

Fracture of Protocol: The Overlooked Role of Vitamin D, Diet, and Exercise in Bone Health

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The Silent Epidemic

- 
- ◆ 29% elderly fall/year
 - ◆ >3.1mil ER visits/year
 - ◆ 290,000 hip fractures/year

The Silent Epidemic

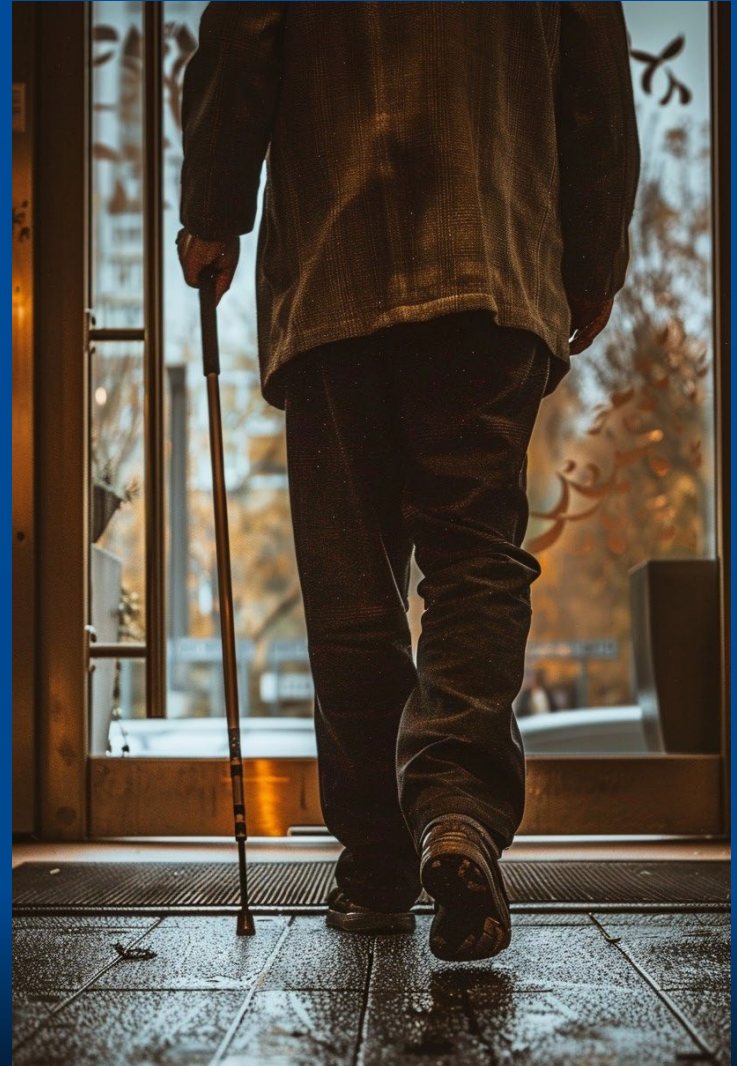
- ◆ 60% cannot get on/off toilet
- ◆ 55% cannot walk 1 block
- ◆ 50% cannot rise from a chair
- ◆ 40% cannot walk 10ft
- ◆ 30% cannot get out of bed

Objectives

- Review the fundamental roles of Vitamin D, exercise, and diet in bone physiology.
- Discuss the prevalence and impact of these deficiencies in the orthopaedic patient population.
- Provide evidence-based recommendations for integrating these lifestyle modifications into clinical practice.

Risk for Fractures

- ◆ Aging
- ◆ Osteoporosis
- ◆ Falls
- ◆ Lifestyle



Fall Risks

Intrinsic factors: non modifiable

- ◇ Age
- ◇ Disabilities that alter gait, balance, or sensation
- ◇ H/o falls

Extrinsic factors: modifiable

- ◇ Psychoactive & Cardiac medications
- ◇ Polypharmacy
- ◇ Rugs or mats with edges
- ◇ Slippery, bright, shiny floors
- ◇ Clutter, cords, cables, tubing

TABLE II Risk of Falling Based on Number of Risk Factors in Older Adults²⁵

No. of Risk Factors	Risk of Falling (%)
0	8
1	19
2	32
3	60
≥4	78

Bone Health Management

- ◆ Pharmacological treatments
- ◆ Calcium supplementation
- ◆ Lifestyle factors



Vitamin D Recommendations

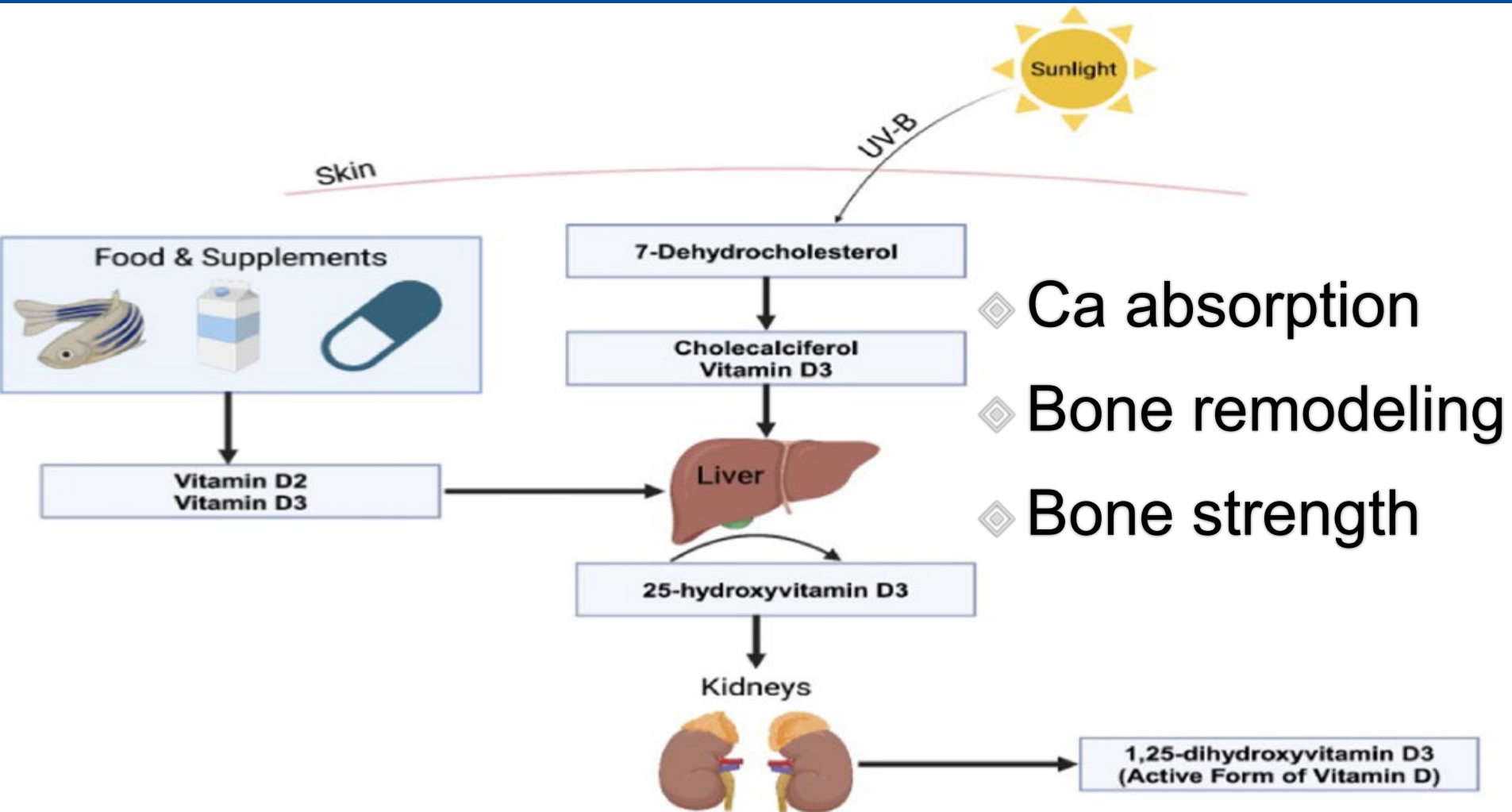
- ◈ Screen for deficiency
- ◈ Treat deficiency
- ◈ Supplement for prevention



Table 1
Current guidelines for vitamin D deficiency and supplementation recommendations.

Guideline Source	Definition of Deficiency	Recommended Daily Intake (Adults)	Target Serum 25 (OH)D Level	Special Considerations
Endocrine Society ⁴⁶	<20 ng/mL (50 nmol/L)	600-2000 IU (maintenance); 50,000 IU weekly for 6–8 weeks if deficient	>30 ng/mL (75 nmol/L)	Higher doses (up to 4000 IU) may be needed in obese, malabsorption, or high-risk patients
Institute of Medicine (IOM) ⁴⁷	<20 ng/mL (50 nmol/L)	600 IU (age <70), 800 IU (age >70)	20–30 ng/mL (50–75 nmol/L)	General population recommendations; no specific fracture healing guidance
American Geriatrics Society ⁴⁸	<30 ng/mL (75 nmol/L)	1000 IU daily for older adults	>30 ng/mL (75 nmol/L)	Supports higher intake in older adults to reduce falls and fractures
National Osteoporosis Foundation ⁴⁹	<30 ng/mL (75 nmol/L)	800-1000 IU for fracture prevention	>30 ng/mL (75 nmol/L)	Recommended in combination with calcium for osteoporosis management
American Academy of Orthopaedic Surgeons ⁵⁰	<20 ng/mL (50 nmol/L)	1000–2000 IU daily, individualized for fracture patients	>20 ng/mL (50 nmol/L)	Emphasizes routine screening in orthopaedic patients with fractures

Vitamin D: The Unsung Hero



Prevalence of Vitamin D Deficiency

Hypovitaminosis D in Patients Scheduled to Undergo Orthopaedic Surgery

A Single-Center Analysis

By Ljiljana Bogunovic, MD, Abraham D. Kim, MD, Brandon S. Beamer, MD, Joseph Nguyen, MPH, and Joseph M. Lane, MD



Prevalence of Low Vitamin D Levels in Patients With Orthopedic Trauma

American Journal of Orthopedics, 2016

Michael A. Hood, MD, Yvonne M. Murtha, MD, Gregory J. Della Rocca, MD, PhD, James P. Stannard, MD, David A. Volgas, MD, and Brett D. Crist, MD

European Journal of Orthopaedic Surgery & Traumatology (2025) 35:33

<https://doi.org/10.1007/s00590-024-04162-8>

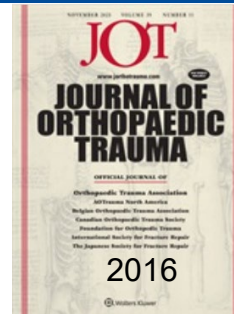
Vitamin D deficiency in hip fracture patients is associated with an increased mortality risk

John M. Bayram¹ · Hariprasath Kanesan¹ · Nicholas D. Clement¹

Vitamin D and Fracture Healing

What Is the Role of Vitamin D Supplementation in Acute Fracture Patients? A Systematic Review and Meta-Analysis of the Prevalence of Hypovitaminosis D and Supplementation Efficacy

Sheila Sprague, PhD,*† Brad Petrisor, MD, MSc, FRCSC,* Taryn Scott, MSW,†
Tahira Devji, BSc,† Mark Phillips, BSc,* Hayley Spurr, BS,‡ Mohit Bhandari, MD, PhD, FRCSC,*†
and Gerard P. Slobogean, MD, MPH, FRCSC*§



The effect of a single early high-dose vitamin D supplement on fracture union in patients with hypovitaminosis D

a prospective randomised trial

Haines et al.
2017

The
Bone & Joint
Journal



Hypovitaminosis D in Orthopaedic Trauma: Which Guidelines Should Be Followed?

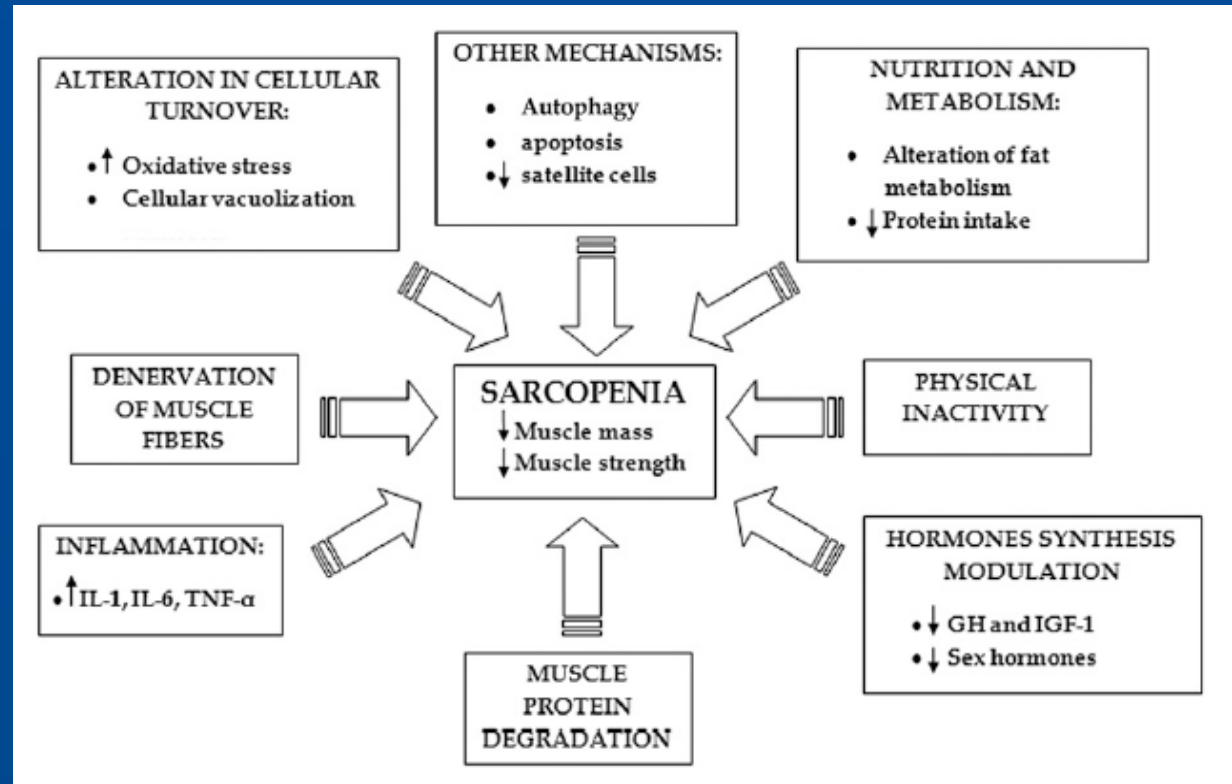
Brett Schiffman, MD,* Hobie Summers, MD,† Mitchell Bernstein, MD,‡ Frank DiSilvio, BS,§
Sarah Foyil, MD,|| and William Lack, MD†



Vitamin D & Sarcopenia

◆ Bone-muscle

◆ “Hazardous Duet”



Sarcopenia and Mortality Risk

Increased Mortality in Elderly Patients with Sarcopenia and Acetabular Fractures

JBJS 2017

Matthew E. Deren, MD, Jacob Babu, MD, Eric M. Cohen, MD, Jason Machan, PhD, Christopher T. Born, MD, and Roman Hayda, MD

Sarcopenia Is Predictive of 1-Year Mortality After Acetabular Fractures in Elderly Patients

Phillip M. Mitchell, MD, Cory A. Collinge, MD, David E. O'Neill, BA, Jesse E. Bible, MD, and Hassan R. Mir, MD, MBA, FACS

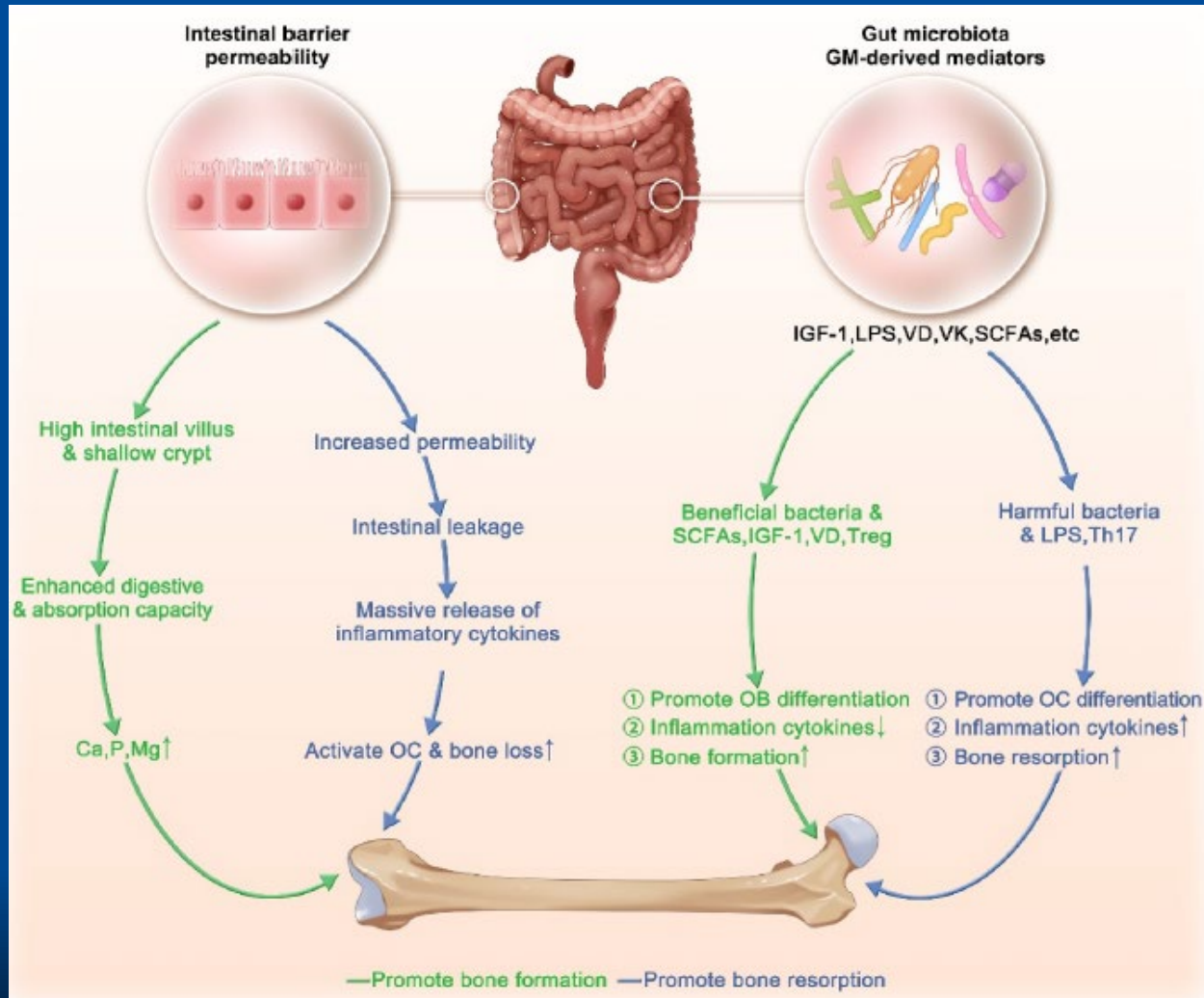
JOT 2018

Effect of Sarcopenia on Postoperative Mortality in Osteoporotic Hip Fracture Patients

J Bone Metab 2018

You Keun Kim, Seung Rim Yi, Ye Hyun Lee, Jieun Kwon, Seok In Jang, Sang Hoon Park

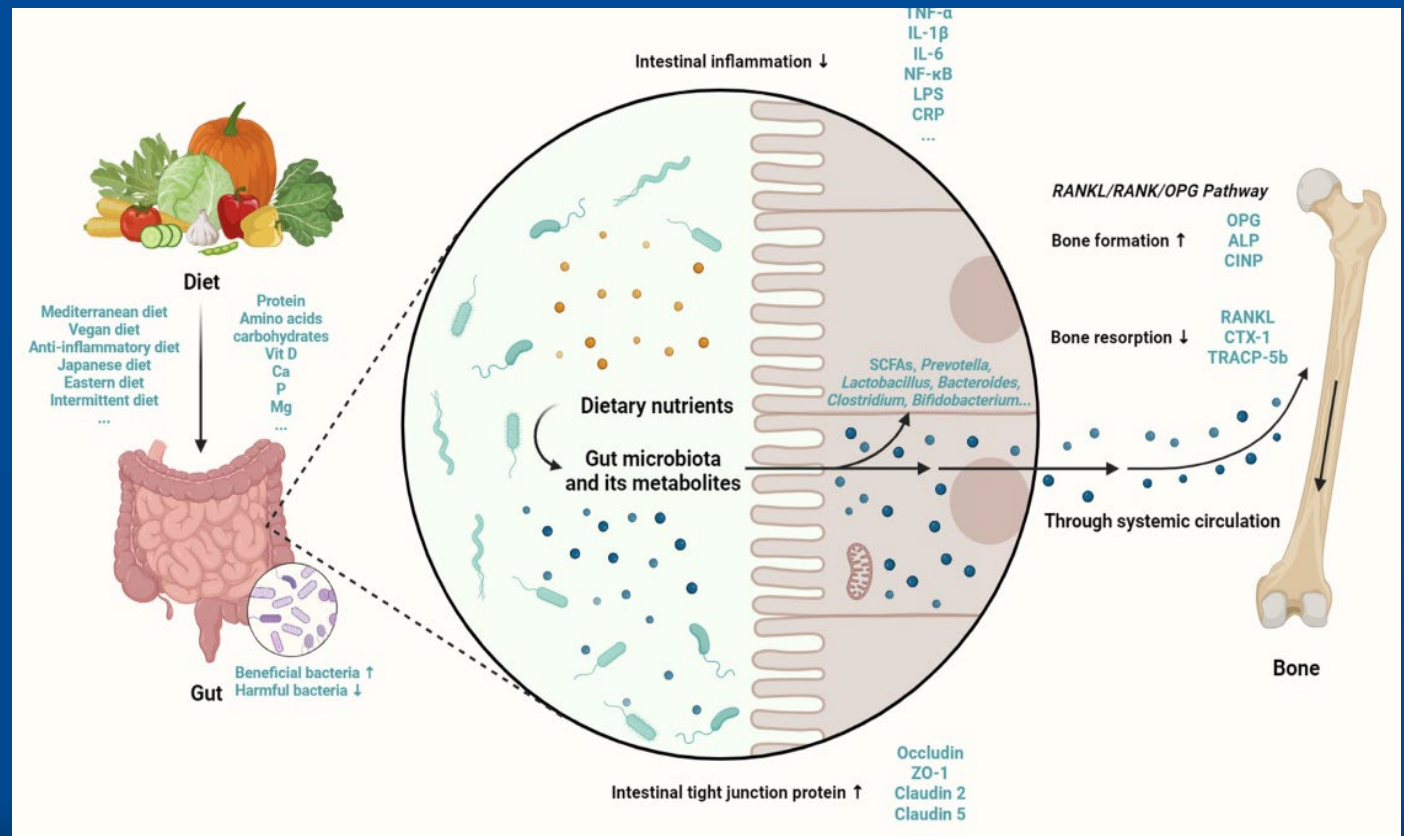
Gut-Bone Axis



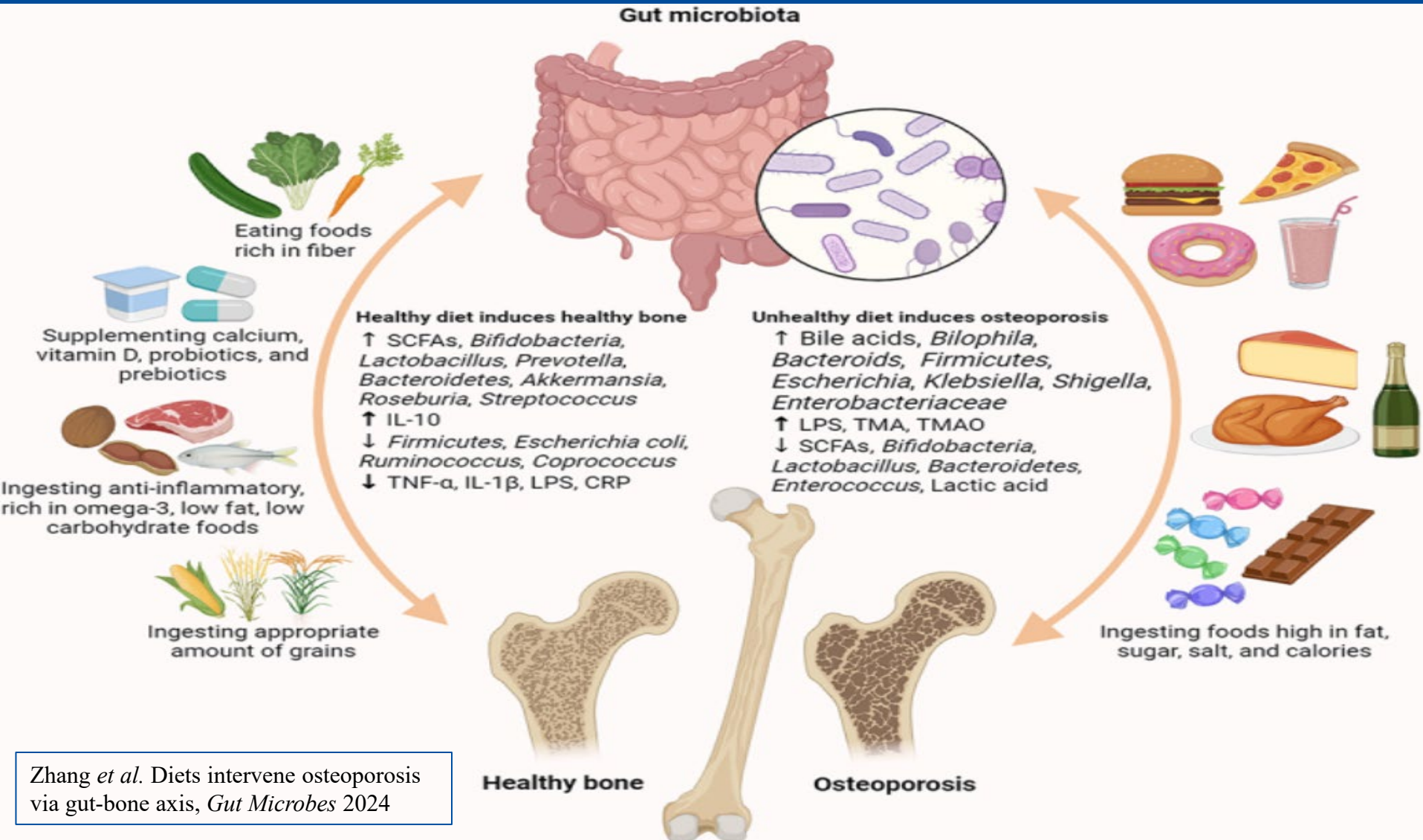
Diet and Bone Health

To prevent osteoporosis

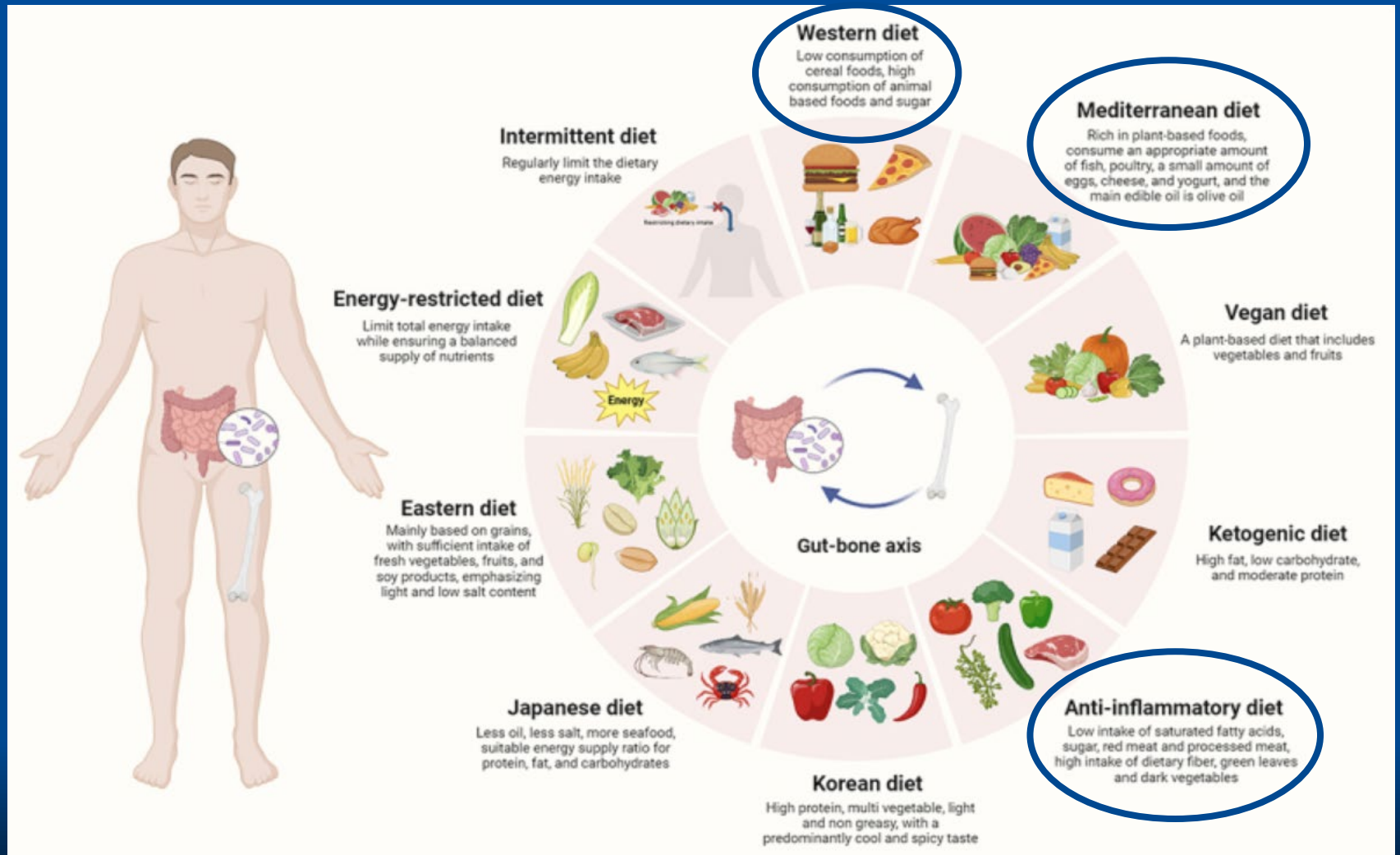
- ◇ High fiber
- ◇ High grains
- ◇ Low sugar
- ◇ Low fat



Recommended Diet



Types of Diets





Review

The Influence of the Mediterranean Dietary Pattern on Osteoporosis and Sarcopenia

María Carmen Andreo-López ¹ , Victoria Contreras-Bolívar ^{1,2,3,*}, Beatriz García-Fontana ^{2,3,4} ,
Cristina García-Fontana ^{1,2,3} and Manuel Muñoz-Torres ^{1,2,3,5}

Observational Study > [Int J Food Sci Nutr.](#) 2020 Nov;71(7):884–890.

doi: [10.1080/09637486.2020.1744533](https://doi.org/10.1080/09637486.2020.1744533). Epub 2020 Mar 29.

Association between adherence to the Mediterranean Diet and circulating Vitamin D levels

Roberta Zupo ¹, Luisa Lampignano ¹, Antonio Lattanzio ², Francesco Mariano ², Alberto R Osella ³,
Caterina Bonfiglio ³, Gianluigi Giannelli ¹, Giovanni De Pergola ²

Affiliations + expand

PMID: 32223463 DOI: [10.1080/09637486.2020.1744533](https://doi.org/10.1080/09637486.2020.1744533)

Mediterranean Diet and Risk of Hip Fracture: A Systematic Review and Dose-Response Meta-Analysis [Get access >](#)

Manel Fa-Binefa, Albert Clara, Claudia Lamas, Roberto Elosua

Nutrition Reviews, Volume 83, Issue 6, June 2025, Pages 1133–1143,

<https://doi.org/10.1093/nutrit/nuae141>

Published: 23 October 2024

Original Investigation | Geriatrics

Mediterranean Diet, Physical Activity, and Bone Health in Older Adults

A Secondary Analysis of a Randomized Clinical Trial

Héctor Vázquez-Lorente, PhD; Jesús F. García-Gavilán, PhD; Sangeetha Shyam, PhD; Jadwiga Konieczna, PhD; J. Alfredo Martínez, MD, PhD; Vicente Martín-Sánchez, PhD; Montserrat Fitó, MD, PhD; Miguel Ruiz-Canela, PhD; Indira Paz-Graniel, BSc, MSc; Ariadna Curto, PhD; Diego Martinez-Urbistondo, PhD; José Antonio de Paz Fernández, PhD; Dora Romaguera, PhD; Nancy Babio, BSc, PhD; Jordi Salas-Salvadó, MD, PhD

- ◇ 924 adults with metabolic syndrome and obesity, age 65yo
- ◇ Tx: Mediterranean diet and increased physical activity
- ◇ Control: Mediterranean diet with no physical activity
- ◇ Beneficial effects on BMD, especially at the lumbar level, over 3yr among women

Probiotics & Prebiotics

- ◇ Pro: “live microorganisms” provide health benefits to host
- ◇ Pre: “food ingredients”, indigestible and used by microbes
- ◇ Increase GM diversity and SCFA production, intestinal barrier permeability
- ◇ Lactobacillus and Bifidobacterium

- ◇ Supplements
- ◇ Yogurt & Kefir:
- ◇ Sauerkraut & Kimchi
- ◇ Miso & Tempeh

Table 1 Summary of microbial-related therapeutics and their effects on bone health

Therapeutic type	Microbial strains	Mechanisms of action	Clinical outcomes
Probiotics	<i>Lactobacillus reuteri</i> , <i>Lactobacillus paracasei</i> , <i>B. longum</i>	Inhibit osteoclastogenesis, promote osteoblast activity, enhance calcium and vitamin D absorption	Increased BMD, reduced bone resorption, prevention of bone loss in clinical trials
Prebiotics	Galacto-oligosaccharides, fructo-oligosaccharides, Inulin-type fructans	Stimulate growth of <i>Bifidobacteria</i> and <i>Lactobacillus</i> , increase short-chain fatty acid production, enhance mineral absorption	Improved calcium absorption, increased bone strength, reduced markers of bone resorption
Synbiotics	Combination of prebiotics and <i>B. longum</i> , <i>Bifidobacterium bifidum</i>	Enhanced probiotic proliferation, increased calcium absorption, reduced inflammation	Greater improvement in bone mineral content and strength compared to prebiotics or probiotics alone
Fermented foods	<i>Lactobacillus</i> , <i>Bifidobacterium</i> strains in yogurt, kefir, tempeh	Natural source of probiotics and prebiotics, enhanced nutrient absorption	Improved calcium and vitamin D absorption, increased BMD in consumers

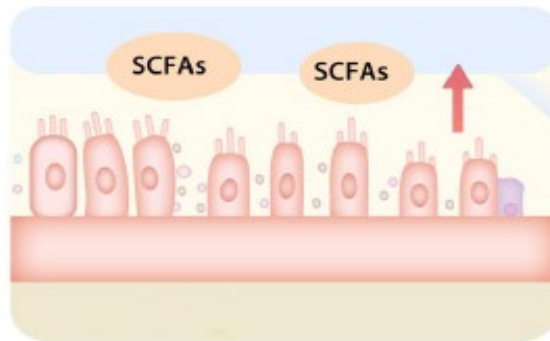
Wei *et al.* Gut-bone axis perturbation: Mechanisms and interventions via gut microbiota as a primary driver of osteoporosis, *J Ortho Trans* 2025

Wang *et al.* Effects of probiotic supplementation on bone health in postmenopausal women: a systematic review and meta-analysis, *Frontiers in Endocrinology* 2024

Shankar *et al.* Cross-talks between osteoporosis and gut microbiome, *World J Orthop* 2025

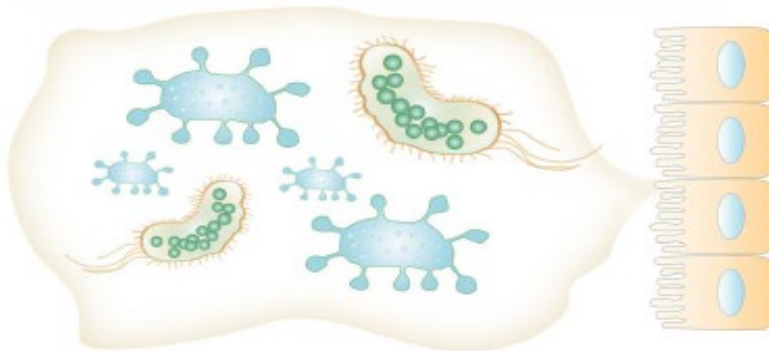
Gut-Muscle Axis

Exercise promotes higher concentrations of gut flora metabolites SCFAs



- Regulate anabolism
- Regulate the balance of fat metabolism
- Promote glucose absorption, improve insulin sensitivity
- Reduce inflammation
- Improve central nervous system function

Exercise reduces systemic inflammation



- Changing the composition of gut microbiota
- Enhance intestinal barrier function
- Reduce Leaky gut



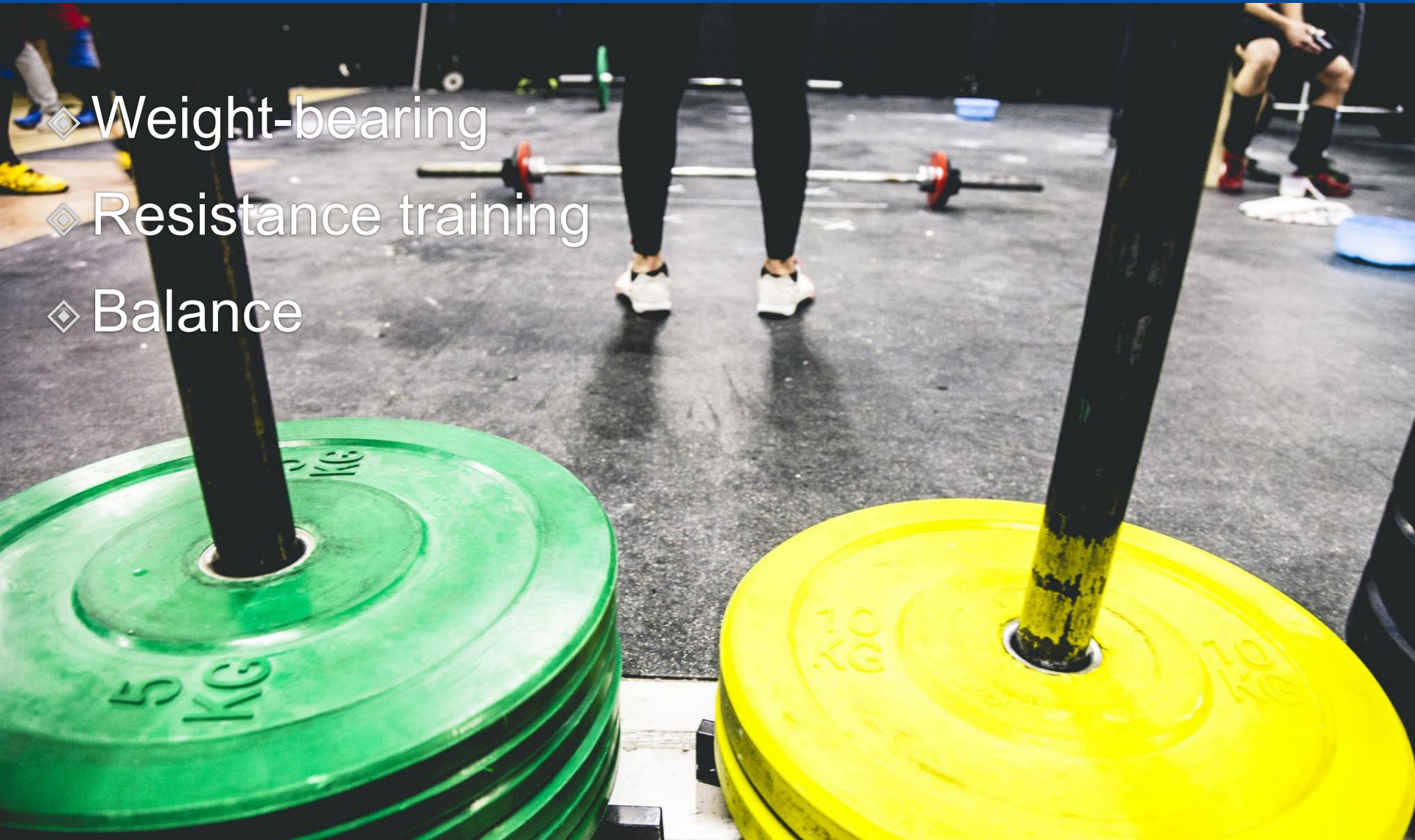
Li *et al.* Gut-muscle axis mechanism of exercise prevention of sarcopenia, *Frontiers in Nutrition* 2024

Wei *et al.* Gut-bone axis perturbation: Mechanisms & interventions via gut microbiota as a primary driver of osteoporosis, *J Ortho Trans* 2025

Gu *et al.* The gut-bone axis in osteoporosis: a multifaceted interaction with implications for bone health, *Frontiers in Endocrinology* 2025

Exercise

- ◆ Weight-bearing
- ◆ Resistance training
- ◆ Balance



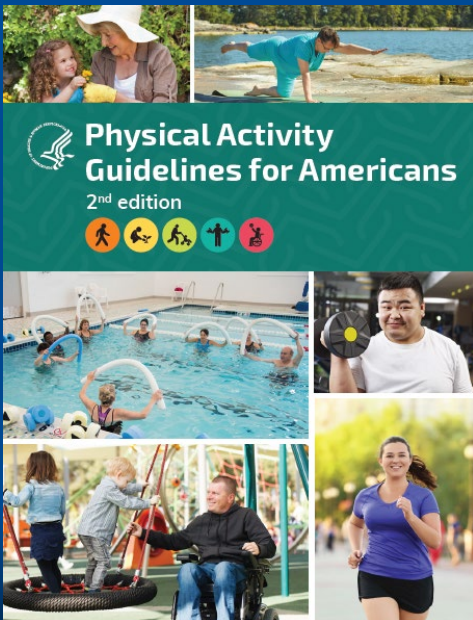
Mechanotransduction of Bone



- ◆ Skeletal unloading
- ◆ Decreased bone maintenance
- ◆ Rapid bone loss

Goals of Exercise

- ◆ Target bone
- ◆ Prevent falls



Exercise to Prevent and Manage Frailty and Fragility Fractures

Elsa Dent¹  · Robin M. Daly² · Emiel O. Hoogendijk^{3,4,5} · David Scott^{2,6}

- ◇ Individual multicomponent program
- ◇ Discourage prolonged sitting/inactivity
- ◇ Exercise + Nutrition
- ◇ Frailty: Supervised progressive resistance training (PRT)
- ◇ Osteoporosis & Fragility Fx: Weight-bearing and PRT
- ◇ Balance + Mobility + Posture

Progressive Resistance Training (PRT)

- ◆ Gradual increase
 - ◆ Adaptation and Overload
 - ◆ Consistency
 - ◆ Proper form
-
- ◆ Increase weight, reps, time, frequency
 - ◆ Decrease rest



Multicomponent intervention to prevent mobility disability in frail older adults: randomised controlled trial (SPRINTT project)

Bernabei *et al. BMJ*, 2022

Sarcopenia and Physical frailty IN older people: multi-component
Treatment strategies

thebmj

- ◆ Multi-center, 1519 patients with frailty or sarcopenia
- ◆ Physical activity, nutritional counseling, information and communication technology solutions
- ◆ Primary Outcome: ability to walk 400m <15min
- ◆ 22% reduction in the incidence of mobility disability in participants with more severe frailty
- ◆ Significant improvements in the overall short physical performance battery score at 24 and 36mo
- ◆ Women had less decline in lean mass and grip strength
- ◆ Long-term diet and exercise is an effective strategy to prevent the onset of mobility disability in those with physical frailty and sarcopenia



Review

The Effects of Exercise Intervention in Older Adults With and Without Sarcopenia: A Systematic Review

Jeremy Cabroler-Molina ¹, Alexandra Martín-Rodríguez ^{1,2,*} and Vicente Javier Clemente-Suárez ^{1,3}

- ◆ 11 RCTs, 792 subjects
- ◆ Physical exercise improved neuromuscular function, physical performance, and postural control in older adults
- ◆ Positive effects were observed in gait speed, stair-climbing ability, grip strength, muscle mass, and BMD
- ◆ Programs integrating strength and balance components yielded the most consistent benefits

Optimal resistance training parameters for improving bone mineral density in postmenopausal women: a systematic review and meta-analysis

J Orthop Surg Res 2025

Fang Zhao^{1,6†}, Wenbo Su^{1*†}, Yaowei Sun², Jing Wang³, Bin Lu^{3,4} and Hezhang Yun^{3,5*}

- ◆ Systematic review: 17 RCTs, 690 subjects
- ◆ Resistance training improves BMD in postmenopausal women
- ◆ High-intensity training 3x/wks
- ◆ Longer training duration: >48wks, sessions >40min

Effect of Tai Chi on Bone Mineral Density in Middle-Aged and Older Adults: A Meta-Analysis

Ortho Rev 2025

Jiqing Cui, Ph.D¹, Chunsheng Qian^{2a}, Yufei Liu, Ph.D^{3b}

¹ WeiFang Institute of Technology, College of Physical Education, Qingzhou, ShanDong, China, ² The 962nd Hospital of The PLA Joint Logistic Support Force, Harbin, Heilongjiang, China, ³ Institute of Sports Science, Harbin Sport University, Harbin, Heilongjiang, China

- ◇ Tai Chi: whole body weight bearing exercise, breath regulation
- ◇ 17 RCTs, 1253 subjects
- ◇ Improved BMC at multiple skeletal sites
- ◇ Regular Tai Chi practice improves BMD in older adults
- ◇ >60yo, increased BMD if regimen is >3x/wk over 6mo





**AMERICAN COLLEGE
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POSITION STAND

Exercise and Physical Activity for Older Adults

MEDICINE & SCIENCE IN SPORTS & EXERCISE
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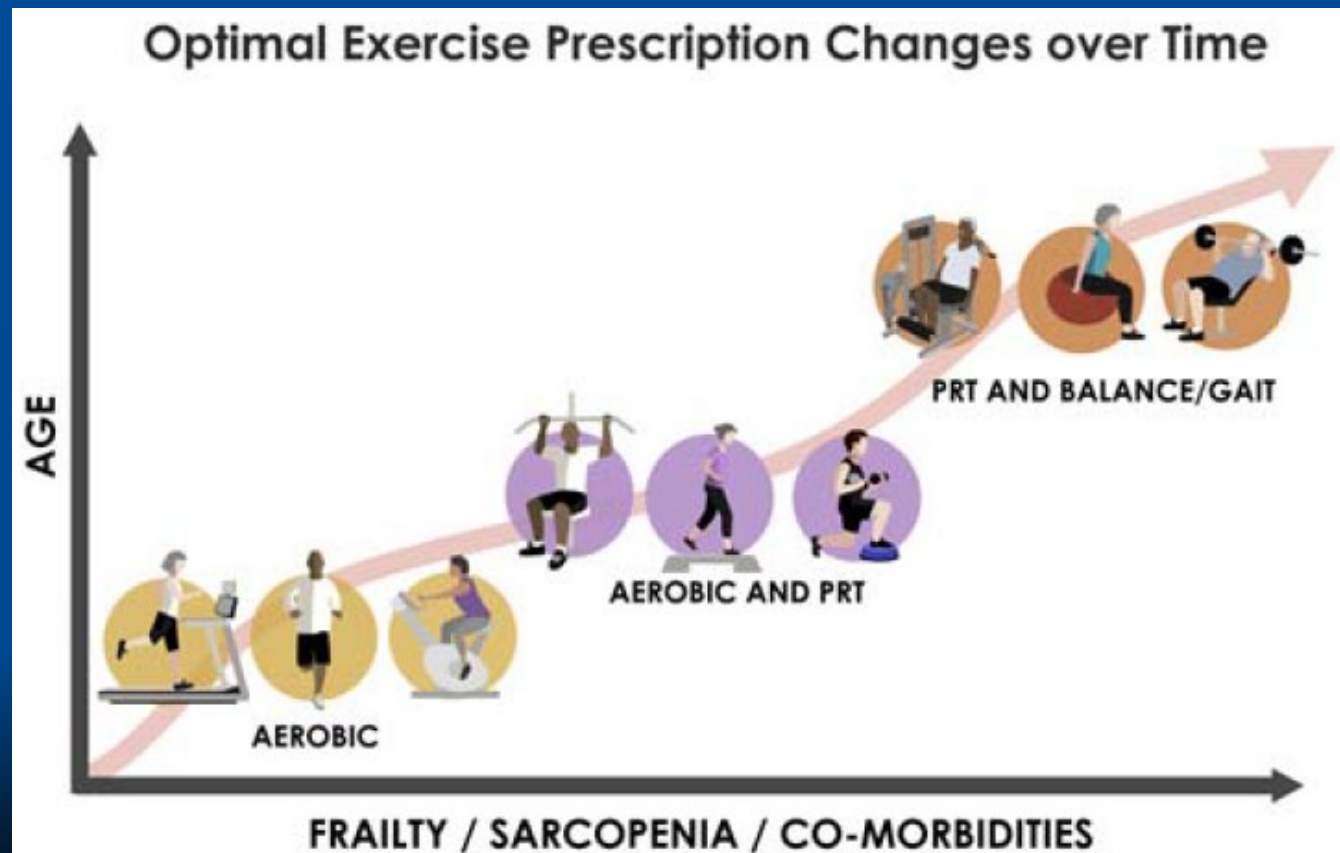
This pronouncement was written for the American College of Sports Medicine by Wojtek J. Chodzko-Zajko, Ph.D., FACSM, (Co-Chair); David N. Proctor, Ph.D., FACSM, (Co-Chair); Maria A. Fiatarone Singh, M.D.; Christopher T. Minson, Ph.D., FACSM; Claudio R. Nigg, Ph.D.; George J. Salem, Ph.D., FACSM; and James S. Skinner, Ph.D., FACSM.

- ◆ AET: 30-60min, varying intensity, walking, aquatic, cycling
- ◆ RET: 2d/wk, major muscles, PRT/calisthenics: 8-10 exercises, 8-12 reps
- ◆ Flexibility: 2d/wk, stretch major muscles
- ◆ Balance: progressively difficult postures, dynamic movements, stress postural muscles, reduce sensory input



Review

Global consensus on optimal exercise recommendations for enhancing healthy longevity in older adults (ICFSR) Izquierdo 2025



Exercise Rx

Table 4
Exercise recommendations for optimal body composition for older adults.

Exercise recommendations	Decreased adipose tissue mass and visceral deposition	Increased muscle mass and strength	Increased bone mass and density and reduced fracture risk
Modality	Aerobic or resistance training	Resistance training	- Resistance training - High-impact activities (jumping using weighted vest during exercise) if tolerated by joints. Not recommended for people with vertebral osteoporosis
Frequency	Aerobic: 3–7 days/week Resistance: 3 days/week	3 days/week	Balance training
Volume	Aerobic: 30–60 min of continuous exercise using large muscle groups / session Resistance: 2–3 sets of 8–10 repetitions of 6–8 muscle groups	2–3 sets of 8–10 repetitions of 6–8 muscle groups	Resistance training: 3 days/week Balance training: up to 7 days/week 2–3 sets of 8–10 repetitions of 6–8 muscle groups 50 jumps per session for high impact ^a 2–3 repetitions of 5–10 different static and dynamic balance postures
Intensity	Aerobic: 60–75% of maximum exercise capacity (VO ₂ max or maximum heart rate) or 13–14 on the Borg Scale of perceived exertion Resistance: 70–80% of maximum strength (one repetition maximum) exertion	70–80% of maximum capacity (one repetition maximum)	70–80% of maximum capacity (one repetition maximum) as load 5–10% of body weight in vest during jumps; jumps or steps of progressive height Practice the most difficult balance posture not yet mastered

^a Thus far, proven only in premenopausal women and adolescents or when combined with resistance training/multi-modality exercise in older adults.

Exercise Rx

Table 5
Role of Exercise in Primary, Secondary and Tertiary Disease Prevention.

Disease	Postulated mechanisms of exercise effect on disease prevention	Considerations for the prescription for secondary and tertiary prevention (disease expression and progression)	Recommended exercise modality
Osteoporosis / Osteoporotic fracture	• Increased bone density • Increased tensile strength • Increased muscle mass • Improved gait stability and balance • Improved nutritional intake (energy, protein, calcium, vitamin D) • Reduced fear of falling, improved self-efficacy • Increased overall activity levels, mobility • Decreased need for drugs associated with postural hypotension, falls, hip fractures (antidepressants, antihypertensives, sedative-hypnotics)	• High-impact, high-velocity activity (e.g., jumping) is potent if tolerable; avoid if osteoarthritis is present. • Resistance training effects are local to muscles contracted. • Balance training should be added to prevent falls and must be challenging	• High-impact exercise • Progressive resistance training • Balance training

Exercise Rx

Table 7
Exercise and geriatric syndromes.

Geriatric syndromes	Considerations for the prescription	Recommended exercise modality
Frailty and Sarcopenia	• Resistance and power training: 2–3 sessions per week, combining slower and faster (power training) muscle actions at intensities of 40–80% of 1RM. • Functional exercises e.g., standing from a chair. • Balance and gait exercises progressing in complexity: line walking, tandem foot standing, standing on one leg, heel-toe walking.	• Resistance training • Balance exercises • Gait retraining • Multicomponent exercise
Falls	• Resistance training aimed to improve muscle strength and power. • Balance and gait exercises progressing in complexity: line walking, tandem foot standing, standing on one leg, heel-toe walking. • Dual task exercises including dual task gait and resistance exercises (counting numbers, naming animals, etc.). • Adapted Tai Chi exercises progressing in complexity. • Dance interventions may improve adherence.	• Resistance training • Balance exercises • Gait retraining • (uncertain evidence) • Multicomponent exercise • Dance interventions (uncertain evidence) • Tai Chi exercises



VIVIFRAIL MULTI-COMPONENT PHYSICAL TRAINING PRESCRIPTION GUIDE

interreg
POCTERA

    aptitude

Multicomponent physical exercise program to prevent frailty
and the risk of falls.
© Mikael Izquierdo

SPPB TEST – PHYSICAL FRAILITY

Add the points of the SPPB test (**1 to 3**) to determine the grade.

Points	WS(6m)*	Type
0-3	> 12 s	A Person with disability
4-6	12 - 7,5 s	B Person with frailty
7-9	7,4 - 6 s	C Person with pre-frailty
10-12	< 6 s	D Robust person

*If due to limitations, you have not performed the SPPB test and you have elected to use the 6-meter walking test, the following values will be used to recommend the physical exercise program.

FALL RISK TEST

The elderly person is at risk of falls if they have answered affirmatively to any of the questions made in tests **4 to 7**.

- ◆ Balance test
- ◆ Walking speed test
- ◆ Getting up from chair
- ◆ Fall risk



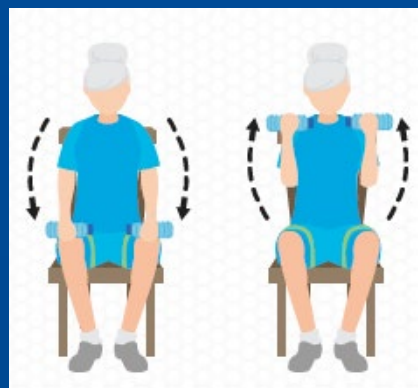
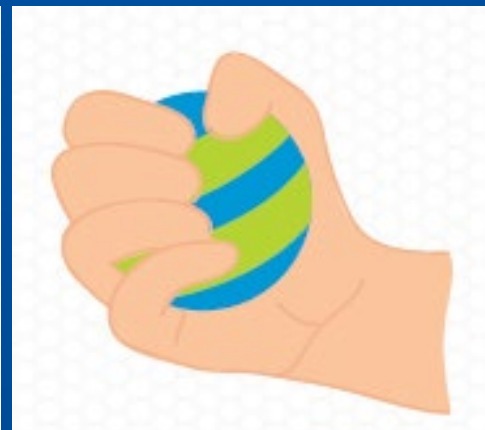
PHYSICAL EXERCISE
PASSPORT

VIVIFRAIL

A

Interreg
EUROPE
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EUROPEAN UNION
optitude

Multicomponent physical exercise program to prevent frailty
and the risk of falls
in elderly residents



Challenges in Current Practices



Limited
Awareness



Inconsistent
Screening



Neglect of
Exercise &
Nutrition

Summary

- ◆ Vitamin D optimizes calcium absorption and muscle function.
- ◆ Healthy diet and gut microbiome are critical for bone health.
- ◆ Weight-bearing, resistance, and balance exercises are crucial for bone density and fall prevention.
- ◆ Consider holistic management beyond medications in your practice.

THANK YOU!