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Osteoporosis as a Lifestyle Disorder: Causes and Management

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Abstract

Osteoporosis is often referred to as a lifestyle disorder because many of the risk factors contributing to its development are associated with modern lifestyle choices, such as poor diet, lack of physical activity, and unhealthy habits. While osteoporosis has genetic and age-related components, it is largely preventable and manageable through lifestyle modifications. It is a progressive bone disorder characterized by decreased bone mass and structural deterioration of bone tissue, leading to increased fracture risk. This condition predominantly affects in older individuals, particularly postmenopausal women, but also occurs in men. This article reviews the Prevention and Management of Osteoporosis through Lifestyle Changes.

Keywords: Osteoporosis, *Prevention*, *Management*, *lifestyle*

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Introduction

Osteoporosis is one of the most common bone diseases, affecting millions worldwide. It results in weakened bones and increases the risk of fractures, particularly in the hip, spine, and wrist. According to the World Health Organization (WHO), osteoporosis is defined by a bone mineral density (BMD) T-score of less than -2.5, measured using dual-energy X-ray absorptiometry (DXA) [1]. India faces a substantial burden of fractures, particularly those related to osteoporosis, trauma from road accidents, and occupational hazards. The demographic trend of an aging population and increasing urbanization has contributed to a rise in fracture cases. There are several types of osteoporosis, typically categorized based on causes, patient demographics,

or underlying conditions. The main types include:

1. Primary Osteoporosis

This is the most common type and is primarily related to aging and hormonal changes.

- **Postmenopausal Osteoporosis (Type I)**: Common in women after menopause due to a decrease in estrogen levels, which leads to rapid bone loss, particularly in the spine, hips, and wrists.
- **Senile Osteoporosis (Type II)**: Occurs in both men and women, typically after the age of 70. It results from age-related changes in calcium absorption and bone formation. It affects the cortical and trabecular bone and is associated with hip and spine fractures.

2. Secondary Osteoporosis

This type occurs as a result of other medical conditions or medications that affect bone health. Some common causes include:

- **Endocrine Disorders**: Conditions like hyperthyroidism, hyperparathyroidism, and Cushing's syndrome can lead to secondary osteoporosis.
- **Medications**: Long-term use of corticosteroids, anticonvulsants, or certain cancer treatments can cause bone loss.
- **Gastrointestinal Disorders**: Malabsorption conditions like celiac disease, Crohn's disease, or gastric bypass surgery can impair nutrient absorption, leading to bone weakness.
- **Chronic Diseases**: Conditions such as rheumatoid arthritis, chronic kidney disease, and liver disease can increase the risk of developing osteoporosis.

Types of Bone Cells

Bone cells are specialized cells responsible for the growth, maintenance, and repair of bones. They work together to ensure the continuous remodelling and strength of bone tissue. There are four main types of bone cells:

1. **Osteoblasts**
2. **Osteoclasts**
3. **Osteocytes**
4. **Bone Lining Cells**

Each type of bone cell has distinct roles in the bone remodelling process, which involves the formation, maintenance, and resorption (breakdown) of bone tissue.

1. Osteoblasts

- **Function**: Osteoblasts are the bone-forming cells. They are responsible for synthesizing and secreting the bone matrix, primarily composed of collagen type I, which later mineralizes to form hard bone [2].
- **Formation**: Osteoblasts originate from mesenchymal stem cells (MSCs), which differentiate into pre-osteoblasts and eventually mature into osteoblasts under the influence of growth factors such as bone morphogenetic proteins (BMPs).
- **Location**: These cells are found on the surface of new bone tissue where bone formation is actively occurring.

2. Osteoclasts

- **Function**: Osteoclasts are the bone-resorbing cells responsible for breaking down bone tissue during the process of bone remodelling. They dissolve the mineral components of bone and digest the collagen matrix [3].
- **Formation**: Osteoclasts originate from hematopoietic stem cells (HSCs), the same lineage that produces macrophages and other immune cells. The RANK/RANKL signalling pathway is critical for the differentiation of osteoclast precursors into mature osteoclasts.
- **Location**: Osteoclasts are typically found on bone surfaces where bone resorption is taking place. They form Howship’s lacunae, small pits in the bone matrix, during resorption.

3. Osteocytes

- **Function**: Osteocytes are the most abundant and long-lived bone cells, functioning as mechanosensors that regulate bone homeostasis [4].
- **Formation**: Osteocytes are mature osteoblasts that become embedded in the bone matrix during the process of bone formation. Once trapped in the matrix, they differentiate into osteocytes.

- **Location**: Osteocytes reside in small spaces called lacunae within the bone matrix, connected to one another and the bone surface via microscopic channels called canaliculi.

4. Bone Lining Cells

- **Function**: Bone lining cells are inactive cells that cover the surface of bones where no active bone formation or resorption is taking place.
- **Formation**: These cells are derived from osteoblasts that have completed their bone-forming duties and have not differentiated into osteocytes.
- **Location**: They line the outer surface of bone (periosteum) and the inner surface of bone cavities (endosteum).

Bone Remodelling Cycle

The bone remodelling cycle is a dynamic process responsible for the continuous renewal of bone tissue throughout life. It is essential for maintaining bone strength, mineral homeostasis, and the repair of micro-damages. The process involves two main cell types: **osteoclasts** (which break down bone tissue) and **osteoblasts** (which build new bone). These cells work together to ensure the balance between bone resorption and bone formation, which is critical for skeletal health [5].

Phases of the Bone Remodelling Cycle

1. **Activation Phase**

The remodelling cycle begins with the activation of osteoclast precursors. Signals such as micro-damage to the bone matrix or mechanical stress trigger this phase. Bone-lining cells retract from the bone surface, and pre-osteoclasts differentiate into mature osteoclasts in response to signalling molecules, particularly receptor activator of nuclear factor kappa-B ligand (RANKL) and macrophage colony-stimulating factor (M-CSF) [3].

2. **Resorption Phase**

Mature **osteoclasts** attach to the bone surface, forming a sealed zone and creating an acidic environment through proton pumps that dissolve the mineralized matrix. Cathepsin K, an enzyme released by osteoclasts, degrades the organic bone matrix, which is primarily made up of collagen. This process of bone resorption typically lasts about 2-4 weeks [6].

3. **Reversal Phase**

Following resorption, osteoclasts undergo apoptosis (programmed cell death), and osteoblast precursors are recruited to the resorbed bone surface. During the reversal phase, bone-lining cells and macrophages prepare the bone surface for new bone formation by cleaning the area and depositing a thin layer of matrix proteins. Coupling signals, including transforming growth factor-beta (TGF-β) and insulin-like growth factors (IGFs), are crucial in attracting osteoblasts to the site [7].

4. **Formation Phase**

In this phase, osteoblasts synthesize new bone matrix, which is primarily composed of collagen type I. Osteoblasts produce osteoid (unmineralized bone matrix), which later undergoes mineralization through the deposition of calcium and phosphate, forming hydroxyapatite crystals. This mineralization process strengthens the bone. Some osteoblasts become embedded in the matrix and differentiate into osteocytes, which help regulate bone metabolism [8].

5. **Resting Phase**

Once the bone has been formed and mineralized, the bone surface enters a quiescent state where it is covered by bone-lining cells. This resting phase can last until the next cycle of remodelling is triggered. During this phase, osteocytes embedded in the bone matrix monitor mechanical and biochemical changes, contributing to bone homeostasis [4].

Molecular Regulation of the Bone Remodelling Cycle

- **RANK/RANKL/OPG Pathway**: The interaction between **RANKL** (produced by osteoblasts and stromal cells) and **RANK** (on the surface of osteoclast precursors) is crucial for osteoclast differentiation and activation. **Osteoprotegerin (OPG)**, a decoy receptor secreted by osteoblasts, inhibits this interaction by binding to RANKL, preventing excessive bone resorption [9].

- **Wnt/β-catenin Signalling**: This pathway is vital for osteoblast differentiation and function. **Wnt proteins** bind to receptors on osteoblast precursors, promoting their proliferation and survival. **Sclerostin**, a protein produced by osteocytes, inhibits the Wnt pathway and reduces bone formation, thus regulating the balance between resorption and formation [10].

Imbalance in the Bone Remodeling Cycle

An imbalance in the bone remodelling process can lead to bone diseases. In osteoporosis, for

instance, there is excessive bone resorption without adequate formation, leading to reduced bone density and increased fracture risk [11]. Conversely, diseases like osteopetrosis result from defective osteoclast function, leading to abnormal bone formation and increased bone density.

Osteoporosis-Related Fractures in India

Osteoporosis, a disease characterized by low bone mass and deterioration of bone tissue, increases the risk of fractures, particularly in older adults. The prevalence of osteoporosis-related fractures is increasing due to the aging population and changing lifestyles.

- **Incidence**: A 2019 study estimated that approximately 50 million people in India suffer from osteoporosis, making them highly susceptible to fractures, particularly of the hip, spine, and wrist [12].
- **Hip Fractures**: The incidence of hip fractures is estimated to be 160 per 100,000 people per year in India, and this number is expected to rise due to the increasing elderly population [13].
- **Age and Gender**: Postmenopausal women and elderly men are most at risk. Women over 50 years old are especially prone to fractures due to hormonal changes after menopause, with a lifetime risk of a fracture estimated to be 1 in 3 for women [14].

Lifestyle Factors Contributing in progression of Osteoporosis

1. **Sedentary Lifestyle**
    - **Impact**: Physical inactivity is a major risk factor for osteoporosis. Weight-bearing exercises like walking, running, and strength training are essential to maintaining bone density. Without regular physical activity, bone mass decreases, increasing the risk of fractures.
    - **Solution**: Engaging in regular physical activity, particularly weight-bearing and muscle-strengthening exercises, helps stimulate bone formation and slow bone loss [15].
2. **Poor Diet**
    - **Lack of Calcium and Vitamin D**: A diet low in calcium and vitamin D leads to reduced bone mineralization, weakening the bones.

- **Excessive Salt, Sugar, and Caffeine**: Diets high in processed foods, sugars, salt, and caffeine can cause calcium depletion by increasing calcium excretion through the urine.
- **Solution**: A balanced diet rich in **calcium** (dairy products, leafy greens), **vitamin D** (sunlight, fortified foods, and supplements), and other nutrients like magnesium, phosphorus, and vitamin K is essential for maintaining healthy bones [16].

3. **Smoking**
   - **Impact**: Smoking has been linked to decreased bone density. Nicotine and other chemicals in cigarettes reduce the body's ability to absorb calcium and inhibit bone formation, accelerating bone loss.
   - **Solution**: Quitting smoking helps improve bone health and reduces the risk of developing osteoporosis, as well as many other diseases [17].
4. **Excessive Alcohol Consumption**
   - **Impact**: Heavy alcohol consumption interferes with the balance of calcium, reduces bone formation, and increases the risk of falls, leading to fractures. It also affects hormone levels, which play a key role in bone health [18].
   - **Solution**: Limiting alcohol intake can help maintain bone density and reduce the risk of falls and fractures.
5. **Low Body Weight**
   - **Impact**: People with a low body mass index (BMI) or those who are underweight are at higher risk of osteoporosis. Low body weight reduces the mechanical stress on bones, which is necessary to stimulate bone growth [19].
   - **Solution**: Maintaining a healthy body weight through a balanced diet and regular physical activity helps ensure bones remain strong.
6. **Hormonal Imbalances**
   - **Impact**: Estrogen plays a crucial role in maintaining bone density. After menopause, women experience a sharp drop in estrogen levels, accelerating bone

loss. Similarly, testosterone levels in men affect bone health, and low levels can increase the risk of osteoporosis [20].

- **Solution**: Hormonal imbalances should be addressed through medical advice.

7. **Excessive Stress**

- **Impact**: Chronic stress can lead to elevated levels of cortisol, a hormone that, in high amounts, can cause bone loss. Additionally, stress often leads to unhealthy habits such as poor diet, smoking, and lack of exercise, further increasing the risk of osteoporosis [21].
- **Solution**: Managing stress through relaxation techniques, physical activity, meditation, or therapy can help reduce the negative effects on bone health.

Diagnosis for Osteoporosis

Osteoporosis is primarily diagnosed through bone mineral density (BMD) testing. DXA remains the gold standard for measuring BMD and assessing fracture risk. Other diagnostic tools include biochemical markers of bone turnover and vertebral imaging to detect asymptomatic fractures [22].

- **DEXA (BMD) Scan**: A DEXA scan is the gold standard for diagnosing osteoporosis. It measures bone density in the spine, hip, and sometimes the forearm. The results are given as T-scores:
  - **Normal**: T-score of -1.0 or above.
  - **Osteopenia** (low bone mass): T-score between -1.0 and -2.5.
  - **Osteoporosis**: T-score of -2.5 or lower.

The DEXA scan is non-invasive, painless, and uses very low levels of radiation

Prevention and management of osteoporosis through balanced Diet.

Diet plays a critical role in the prevention and management of osteoporosis, a condition where bones become weak and more prone to fractures. Consuming a variety of nutrient-rich vegetables and fruits as part of a balanced diet can help **maintain bone density** and **reduce the risk of osteoporosis**. These foods provide essential nutrients such as calcium, magnesium, vitamin K, vitamin C, and antioxidants, all of which are crucial for bone health.

1- Key Vegetables and Fruits for Bone Health

1. Leafy Green Vegetables

Leafy greens are packed with calcium, magnesium, and vitamin K, which are vital for bone health.

- **Examples**: Kale, spinach, bok choy, collard greens, mustard greens, and turnip greens.
- **Benefits**:
    - **Calcium**: Crucial for bone formation and strength.
    - **Vitamin K**: Helps regulate calcium in the bones and supports bone mineralization, reducing the risk of fractures [23].

2. Cruciferous Vegetables

Cruciferous vegetables are high in calcium, magnesium, and vitamin C, all of which are essential for bone strength and collagen production [24].

- **Examples**: Broccoli, cabbage, Brussels sprouts, and cauliflower.
- **Benefits**:
    - **Calcium**: Supports bone density.
    - **Vitamin C**: Promotes collagen formation, which is a key component of the bone matrix.

3. Root Vegetables

Root vegetables are good sources of minerals such as potassium and magnesium, which help maintain bone health by neutralizing acids that can leach calcium from the bones.

- **Examples**: Sweet potatoes, carrots, beets, and turnips.
- **Benefits**:
    - **Magnesium**: Helps convert vitamin D into its active form, which supports calcium absorption.
    - **Potassium**: Balances the effects of a high-sodium diet, reducing calcium loss from bones.

4. Citrus Fruits

Citrus fruits are rich in vitamin C, which is important for the production of collagen, a protein that gives bones their flexibility and structure [25].

- **Examples**: Oranges, lemons, limes, and grapefruits.
- **Benefits**:
    - **Vitamin C**: Promotes collagen formation, which is essential for maintaining the bone matrix.
    - **Antioxidants**: Help protect bone cells from oxidative stress.

5. Berries

Berries are packed with antioxidants and vitamin C, both of which support bone health by reducing oxidative stress and promoting collagen synthesis [26].

- **Examples**: Strawberries, blueberries, blackberries, and raspberries.
- **Benefits**:
    - **Antioxidants**: Protect bones from oxidative damage, which can weaken bones over time.
    - **Vitamin C**: Enhances collagen production and bone formation.

6. Apples

Apples are rich in flavonoids such as quercetin, which have anti-inflammatory properties that can help protect against bone loss [25].

- **Benefits**:
    - **Flavonoids**: Help reduce inflammation and oxidative stress, both of which contribute to bone degeneration.
    - **Potassium**: Aids in calcium retention, which is important for bone density.

7. Bananas

Bananas are an excellent source of potassium, which helps prevent the loss of calcium from bones [27].

- **Benefits**:
    - **Potassium**: Supports calcium retention and helps regulate bone metabolism.
    - **Magnesium**: Important for maintaining bone density and promoting the proper functioning of osteoblasts (bone-forming cells).

8. Prunes

Prunes are rich in vitamin K, boron, and potassium, all of which contribute to bone health. Research shows that consuming prunes regularly may help slow bone loss.

- **Benefits**:
    - **Vitamin K**: Important for bone mineralization.
    - **Boron**: Plays a role in calcium metabolism and bone maintenance.

9. Figs

Figs are an excellent plant-based source of calcium and magnesium, both of which are important for bone strength.

- **Benefits**:
    - **Calcium**: Strengthens bone and supports bone formation.
    - **Magnesium**: Helps in converting vitamin D into its active form, which is essential for calcium absorption.

10. Tomatoes and Bell Peppers

Tomatoes and bell peppers are rich in vitamin C and lycopene, both of which are important for protecting bone cells from damage.

- **Benefits**:
    - **Lycopene**: An antioxidant that may protect bones from oxidative stress.
    - **Vitamin C**: Helps in collagen production, which provides a framework for strong bones.

Nutrients in Vegetables and Fruits that Support Bone Health

1. **Calcium**: Vital for the formation and maintenance of strong bones. While dairy is a well-known source, many vegetables like kale, broccoli, and figs also provide calcium.
2. **Magnesium**: Found in leafy greens, bananas, and root vegetables, magnesium helps with calcium absorption and bone formation.
3. **Vitamin K**: Important for bone mineralization, and it helps direct calcium into bones. Leafy greens and prunes are rich sources of vitamin K.
4. **Vitamin C**: Found in citrus fruits, berries, and peppers, vitamin C promotes collagen production, a key component of bone structure.

5. **Potassium**: Helps maintain the acid-base balance in the body, preventing the loss of calcium from bones. Foods like bananas, sweet potatoes, and tomatoes are good sources.

6. **Antioxidants**: Found in berries, apples, and citrus fruits, antioxidants protect bone cells from damage caused by oxidative stress [25].

Prevention and Management of Osteoporosis through Lifestyle Changes.

1. Regular Physical Activity

- **Weight-Bearing Exercises**: These include activities such as walking, jogging, climbing stairs, and dancing, which help build bone mass by stimulating bone-forming cells (osteoblasts) [32].
- **Strength Training**: Lifting weights or resistance exercises improve muscle strength and stimulate bones to maintain density.

2. Balanced Diet

- **Calcium-Rich Foods**: Include dairy products like milk, yogurt, and cheese, as well as leafy green vegetables, tofu, and fortified plant-based milk [33].
- **Vitamin D**: Get adequate sunlight exposure and include vitamin D-fortified foods such as orange juice, cereals, and fatty fish (salmon, mackerel).
- **Other Nutrients**: Ensure intake of magnesium (nuts, seeds, leafy greens), vitamin K (broccoli, kale), and protein (lean meats, legumes) to support bone health.

3. Avoidance of Unhealthy Habits

- **Quit Smoking**: Stopping smoking reduces bone loss and improves overall health.
- **Moderate Alcohol Consumption**: Limiting alcohol to moderate levels (up to one drink per day for women and two for men) helps prevent bone deterioration.

4. Stress Management

- **Mental Health**: Practicing mindfulness, meditation, and relaxation techniques can reduce stress, lowering cortisol levels that may negatively impact bone health [34].

5. Bone Density Monitoring

- **Bone Density Tests (DEXA Scan)**: Regular bone density screenings, particularly for postmenopausal women and older adults, help assess the risk of osteoporosis and the need for lifestyle adjustments or treatment.

Pharmacologic Interventions

- **Bisphosphonates**: These drugs inhibit osteoclast-mediated bone resorption, thus preserving bone mass. Studies have shown that bisphosphonates such as alendronate and risedronate reduce fracture risk in osteoporotic individuals [28].
- **Denosumab**: A monoclonal antibody that inhibits the RANKL pathway, essential for osteoclast formation. Clinical trials have demonstrated its efficacy in reducing vertebral, non-vertebral, and hip fractures [29].
- **Selective Estrogen Receptor Modulators (SERMs)**: Drugs like raloxifene mimic estrogen's bone-preserving effects without stimulating breast or uterine tissues. They are particularly useful in postmenopausal women [30].
- **Parathyroid Hormone (PTH) Analogues**: Teriparatide is an anabolic agent that stimulates bone formation and improves bone strength in patients with severe osteoporosis [31].

Conclusion

Osteoporosis is a significant public health issue, with serious implications for individuals' quality of life due to fracture risk. Early diagnosis through BMD screening and the implementation of both pharmacologic and lifestyle interventions are essential in managing the disease. Continued research is necessary to develop novel treatments that target the molecular pathways involved in bone remodelling.

Variety of fruits and vegetables in your diet is an effective way to prevent and manage osteoporosis. The nutrients in these foods—especially calcium, magnesium, potassium, vitamin C, and vitamin K—are essential for maintaining bone density and promoting overall bone health. Combined with regular exercise, a plant-rich diet can significantly reduce the risk of osteoporosis and related fractures.

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