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What the Doctor Never Told You About Osteoporosis and Aquatics

1. The definition of osteoporosis includes all of the following components EXCEPT:

A. Bone loss is always quite painful, making the individual weak and disabled.
B. Osteoporosis has two main groups so designated by the classification of bone metabolism
C. Osteoporosis is a systematic skeletal disease characterized by decreased bone mass and altered microarchitecture of bone tissue
D. Osteoporosis is a progressive disease of bone fragility, placing the individual at increased risk to fracture

2. Which of the DXA Z-scores is sufficient to diagnose the individual with Osteoporosis?

A. -1.0
B. -.5
C. 1.0
D. -2.5

3. In the body, there is an ongoing process of bone growth and resorption. Which is true of the osteoporotic, but NOT the normal bone process?

A. There is decreased bone resorption with osteoporosis but not with normal bone
B. Bone metabolism for the osteoporotic individual is dependent only on neural factors whereas normal bone growth depends on gravitational loading as well
C. With osteoporotic bone, resorption occurs at a greater rate than normal bone formation, which weakens bone, making the bones at increased risk to fracture
D. All of the above occur the same in normal and osteoporotic bone

4. It is widely accepted that genetics play an integral role in the osteoporotic process. What other factors influence growth?

A. Mutational genetics is also noted as an important component of bone density/growth
B. External gravitation loading—ground reaction forces—influence bone growth
C. Internal loading---muscle contraction—influences bone growth
D. All of the above statements do impact bone density and growth

5. Is there a molecular link between muscle contraction and bone growth?

A. The only link between muscles and bone growth stimulation is the force generated by the muscle when it contracts and pulls on the bone

B. Muscle, a source of mytokines, provide a “cross-talk” between muscles/bones, that physiologically stimulate bone growth when muscles contract

C. The only physiological response between muscles/bones occurs with the bone’s release of osteoclastin + connex which impacts muscle strength

D. The only metabolic relationship has to do with RNA mutations that occur as muscles contract

6. The hypotheses for why osteoporosis occurs includes which of the following?

A. Nutrition deficits over time affect the bone integrity

B. The complex system controlling local adaptations to mechanical stress is impaired during aging which affects bone integrity

C. Inactivity promotes decreased stress on the bones which changes the local response both at the cellular level and with respect to muscle-bone cross-talk

D. All of the above are correct

7. The relationship between frailty, sarcopenia and osteoporosis includes which of the following components?

A. Muscle atrophy contributes to bone loss via increased bone resorption by osteoclasts. Additionally, muscle atrophy is a component of sarcopenia, which ultimately affects the frailty status

B. Fragile bones always initiate one's downward spiral into frailty

C. Muscle atrophy spells sarcopenia; frailty is always a part of bone fragility

D. Frailty is always the 1st step to bone fragility and sarcopenia

8. Which of the following is/are an outward physical presentation of osteoporosis?

A. Stiff abdominal muscles and an anteriorly positioned pelvis

B. Forward head posture

C. Thoracic kyphosis

D. B and C are correct

9. Which of the following exercise guidelines is most easily addressed with aquatic interventions?

A. It is critical to accentuate spinal end range ballistic rotational and flexion/extension motions to adequately mimic land-based ADL's

B. Osteoporotic individuals should perform daily exercises that increase muscle endurance of the spinal extensors

C. To accentuate bone growth, exercises where the spine is maximally loaded should be incorporated daily

D. Hip progressive resistance exercises should include ballistic end range rotation to maximize bone remodeling

10. In defending aquatic interventions for an osteoporosis client, which of the following statements would be both accurate and helpful for a client to feel confident in its benefits?

A. Warm water assists in stimulating bone growth due to it thermoneutral effects

B. Because water provides a buoyancy effect, there is no risk for spinal fractures

C. Water can provide assistance in managing anterior/posterior reaction forces as postural deformation occurs with movement

D. There is no fracture risk as viscosity provides sufficient force to counteract any attempted ballistic movements

What Your Doc Never Told You About Osteoporosis and Aquatics

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Learning Outcomes

As a result of this course, participants will be able to:

- List at least four elements of the disease process included in the definition of osteoporosis that impact function.
- Identify at least three key components involved in the bone metabolic process that occur with osteoporosis different from normal bone metabolism.
- Identify at least three components of sarcopenia and frailty that can be positively impacted with exercise.
- Identify at least four physical changes that occur with osteoporosis, which can be addressed with an appropriate exercise regiment.
- Identify at least four exercise guidelines that are critical for the osteoporotic client, and link to why water is an optimal medium in which to manage such clients

CONTINUED

Introduction

- In the United States, fragility fractures account for 2 million fractures annually.
  - 8.2 million women + 2 million men have Osteoporosis
  - 27.3million women + 16.1 million men have low bone mass
  - Fractures = $20 billion annually
- Worldwide: 200 million people are affected2
  - 8.9 million fragility fractures occur worldwide annually.

CONTINUED

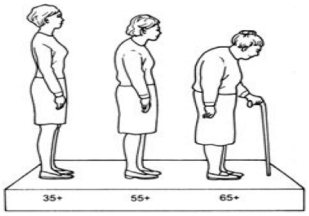
Consider that……..

- 1 in 2 women 50 yrs. of age and older will sustain an osteoporotic fracture in their lifetime3
  - Vertebral Fractures: 25% of women over 50, & 40% women over 80 sustain a vertebral fracture4
  - Risk of death with vertebral fracture is 2.7x greater than without a fracture5
  - 1/3 vertebral fractures are due to a fall BUT 1/2 occur without any trauma4
  - Since imaging is required to establish a fracture diagnosis, world-wide, it is estimated that only ~ 1/3 of these come to clinical attention.

CONTINUED

Osteoporosis Overview

- Progressive, systemic disease, causing bone fragility
- Majority of fractures occur with bone mineral density (BMD) T-score of > -2.5
- Factors other than bone mass influence bone strength including micro architectural deterioration.
- Lifetime risk of an osteoporosis fracture: 6
  - 50% for women
  - 20-25% for men
- Termed “the SILENT THIEF”: asymptomatic bone loss occurs until the 1st fracture



Osteoporosis Defined

- Osteoporosis is"…a systematic skeletal disease characterized by decreased bone mass and altered microarchitecture of bone tissue, leading to enhanced bone fragility and risk of fractures." (Who 6)
- "Bone loss is asymptomatic and progressive without pain….until the occurrence of a fracture."

Osteoporosis Defined (1,6-7)

- PRIMARY: occurs in both genders, all ages
  - Subgroup I: post menopausal women 50-65 y/o
    - Due to estrogen deficiency + increased trabecular bone resorption
    - Fracture mainly involves the spine or wrist
  - Subgroup II: Senile osteoporosis related to loss of bone mass due to aging of cortical + trabecular bone
- SECONDARY:
  - Caused by various diseases, medications, lifestyles

CONTINUED

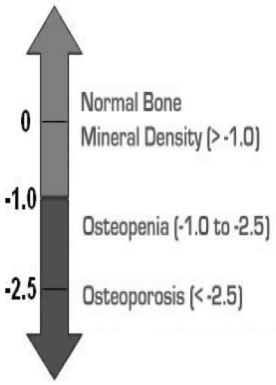
Secondary Causes of Osteoporosis (7)

- Parental h/o hip Fx
- Current smoking
- Rheumatoid Arthritis
- Organ Transplant
- Hyperthyroidism
- Chronic Live Disease
- Autoimmune Diseases
- Depression
- IMMOBILITY/INADEQUATE PHYSICAL ACTIVITY
- Glucocorticoid Rx
- Current Alcohol Consumption
- Untreated Hypogonadism
- Type I Diabetes
- Mellitus
- Gastrointestinal Disease
- COPD
- Hematological Disorders
- Neurological Factors

CONTINUED

Diagnostic Definition of Osteoporosis (8)

- DXA: Individual's bone density compared to bone density of average young adult
  - T-score calculated describes bone density of spine + hips
  - T-score expressed in units --Standard Deviations---indicates how far score deviates from normal young adult
- T-score > 1 SD = normal
- Robust correlation between BMD and fracture risk
- 2-fold increase in fracture per 1SD decrease in bone density



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2nd Diagnostic Definition of Osteoporosis

- 2008 WHO launched a fracture risk assessment tool (FRAX)
- Takes into account factors to calculate the absolute 10-yr risk of an osteoporotic fracture
  - BMI (weight to height ratio)
  - Parental Hip Fracture
  - Rheumatoid Arthritis
  - Other secondary conditions contributing to bone loss
  - Current Smoking
  - Alcohol intake (3 or > drinks per day)

CONTINUED

Diagnostic Importance of Falls (9)

- While not currently included in FRAX…..
- Falls in a previous year independently predict major osteoporotic fracture in the year following
- Recurrent falls—possible intrinsic factors---high fracture risk
- Neither single nor recurrent falls predict fracture risk in women
  - Women tend to fall more and fracture more but data is not of robust predictive nature

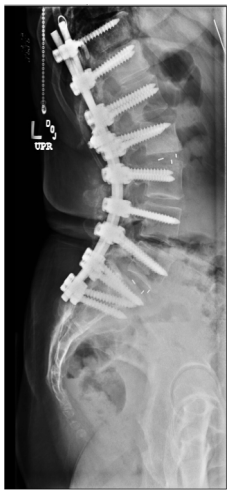
CONTINUED

Other Clinical Factors to Consider for High Risk Fracture Patient (8)

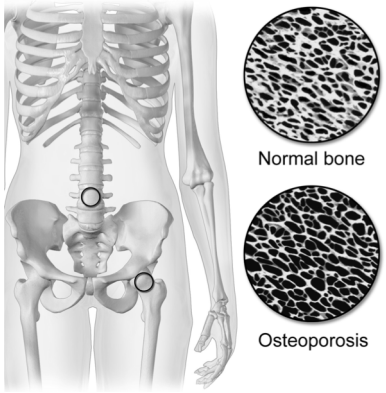
- Age + Medical History
  - Nutritional deficiencies
  - Gastric surgery
  - Stage 5 chronic kidney disorders
  - Medications with adverse skeletal effects
  - Paget's disease, hypercalciuria due to celiac disease
- Skeletal deformities
- Fall History
- Lifestyle Factors + Exercise History

CONTINUED

- BONE HOMEOSTASIS
- Bone Mass
- Bone Turnover
- Bone Adaptation
- Bone Loss
- OSTEOPOROSIS



Bone Composition
Normal vs. Osteoporotic Bone



Hypothesis- Why It Occurs

- The complex system controlling local adaptation to mechanical stress is impaired during the aging process (7,10)
- Bone adapts its growth to functional forces acting upon it
- Direct correlation between direction of principle stresses and pattern of bone alignment
- Thus, changes may occur in production of local factors that provide response to mechanical stress
  - Nutritional Factors
  - Endocrine Response

CONTINUED

Osteoporosis: An Overview of the Process

- Healthy bone requires crucial balance between osteoblastic—bone formation—AND osteoclastic activity—bone resorption– **but in osteoporosis, osteoclastic activity is prominent** (6)
  - Osteoclasts degrade bone mineral by secreting protons creating acidic environment.
  - Regulated by complex neural involvement and genetic factors 11

CONTINUED

Bone Turnover

- Factors influencing balance between formation and resorption
  - Regulated by parathyroid hormone response which increases calcium into blood
  - Gonadal hormones assist with regulation: estrogen + androgens
  - Growth hormone
- Affects bone quality: Resorption > formation = poor bone micro-architecture
- Nervous system: pivotal role in modulating bone biology, local blood flow and bone remodeling (6)

CONTINUED

Nervous System Interaction (12)

- When acidic microenvironment created due to osteoclastic activity……
  - Activation of potential vanilloid receptor type (TPRV)1 channels occur
  - Induces neural peptide release –substance P--- that promotes bone degradation
- Modifies bone homeostasis when catabolic metabolism is present

CONTINUED

Osteoporosis: the Process

- BMD: Consider the bone at the source: best predictor of primary osteoporosis fractures (12)
- Strong genetic component 46-84%---mutational genetics vs. familial genetics
- Functional variants for BMD influencing RNA-protein interactions
  - Provides RNA-editing regulating downstream events
  - N-methyladenosine (m6A) 1st example of reversible RNA methylation
  - Plays an important role in osteoporosis pathology

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Osteoporosis: the Process

- BMD loss due to decreased mechanical loading
- 1st External gravitational loading via ground reaction forces
- 2nd Internal loading via **muscle contraction**

- **Association between muscle atrophy & bone loss** (13)
  - Systemic factors
  - Local factors including muscle/bone
  - Cross-talk

CONTINUED

Resistance Training + Bone Formation Markers for Low BMD Women (14)

- **Study:** 3-month weight-bearing + resistance training and the effect on osteogenic cells (OC's) + QoL
- **Results: Significant increases in:**
  - OC's+ pro-collagen peptides, markers of bone formation;
  - Height increase;
  - Improved 1RM for lat pull & leg press;
  - Increased mean VO2max;
  - Improved QoL respective of decreased pain, improved physical/mental function

CONTINUED

Resistance vs Resistance and Weight-Bearing: Effects on BMD (15)

- STUDY: The effects of differing resistance training modes on the preservation of bone mineral density in postmenopausal women: a meta-analysis.
- RESULTS:
  - Both Resistance Training & Tesistance Training + weight-bearing High intensity exercises signficantly improve BMD at femoral neck + lumbar spine.
  - Non-significant difference with resistance + weight-bering program showing greater improvemetn in femoral neck and Lumbar spine BMD

CONTINUED

Molecular Link Between Muscles & Bones (13)

- Muscle: a source of myokines that stimulate bone formation + contribute to bone loss
  - Sarcopenia: progressive low muscle mass exhibiting poor strength and/or mass + loss of function
  - Muscle contraction releases cytokines with contraction
- Bones: secrete osteoclastin + connexin directly affecting muscles
- Combination of these 2 pose serious risk for fragility fractures- hip – and for falls

Photography: Brian Donnelly, LifeSpan Furnishings, LLC; provided to the CDC by Richard Duncan, MRP, Sr. Proj. Mgr, North Carolina State University, the Center for Universal Design [Public domain]

CONTINUED

Muscle & Bone Loss Spaceflight or Bed Rest (13)

- Long Term Bed Rest: Microgravity condition stimulates physiological decreased muscle volume + force AND decreased bone mass
  - Muscle atrophy precedes decline in bone mass
- Spaceflight: well documented muscle atrophy + decreased bone mass with space flight
  - Return to normal gravity promotes a 6x faster muscle mass to bone mass return
- Muscle atrophy contributes to bone loss via increased bone resorption by osteoclasts.
  - Force produced by muscles contracting far exceeds loads applied via ground reaction forces

CONTINUED

Life Considerations with Sarcopenia & Low BMD (16)

- Study: Comparing sitting time and decreased lean mass in community dwelling older adults
- For every hour sitting/day associated with lower muscle mass.
- Frequent breaks in sitting associated with decreased pre-sarcopenia risk
  - Each 10 sit→stand transitions/day associated with 45% lower odds of pre-sarcopenia

CONTINUED

Sarcopenia- Predictive Factor for Fractures (17)

- Plausible mechanisms for this association
- Low muscle mass changes in muscle related proteins also associated with abnormal glucose metabolism…greatly impacts bone metabolism.
- Sarcopenic individuals are at increased fall risk…leads to increased fractures
- Decline in muscle function/strength associated with low mechanical loading…directly affects bone mass.
- BUT this significance is only accurate for males as per this study

CONTINUED

Weak Bones + Weak Muscles = FRAILITY

- Functional decline in multiple physiological systems that predispose one to disability, dependency, and death.
- Most Obvious decline in musculoskeletal system affects:
- Bone + muscle mass resulting in
  - Balance
  - Mobility
- NOTE: Elevated BMI (body mass index) vs. BMD more accurate indicator of frailty

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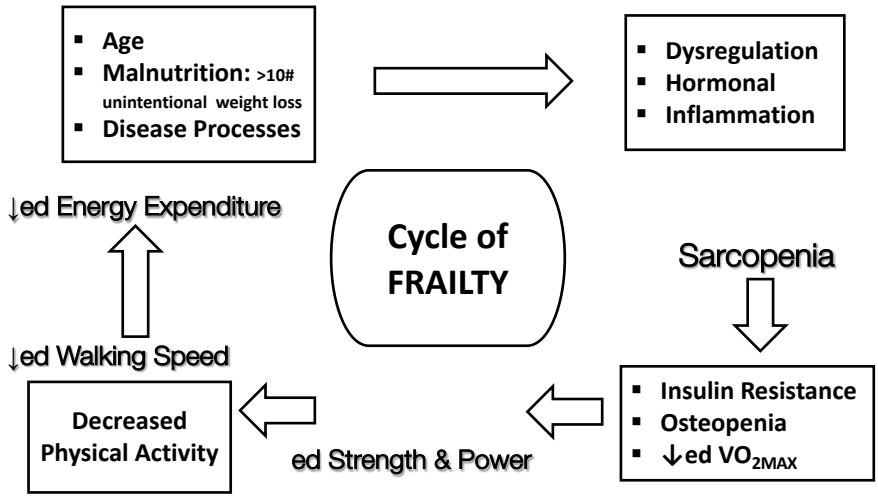
Frailty: Overview of Decline[18]



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Frailty: Multiple Components = Decline (18)

- Wasting of muscle + strength resulting in sarcopenia
- Involuntary weight loss
- Loss of endurance
- Slowed performance for functional tasks
- Relative Inactivity
- Potential cognitive decline
- Fracture→ Pain/Decreased Function → Fracture→ Immobility/decreased function → Fracture = FRAIL

CONTINUED

Frailty: Inflammation + Multi-System Dysregulation (19)

- Chronic Inflammation: Its impact on the musculoskeletal system
  - Detrimental effects on musculoskeletal system as it is direct contributing factor in sarcopenia
  - Direct relationships to onset of osteopenia/osteoporosis
  - Causes decreased levels of Vitamin D
  - Inflammation is associated with obesity– mid-life obesity is predictive for development of frailty

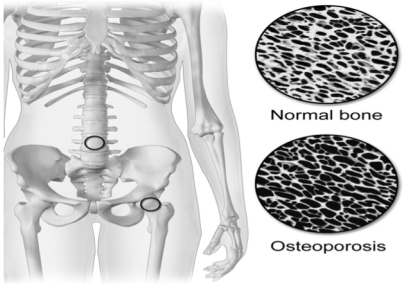
CONTINUED

Frailty: Its Affect on Function

- Sarcopenia: affects muscle strength predisposing one to:
  - Increased fall risk
  - Decreased ability to lift and perform ADL's
  - Negatively impacts transitional movements
- Decreased Endurance
  - Deconditioned
  - Inability to carry out daily tasks
  - Sedentary lifestyle
- Decreased activity further weakens bones and muscles

OSTEOPOROSIS

- FRACTURES
- POSTURAL IMPLICATIONS
- LIFESTYLE CHANGES



OSTEOPOROTIC CHANGES

- Fractures: vertebrae, hip/femur, ribs, + radius
  - Fractures initiate the cascade of decreased sedentary lifestyle
- Postural changes that also affect fall risk
  - Lax abdominal muscles; protruding abdomen
  - Forward head
  - Kyphosis with internally rotated shoulders
  - Posterior pelvic tilt
  - Knee hyperextended
- Significant loss of height predisposing one to multiple systems involvement

CONTINUED

Fragility Fracture-Component of Osteoporosis

- Based on Cause of Fracture
  - Low Trauma: Fall equal to/less than standing height OR no apparent trauma
  - Low Energy
- Robust correlation between BMD & fracture risk
  - For every SD decease in BMD there is 2-fold increase in fracture risk8
- Based on the Site of the Fracture
  - Spine: thoracic > lumbar noted with increased age
  - Hip: femoral neck differentiated from proximal femur
  - Proximal Humerus
  - Distal forearm-radial/ulnar or wrist

CONTINUED

Overview: Osteoporotic Fractures (20)

- Patient age AND skeletal site of initial fracture strongly influence magnitude of subsequent fracture risk
- Fractures occur more commonly + earlier women vs. men
- Associated with increased mortality, disability + long-term functional decrements
- Recent fracture is among top predictors for future fracture
  - Recently also recognized as a sign to diagnose/treat osteoporosis
- Risk of subsequent fracture increases with age for all points except hip

CONTINUED

Osteoporotic Fracture as Predictor of Subsequent Fracture (20)

- Increased risk of additional fractures predictive with prior fracture.
  - Relative risk varies by fracture location
  - 7-fold increase risk of vertebral fracture with h/o prior fracture for women
  - Wrist, shoulder and hip initial fracture sites vary from vertebral or hip according to age and comorbidities
- Increased risk for subsequent fracture(s) is independent of BMD scores.
- Increased fracture risk is acute immediately following a fracture

CONTINUED

Osteoporotic Fracture & Risk of Death[20]

Mortality rates within 1, 3 and 5 years following initial fracture.

SITE	Ist Year	3rd Year	5th Year
Hip	19%	31%	64%
Vertebral	14%	24%	54%

CONTINUED

Common Fracture Sites- VERTEBRAL (21)

Most common fracture & a strong predictive factor for subsequent fracture:

VERTEBRAL FRACTURE CASCADE

- Occurs at the anterior portion of vertebral body
  - If fracture is posterior there is usually an underlying cause
- Frequently occurs during flexion-based motion
- Severe back pain often associated with fracture but vertebral fracture can be asymptomatic

CONTINUED

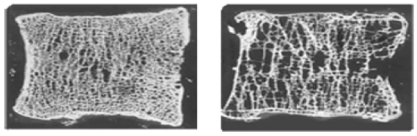
Osteoporotic Fractures- VERTEBRAL (20-22)

- Importance noted for prevalence of minor vertebral deformities (MVD) + increased incidence of vertebral fractures.
  - Significance in assessment process as MVD markedly increases fracture risk
- Common comorbidities:
  - History of Cancer
  - Chronic Inflammatory Disease including Rheumatoid Arthritis
  - Asthma
  - Chronic Obstructive Pulmonary Disease
  - Diabetes Mellitus

Osteoporotic Fractures- VERTEBRAL

- Most Common site for Vertebral Fracture: 1st: thoraco-lumbar junction, 2nd T12, 3rd L322
- Multiple vertebral fractures create severe thoracic kyphosis7
  - Impedes pulmonary function as it alters respiratory muscle functional activity resulting in restrictive lung disease & heart involvement.
  - Decrease distance between ribs and pelvis
  - Alter abdominal anatomy causing constipation, gastrointestinal complaints, premature satiety
  - Significant height loss

Figure 1: Bone Comparison*



Normal Bone Osteoporotic Bone

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Turner Biomechanics Laboratory [CC0]

Impact of Thoracic Kyphosis

Predictor of Vertebral Fractures

Magnitude may be related more to strength

Thoracic Kyphosis

Increases with each additional Fracture

Increases Postural Sway + Risk for FALLS

CONTINUED

Vertebral Fractures = Silent Fractures

- 60% of vertebral fractures are "silent"
  - Not always accompanied by pain or immediate structural change
  - 4 Measures to identify these fractures
    - Historical Height Loss: Height Loss over Lifetime
    - Prospective Height Loss: > 2" in 3 yrs.
    - Wall-occiput Distance: > 5cm indicative of vertebral Fx
    - Rib-Pelvic Distance: > 2 finger-breaths suggests presence of vertebral fracture

CONTINUED

Osteoporotic Fracture- HIP

- Debilitating and frequently alters the course of life… initiates functional decline….frailty
- CONCERN: Did client fall AND fracture OR Fall because weakened bone fractured first?
  - Frequently due to backward fall, tripping or landing directly on one's side
  - 20-24% of individuals sustaining a hip fracture die within first 12 months post fracture
  - ½ hip fracture survivors NEVER regain prior quality of life
  - 6 months post only 15% walk unassisted

CONTINUED

Osteoporotic Fracture- HIP

- Study by Fischer et al noted that functional recovery is largely completed within 1st 6 months (23)
- TUG + LE flexion/extension score improved significantly first 6 months post…but not after that
- SF-36 improved significantly from 3 to 9 months post and no more afterward
- Improvement post hip fracture positively affected by
  - Age (<85 yrs)
  - Living at home prior to fracture
  - Cognitively intact
  - Grip strength good indicator for walking ability

CONTINUED

Osteoporotic Fracture- HIP

- Regarding BMD s/p hip fracture (24)
- Greater loss of hip BMD post fracture for 4-yr follow-up than post vertebral or clavicular fracture
- Increased loss of BMD noted for contralateral hip 1yr. post hip fracture
- ~5% BMD loss at femoral neck + 3.5% BMD loss for total hip 1yr after hip fracture
- Urban areas: increased incidence of hip fracture7
- Loss of BMD following hip fracture partially attributed to…. Decreased activity AND mechanical loading of LE's

Osteoporotic Fracture- WRIST

WRIST FRACTURES:

- Most often due to a fall on an out-stretched arm
- Should be considered a RED FLAG for increased cortical bone loss when this fracture occurs in older adults
- Results in decreased pronation/supination that affects function/ADL's

Aging Bones & Exercise

Photo left by: Ilka Cole

Bill Branson (Photographer) [Public domain]

How can we be safe if our bones are fragile?

Mechanical stress to improve bone quality

CONTINUED

Osteoporosis & Exercise: Starting Point

- Mechanical loading produces thickening of trabecular and cortical bone—improved bone density
  - Mechanical stimulation of bone inhibits production of sclerostin by osteocytes-associated with cortical bone thickening14
- Physical Activity improves muscle strength, flexibility coordination, balance, reaction time endurance
- No physical training program for postmenopausal women effective in increasing bone mass BUT
  - Combination aerobic/resistance training significantly decreases bone loss (14)

CONTINUED

Osteoporosis & Exercise-Guidelines (25)

- Exercise protocols involving specific muscles that attach to lumbar spine show positive results
- Majority of osteoporotic individuals are deconditioned
  - Consider mechanical limitations imposed on respiratory muscle function with severely kyphotic client
  - Balance may also be altered due kyphosis
- No exercise is without risk but DO EXTENSION with appropriate posture

CONTINUED

Exercise Movement Guidelines (25)

- SPINE: Limit repeated/sustained, end-range, rapid/forceful or combinations
  - Mid-range flexion, extension, rotation, side bending
  - Reduce cumulative effect of flexion/slouching
  - Ergonomics for lowering heavy objects/lifting overhead especially if kyphotic
- HIP: No forced end range ballistics

CONTINUED

Osteoporosis Exercise Guidelines (25)

- Adults With Osteoporosis and NO FRACTURE
  - Engage in multi-component exercises—resistance + balance training
  - Weight-bearing Activities most often
  - Progressive Resistance Training designed to increase muscle strength of 5-8 intensity on 10-point RPE
  - Balance Training 2hrs/wk or 20 minutes per day
  - Daily exercise to increase muscle endurance of spinal extensors

CONTINUED

Osteoporosis Exercise Guidelines (25)

- Adults With Osteoporosis and FRACTURE
  - 150min/wk moderate intensity aerobic activity in bouts of >10 min
  - Progressive resistance training to increase muscle strength-emphasis on form/alignment
  - Balance training x2hrs/wk or 20min/day
  - Daily exercise to increase muscle endurance of spine extensors
  - Perform Exercises where spine is least loaded when possible; loads in supine> standing> sitting

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OSTEOPOROSIS EXERCISES (25)

TYPE	How Often per WEEK	How Hard should I Work	Examples and Comments
Strength Training	≥2days/wk	8-10 reps per exercise Intensity 5-8 on 10 scale	Min: 1 exercise for legs, arms, chest, shoulders. Train at ↓ed intensity initially if sedentary
Balance Training	Daily for ≥ 15-20min	Progressive from standing still to dynamic	Can do with ADL's or walks: Stand: ↓ Base of support; tandem stand; one-leg stand Dynamic: Tai Chi, Tandem Walk
Aerobic Exercise	➢ 5days/wk ➢ ≥30min/day	Moderate to vigorous intensity	Do bouts of 10min or more- Intensity: 5-8 on 10-point scale
Spine Sparing	During Daily Activities	Alignment vs. intensity	Modify trunk flex, rotation w/ rapid, bending– consider mid-range
Back Extensor Training	Daily for 5-10 min	Perform 3-5sec holds	Bone Fit Extensor Strengthening Exercises

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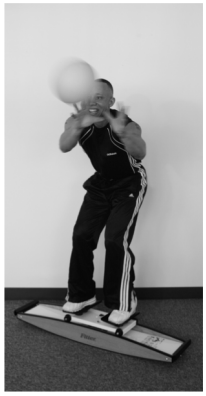
Research: Fernandes Moreira LD. et al (26)

EXERCISE MODALITIES	FINDINGS: summary of present knowledge on effects of various exercises on bone metabolism + function.
Impact+ Aerobic	▪ Impact promoted by walking improved femoral BMD, but no effects on lumbar spine, radius or whole body. ▪ High-impact promoted improved BMD for hip/femur. ▪ PA involving impact both gravitational + muscle loading, slightly better effect on bone metabolism + reduction of fracture risk.
Resistance	▪ Beneficial effect on domains of physical function + ADL's. ▪ Performed 4x/wk @ 70%-90% 1RM x6 R recommended ▪ Strength training decreases vertebral fractures
Balance Proprioception	▪ Decrease number of falls ▪ TaiChi: 12wks x3x/wk improved knees extensor strength x17%
Whole Body Vibration	▪ Vibrating platform mitigates bone loss ▪ Risk to arthroplasties
Aquatic Exercise	▪ 24wk intense AE decreased falls, improved bone marker (P1NP), decreased rate of bone resorption, prevented femoral bone loss.

CONTINUED

Research: Strength & Power Training

- Missko TA. et al. Effects of strength and Power Training on Physical Function in Community-Dwelling Older Adults.27
- Power training is more effective than strength training to improve whole body physical function.
  - Power Group performed less absolute total work that strength training group
- Velocity of movement + intensity of exercise has greater impact on physical performance that total work
- Power training group able to perform tasks faster due to possible greater neural activation
- Strength training group able to carry more weight post training



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Research: Exercise as Prevention

Senderovich H. et al. Purpose of review is to investigate what types of exercises can potentially prevent osteoporosis and associated fractures in high-risk populations.

- High-impact loading: Improved femoral neck BMD; thus, improving skeletal integrity for premenopausal women.
- High-intensity Progressive Resistance: Improved vertebral height, functional performance, lumbar spine + femoral neck BMD in postmenopausal women.
- Walking: Postmenopausal women, after walking 7 days, showed decreased urinary deoxypyridinoline (DPD), which mirrors bone resorption.
- Tai-Chi: Osteopenic postmenopausal women showed increased femoral BMD.

CONTINUED

Concerns Regarding Land-Based Exercise

- Excessive kyphosis precludes appropriate balance for standing exercises
- Alterations in posture = altered spine loading increase vertebral fracture risk
- Altered postural muscle control makes prolonged standing difficult
- Pain
- Exercises challenging balance place individuals at increased fall risk
- Power moves that are indicative of improved strength/function can increase fracture risk

CONTINUED

Aquatic Interventions

Alternative Exercises for the Osteoporotic Client

CONTINUED

Aquatic Interventions for Osteoporosis Client

- 1st Can this client perform something s/he cannot do on land?
  - Consider safety, decreased pain, postural/balance assistance
- 2nd Is the water appropriate for this client at this time in the rehab process?
- 3rd Is a plan in place to transition to land, meaning objective tests, functional upgrades, etc? OR is water being initiated as the most appropriate exercise venue?

CONTINUED

Defensible Justification for Aquatic Intervention

- Decreased weight-bearing = deceased pain through spine + hips
- Balance assistance: due to viscosity
  - Significantly decreased fall risk AND injury if LOB occurs
  - Able to improve balance strategies due to unpredictable perturbations
  - Sensory cues are improved due to viscosity + hydrostatic pressure
  - Closed chain strength acquisition well- tolerated critical to balance improvements in the elderly

CONTINUED

Defensible Justification for Aquatic Intervention

- Balance continued
  - Can challenge CoM boundaries safely and develop strategies to maintain balance safely
- Strength Training:
  - Self-selected speeds provide self-regulation of resistance
  - Tri-planar resistance easily
  - provided
- Flexibility: exercises provided without risk for fracture and with buoyancy assistance

CONTINUED

Defensible Justification for Aquatic Intervention

- Postural Support:
  - Depth-specific assistance when stationary
  - Water requires assistance in managing anterior/posterior reaction forces- postural deformation occurs with movement

- Aerobic Training:
  - Performed in standing or prone/supine
  - Risk for osteoporotic individuals with multiple thoracic vertebral fractures- 8% decreased lung volume/fracture

CONTINUED

Defensible Justification for Aquatic Intervention

- High Intensity Interval/Power Training
  - Utilized with less post-Rx muscle pain
  - Quick directional changes, start-stops assists with dynamic balance/ADL's upgrades
  - Able to initiate neuromuscular program for quick movements without fall risk
  - Greater intensity in shallow water for activities enhances weight-bearing status.

CONTINUED

Physiological Adaptations that Occur with Immersion (28)

- Sustained decreased blood pressure hours post aquatic exercise
- Decreased Heart Rate
- Improved ventilation due to hydrostatic pressure on diaphragm
  - Promotes improved inhalation
  - RISK: severely decreased inspiratory capacity ---seen in frail osteoporotic client---water may be contraindicated.
- Decreased peripheral edema

CONTINUED

GOALS of Aquatic Rx for Osteoporotic Client

- Increase Muscle Mass, Strength and Power to stave off frailty
- Protect the Spine with Increase extensor strength
- Slow Rate of Bone Loss
  - Aerobic Activity: does not significantly improve strength/ bone mass in normal/healthy individuals BUT is good exercise functionally
  - Increasing functional strength
- Practice transitional + functional movements safely
- Prevent Falls
  - Increase LE strength
  - Provide Biomechanical Progression for better balance
- Achievement of CONSISTENTLY good alignment/posture in all positions

CONTINUED

Planning an Aquatic Intervention

- Weight-bearing specifics
- Current condition of patient using objective tests + physical test indicators
- Dosage: RPE, Heart Rate, land based 1RM
- Risk Factors
  - locker room → pool
  - Depth
  - Comorbidities: cardiorespiratory function, cognitive, sensory
  - Posture that increases fracture risk

CONTINUED

Weightbearing at Given Immersion Levels and Movement Intensities (28)

STANDING			SLOW-PACED AMBULATION	
Level of Immersion	**FEMALES**	**MALES**	**FEMALES**	**MALES**
C7	**8-10%**	**8-10%**	**25%**	**25%**
Xiphoid Process	**35%**	**28%**	**25-50%**	**25-50%**
ASIS	**47%**	**54%**	**50-75%**	**50-75%**

CONTINUED

DOSING: Difficulty with Aquatic Interventions

- Level of intensity linked to muscle activation
  - Increasing surface area- increases force output-muscle activation
  - Changing lever arm changes activation
  - Increasing cadence increases muscle activation
- Tools Used in Dosing
- Surface EMG
- Heart Rate
- RPE Scales

CONTINUED

Resistance Training Considerations (29)

Training Effect

- Hypertrophy capacity decreases as one becomes more trained
- Gender Factor: men gain > muscle on absolute basis
- De-training effect begins ~ 72 hrs. post sedentary status

Affects of Aging

- 1-2% muscle loss annually after age 50; 3% loss annually after 60yrs.
- Chronic inflammation compromises muscle protein metabolism
- Elderly require > wkly minimum training dose to maintain muscle
- Muscle loss more pronounced in Type II fibers

CONTINUED

Resistance Training Principles

SUMMARY 30-31

- VOLUME:
  - 40-70 reps per muscle group per bout
- FREQUENCY:
  - 2-3x/wk
- INTENSITY/LOADS:
  - Heavy: 1-5 RM
  - Medium: 6-12RM
  - Light: 15+ RM

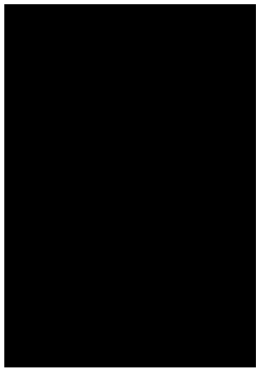
ACSM GUIDELINES 32

- For physical activity
  - Very Light <50%Max HR
  - Light 50-64% Max HR
  - Moderate 64-77% Max HR
  - Vigorous 77-94% Max HR
  - Very Hard 94-100% Max HR

CONTINUED

Aquatic Considerations with Strength Training (28)

- Viscosity makes water a useful strengthening medium
- Doubling the speed requires 8X the power to continue
- Resistance becomes ZERO upon cessation of motion – provides for patient control of force
- Turbulent flow increases as a log function of velocity
- Faster movements EQUAL > drag due to turbulent flow.
- Intensity varied with change of speed, surface area, ROM



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Aquatic Balance Treatment Progression

- Increase stability by increasing speed of weight shift
  - Predictable to unpredictable shifts
- Directional changes
  - Predictable/unpredictable
  - Spatial challenges
  - Avoidance of obstacles
- BOS Changes
  - Bilateral stance →Unilateral challenges emphasizing toes involvement
- Add Resistance
  - Lower extremity closed chain exercises for speed
  - Alter buoyancy of lower extremities
  - Adaptations for increased trunk strength
- OPTIONAL: Practice eyes open -progress to eyes closed

CONTINUED

Research: Aquatics & Osteoporosis

Chaves-Averio M. et al.33

- **Objective:** Compare effects of land or water intervention on postural control for women with osteoporosis.
- **N =** 36 postmenopausal, women diagnosed with osteoporosis divided into LAND or WATER groups
- **Methods:** 12-wk, 2x/wk 45-min. Land or water exercises devised by physical therapist.
- **RESULT Water Group:** Significant decrease in mediolateral postural sway in quiet stance; increased time for tandem and single leg stance noted. No significant change for any parameters in water exercise group.

CONTINUED

Research: Aquatics & Osteoporosis

1. Chaves-Averio M. et al.-continued33

- Discussion: Subjects were all independent community-dwelling adults and in pre-testing scored a low fall risk on Berg Balance Test, but score lower on TUG than expected. Since mediolateral parameters are predictors of fall risk, it is thought that water interventions can be a tool in decreasing the risk of falls for postmenopausal osteoporotic women.

CONTINUED

Research: Aquatics & Osteoporosis

2. Pernambuco CS. et al34

- Objective: Evaluate the effects of an aquatic exercise program on BMD, osteoclastic and Functional autonomy in older women.
- N = 67 postmenopausal women with low BMD, 60 to 77 yrs of age. Randomly assigned (36)Aquatic Exercise Group or (31)Control Group
- Method: 8 months of 2x/wk 50 min sessions performed using: stretching/warm-up; 5 phases of aerobic, strengthening, jumping + strengthening U/LE.

CONTINUED

CONTINUED

Research: Aquatics & Osteoporosis

2. Pernambuco CS. et al continued34

- Results: Significant improvement noted with aquatic exercise with respect to functional battery of tests. Improved BMD noted although not statistically different for L2-L4 or femoral neck. Increased level of serum osteoclastin noted for aquatic exercise group.
- Discussion: An 8-month aquatic exercise program can improve osteoclasin levels in older women, although no significant change noted for BMD.

CONTINUED

Research: Aquatics & Osteoporosis

3. Moreira LFD. et al.35

- Objective: Evaluate the effects a 24-wk high-intensity aquatic exercise program on bone remodeling markers + bone mass in postmenopausal women.
- N = 108 women 58.8+6.4 yrs. Randomized into AEG = 64; CG = 44.
- Methods: 3x/wk x 24 wks x 50-60min/session. Bout consisted of 10 minute warm-up, strength/power training, cardiorespiratory segment, 10 min stretching and balance. During exercise session, instructed to perform at maximal effort

CONTINUED

Research: Aquatics and Osteoporosis

3. Moreira LFD. et al continued35

Results: Significant lowering of serum values which is a marker for resorption.. No BMD difference between groups except at the trochanter which showed a significant decrease in CG. AEG showed a 15.8% increase in P1NP bone formation marker.

Discussion: Authors state that improvement in bone metabolism and mass *not a result of impact exercise, but a consequence of resistive muscle training against water.*

CONTINUED

Summary

- Well-planned consistent water exercise program can improve bone health without the risk associated with land—falls.
- It is not impact but water's resistance that improves bone health.
  - Note that the research for land weight-bearing is also inconsistent.
- The safety + resistance + balance assistance + ability to provide functional training with power = improve functional benefits

CONTINUED

Thank you for Attending!

Questions?