NMDC221 Session 24: Musculoskeletal System Disease Part I
Recommended reading

Topic Summary

Musculoskeletal System Disease: Part I

- Principles and considerations in nutritional medicine management of the musculoskeletal system
- Review anatomy & physiology of the musculoskeletal system

Nutritional treatment of specific musculoskeletal conditions and consideration of drug-nutrient interactions

- Osteoarthritis
- Gout
- Osteoporosis
Musculoskeletal System Disease

Functions of the Skeletal System

- Support
- Protection
- Body Movement
- Haematopoiesis
- Mineral Storage

- There are two types of bone; spongy and compact bone tissues.

(Tortora & Derrickson, 2009)
Musculoskeletal System Disease

- Bone maintenance is under hormonal control, and nutrients play a major role in this
  - Parathyroid Hormone
  - 1,25-Dihydroxyvitamin D3
  - Negative Feedback Control of Calcium and Phosphate Balance
  - Calcitonin

(Tortora & Derrickson 2009)
Musculoskeletal System Disease

In a normal joint, healthy cartilage, lubricated by synovial fluid, cushions the bones and allows them to move easily.

Osteoarthritis, viewed 24th Oct 2007
http://www.prism.gatech.edu/~gt7704b/images/osteoarthritis.gif

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endeavour.edu.au
Osteoarthritis
Osteoarthritis

Healthy knee joint

Hypertrophy and spurring of bone and erosion of cartilage

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Osteoarthritis

Synovial joints present with cartilage loss and significant inflammation to articular and peri-articular structures.

- Morning stiffness (better for movement)
- Grinding of joints (crepitus)
- Loss of mobility, range of movement
- Pain after prolonged activity
- Pain relieved by rest
- Muscle contractures and spasms
- In advanced OA, redness, heat, swelling, enlargement of joint, bone spur formation.

(Rona, 2000)
Osteoarthritis

Predisposing factors:
- Obesity
- Heredity
- Gender
- Biochemical abnormalities
- Previous trauma or inflammation

Investigations
- Blood tests (ESR & CRP)
- X-ray, ultrasound & MRI

(Kumar & Clarke 2009; Tortora & Derrickson 2009)
Osteoarthritis

**Treatment Aims**

- Support pain management and anti-inflammatory action
- Maintaining adequate microcirculation to the joints
- Minimize load bearing exacerbation (obesity) while still encouraging / sustaining activity of the joints while supporting appropriate muscular articulation and preventing further joint injuries
- Nutritional support for proteoglycan synthesis and cartilage reconstruction
- Remineralisation of the calcified cartilage / bone junction
- Adjust the diet to have a less acidic load

(Sarris & Wardle, 2010; Mills & Bone, 2005, p.249)
# Osteoarthritis

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Dosage</th>
<th>Therapeutic Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proline</td>
<td>500-1000mg</td>
<td>Mucopolysaccharide component – major amino acid combined with collagen</td>
</tr>
<tr>
<td>Lysine</td>
<td>300-3000mg</td>
<td>Required for collagen synthesis &amp; elastine</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>250-10,000mg</td>
<td>Collagen, elastin &amp; proteoglycan production, deficiency presents with unstable helix structures</td>
</tr>
<tr>
<td>Copper</td>
<td>2-5mg</td>
<td>Controls expression of inflammation, recovery of proteoglycan synthesis in inflammatory states</td>
</tr>
<tr>
<td>Manganese</td>
<td>2-50mg</td>
<td>Co-factor in cartilage production</td>
</tr>
<tr>
<td>Omega 3</td>
<td>1-12gms</td>
<td>Encourage the production of anti-inflammatory cytokines</td>
</tr>
</tbody>
</table>

(Pasqualicchio et al 1996; Setty & Sigal, 2005; Osiecki, 2006; Lokireddy et al. 2008; Braun & Cohen, 2010)
## Osteoarthritis

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<th>Nutrient</th>
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<tbody>
<tr>
<td>Methyl-sulfonyl-methane</td>
<td>3000-6000mg</td>
<td>MSM significantly decreased pain, swelling and increased movement in damaged joints</td>
</tr>
<tr>
<td>Glucosamine</td>
<td>600-3000mg</td>
<td>Proteoglycan component stimulating cartilage formation, reduce pro-inflammatory cytokine production</td>
</tr>
<tr>
<td>Chondroitin</td>
<td>1500mg</td>
<td>Proteoglycan stimulate cartilage formation (RNA synthesis by chondrocytes, partially inhibits leukocyte elastase, overcomes dietary deficiency of sulphur-containing amino acids.”</td>
</tr>
<tr>
<td>Calcium</td>
<td>1000-2000mg</td>
<td>Bone formation, muscle contractibility</td>
</tr>
<tr>
<td>Magnesium</td>
<td>300-1000mg</td>
<td></td>
</tr>
</tbody>
</table>

(Usha & Naidu, 2004; Osiecki, 2006; Anandacoomarasamy & March, 2010; Braun & Cohen, 2010)
<table>
<thead>
<tr>
<th>Drug</th>
<th>Action</th>
<th>Side Effects</th>
<th>Interactions</th>
</tr>
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<tbody>
<tr>
<td>Non-Opioid Analgesics:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paracetamol</td>
<td>Inhibits prostaglandin &amp; some COX production within the CNS (no anti-inflammatory benefits). Analgesic &amp; antipyretic. Used in osteoarthritis for symptomatic relief.</td>
<td>Skin rash &amp; nausea Overdose (10-15gms or 20-30 tablets) will cause severe liver damage due to depletion of glutathione, and possibly lead to death.</td>
<td>Alcohol: greater potential to cause liver damage when taken together</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vitamin C: prolong the amount of time paracetamol stays in the body</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Beta-Carotene: Reduces toxic effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quercetin, Taurine and thioproline, Oleanolic acid, OPCs (Grape seed), N-acetyl cysteine, methionine and SAMe: reduce liver damage from toxicity by stimulating glutathione production.</td>
</tr>
</tbody>
</table>
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<tr>
<td>Non-Steroidal Anti-</td>
<td>Anti-inflammatory</td>
<td>Nausea, vomiting, diarrhoea/</td>
<td>Vitamin E &amp; fish oil, turmeric, garlic: additive pain relief</td>
</tr>
<tr>
<td>inflammatory Drugs (NSAID's):</td>
<td>inhibits PG, reduced cyclo-oxygenase enzymes</td>
<td>constipation, gastritis as</td>
<td>Garlic, Ginger, Grapeseed, Turmeric: increased blood thinning</td>
</tr>
<tr>
<td>ibuprofen, aspirin,</td>
<td>(aspirin, ibuprofen, paracetamol)</td>
<td>inhibits mucous productive</td>
<td>when used with aspirin.</td>
</tr>
<tr>
<td>diclofenac, indomethacin,</td>
<td>Used for symptomatic relief in Osteoarthritis</td>
<td>PG.</td>
<td>Glutathione, Capsaicin, Colostrum &amp; Phosphatidylcholine: reduce gastric mucosa effects &amp; reduce</td>
</tr>
<tr>
<td>piroxicam</td>
<td></td>
<td>Paracetamol can present</td>
<td>aspirin-induced damage.</td>
</tr>
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(Kumar Clark, 2005; Bullock et.al, 2007; Bryant & Knights, 2011)
## Osteoarthritis

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<tr>
<td><strong>Corticosteroids</strong></td>
<td>Inhibits phospholipase A &amp; cyclo-oxygenase to reduce inflammation.</td>
<td>Side effects include pain &amp;/ or infection at injection site, post-injection joint pain, tendon damage, loss of bone mass (long term therapy).</td>
<td>None listed</td>
</tr>
<tr>
<td>Intra-articular</td>
<td></td>
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</tbody>
</table>

(Bullock et.al. 2007; Bryant & Knights, 2011)
Gout
Gout

- Gout is an inflammatory arthritis associated with hyperuricaemia (raised urate levels in the blood).
- Increased action of xanthine oxidase. This increases the clearance of purines, however, a failure of the kidneys to effectively clear the generated metabolite results in the compound continuing to circulate throughout the body.
- This leads to deposition in joints
  (Kumar & Clark 2009; Tortora & Derrickson, 2009)
Gout

Investigations

- joint fluid microscopy
- serum uric acid levels
- serum urea and creatinine clearance to monitor renal function

(Haslett et al. 2002; Kumar & Clark 2009)
endogenous purine synthesis

- dietary purines
  - low purine diet reducing weight reducing alcohol intake
- tissue nucleic acids
  - allopurinol

p urine nucleotides
- purine bases
  - uric acid pool
    - urinary secretion
    - reducing weight reducing alcohol intake, withdrawing drugs, e.g., diuretics aspirin, probenecid, sulphinpyrazone, benzbromarone

intestinal elimination
  - benzbromarone
Gout

Therapeutic Actions
Vitamin C

Huang et al. (2005) found that the incidences of hyperuricaemia were higher in males and those that suffered chronic illness.

The study found that:

“Supplementation with 500mg/d of vitamin C for 2 months reduces serum uric acid, suggesting that vitamin C might be beneficial in the prevention and management of gout and other urate-related diseases”. (pp. 1845)
Gout

Therapeutic Actions

Anthocyanidins & Pro-anthocyanidins

- Consuming 200gms of fresh or canned cherries per day has been shown to be very effective in lowering uric acid levels.

- Cherries, hawthorn berries, blueberries and other dark red-blue berries are rich sources of anthocyanidins and pro-anthocyanidins which supports collagen structures.

(Haslett et al. 2002; Jacob, 2003)
Gout

Nutritional Considerations

Alcohol
- Alcohol increases uric acid production by accelerating purine nucleotide degradation and reduces uric acid excretion by increasing lactate production which impairs kidney function
  (Lyu et al. 2003; Pizzorno & Murray 2006)
- It has been found that groups with gout have double the alcohol intake of healthy controls
  (Sharpe, 1984 too old!)
Gout

Nutritional Considerations

Refined sugars

- Hyon et al. (2008) found in a longitudinal study of males with no history of gout that consumption of sugar sweetened soft drink and fructose rich fruit drinks increased the incidence of gout.

- The increased presentation was four times that of the normal distribution of disease incidence.
Gout

Nutritional Considerations
Folate, Vitamin C, Fibre and Obesity

- Lyu et al (2003) found that “food sources rich in dietary fibre, folate, and vitamin C, such as fruit and vegetables, protect against gout. Waist-to-height ratio, which indicates central obesity, has a significant linear effect on gout occurrence, independent of body mass index.” (pp. 699)
Gout

Nutritional Treatment

- Eat low purine foods (purine rich foods include yeast, shellfish, organ meats & offal) while eliminating refined sugar in drinks, food & alcohol
- Consumption of fibre, folate, vitamin C rich foods & coffee was associated with a lower risk & lowered rate of flare-ups.
- High essential fatty acid intakes & drinking a minimum of 2 litres /day of filtered water is beneficial
- Reduce an unhealthy waist-to-height independent of body mass index

(Lyu et al. 2003; Pizzorno & Murray, 2006; Jasvinder et al. 2010)
## Gout

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<tr>
<td>Folic acid</td>
<td>10000-12000mcg</td>
<td>Inhibits xanthine oxidase. Low in gout clients</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>200-800mg</td>
<td>Inhibits the production of leukotrienes, Antioxidant</td>
</tr>
<tr>
<td>Omega 3</td>
<td>1-12gms</td>
<td>Limits the production of leukotrienes</td>
</tr>
<tr>
<td>Ginger</td>
<td></td>
<td>Gingerols &amp; diarylhepatanoids inhibits Prostaglandin and leukotriene synthesis.</td>
</tr>
<tr>
<td>Bromelain &amp;</td>
<td>750-1000mg</td>
<td>COX – 2 Inhibitor Bradykinin inhibitor proteolytic enzyme</td>
</tr>
<tr>
<td>Quercetin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alanine</td>
<td>200-600mg</td>
<td>Reduced resorption of uric acid in the renal tubules</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>1500-2000mg</td>
<td></td>
</tr>
<tr>
<td>Glutamine</td>
<td>500-3000mg</td>
<td></td>
</tr>
<tr>
<td>Glycine</td>
<td>4-30mg</td>
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(Kiuchi 1992; Gaspani L, 2002; Lyu et al, 2003; Setty & Sigal, 2005; Pizzorno & Murray 2006)
## Gout

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<td>Xanthine Oxidase Inhibitor:</td>
<td>Reduces the synthesis of uric acid (inhibits xanthine oxidase). This</td>
<td>Skin irritation (itch, rash, dermatitis, alopecia), abdominal irritation (diarrhoea, vomiting), Liver toxicity, kidney damage</td>
<td><strong>Iron:</strong> Concurrent usage can lead to excessive storage of iron in the liver</td>
</tr>
<tr>
<td>Allopurinol</td>
<td>increases xanthine’s use in nucleic acid synthesis which in turn</td>
<td></td>
<td><strong>Tryptophan:</strong> Allopurinol decreases tryptophan breakdown. Concurrent usage</td>
</tr>
<tr>
<td></td>
<td>inhibits purine synthesis. Useful for urate deposits in the joints</td>
<td></td>
<td>can aid depression and help pain management.</td>
</tr>
<tr>
<td></td>
<td>(Gout) &amp; urate kidney stone formation</td>
<td></td>
<td><strong>Vitamin D:</strong> Allopurinol has been found to elevate serum vitamin D levels. Monitor for vitamin D toxicity signs with concurrent administration</td>
</tr>
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(Stargrove et al. 2008; Bryant & Knights, 2011)
# Gout

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| Colchicine | Plant alkaloid used in the acute attacks to reduce inflammation. No preventative effect. | Diarrhoea, nausea, vomiting, abdominal pain, anorexia & alopecia (long term use) Narrow therapeutic window – used with caution in individuals with liver or kidney impairment | **Beta-carotene, Vitamin A:** Blocks the absorption of beta-carotene and vitamin A from the GIT. Blocks release of retinol binding proteins.  
**Calcium:** depletion & bone loss, **Magnesium, Potassium:** reduced absorption  
**Folate** levels have been found to be decreased.  
**Vitamin B12** absorption & metabolism has been found to be inhibited. |

(Bryant & Knights, 2011)
# Gout

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| Probenecid | Competitively inhibits urate reabsorption in the kidneys, increasing excretion. | Headaches, Abdominal irritation (anorexia, nausea, vomiting), Skin irritation (dermatitis), Kidney irritation (haematuria, increased frequency, stone formation, kidney damage), Anaemia, leukopenia | **Vitamin B2**: Impairing absorption, inhibiting urinary excretion. Concurrent usage has been found to reduce drug side effects.  
**Niacin**: Doses of vitamin B3 (above 50mg/day) have been found to reduce uric acid excretion.  
**Ascorbic Acid**: combined use has been found to increase uric acid excretion. Higher doses of ascorbic acid have been found to cause gout attacks. |

(Stargrove et al. 2008; Bryants & Knights, 2011)
Osteoporosis
Osteoporosis

- A generalised, progressive loss of bone density, causing skeletal weakness, although the ratio of mineral to organic elements is unchanged.
- Bones become porous, brittle and less dense as a result of a loss of bone mass due to osteoclast dominance (Kumar & Clark 2009; Tortora & Derrickson 2009; Vardaxis, 2010)
Osteoporosis

- Bone mass peaks in the middle of the 20’s and plateaus for about 10 years.
- Turnover of bone is constant, with bone formation approximately equalling bone resorption.
- Menopause and andropause causes accelerated bone loss (may be increased tenfold at the rate of 3 to 5%/year).
- The movement of calcium and phosphorous in and out of bone is under the control of Parathyroid hormone (PTH), 1,25 Vitamin D3 (calcitriol), Calcitonin.
- Gonadal hormones also play a major regulatory role.

(Haslett et al. 2002; Vardaxis, 2010)
Osteoporosis

Bone Loss Associated factors:
- Cushing's syndrome
- Hyper parathyroid
- Anorexia nervosa
- High intake of alcohol
- Smoking
- Drug usage (corticosteroids, progesterone, anticonvulsants, thyroid hormones, methotrexate, cyclosporin, non-thiazide diuretics, aluminum antacids, anti-coagulants and high dose vitamin A and vitamin D)

(Vardaxis, 2010)
Osteoporosis

Symptoms:
- Usually asymptomatic until severe backache
- Common in postmenopausal women
- Fractures to hips and vertebra
- Decrease in height
- Demineralization of the spine and pelvis

(Haslett et al. 2002; Pizzorno & Murray 2006)
Osteoporosis

Therapeutic Actions
Insoluble Fibre

- Robefroid (2000) found that “…a high concentration of short-chain carboxylic acids resulting from the colonic fermentation of the non digestible carbohydrates facilitates the colonic absorption of minerals, particularly Ca$^{2+}$ and Mg$^{2+}$.”

- Insoluble fibre fractions such as inulin can increase in water retention in the bowel allowing minerals to dissolve and increase in concentration. This encourages passive diffusion and subsequent increased absorption.
Osteoporosis

Therapeutic Actions
Vitamin D, Calcium and Garlic oil

- Rasheed et al. (2009) found that animal trials supplemented with “...vitamin D, calcium and oil extract of garlic could effectively restore the reduced calcium level, correct the high rate of bone turnover, elevate the reduced serum estradiol level and improve both BMC and BMD after ovariectomy. This effect was better in the group co-administered with the three components”.

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[Image]
Osteoporosis

Therapeutic Actions
Calcium and BMI

- Varenna et al. (2007) found that “…the negative effect of a low dietary calcium intake on BMD values in the first years after menopause can be attenuated by a greater BMI found in women with a low calcium intake.”
Osteoporosis

Therapeutic Actions

Soy Isoflavones

- Scheiber et al (2001) conducted a study to determine the effects of dietary inclusion of soy foods on clinical markers for cardiovascular disease (CVD) and osteoporosis in normal postmenopausal women.

- The conclusion was that “dietary soy foods containing 60mg/day of isoflavones results in significant increases in serum levels of phytoestrogens and a subsequent reduction in clinical risk factors for CVD and osteoporosis.”
Osteoporosis

Soy

- Beneficial effects of soy on bone density have been reported in epidemiological studies.
- One study gave 200 women 66mg of isofalnones or a soy protein supplement/day (equivalent to an Asian diet intake) for six months.
- The researchers investigated changes in the women's bone activity by measuring certain proteins (βCTX and P1NP) in their blood (responsible for bone breakdown) & found that the women on the soy diet with isoflavones had significantly lower levels of βCTX than the women on soy alone, suggesting that their rate of bone loss & risk of developing osteoporosis was reduced.
- Women taking soy protein with isoflavones were also found to have decreased risk of cardiovascular disease than those taking soy alone.
- Conclusion - soy protein and isoflavones are an effective option for improving bone health in women during early menopause. The actions of soy appear to mimic that of conventional osteoporosis drugs

(Society for endocrinology 2015)
Osteoporosis

Nutritional Treatment

- Eliminate soft drinks (high in phosphates)
- Increase dietary and supplementary calcium intake
- Consumption of leafy green vegetables (vitamin K, boron, and calcium)
- Increase intake of foods high in Vitamin D and ensure exposure to sunlight
- Reduce fat intake, eliminate refined sugar, avoid smoking & drink alcohol in moderation
- Participate in weight bearing exercise daily & maintain ideal body weight

(Kohlmeier, 2003; Pizzorno & Murray 2006; Schlenker & Long 2007; Straub 2007; Rasheed et al. 2009)
Osteoporosis

Preventative Strategies include:

- Maximizing peak bone mass (peak bone mass achieved at age 30 years)
- Avoidance or modification of lifestyle and environmental factors that cause bone loss
- Use of treatments such as oestrogens to prevent postmenopausal bone loss
- Maintenance of postural stability and prevention of falls

(Haslett et al. 2002; Kumar & Clark 2009)
Osteoporosis

Treatment Aims

- In patients with established osteoporosis, the aim of all treatment strategies (nutritional, dietary and pharmaceutical) is very similar. These include;
- Alleviate the patient's symptoms (e.g. pain) if applicable
- Reduce the risk of fracture
- Improve bone mass
- Treat, any underlying or contributing causes such as thyroid dysfunction, diabetes, achlorhydria, drug therapies e.g. corticosteroids

(Haslett et al. 2002; Kumar & Clark 2009)
## Osteoporosis

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<tr>
<td>Calcium</td>
<td>1200-2000mg</td>
<td>Major mineral in bone deposition, deficiencies present with bone loss</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>10-40mcg</td>
<td>Deficiencies present with impaired calcium absorption, secondary hyperparathyroidism, bone loss, and osteoporosis</td>
</tr>
<tr>
<td>Silica</td>
<td>5-10mg</td>
<td>Cross-linking collagen strands for the strength &amp; integrity of connective tissue matrix of bone. Recalcification in bone modeling</td>
</tr>
<tr>
<td>Boron</td>
<td>2-7mg</td>
<td>Accelerate bone and cartilage healing, improves growth, mineralization and mineral retention in bone</td>
</tr>
</tbody>
</table>

(Kohlmeier 2003; Pizzorno & Murray 2006; Straub 2007)
# Osteoporosis

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<tr>
<td>Vitamin K</td>
<td>2-5mg</td>
<td>Stimulates osteocalcin, matrix Gla protein and protein S for bone mineralization</td>
</tr>
<tr>
<td>Magnesium</td>
<td>300-1000mg</td>
<td>Improvement in bone density</td>
</tr>
<tr>
<td>Omega 3</td>
<td>1-12gms</td>
<td>Decreases bone resorption by reducing excessive inflammatory prostaglandin production</td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>1.5-3mg</td>
<td>Collagen cross linking. Metabolism of Homocysteine</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td></td>
<td>Essential for collagen formation, deficiency presents with reduced osteoid tissue and ground substance.</td>
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(Kohlmeier 2003; Pizzorno & Murray 2006; Straub 2007; Sarris & Wardle 2010; Vardaxis 2010)
# Osteoporosis

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<td>Bisphosphonates</td>
<td>Bind to bone hydroxyapatite crystals, becoming a permanent part of bone. This new matrix is resistant to enzymatic degradation and inhibits osteoclast activity.</td>
<td>Gastrointestinal irritation (dyspepsia, nausea, vomiting, oesophageal irritation, gastritis, abdominal pain, diarrhoea) Osteomalacia, hypocalcaemia Musculoskeletal pain, arthralgia, headache</td>
<td>Calcium, Magnesium, Iron, Zinc: reduces drug absorption, separate by 2 hours. Ca &amp; Mg Is required to stabilize condition. Vitamin D Calcium absorption requires the presence of vitamin D. Concurrent usage with Bisphosphonates is warranted.</td>
</tr>
</tbody>
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(Bullock et al. 2007; Stargrove et al. 2008; Braun & Cohen, 2010; Bryant & Knights 2011)
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<tr>
<td>Calcitonin</td>
<td>Thyroid hormone that inhibits osteoclast bone resorption by blocking the PTH action on these cells. Most effective in early menopause.</td>
<td>Gastrointestinal upset (nausea, vomiting) Dizziness Inflammation and pain at injection site</td>
<td>Calcium &amp; Vitamin D Adequate levels of calcium and vitamin D are required to sustain the bone-sparing effect of calcitonin</td>
</tr>
</tbody>
</table>

(Bullock et al. 2007; Stargrove et al. 2008; Mahan & Escott-Stump 2008)
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<td><strong>Hormone Replacement Therapy</strong></td>
<td>Synthetic oestrogen (&amp; progesterone) reduces bone turnover &amp; loss, increases calcium absorption, retention &amp; increases calcitriol concentrations.</td>
<td>Increased risk of coronary heart disease, breast cancer, stroke and pulmonary embolism</td>
<td><strong>Chromium</strong>: Inhibits IL-6 (increases bone resorption) <strong>Calcium &amp; Vitamin D</strong>: Increases bone mineralization <strong>Boron</strong>: elevates oestradiol levels, l(limits calcium losses &amp; supports bone mineralization). <strong>Vitamin E</strong>: minimizes HRT induced thrombosis <strong>Zinc &amp; Vitamin B6</strong>: depleted by HRT <strong>Magnesium</strong>: HRT increases bone delivery</td>
</tr>
</tbody>
</table>

(Dimitris et al. 1998; Stargrove et al. 2008; Braun & Cohen 2010; Bryant & Knights 2011)
## Osteoporosis

<table>
<thead>
<tr>
<th>Drug</th>
<th>Action</th>
<th>Side Effects</th>
<th>Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raloxifene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamoxifen</td>
<td></td>
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</tr>
<tr>
<td>Androgen Replacement Therapy</td>
<td>Testosterone replacement maintains bone mass &amp; prevent fractures.</td>
<td>Prostate growth</td>
<td>Boron: Can elevate testosterone levels, limiting calcium losses and supporting bone mineralization</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

(Mahan & Escott-Stump 2008; Stargrove et al. 2008; Braun & Cohen 2010; Bryant & Knights 2011)
References


References


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Images Retrieved from


- Osteoarthritis, [http://www.prism.gatech.edu/~gt7704b/images/osteoarthritis.gif](http://www.prism.gatech.edu/~gt7704b/images/osteoarthritis.gif)
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