

Children's National and the Pediatric Health Network

Building Better Bones For All of Our Children

January 29, 2025

Introduction and Welcome

Claire Boogaard, M.D., M.P.H.

Pronouns: she/her

Medical Director

Pediatric Health Network



Notes About Today's Webinar:

- All lines are muted throughout the presentation.
- Please use the Q&A to ask questions or make comments.
- We will be recording the session.
- Today's recordings and materials will be posted to the Children's National website and the Pediatric Health Network website following the presentation.
 - ChildrensNational.org
 - PediatricHealthNetwork.org

Learner Notification

Disclosure of Conflict of Interest

The planning committee and presenters have no relevant financial relationships with ineligible companies identified conflicts of interest.

Acknowledgement of Commercial Support

No financial or in-kind commercial support was received for this educational activity.

Instructions to claim CE will be provided at the end of the course.

Building Better Bones For All of Our Children



Laura L. Tosi, MD
Orthopedic Surgeon
Director, Bone Health Program



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Pediatric Endocrinologist
Director, Endocrine Bone Metabolism
Program



GOALS

- Recognize the factors that impact the development of peak bone mass in the growing child
- Identify laboratory and diagnostic studies that aid in the evaluation of a child's bone health status
- Review therapeutic options for supporting the child at risk for reduced bone mass



Bone Health



EVER AFTER

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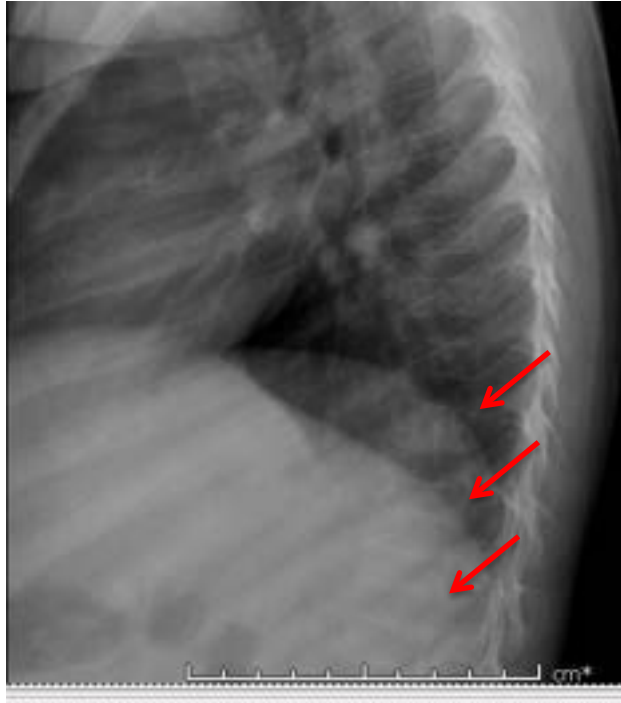


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Independence and Quality of Life

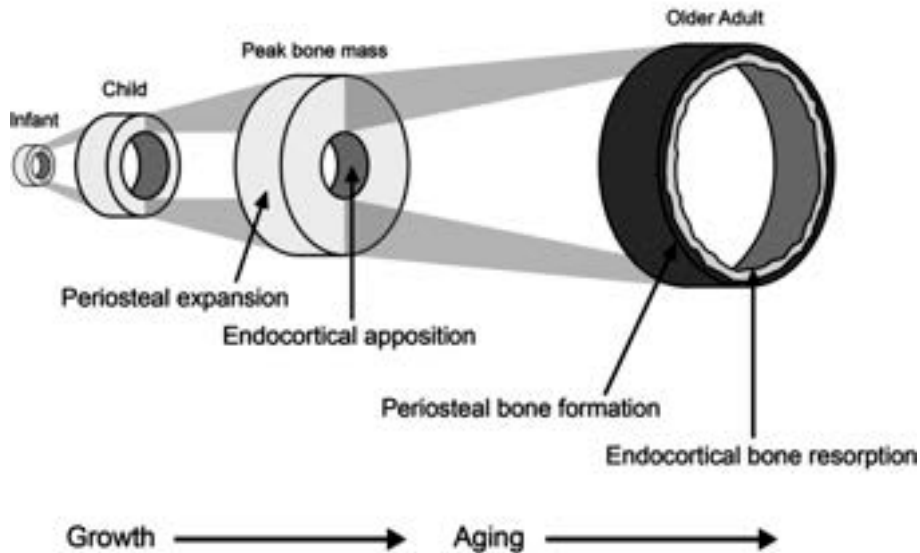


- “his entire back hurts”
- “intermittent episodes of severe back”
- “The pain is so severe that he doesn't want to walk in the morning”

Chronic back pain
Disability
Decreased ambulation
Neurologic injury

Bone is a Unique Dynamic Organ

Growth and Bone



Adults and Children:

- **Remodeling** = Bone mass is unchanged
 - Interplay between bone resorption and formation
 - First year of life: 100% of skeleton is replaced
 - Young children: ~ 50% per year
 - Adults: ~ 10% per year

Only Children

- **Modeling** = Bone mass and size increases
 - Formation >> resorption





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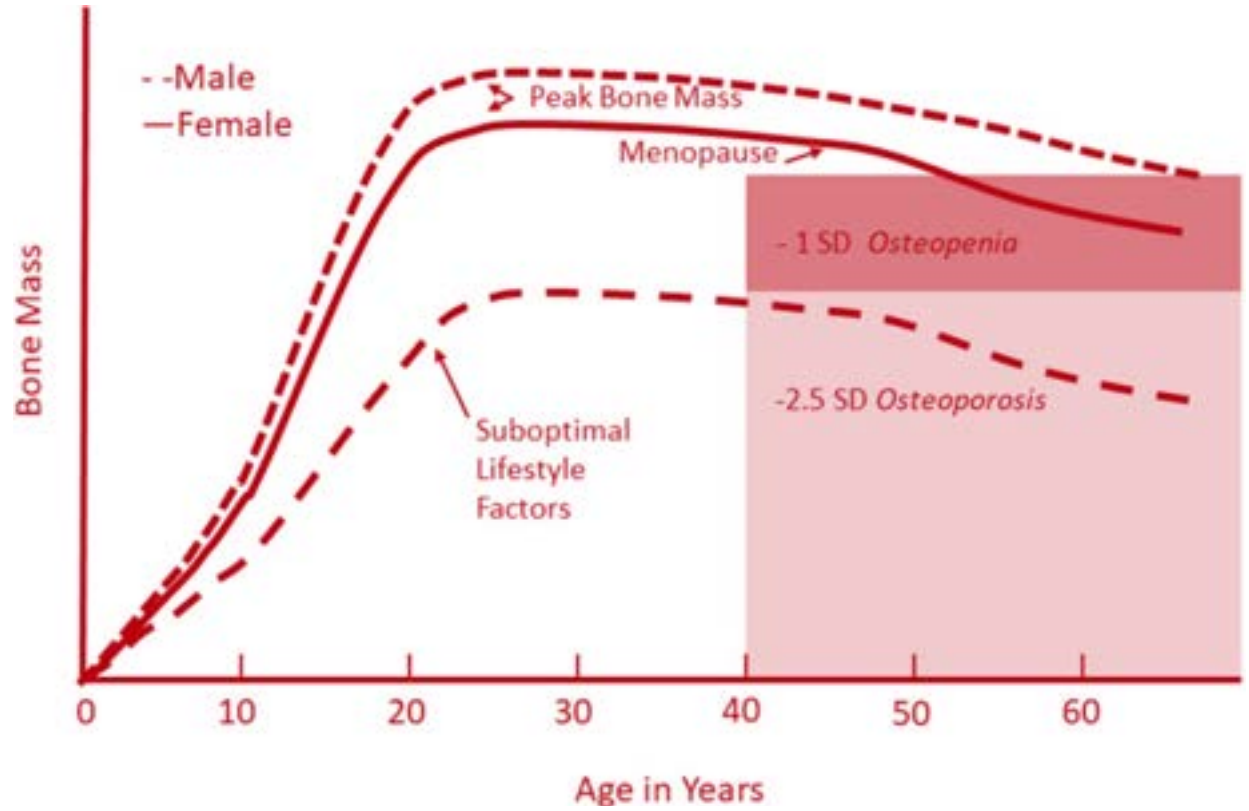


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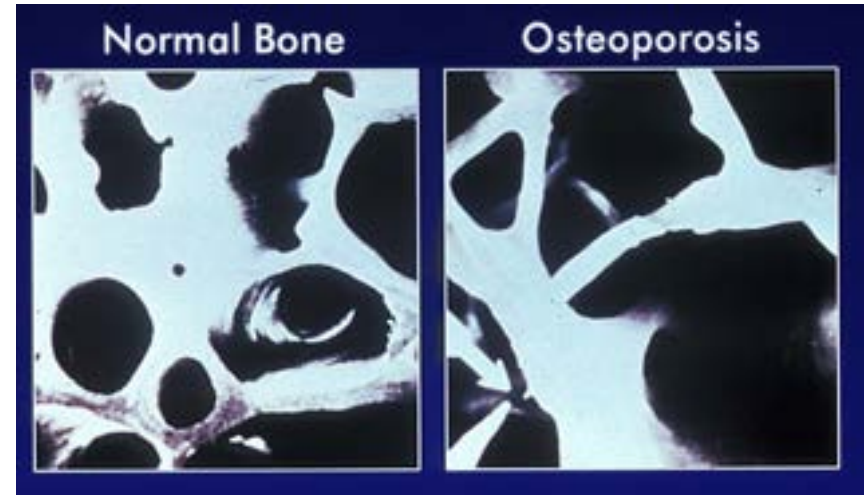
Peak Bone Mass Accrual



Kralick AE, Zemel BS. Evolutionary perspectives on the developing skeleton and implications for lifelong health. *Frontiers in Endocrinology*. 2020 Mar 4;11:99.

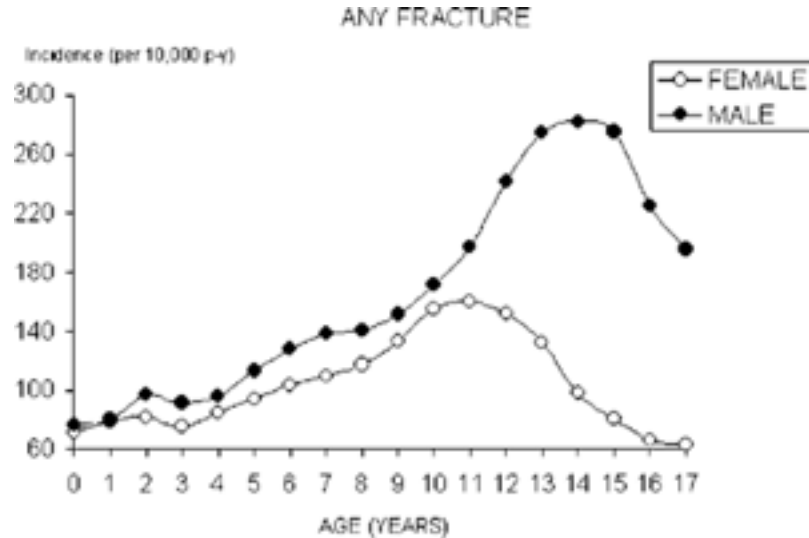
Why Does Peak Bone Mass Matter

- Childhood bone mass is predictive of fracture risk during childhood
 - 89 % increase in fracture risk per SD decrease in height-adjusted bone mass



Clark EM, Ness AR, Bishop NJ, Tobias JH, J Bone Miner Res, 21:1489–1495, 2006

Fractures in Childhood are Common



- 40-50% of all children will sustain at least one fracture before the age of 18 years
- Approximately 40-50% of boys and 20-40% of girls will fracture a bone in childhood

(Journal of Bone and Mineral Research, Volume: 19, Issue: 12)

Who Warrants Evaluation?



Usual vs Pathologic?

No definition or guidelines on how to distinguish
Long bone fractures most common
Low trauma *non-vertebral* fractures are most common



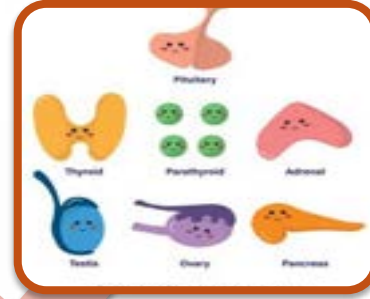
When to Consider Referral:

Recurrent long bone fractures
Vertebral fractures

Genetics



Hormones



Peak
Bone
Mass



Nutrition



Mechanical Factors

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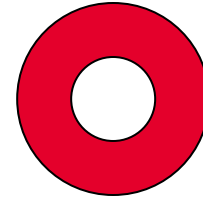
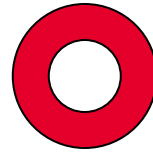


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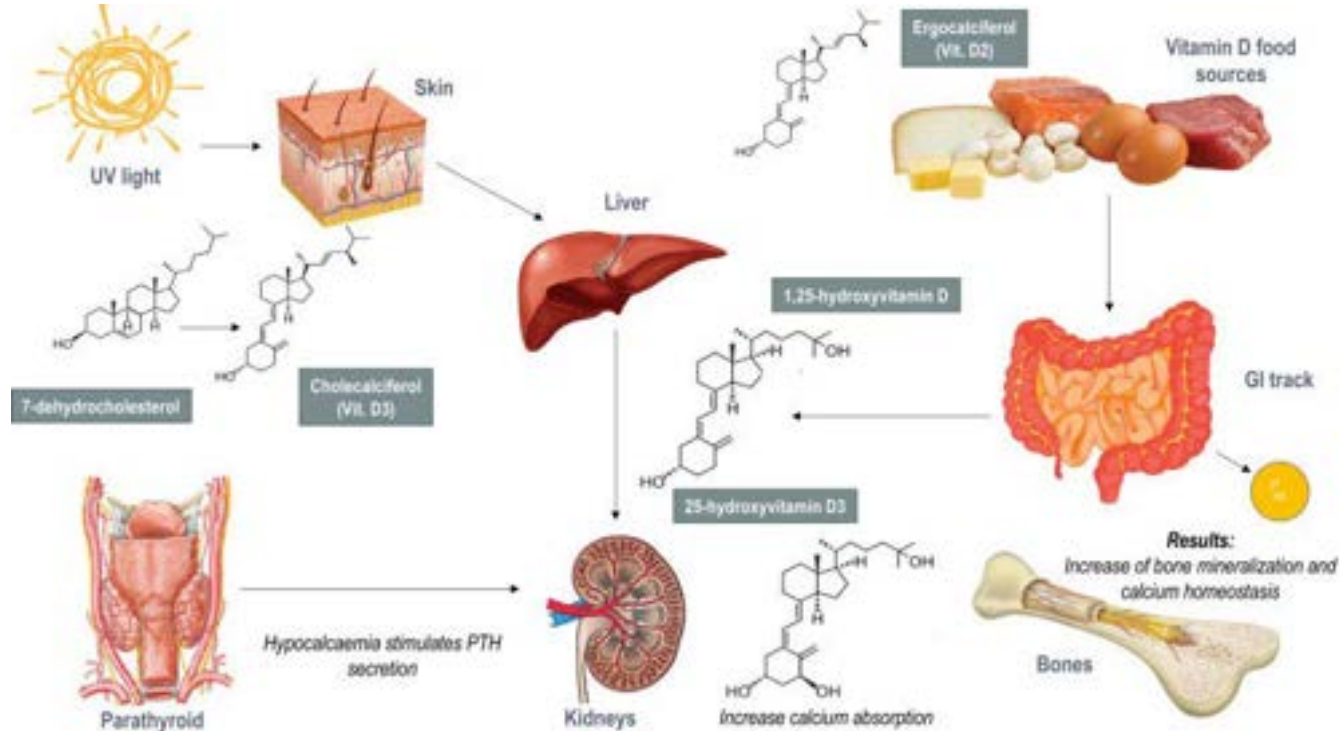


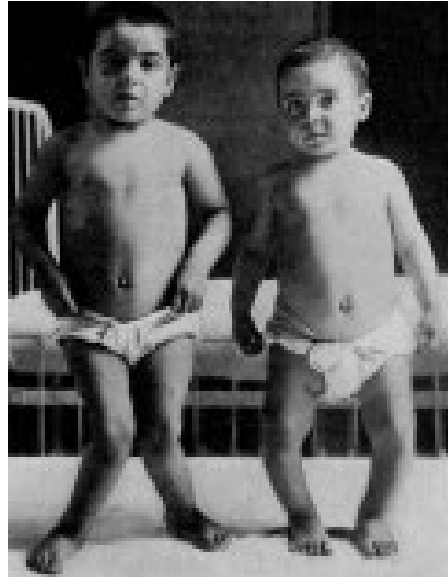
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Dominant vs Non-Dominant Arm



Vitamin D and Peak Bone Mass





Normal anatomy



Rickets



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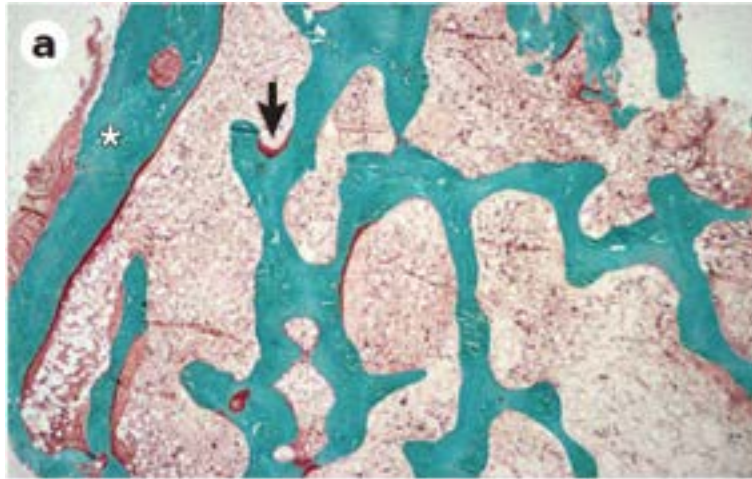


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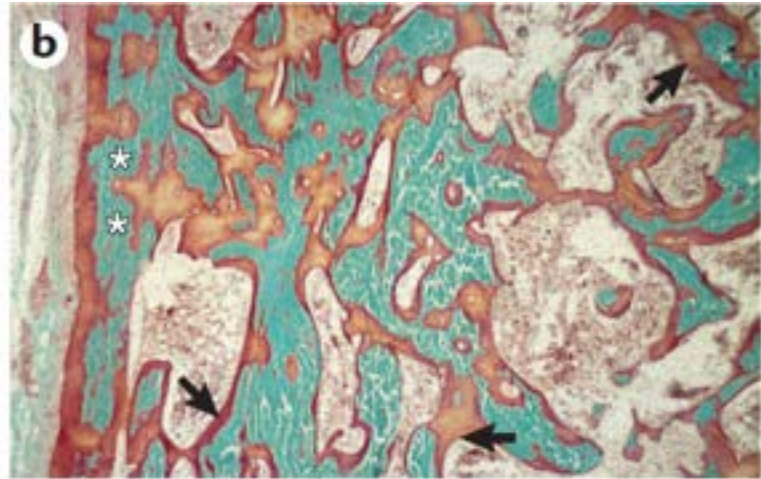
What is Rickets?

- Impaired bone mineralization during bone modeling

Control



Osteomalacia



Risk Factors

- Dark skin pigmentation
- Dairy restriction
- Picky eater
- Vegan diet
- Breastfeeding with most not supplementing

Bustamante VH, Estrada A, Merchant N. J
 Pediatr Endocrinol Metab. 2023;36(8):749-752

Variable, age (years)	All	0 to <2	2 to <10	10 to <18
n, %	38	14 (37)	9 (10)	15 (41)
Demographics				
Race/ethnicity				
- Caucasian (non-Hispanic)	2 (5)	0	1	1
- Latino/Hispanic				
- Black/African American	28 (74)	12	9	12
- Hispanic/Latino/Spanish	2 (5)	0	1	1
- Asian	1 (3)	0	0	1
- Other	1 (3)	1	1	3
Clinical characteristics				
Symptoms				
- Seizures	10 (26)	5	1	4
- Neurological symptoms	8	0	1	7
- Parosmia	5	0	1	4
- Spasm	8	0	1	7
- Tiring	2	0	0	2
- Bone abnormalities*	8 (14)	4	2	0
- IUG changes*	16 (42)	3	4	7
Underlying condition*				
- Neurological condition	9	1	2	6
- Autism	4	0	1	3
- Allimentary allergies	7	2	1	4
- Kidney disease	5	1	1	2
- Pseudohypoparathyroidism	1	0	1	0
- Angioid streaks/eye	1	0	1	0
- deficiency				
- Cystic fibrosis	1	0	0	1
Diet				
- Breastfed	8 (21)	8 (57)	N/A	N/A
- Vegan/vegetarian	7 (18)	5 (35)	2 (22)	0
- Dairy restrictions	7 (18)	3 (21)	1 (11)	3 (17)
- Picky eater	10 (26)	0	3 (33)	7 (46)
- Vitamin D supplementation	8 (14)	1 (7)	1 (11)	4 (22)
Median length of stay in days (range)	4.5 (1-10)	4.5 (1-10)	4.5 (1-24)	4.5 (1-24)

*Patients may have had

CNH Inpatient Admissions Due to Vitamin D Deficiency Hypocalcemia

Admissions with Vitamin D < 10 ng/mL and Calcium < 8 mg/dL

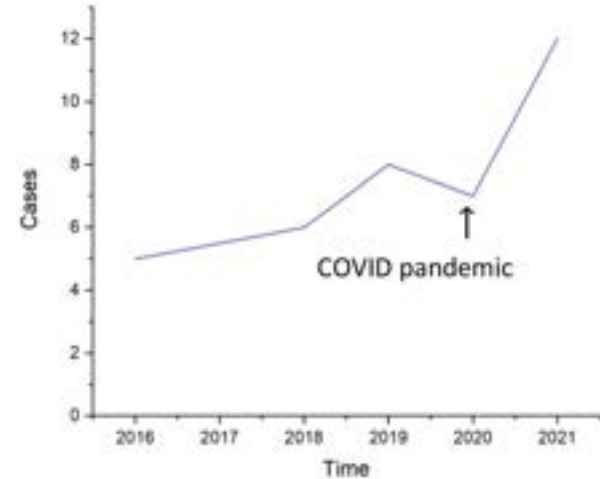
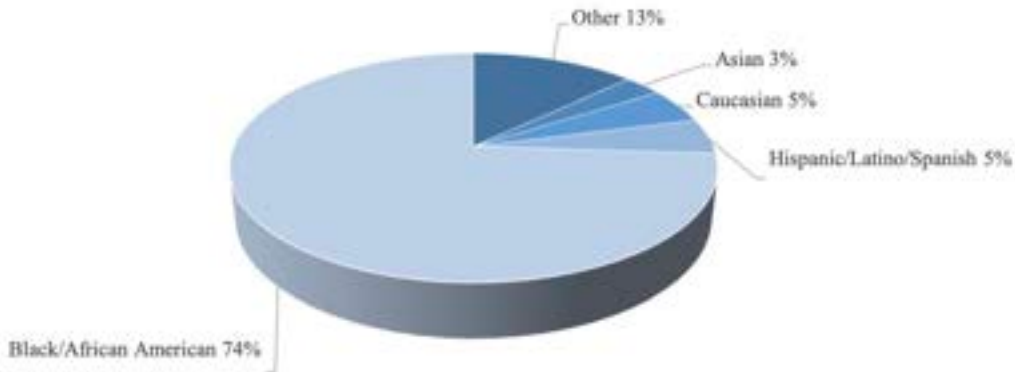


Figure 2: Cases per year from 2016 to 2021.

Bustamante VH, Estrada A, Merchant N. *J Pediatr Endocrinol Metab.* 2023;36(8):749-752

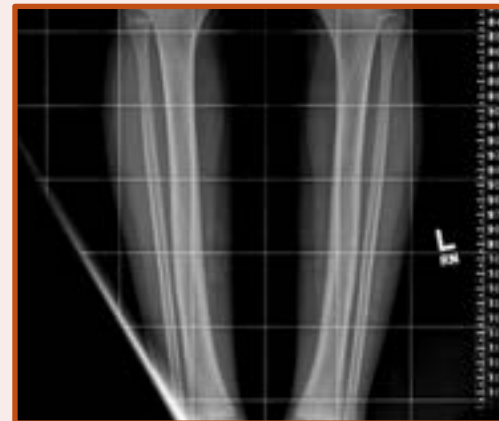
Long Term Follow Up is Crucial



23 months



28 months



8 years

Rx FOR STRONG BONES: VITAMIN D



Dietary Reference Intakes for Calcium and Vitamin D

to Review Dietary Reference Intakes for
Marine Ross, Christine L Taylor, Ann L

Press (US); 2011.



STATE-OF-THE-ART REVIEW ARTICLE

Vitamin D Deficiency Management: Revised Recommendations

Madhusmita Misra, MD, MPH¹, Danièle Pacaud, MD, PhD², on behalf of the Drug and Therapeutics Committee

¹Pediatric Endocrine and Neuroendocrine Units, Massachusetts General Hospital, Harvard Medical School, Boston, MA; ²University of Calgary, Alberta Children's Hospital, Calgary, Alberta; ³Escola de Diabetes e Endocrinologia, Rio de Janeiro, Brazil; ⁴CHU de Québec, Québec, Québec

The authors have indicated they have no financial relationships relevant to this article.

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Low Bone Mass in Chronic Disease



Disease-related

Chronic inflammation

Decreased weight-bearing activity

Impacts on nutrition

Delayed puberty



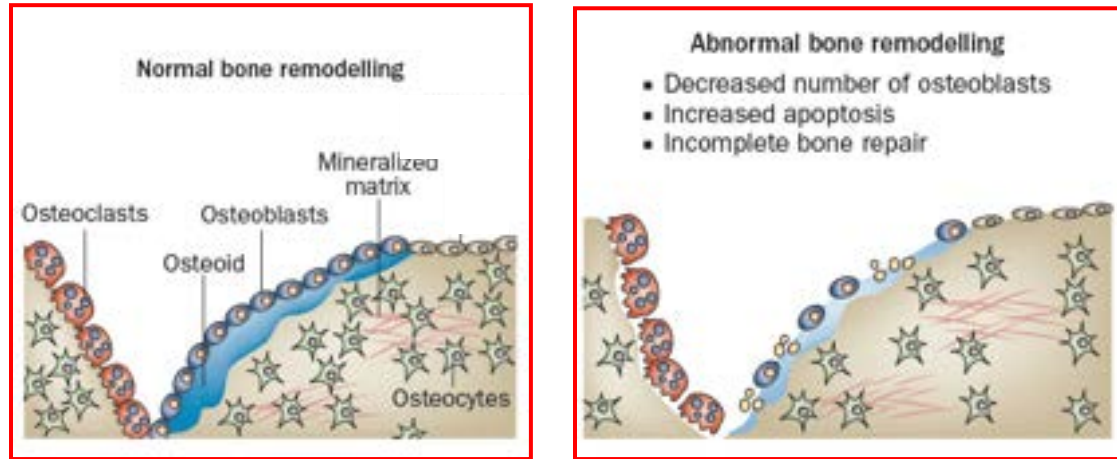
Treatment-related

Medications

Radiation

Reduced engagement in exercise

Glucocorticoids Disrupt Bone Remodeling



- Short-term: ↑ bone breakdown
- Long-term: ↓ bone formation
- Indirect: ↓ intestinal Ca absorption, ↑ urine Ca excretion, downregulates GH and sex steroid activity

Glucocorticoids Impact Trabecular Bone

- Bone loss most rapid in first 12 months
- Most associated fracture: occult vertebral compression
- **ST**eroid-induced **O**steoporosis in the **P**ediatric **P**opulation research program demonstrated that VF are the most common manifestation of low bone mass in children with glucocorticoid-treated leukemia (Ward et al, JBMR 2018)

Primary Causes of Low Bone Mass

Osteogenesis imperfecta – highly variable disease

- Type I collagenopathy
- Mutations in genes involved in bone formation/differentiation

Specific Genetic Syndromes

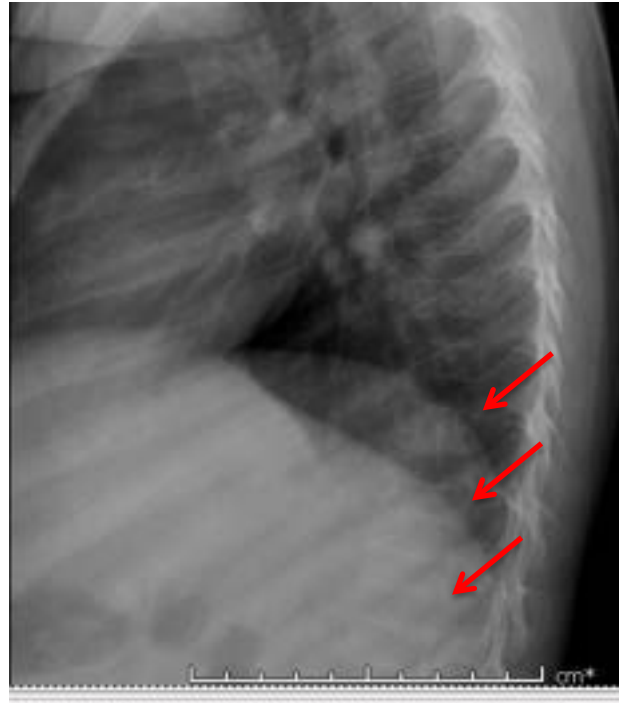
- Ehlers Danlos – Type II procollagen
- Marfan syndrome – Fibrillin-I
- Osteopetrosis
- Hypophosphatasia
- Homocystinuria

Idiopathic juvenile osteoporosis – rare diagnosis of exclusion

Secondary Causes of Low Bone Mass

Chronic Inflammatory Disease	Endocrine
<ul style="list-style-type: none"> • Rheumatologic disease • Inflammatory bowel disease • Nephrotic syndrome 	<ul style="list-style-type: none"> • Hypogonadism • Growth hormone deficiency • Cushing syndrome
Reduced Mobility/disuse	<ul style="list-style-type: none"> • Hyperthyroidism • Type 1 DM
<ul style="list-style-type: none"> • Cerebral palsy • Muscular dystrophy/atrophy • Post traumatic 	Nutritional
Infiltrative	<ul style="list-style-type: none"> • Celiac Disease • Cystic fibrosis • Anorexia nervosa • Energy Deficiency Disorder / REDs
<ul style="list-style-type: none"> • Oncologic • Thalassemia • Inborn errors of metabolism 	Iatrogenic
Renal	<ul style="list-style-type: none"> • Glucocorticoids • Anticonvulsants • Radiation
<ul style="list-style-type: none"> • Chronic kidney disease • Secondary hyperparathyroidism 	

Case 1: 6-year-old male with back pain



CC Case 2: 12 yo female athlete, balanced diet; presents with non-healing sacral stress fracture

- PMH: 3 traumatic fractures
- Labs: Vitamin D 20 ng/mL, despite heavy supplementation
- Additional lab: tTG-IgA +; confirmed by GI
- FU: Even with strict gluten free diet, it took almost 6 mo to heal the stress fracture; vitamin D 40 ng/mL; back in sports

CC Case 3: 12 yo nonverbal female with T21 presents with 6 mo of worsening gait and frequent falls



- PMH: Severe food avoidance
- Diet: No milk products; no supplements
- PE: difficult but unremarkable
- Labs: vit D 4 ; alk phos >600; PTH >200
- Started immediately on vitamin D drops *and* calcium carbonate
- 3- week follow up: Limp resolved and no longer falling
- PEARL: Supplement Calcium to avoid hungry bone syndrome

Case 4: 14 yo ambulatory black male with severe autism; suffered a seizure and then stopped walking



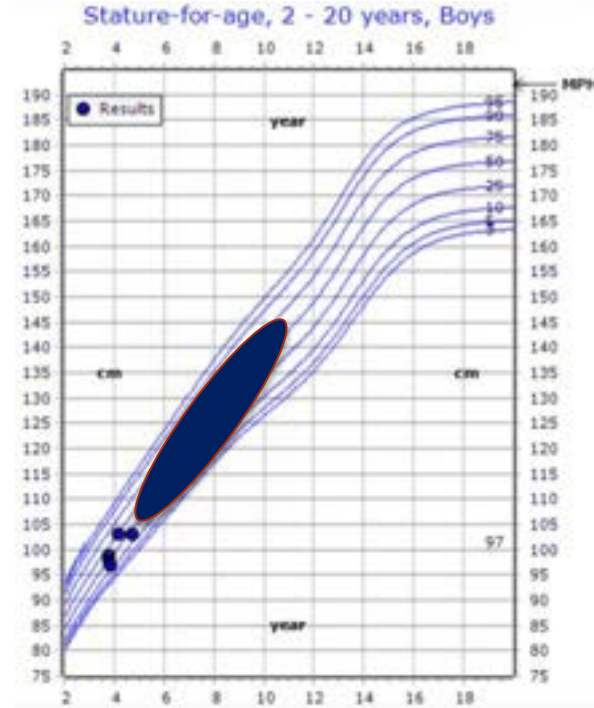
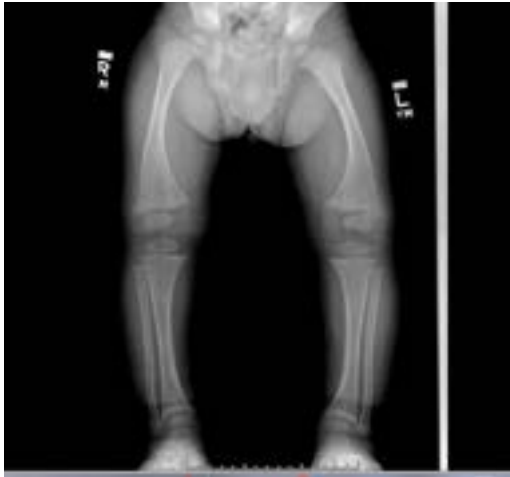
- PMH: Calcium avoider; no supplements
- Activity: Limited outdoor activities
- Lab:
 - Vitamin D 4 ng/mL
 - Calcium 6.4 mg/dL

Case 4: 14 year follow up



- Ambulatory,
- Vitamin D normalized; poor candidate for reconstructive procedure

CC Case 5: 3 yo multiple evaluations for physiologic bowlegs



- Beware: XLH can look like rickets

Evaluation of Low Bone Mass Requires Thorough History



Key Elements of the History

- Fracture Details
 - Mechanism of injury – ie - height of fall/velocity of impact
 - Specific bones fractured
 - Decipher between re-injury of a healing fracture vs. new injury
 - Documented fracture
- Dietary History
 - Estimation of servings of calcium and vitamin D intake
 - Protein intake
- Ambulatory Status and Physical Activity
 - Type – impact loading vs. nonimpact loading
 - PT services/stander/gait trainer – length of use
- Pubertal history
 - Detailed Menstrual History
- Dental History
- Hearing and vision
- Family history of fracture/nephrolithiasis/calcium disorders/osteoporosis
- Review of medications and supplements

OBTAIN CD OF ALL FILMS

Physical Exam

- General: Height, weight and BMI percentiles – GROWTH CHART
- HEENT: Frontal bossing, head circumference, dentition, sclera, thyromegaly
- GU: Pubertal stage
- MSK: Joint flexibility, bowing, body proportions, pinpoint back pain, observe gait
- Skin: Skin texture, plasticity of the skin



Laboratory Analyses

Lab Ordered	Why we get it
CMP	Liver enzymes, renal function, RTA, glucose, serum calcium (with the albumin!), alkaline phosphatase
Phosphorus	Rule out hypophosphatemia and assessment of iPTH action
25 – OH – Vit D3	Common
iPTH	Assessment of biochemical bone and mineral signaling
Urine Calcium/Cr	Assess for hypercalciuria
Urinalysis	RTA
TSH/Free T4	Hyperthyroidism
Tissue Transglutaminase IgA and IgA level	Celiac
ESR	IBD/Rheumatologic disease
CBC	Chronic disease/anemia/nutritional deficits

Plain Radiographs

- Poor sensitivity
 - Osteopenia unnoticed until ~30 % of bone mass is lost
- Poor precision
- Higher radiation
- Useful for assessing fractures and deformity
 - Localized Pain
 - Rickets
 - Suspicion for Skeletal Dysplasia



Dual energy X-Ray Absorptiometry (DXA)

- Estimates BMD
- Applies pediatric specific algorithms and normative data to calculate bone mineral content (BMC) within that map
- Adjuvant tool NOT diagnostic



Special Populations and Considerations

- Contractures
- Movement disorders
- Cooperation limiting positioning



Distal Lateral Femur

Pediatric DXA

- Widely available at pediatric hospitals
- Inexpensive
- Low radiation
- Fast
- Highly reproducible
 - **KEY CONSIDERATION:** Many factors affect the accuracy of DXA including **intermachine variance**
 - Repeat DXA ideally should be with the **same machine**

Now What Do We Do?

- In case of secondary osteoporosis
 - Manage the underlying disease
 - Minimize the insult
- Optimize Dietary Calcium and Vitamin D
 - Do not forget other micronutrients, vitamins and protein
- Impact Loading exercise

Recommended Daily Intake

Institute of Medicine and Endocrine Society



Age	Elem Calcium (mg/day)	Vitamin D (IU/day)
0-6 mo	200	400
6-12 mo	260	400
1-3 yr	700	600
4-8 yr	1000	600
9-18 yr	1300	600

Vitamin D Deficiency:
Institute of Medicine* and
Endocrine Society: < 20 ng/mL

Most bone docs aim for:

- At risk populations > 30 ng/mL
- Everyone else > 20 ng/mL

Dietary Sources of Vitamin D

Food	Vitamin D (IU) Content
Cow's milk, fortified (8 oz)	100
Yogurt, fortified (8oz)	100-200
Cereals, fortified (1 serving)	100
Egg yolk	15-40
Cheddar Cheese (1 serving)	12
Swiss Cheese (1 serving)	44
Tofu, fortified (1/5 block)	120
Cod Liver Oil (1 tsp)	400-1000
Fresh shitake mushrooms (100 g)	100
Dried shitake mushrooms (100g)	1660
Wild Salmon (3.5 oz)	600-1000

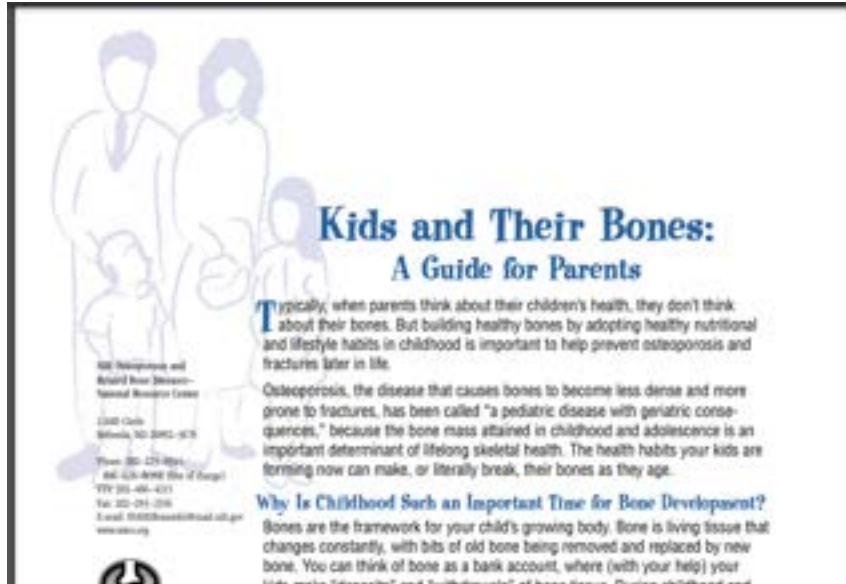
How do we optimize calcium?



Nutritional intake preferred

Reserve supplements for those who cannot meet calcium requirements with diet

Resources



Kids and Their Bones

- <https://www.niams.nih.gov/health-topics/kids-and-their-bones>

Pediatric Bone Density Calculator

- <https://zscore.research.chop.edu/calcpedbonedens.php>

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When diet and exercise are not enough ...



Bisphosphonates

- Inhibit bone resorption
- Half life > 10 years
- Use in pediatric population expanding as RCT evidence expands
 - Osteogenesis imperfecta
 - Cerebral palsy
 - DMD/Muscular dystrophy
 - Crohn's disease
 - CF

Bisphosphonates: Current Practice

- Routine use only in moderate to severe OI
 - In OI, treat until completion of skeletal growth.
- Considered in:
 - Pathologic fractures –especially vertebral fractures
 - Bone pain related to fracture or primary bone disorder
 - Continual reassessment – typical course 2-3 years and reassess

Children's National Bisphosphonate Infusion Program

- Lauren Sabot, NP
- Bonehealth@childrensnational.org



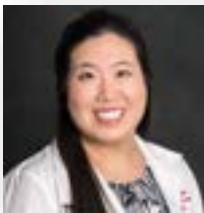
Take Home Points

- Fractures in childhood are common
- Underlying systemic conditions should always be considered in the assessment of atypical fracture
- Assessment of low bone mass in childhood is a *functional* approach with the goal of early identification of those at increased risk
- Recognize there are special considerations for appropriate interpretation of DXA in pediatrics
- The mainstays of treatment include:
 - Identification and optimization of underlying risk/pathology
 - Nutritional optimization
 - Weight bearing activity



Our Multidisciplinary Team

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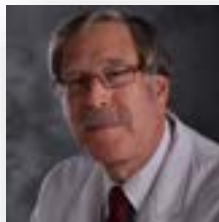


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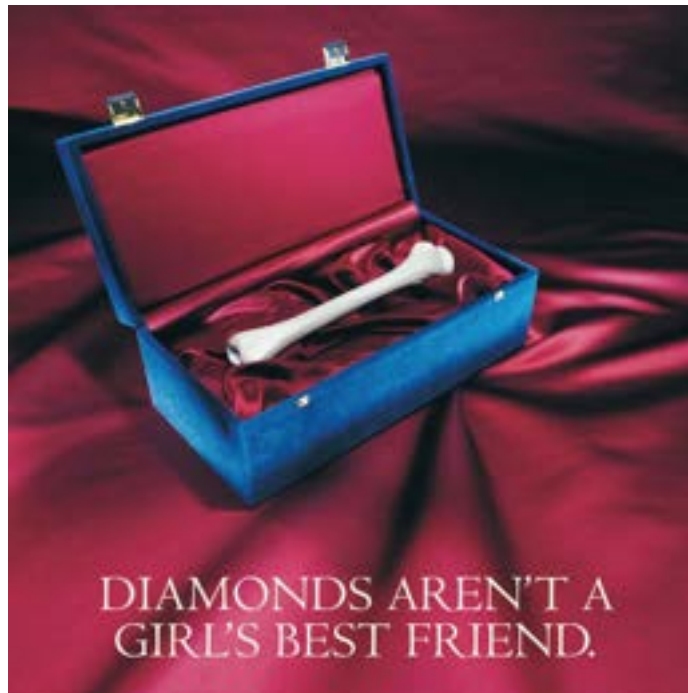


Kenneth Rosenbaum, MD



Deepika Burkardt, DO

Thank you



DIAMONDS AREN'T A
GIRL'S BEST FRIEND.

Looking good on the outside begins by being strong on the inside. That's because later in life, especially for women, strong bones help prevent fractures and height loss. Your window to build maximum bone density is now, during your late teens and early twenties. So eat wisely, get plenty of calcium and vitamin D, and do weight-bearing exercises every day. To devise a plan that's right for you, go to aads.org or dps.org.

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We welcome your questions, feedback,
suggestions:

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THANK YOU!

