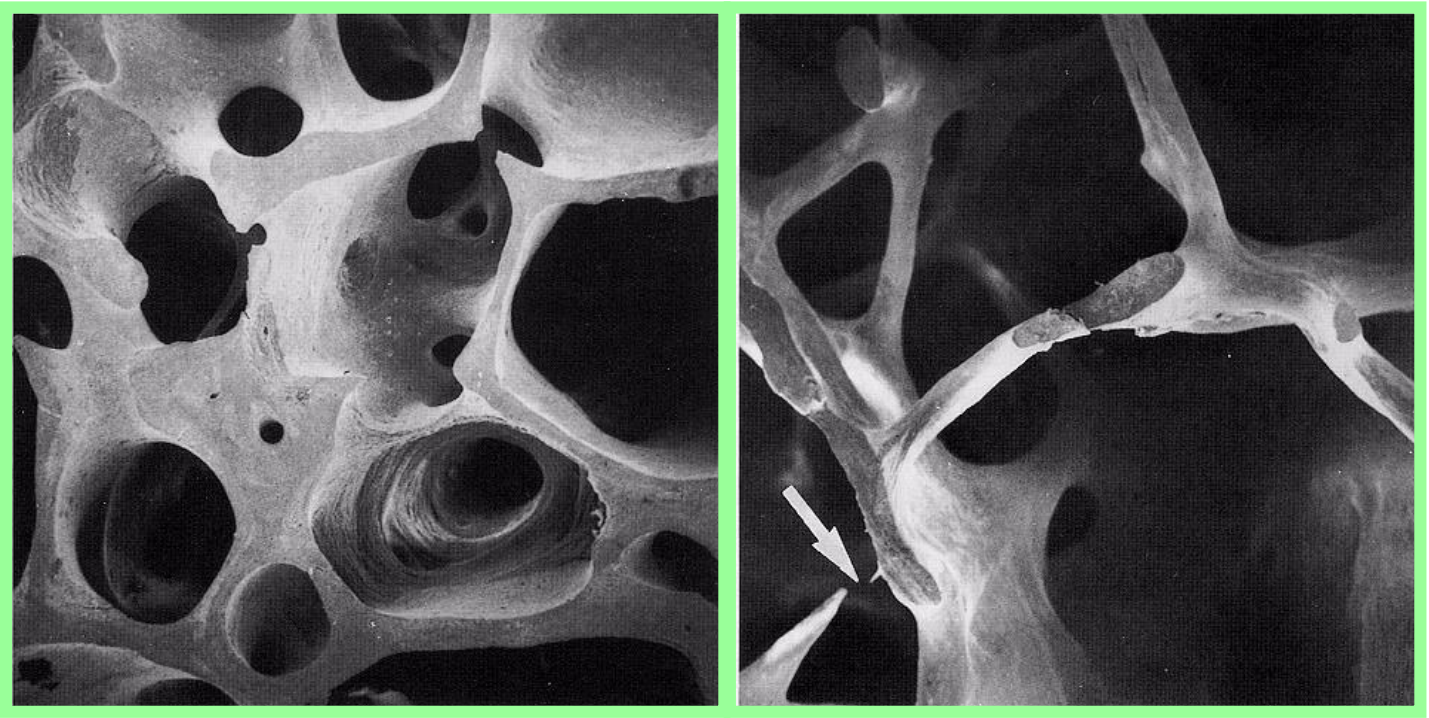
# Annual Incidence of Common Diseases




*National Osteoporosis Foundation (2013)
‡http://www.cdc.gov/stroke/ (2013)
♥ http://www.cdc.gov/heartdisease/facts.htm/ (2010)
‡http://www.breastcancer.org/symptoms/understand_bc/statistics (2013)

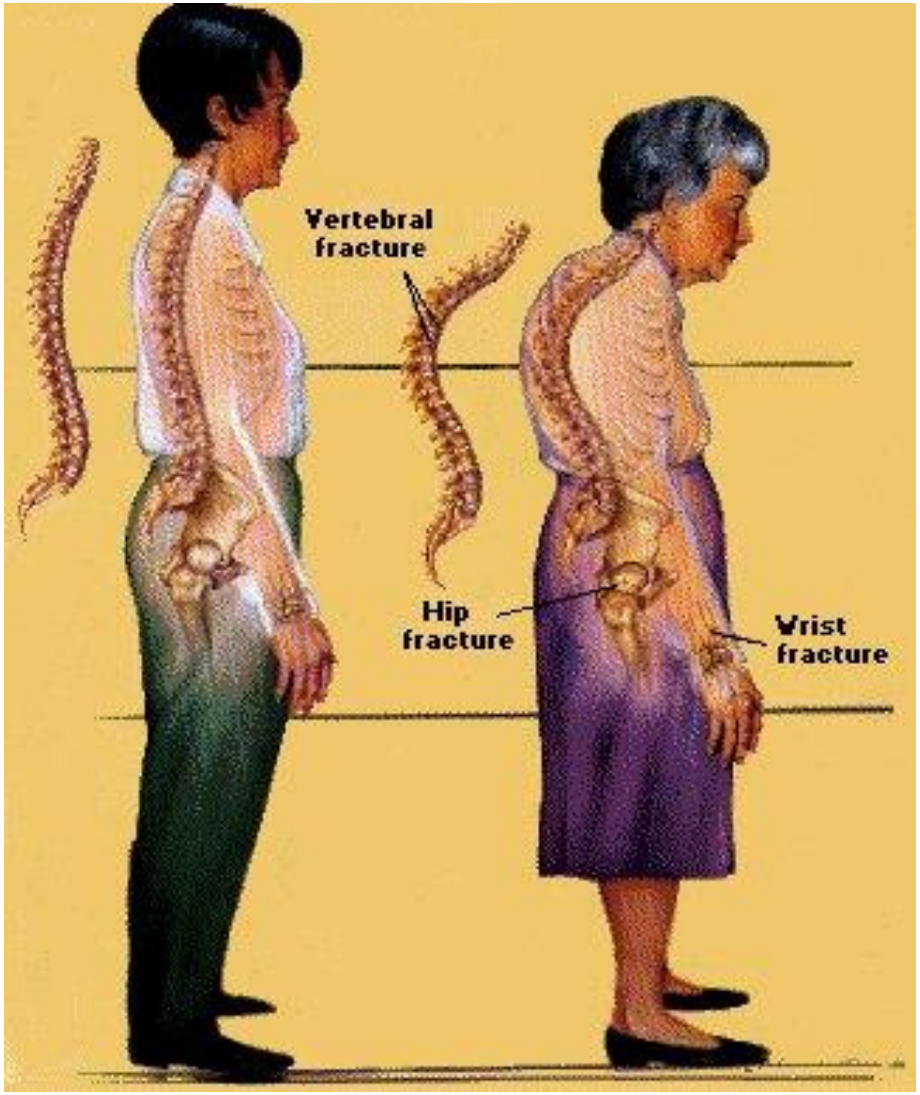
# What is Osteoporosis?

**Normal Bone** **Osteoporotic Bone**



Reproduced from *J Bone Miner Res.* 1986;1:15-21
with permission of the American Society for Bone and Mineral Research

# Consequences of Osteoporosis




Women may lose 15% of bone mass in first 5 years after menopause (Hansen et al. 1991), with osteoporosis affecting 1 in 3 postmenopausal women.

Proportion of population > 80 years is increasing rapidly and is projected to triple between now and the year 2050.

Overall prevalence of osteoporosis and related fractures will likewise increase.

# Osteoporosis

- Costs
  - $22 billion in 2008

  *(National Osteoporosis Foundation)*
  - 2 Million fractures/yr
- Risk factors
  - Modifiable: low physical activity, low calcium intake, vitamin D deficiency
  - Non-modifiable: genetics, female, advanced age, Caucasian
- Incidence
  - 15.8% white female, 3.9% white male
  - 7.7% African American female, 1.3% African American male
  - 20.4% Mexican American female, 5.9% Mexican American male
  - ½ hip fracture patients → long term care, 20% die within 1 yr

# Prevalence of Osteoporosis and Low Bone Mass (spine and femoral neck) in US

## NHANES 2005-2010

Overall:

10.3% prevalence of osteoporosis

10.2 M have osteoporosis

43.9% prevalence low bone mass

43.4 M have low bone mass

Total 53.6 M

Wright et al. JBMR 29:2520-6, 2014

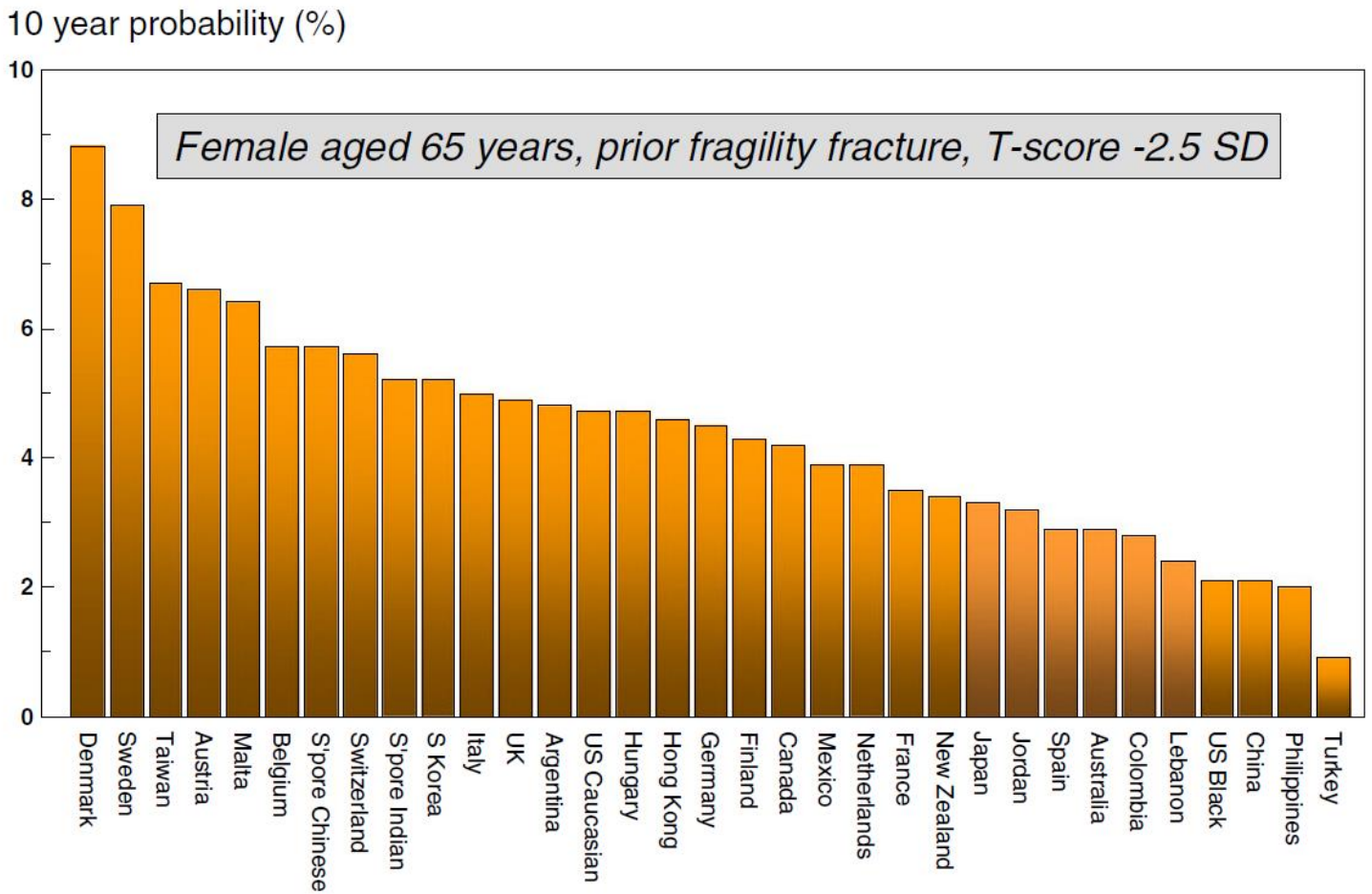
# Predictors of BMD

- Genetics
- Diet
- Exercise
- Hormones

# Clinical Risk Factors for Osteoporosis Independent of BMD

- Age>65
- Low body weight
- Family history of fracture
- History of postmenopausal fracture (including vertebral fracture)
- Genetic factors

# 10 yr probability of hip fracture in women ≥65 y with prior fracture and DXA T-score ≤-2.5 SD at femoral neck by country




Kanis et al. *Osteoporos Int 22:2395-2411, 2011*

# Current Treatment Options

- Hormone replacement therapy increased risk of coronary heart disease, stroke, breast cancer (Rossouw *et al.,* JAMA. 2002)
- Bisphosphonates
  - Linked to atypical fractures (Russell *et al.,* Osteoporos. 2008)
  - Osteonecrosis of the jaw (Arrain *et al.,* Dent Update. 2008)
- Lifestyle choices – Ca, vitamin D, weight bearing exericse
- Increased interest in botanicals

# Bone Building Nutrient – Calcium

- Constant uptake and release = bone turnover
- Only 10 – 30% of calcium is actually absorbed
- Absorption is best in <500 mg doses

## NEW – Estimated Average Requirement

- 4-8 year olds – 800 mg/day
- 9-18 year olds – 1100 mg/day
- Adults <51 – 800 mg/day
- Males 51-70 – 800 mg/day
- Females 51-70 – 1,000 mg/day
- All adults >70 – 1,000 mg/day

## Sources

- Dairy products
- Fortified foods
- Broccoli, kale



Institute of Medicine, National Academies, 2010

# Bone Building Nutrient – Vitamin D

- **Cholecalciferol (D3) & ergocalciferol (D2) are both bioactive**
- **Enhances absorption of calcium and phosphorous**
- **Found naturally in very few foods**
  - Fortified foods provide ~70% of Vit D in the diet

## NEW – Estimated Average Requirement

- **All ages – 400 IU/day**

## Sources

- **Fortified dairy products**
- **Fortified cereal and juice**
- **Fatty fish**


J Nutr 2005; 135:2478 & Institute of Medicine, National Academies, 2010

There is much confusion in the literature about calcium, dairy and bone

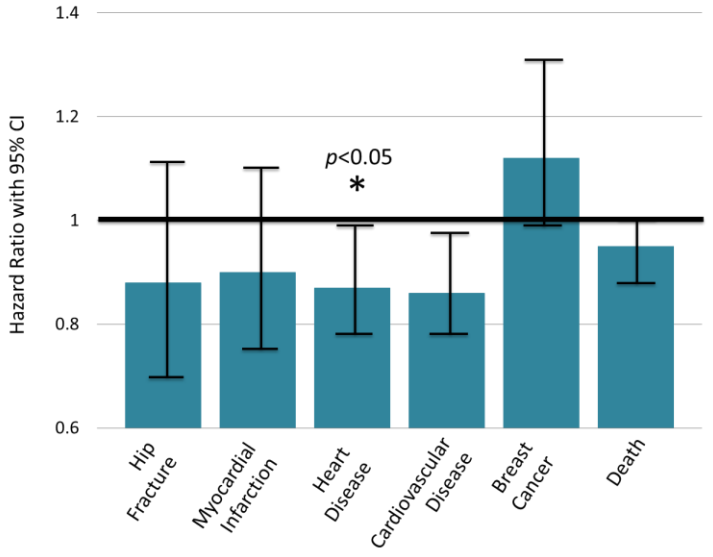
- Poor compliance and baseline status in RCTs
- Methods for assessing intake weak
- Life stage, sex, genetic dependent

# What is the relationship between calcium and vitamin D and hip fracture?

Women's Health Initiative RCT of CaD
(n=68,719 postmenopausal women)

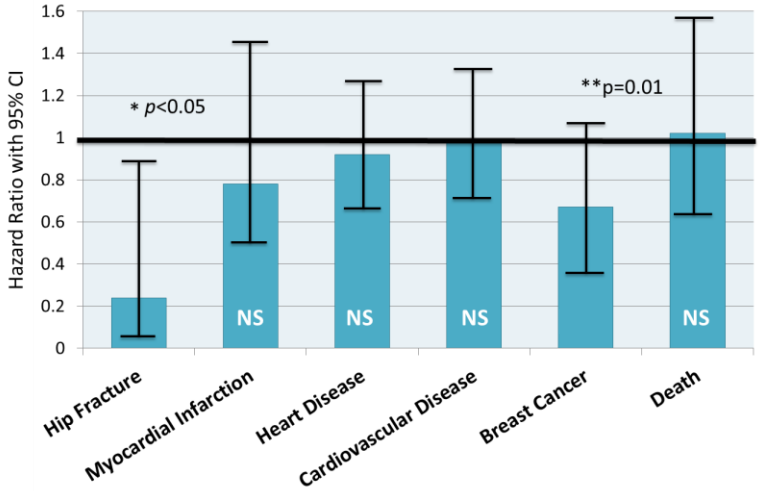
- All subjects including those taking own supplements

No relationship



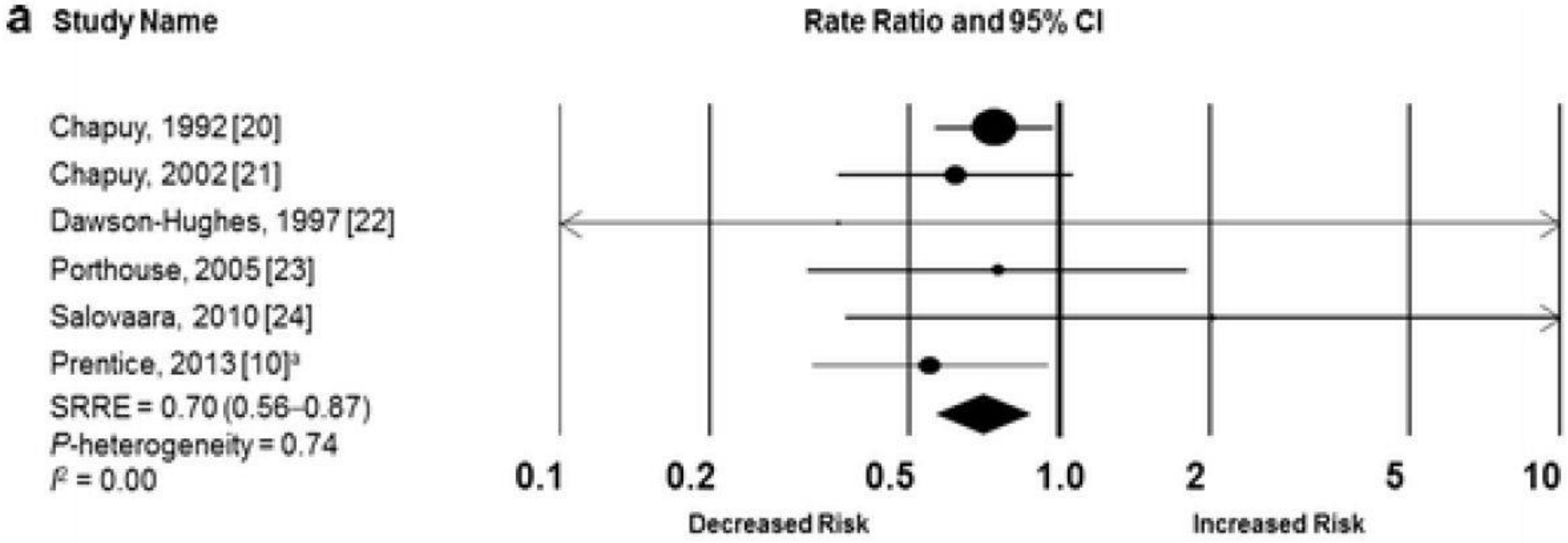

- >5 Year CaD Intervention-related Health Outcomes in Subjects Adherent & Not Taking Baseline Supplements

Large benefit



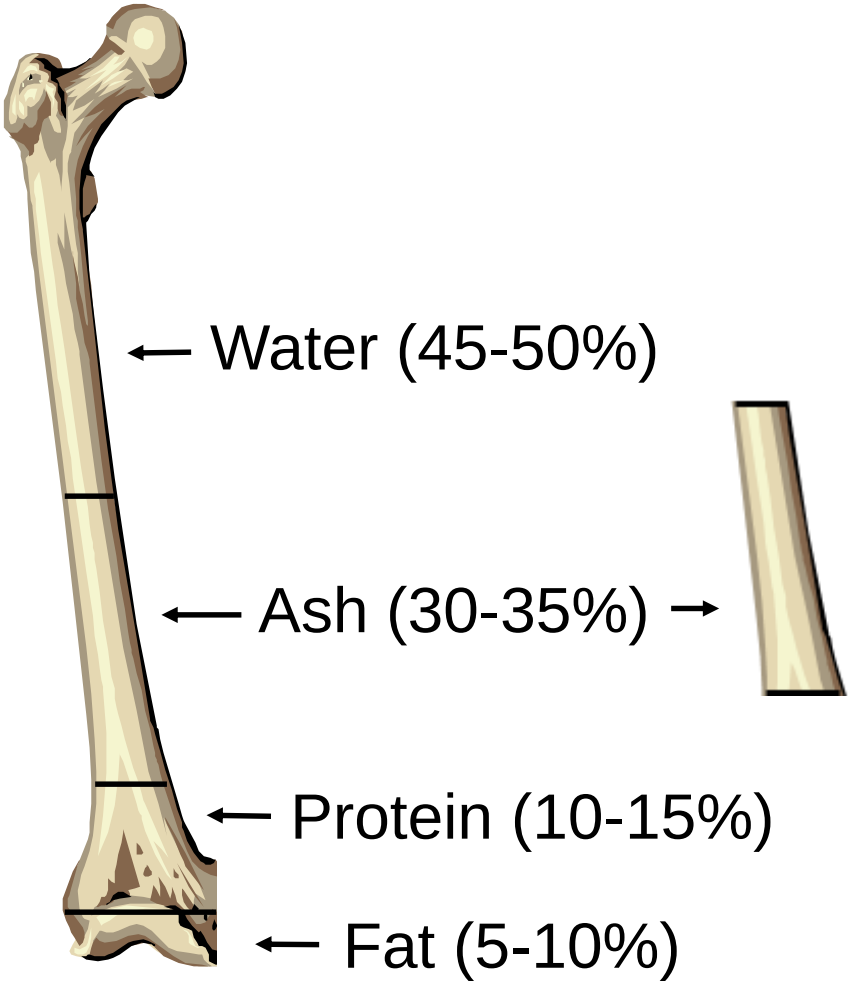

*Prentice et al., Osteopor Int 24:567, 2013*

# Meta analysis shows Calcium plus vitamin D reduces risk of hip fractures by 30%




*Weaver et al., OI DOI 10.1007/s00198-015-3386-5, 2015*

# Figure 1. Composition by weight of bone and dietary sources




Calcium (36%) from diary products
Phosphorus (17%) from dairy, meats, processed foods
Magnesium (0.8%) from green leafy vegetables, nuts, whole grains, dairy

# Milk Provides Essential Nutrients

| 3 cups low-fat milk provide about: | |
|---|---|
| Calcium | >100% |
| Phosphorus | 99% |
| Vitamin D | 86% |
| Protein | 54% |
| Riboflavin | 32% |
| Potassium | 28% |
| Magnesium | 25% |
| Vit B, Vit A, Zinc, and more… | |

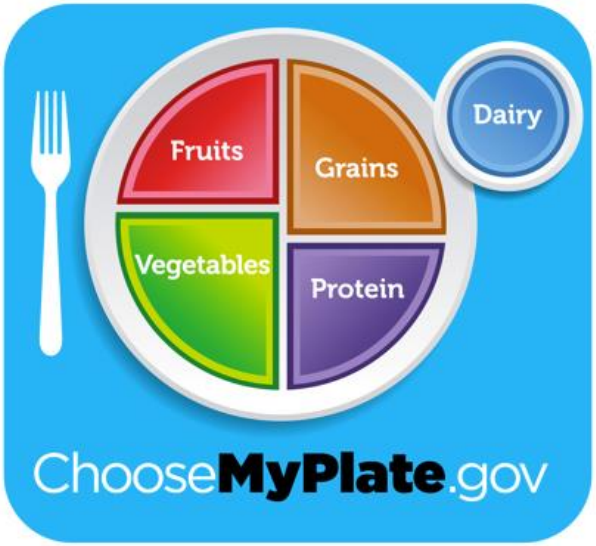
Percentages for vit D and calcium based on EAR, percentages for all others based on RDA

# Conclusion

**The source matters but intake matters more!**

# Prudent Recommendations

- 3 cups of low-fat dairy product equivalents/day



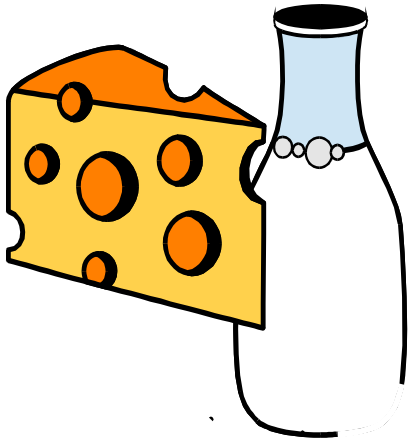

- 300mg calcium supplement for each serving missed

# Overall Conclusions

- Building peak bone mass and reducing bone loss later in life are two strategies to reduce osteoporosis
- Increasing peak bone mass by 5-10% can reduce fracture risk substantially
- Lifestyle choices can modify both peak bone mass and bone loss
- Several of the essential nutrients important to bone are shortfall nutrients as identified by the Dietary Guidelines for Americans, i.e., calcium, vitamin D, magnesium

## Bone healthy diet:

Calcium rich foods, dairy
Fruits/Vegetables
Whole grains



## Benefits of Diet:

Maximize peak bone mass
Minimize bone loss
Promote overall health