Physical Activity and Osteoporosis

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Determinants of Peak Bone Mass

- Race
- Sex
- Family history (genetics)
- Exercise
- Leanness
- Calcium intake & Vit. D
- Menstrual history

Start young.....
Determinants of Rate of Bone Loss

- Menopause
- Other hormonal changes
- Smoking and alcohol
- Reduced calcium absorption (↓ Vit. D)
- Inactivity/activity

Astronauts lose bone in the weightless environment
Similar to prolonged bed rest
Worst in weight-bearing sites eg. legs and spine
Activity & Hip Fracture Risk

- Epidemiological evidence suggests that being physically active can reduce the incidence of hip fractures by 50%.
- Effect could be due to improved BMD, strength, balance and co-ordination.
- Activities such as standing, walking and stair-climbing important.
Sedentary vs active lifestyles

• >3 hrs per week targeted exercise
  – Osteoporosis - 2 x less likely
  – Fall-related injuries - 2 x less likely
  – Hip fracture - 2 x less likely

• WHO, 1996 “regular physical activity helps to
  – “preserve independent living” and
  – “postpone the age associated declines in balance and co-ordination that are major risk factors for falls”

Systematic Reviews

• Cochrane 2002 – Bonaiuti et al.
  – Up to year 2000, 18 RCTs, poor methodology generally
  – Aerobics, weight bearing and resistance exercises effective on spine BMD
  – Brisk walking effective on spine and hip BMD

• Maturitas 2009 – Schmitt et al.
  – 2000 to 2008, 7 more trials, 3 were RCTs
  – Individually adapted, intense, high impact exercise programmes most effective at increasing BMD
  – Public health basis – brisk walking, aerobics, Tai Chi help maintain BMD (if not increase it) but adherence much better
Lifestyle Impact on bone

- Outcomes over 6 years
  - 1994/5 (aged 50-74) and 2001 (aged 56-80).
  - Distal and ultradistal forearm (SXA)
- Sedentary, smoking, thin people have an increased forearm risk of 69% in men and 85% in women
- Better to have BMI >30kg/m2; not smoke and be active (>3 hrs/wk).


Physical Activity and Osteoporotic Fractures

- Moderate to vigorous physical activity ➔ hip fracture risk reduction
  - 45% (95 CI 31-56) in men
  - 38% (95 CI 31-44) in women
- But…U shaped curve of risk, those most and least active more likely to fracture
- Huge RCT needed
  - Fractures (hip)
  - Rate ratio 0.75, 7129 european women or 3467 high risk women or 21781 european men!

Moayyeri A. Ann Epidemiol. 2008
BMD in Male Athletes

Nilsson & Westlin, 1971

BMD in Females athletes: % difference from sedentary controls

However, swimming may have beneficial effects to elasticity and microstructure of bone, if not density (Yung et al., 2005)
Tennis Players
“Site specificity”

Changing incidence of fractures with increasing age

- 50 to 65 yrs - wrist
- 55 to 85 yrs - spine
- 75 to 85 yrs - hip
  (because of poor reaction, coordination and reflexes)

Hoapasalo et al, 2000
But increasing physical activity may not always be safe......!

Some exercise is risky for bone...

- Women, upper arm fracture
- Excluded
  - bisphosphonates, survival < 1yr, cognitive impairment, too frail
- Intervention: Brisk walking
- Control: exercise of upper arm
- Falls risk (Brisk walking > control)

Ebrahim et al. (1997)
Potential Dangers of Exercise

<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Reoccurrence of Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back extension</td>
<td>16%</td>
</tr>
<tr>
<td>Flexion (abd. curls)</td>
<td>89%</td>
</tr>
<tr>
<td>Combined</td>
<td>53%</td>
</tr>
<tr>
<td>No exercise</td>
<td>67%</td>
</tr>
</tbody>
</table>

*Sinaki & Mickelson 1982*

Proposed Conceptual Model

Positive effects on fall risk factors:
- balance
- strength & power
- functional ability
- depression
- coordination
- mobility
- gait
- fear of falling

Fall risk reduced:
- Only with sufficient tailoring, duration, frequency, intensity and with specific components.
- For example:
  - balance and Tai Chi
  - strength and power
  - co-ordination

Fall risk increased:
- unsafe practice
- acute fatigue
- displacement of centre of gravity
- environmental risk exposure

Fall injury (e.g. head injuries, fractures)

Adapted from Skelton, 2001, *Age Ageing*
### Insufficient tailoring or specificity

<table>
<thead>
<tr>
<th>Study</th>
<th>Duration</th>
<th>Interventions</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>Bassey et al. 1995</td>
<td>6 months</td>
<td>Heel drops, low impact, supervised once per week</td>
<td>Non significant increase in hip BMD</td>
</tr>
<tr>
<td>Nelson et al. 1991</td>
<td>12 months</td>
<td>Walking rapidly, 8lb belt</td>
<td>Spine and hip BMD</td>
</tr>
<tr>
<td>Bravo et al. 1997</td>
<td>12 months</td>
<td>Walking rapidly, Osteopenic, water-based jumping and strength</td>
<td>Hip BMD</td>
</tr>
<tr>
<td>Cavanaugh et al. 1988</td>
<td></td>
<td>Water-based jumping and strength</td>
<td>Spine BMD</td>
</tr>
<tr>
<td>Hatori et al. 1993</td>
<td></td>
<td>Walking below anaerobic threshold</td>
<td></td>
</tr>
<tr>
<td>Sinaki et al. 1996</td>
<td></td>
<td>Non strenuous weight training, supervised once per week</td>
<td>Spine, hip or radius BMD, muscle mass</td>
</tr>
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### Specificity to prevent or manage OP

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<th>Study</th>
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<tr>
<td>Sinaki et al. 1984</td>
<td>1-6 years</td>
<td>Back extension and flexion (in prone and sitting), combined</td>
<td>Extn: 16% further spinal wedging</td>
</tr>
<tr>
<td>Ayalon et al. 1987</td>
<td>5 months</td>
<td>Limb loading, torsion, tension, hanging, pulling, pushing</td>
<td>▲ 3.8% distal forearm BMD</td>
</tr>
<tr>
<td>Simpkin et al. 1987</td>
<td></td>
<td></td>
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# Specificity to prevent or manage OP

## OSTEOSPOROSIS MANAGEMENT – PRE AND POST MENOP. WOMEN

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<th>Study</th>
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<th>Frequency</th>
<th>Group Type</th>
<th>Intervention</th>
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<tr>
<td>Pruitt et al. 1992</td>
<td>1 yr</td>
<td>3 p/w</td>
<td>Post Menopausal women.</td>
<td>Weight training machines incl. Back extension and flexion</td>
<td>▲ 1.6% spine BMD</td>
</tr>
<tr>
<td>Nelson et al. 1994</td>
<td>1 yr</td>
<td>3 p/w</td>
<td>Post Menopausal women.</td>
<td>Weight training</td>
<td>▲ 1% spine BMD and hip BMD</td>
</tr>
<tr>
<td>Bassey et al. 1994</td>
<td>6 mths</td>
<td>Daily</td>
<td>Pre Menopausal women.</td>
<td>High impact jumping supervised once a week, daily at home</td>
<td>▲ 3.4% hip BMD</td>
</tr>
<tr>
<td>Kohrt et al. 1995</td>
<td>1 yr</td>
<td>3 p/w</td>
<td>Post Menopausal women.</td>
<td>Impact loading; vigorous walking; jogging; stair-climbing</td>
<td>▲ 2.3% spine and 3.3% hip BMD</td>
</tr>
<tr>
<td></td>
<td>1997</td>
<td></td>
<td></td>
<td>Stair-climbing / descending</td>
<td>▲ 1.8% spine BMD; ▼ hip BMD</td>
</tr>
<tr>
<td></td>
<td>1997</td>
<td></td>
<td></td>
<td>Weight training; free weights; machines; standing</td>
<td>▲ 1.5% spine BMD; ▼ hip BMD</td>
</tr>
<tr>
<td>Welsh et al. 1996</td>
<td>1 yr</td>
<td>3 p/w</td>
<td>Post Menopausal women.</td>
<td>Seniors fitness medium to low impact jumps; step; floor strength and wrist loading; free weights</td>
<td>▲ 1.6% hip BMD</td>
</tr>
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## Specificity to prevent or manage OP

## OSTEOSPOROSIS MANAGEMENT - POST MENOPAUSAL WOMEN

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<tr>
<td>Nelson et al. 1991</td>
<td>1 yr</td>
<td>3 p/w</td>
<td>Post Menopausal women.</td>
<td>Walking with weighted belt + Calcium</td>
<td>▲ 3% spine BMD</td>
</tr>
<tr>
<td>Notelowicz et al. 1991</td>
<td>1 yr</td>
<td>3 p/w</td>
<td>Post Menopausal women.</td>
<td>Exercise + HRT</td>
<td>▲ 8% spine BMD</td>
</tr>
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</table>
Whole body Vibration

- RCT, 70 post menopausal women (58-74 yrs)
- Whole Body Vibration vs Resistance Training vs Control
- 35-40Hz
- 3 x p/w, 24 weeks, <20 mins
- WBV – strength 15%, Hip BMD 1%
- Resistance – strength increased but not BMD
- No vibration related side effects


Exercise in Older Men – 1 Year

- 180 men aged 50-79, Australian, healthy, normal to below average hip BMD (+0.4 to -2.4 SD)
- RCT – Exercise only; Exercise and fortified milk; Fortified Milk; Control – 12 months
- Interventions
  - High intensity progressive resistance training, 3 x p/w (60 to 75 mins) in groups with qualified instructors. Plus weight bearing exercises (lunges, jumps) with ground reaction forces greater than 1.5x body weight
  - Fortified Milk – per day, 1000mg Calcium + 800 IU Vit D
- Results
  - Exercise led to 1.8% net gain in femoral neck BMD (DXA)
  - Compliance 67% exercise, 90% milk
  - Additional fortified milk made no difference
  - All treatment groups led to a 1.5% net gain in lumbar spine BMD

Kukuljian et al. Osteop Int 2009
Pre-menopausal women, 9 mths

• 58 pre-menopausal women aged 30-50 yrs, USA
• RCT – Strength training vs control
• Interventions
  – RCT Strength training 2 x p/w 15 weeks then unsupervised for remaining 39 weeks (Gymnasium instructor to 4 participants)
  – Control
• Results
  – At 15 wks and at 39 wks no between group difference in total body and regional BMD (DXA) or lean / fat mass
  – Compliance 92% first 15 wks, 89% up to 39 wks
  – Trend (NS) 2.2% net gain in spine

Singh et al. Joint Bone Spine 2009

Post-menopausal women, 18 mths

• 64 post-menopausal women aged 55-74 yrs, Japan
• RCT – Multimodal exercise vs control
• Interventions
  – Aerobic; antigravity (sumo style stamping etc); circuit; strength training + home based exercise. Initially 1 p/wk supervised and 3 p/wk home, > 3 mths only 1 supervised session/mth and 3 p/w home.
  – Control
• Results
  – Bone strength (speed of sound, ultrasound) calcaneus maintained in both groups at 12 mths
  – One leg stance balance improved in the exercise group
  – Half of exercise group remained exercising 3 p/wk after 12 mths
  – At 18 months bone strength significantly lower in controls (-0.8%) & returned to baseline in exercisers
  – Only those exercising 3 p/wk or more maintained balance

Cao et al. J Bone Min Res 2009
Physical Activity and Bone post-menopausal women

- Population – 136 Women aged 68 ± 7 yrs (BMI 26 ± 4), USA
- Outcomes every 6 mths for 3 yrs
  - PA (ADNFS)
    - Heavy housework, gardening, DIY, stairs, walking and pace, sports and recreation and total activity
  - Total body, femur and spine BMD (DXA)
- Results
  - Drop out rate nearly 30% (n=39)
  - More hours/week of brisk walking – higher total body, femur and spine BMD, higher spine BMC (1-4%)
  - More weight bearing activity – higher femur BMD
  - More sports/recreational activities – higher total body BMD (1-2%)
  - Heavy housework (>1.3 hrs/wk) - higher BMD at femur and spine (1-3%)

Ilich et al. Calc Tissue Int. 2008

FaME – BONE Results

9 month duration
3 p/w – 1 hr
DURING FOLLOW UP
Exercisers had half the risk of falls compared to controls (RR 0.53)
+ less likely to sustain injurious falls (RR 0.39)

Significant difference with time and group for L2-L4 spine and Wards Triangle (F=3.46, p<0.05). Exercisers n=32, Controls n=14. Time between visit 1 and visit 2 = mean 10.9 (sd 2.7) months

Skelton et al. JAPA 2004; Age Ageing 2005
Exercise for Patients with Osteoporosis

• Carter et al., 2002
  – Osteofit programme, 2 p/w 20 weeks
  – Improved balance and strength
• Sinaki et al., 2005
  – SPEED programme, 2 supervised sessions then 4 weeks at home
  – Reduced pain, improved strength and balance
• Grahn Kronhed et al., 2005
  – Community 10 yr education programme, increase PA, diet, smoking and environment
  – Reduction in fractures

EXERCISE ACTIVITIES

• Targeted Bone Loading (propulsion/resistance)
• Targeted Bone Protecting (resistance)
• Dynamic Endurance (walking/stepping/circuits)
• Dynamic Balance
• Flexibility & Postural

ACSM Position Stand 2004
Physical Activity and Bone Health

• Basic principles of training:
  – Specificity (site)
  – Overload (progressively)
  – Reversibility (Keep at it)
  – Initial values (lower starting BMD, greater response)
  – Diminishing Returns (plateau / ceiling)
ACSM Position Stand 2004
Physical Activity and Bone Health

• MODE
  – Weight bearing activities

• INTENSITY
  – Moderate to high, in terms of bone loading forces

• FREQUENCY
  – Weight bearing endurance activities 3-5 x p/w
  – Resistance Exercise 2-3 x p/w

• DURATION
  – 30-60 mins of a combination of weight bearing endurance and resistance exercise targeting all muscle groups

Exercise and Osteoporosis Prevention
and Management Guidelines CSP

• Severe Osteoporosis - BMD < 2.5 + #
  – Targeted gait and postural balance training
  – Functional local muscular endurance and strength training (eg. Sit to stand, stairs)
  – Functional ROM and flexibility training

• Osteoporosis - BMD <2.5 without #
  – Targeted postural, gait and low impact endurance training (eg. Stepping)
  – Functional and open chain strength and bone loading training
  – Functional ROM and flexibility training

• Osteopenia - BMD <1 to <2.5
  – Targeted low-medium impact and endurance training (post menopausal)
  – Targeted medium impact and endurance training (pre menopausal)

• Normal - BMD >1
  – Medium – High impact endurance training
  – Open / closed chain strength training
  – Complex challenging balance training
  – Flexibility

Warm-Up ► Work Out incl. Correct lifting ► Warm-Down
EFFECTS OF TRAINING

Exercise can slow or reverse age related bone loss provided it is:

Weight resisted
- weight training
- impact
- loading

Site specific
- wrist, hip, spine

Peak Strain
- hold the movement

Fast Strain
- effective and brief

Error Rich
- tennis, squash, fitness class

Strategy = short periods of site specific, high strain rate in unusual relationships

Exercise and Bone

• Physical activity becomes more important as you grow older.
• Physical activity can reduce falls and fractures.
• Physical activity can maintain independence.
• Posture and balance are essential.
• Strength, flexibility and stamina also important.
• Long term commitment is essential.
“Man does not cease to play because he grows old. Man grows old because he ceases to play”

George Bernard Shaw

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