

# Osteoporosis - The Importance of Screening

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## Objectives

1. Describe the basic structure of bone and the cells and hormones involved in bone construction and remodeling.
2. Explain what the risk factors are developing osteoporosis and the impact of this disorder on the healthcare system.
3. Discuss the symptoms seen when osteoporosis occurs, the effectiveness of available diagnostic modalities, and the current potential treatment options.

## Article

### Osteoporosis – The Importance of Bone Mineral Density Testing

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## Introduction

As the average age of the population increases, metabolic degenerative bone diseases are a major health problem in today's society. Osteoporosis can decrease a person's quality of life by producing pain and promoting immobility. With the advancement of diagnostic tools, the treatment and prevention of osteoporosis are now viable options for improving a patient's overall clinical status. Bone mineral density testing provides a reliable and accurate mechanism for diagnosing and assessing treatment. To better understand osteoporosis, this article will review how bone is created, and will cover the basic structure of bone and what factors increase the risk for developing this disorder.

## Bone Construction

People usually think their bones are an unshakable foundation. However because our skeletal structure isn't completely solid, it needs a balance of minerals and hormones in order to stay strong. The body balances the process of building new bone and removing old bone through the actions of the hormones and minerals discussed below.

"Os" is the Latin word for bone and thus, ossification refers to the formation of bone cells and the deposition of calcium phosphate about these cells and their processes. Bone is composed of living cells that contain intercellular substances that are calcified. Bone composition in the average adult consists of inorganic matter or bone mineral (which accounts for about 60% to 70% of total bone volume), water (which is only 5% to 10% of the volume) and organic matter or cells (which account for the remaining 25% to 30%). There are 3 basic types of bone cells, which are:

- Osteoblasts – Immature bone cells that are active in the production of new bone. These cells contribute to the initial formation of bone and the repair of fractured bone.
- Osteoclasts – Large cells with multiple nuclei that are associated with bone resorption and that have the ability to release enzymes that digest protein.

- Osteocytes – The principle cell of mature bone. These cells are osteoblasts that have become surrounded by bone matrix, but they are still connected to the blood supply by a series of canaliculi.

The bone mineral of the matrix primarily contains the elements of calcium, phosphate, and hydroxylate. Even after bone growth is completed, osteoblastic and osteoclastic activity continues. Thus, bone is continually being deposited and resorbed. The resorption phase in most bone is usually more intense, but it does not last as long as the formation phase. Therefore, under normal circumstances, there are usually more sites of active formation than of resorption. Osteoporosis may be related to an imbalance in this process, with more resorption occurring than formation.

Before we move on to the structure of bone, three hormones should briefly be discussed. The first is parathyroid hormone, which is produced by the parathyroid glands. The function of this hormone is to maintain the extracellular calcium level. When the blood level of calcium drops, parathyroid hormone levels increase. This hormone will increase osteoclastic activity (resulting in the breakdown of bone, thereby releasing calcium into the bloodstream); will decrease the kidney clearance of calcium (which results in more calcium being saved by the kidney); and will increase the production of active vitamin D (which increases the absorption of calcium from the intestine). Therefore, an elevated level of parathyroid hormone can result in the loss of bone mass.

Calcitonin is a hormone that opposes parathyroid hormone. It will lower the level of calcium in the blood by decreasing bone resorption and by increasing the renal clearance of calcium. Calcitonin is produced by the C-cells of the thyroid gland. The last hormone is vitamin D, which is really a hormone rather than a vitamin. The active form of vitamin D (which is 1,25-dihydroxy-vitamin D) helps improve the absorption of calcium from the intestine and works with parathyroid hormone on bone.

### **Structure of Bones**

Though many different classifications and sub-classifications for bones exist, for the purpose of discussing structure, the two main categories are long bones and flat bones. Long bones develop as a central portion called the diaphysis. At each end of the diaphysis, there is a zone of growth called the metaphysis. The other separate centers of bone formation are found at the two ends called the epiphyseal discs. In the adult, the epiphyseal discs have joined the metaphysis portion of the diaphysis to form one long bone. The shaft of these long bones is covered by the periosteum, which is a tough fibrous layer that is continuous at the ends with the joint capsule, but does not cover the articular cartilage. The shaft of the long bones consists of compact bone (which lies under the periosteum) with a central cavity called the medullary cavity. A thin layer of cells called the endosteum lines this medullary cavity.

Bone that consists of irregular anastomosing bars that is porous and loosely constructed, like a sponge, is called cancellous bone. Cancellous bone is found in flat bones, in the vertebral bodies, and at the junction of the metaphysis and epiphyseal discs in the long bones. The bone marrow is the tissue that occupies the medullary cavity of the long bones and the trabecular spaces within the cancellous bone. Red bone marrow is responsible for the formation of red blood cells and some forms of white blood cells. As time progresses, the amount of fat within the red marrow begins to increase, which results in a decrease in the production of red cells. This form of bone marrow is called yellow bone marrow.

### **Osteoporosis and its Risk Factors**

Osteoporosis is a condition characterized by a loss of bone density (or rarefaction). It may also be described as a reduction in the amount of calcified bone mass per unit volume of skeletal tissue. Osteoporosis is a preventable condition that causes bones to become fragile and overly susceptible to fractures. By the age of 30 to 35 the largest amount of bone mass in the body has developed for most people. In men, there is gradual decline in this bone mass that continues until death. For women, this maximum bone mass level plateaus until menopause. Once menopause has occurred, the production of estrogen greatly decreases causing the symptoms of vasomotor instability (or hot flashes). However, estrogen also plays a role in bone metabolism in that it facilitates the absorption of calcium from the intestine into the bloodstream, it decreases the urinary excretion of calcium, and it inhibits the loss of calcium from bone. Thus, a decrease in estrogen allows the osteoclasts (cells that remove old bone) to become more active than the osteoblasts (cells that build new bone), leading to a faster rate of bone loss (a rate of decline that is greater than that seen in men). This rapid decrease in bone mass for women leads to a greater potential for developing osteoporosis later in life.

The average age for menopause to occur is 51. Without treatment, women can lose up to 20% of their bone mass in the

first 5 to 7 years after menopause. Osteoporosis affects about half of all women in the United States over the age of 50. For women in the high-risk categories, thinning or weakened bones are not strong enough to withstand everyday activity and fractures can occur. It is estimated that 1.3 million fractures are caused by osteoporosis each year in the United States. The most common bones for fracture due to osteoporosis are the vertebral bodies in the spine, followed by the head of the femur (hip) and the bones of the wrist. Factors that can increase the risk for developing osteoporosis include:

- Natural menopause
- Iatrogenic menopause (i.e. removal of the ovaries)
- Heredity (history of broken bones in older relatives)
- Physique (small-boned or very slender individuals)
- Asian or Northern European descent
- Smoking
- Substance Abuse (alcohol and some illicit drugs)
- Certain diseases, such as hyperthyroidism and diabetes mellitus
- Prolonged usage of glucocorticoid drugs and heparin

The amount of bone mass that is present when skeletal growth is complete will play a role in the amount of bone that is present later in life. Therefore, if a person is small-boned to begin with, his or her risk for developing osteoporosis is greater. In addition, the bone mineral content in African-American men and women is greater than that (on average) of Caucasian and Asian men and women (which is one of the reasons why osteoporosis is not as common in the African-American population).

The primary source of estrogen production in women is from the ovaries. However, some estrogen can be produced in fat cells. If a woman (or a man) is overweight, there will be a higher level of circulating estrogen, which again would have a protective effect on bone. Likewise, a thin person would have lower levels of estrogen production. Cigarette smoking and excess alcohol consumption appear to directly affect new bone formation, which results in an overall net decrease in the amount of bone.

Prolonged usage of the anticoagulant, heparin, has been associated with osteoporosis because the drug appears to potentiate bone resorption. The rate of bone resorption reverts to normal when the heparin usage is discontinued. A similar finding of excessive bone resorption occurs in patients with hyperthyroidism. However, if the hyperthyroidism is adequately treated, the rate of bone resorption again returns to normal.

The exact cause for a higher level of osteoporosis in patients with diabetes mellitus is uncertain. However, the altered glucose metabolism seen in diabetics has a global effect on numerous bodily functions. Therefore, the higher level of osteoporosis in patients with diabetes is probably related to a general decrease in effective bone formation. The bone loss seen in patients with prolonged usage of glucocorticoid drugs is accounted for by a combination of decreased bone formation (because these drugs depress collagen synthesis and delay wound healing) and a higher rate of bone resorption.

One unique disorder that warrants a brief discussion is the "female athletic triad" (excessive physical activity, amenorrhea, and osteoporosis). This disorder consists of related problems that can result in the development of osteoporosis at a younger age. Female Athletic Triad is often precipitated by the participation of a woman in a particular sport that results in a chronic amount of extreme exertion (such as marathon running). The overly excessive activity can result in the lack of ovulation. When ovulation does not occur, menstrual flow will cease (amenorrhea) and the production of estrogen by the ovary greatly diminishes (similar to what occurs in menopause). This drop in estrogen allows for the onset of osteoporosis to occur at a much younger age. Women in their thirties have been found to have bone mineral density testing that was equivalent to a female of approximately fifty years of age. A similar problem is also seen in women who exercise extreme diet control for pathologic reasons (anorexia or bulimia) or for an activity that values a particular body physique such as modeling, cheerleading, and figure skating. The extreme diet control can also lead to a lack of ovulation and the development of early onset osteoporosis, as described above.

### **Diagnosing Osteoporosis**

In the majority of cases, the loss of bone mass is an asymptomatic process (no symptoms) until a fracture occurs. A broken bone, for some women, may be the first warning sign that osteoporosis has occurred. An x-ray of a fractured bone that occurred from a minor jolt or a simple fall may confirm the extent to which the break was caused by deterioration of the bone structure. Other signs and symptoms related to osteoporotic related fractures include:

- Backache – because the vertebrae (bones of the spine) are the most common sites of fracture in osteoporosis, early symptoms related to these fractures are a persistent lower backache and or muscle spasm.
- Loss of height – anywhere from 2 ½ inches up to 8 inches in height can be lost once the vertebral bones begin to break.
- "Dowager's or Widow's Hump" – which is a distortion of the spine's natural curvature in association with a loss of height due to vertebral fractures. The upper back protrudes (exaggerated cervical lordosis) and the chest area is shortened leaving the ribs practically sitting on the pelvic region.

In regard to diagnostic modalities, Quantitative Computerized Tomography (QCT) produces images of the vertebral bodies, but should not be relied upon as a basis for treatment because of its poor precision (reproducibility). It is relatively unreliable for following bone density changes post treatment, and it does not measure femoral neck density.

Ultrasound can be applied to various areas and is portable and radiation free. Although, ultrasound can image such bones as the patella, tibia, or radius, it does not measure bone density. Instead, it assesses characteristics of sound attenuation and speed of transmission through bone. Because ultrasound results for a given individual may vary greatly, this modality should not be used to follow a patient for changes in bone density. Therefore, ultrasound should not be relied upon for managing a patient that may have or is developing osteoporosis.

Dual Energy X-Ray Absorptiometry (DEXA) scanning is currently the most reliable source for assessing and diagnosing osteoporosis. It is the procedure of choice for the medical community because:

- It uses minimal amounts of radiation
- It has a high degree of precision (reproducibility). (In addition, each time a patient returns for a follow-up scan, the prior analysis can be used to determine if a change has occurred.)
- It measures both the lumbar spine and femoral neck. (The precision is around 1% for the spine and 2% to 3% for the femoral neck region.)
- It allows for standardization of data based on age, weight, height, and ethnic background.

A comprehensive DEXA scan report can include the demographic data on the patient, the radiographic images, a detailed analysis of the results, reference population graphs, and referring physician information (figure 1). Because DEXA scans are computer-based programs, these bone mineral density (BMD) test results have the ability to be transmitted over a computerized network and be archived on "picture archiving communication systems" (PACS) that can be referenced for distribution to others on the PACS network.

Bone mineral density tests help in diagnosing osteoporosis and are more sensitive than ordinary x-rays by detecting bone loss at an earlier stage. Normal x-rays are not sensitive enough in detecting bone loss until at least 30% of bone mass has been lost. Because osteoporosis is asymptomatic in its earlier stages, the importance of such testing cannot be overemphasized. Establishing a baseline for bone mineral density is of vital importance for all women as they make the transition from monthly ovulatory cycles to the menopausal stage and for athletes in the early stages of training.

### **Osteoporosis Treatment and Prevention**

Osteoporosis has become a high priority health issue in the United States. As the average age of the population increases the number of senior citizens with this disorder will also increase. By the year 2000, there were over 50 million people in the United States over the age of 50. This means that osteoporosis is a problem that will be seen more frequently in the years to come and its prevention and treatment are of great importance.

Because menopause is the primary time period of concern for women, being aware of its onset is important. Normal ovulation usually results in regular periods. When menstrual cycles become irregular as age progresses, this could be an indicator that menopause is soon approaching. It is important for women to be aware of this time period in order for them to be followed closely by the healthcare system and initiate treatment and education on ways to minimize the development of osteoporosis.

Treatment usually consists of vitamin D, adequate calcium intake, exercise, and possibly hormone replacement therapy (primarily for postmenopausal women). An exercise program that is designed for strengthening the back and hips in order to maintain flexibility and a steady gait is often recommended. It is recommended that men over the age of 50 and postmenopausal women (who are on estrogen replacement) take 1000 mg of elemental calcium per day. Postmenopausal women not on estrogen replacement should take 1500 mg of elemental calcium per day. However, the

preservation of bone mass in postmenopausal women not on estrogen replacement is lower than those women who use estrogen, despite a higher amount of calcium intake.

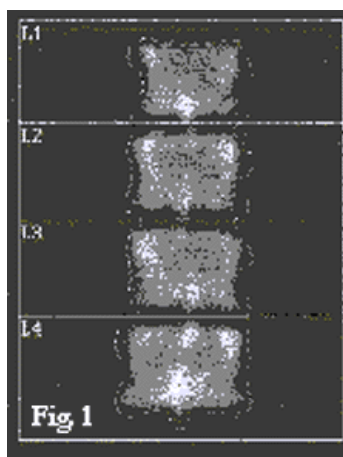
Some postmenopausal women cannot take estrogen for medical reasons. Fortunately, research in the area of osteoporosis has resulted in the development of newer medications (called selective estrogen receptor modulator drugs – SERM drugs) that stimulate estrogen receptors in bone and decrease the resorption process. These drugs and others may eventually play a major role in the treatment and prevention of osteoporosis in women.

For severe spinal fractures caused by osteoporosis, one available treatment option is percutaneous vertebroplasty (PVP). This treatment was developed in 1984 in France and is a non-surgical procedure performed under local anesthesia using fluoroscopic or CT guidance to place a needle into the spinal fracture site. Once the area is localized, an injection of acrylic cement is used to fill and reinforce the broken vertebrae, which strengthens the spine and reduces the patient's chronic pain.

Osteoporosis is a devastating disease. Eighty percent of all hip fractures are associated with osteoporosis. Once a fracture occurs, only 50% to 60% of patients maintain their current activity levels, approximately 20% lose mobility and another 20% are institutionalized. In most studies, between 10% and 20% of patients with a hip fracture die due to the fracture or its complications (surgical, cardiopulmonary, or embolic) within three months. Because of this statistic and others mentioned in this article and the fact that the population of the United States is becoming older, knowledge about the risk factors for osteoporosis, how the problem should be screened and followed, and the available prevention options is of extreme importance to the healthcare profession.

### Figures

1. This is an example of a DEXA scan of the lumbar spine from L1 to L4. The patient is a Caucasian Female – Age 59 – Height of 5 feet 2 inches – Weight of 105#. The table compares her scan, matched by age and sex.



Region	Area (cm <sup>2</sup> )	BMD (grams)	BMD (gms/cm <sup>2</sup> )	T	Z
L1	10.45	10.05	0.962	+0.34 (104%)	+1.54 (121%)
L2	12.76	12.04	0.944	- 0.76 (92%)	+0.57 (107%)
L3	12.95	12.85	0.992	- 0.83 (92%)	+0.57 (107%)
L4	15.00	15.05	1.003	- 1.02 (90%)	+0.42 (105%)
L1 – L4	51.16	49.99	0.977	- 0.63 (93%)	+0.73 (109%)

T = Peak bone mineral density matched for age, weight, height, and ethnicity

Z = Average bone mineral density matched for age, weight, height, and ethnicity

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### About the Author(s)

Theresa D. Roberts, MHS, RT(R)(MR), graduated from Quinnipiac College with a Master in Health Sciences. She is a Registered Radiologic Technologist specializing in magnetic resonance imaging and is employed as the Imaging Systems Manager at Hollywood Medical Center. She completed her undergraduate studies at New Hampshire College receiving a Bachelors of Science in Human Resources. She then attended South Central Community College receiving her Associates of Science in Radiologic Technology. She has 10 years experience as an educator and prior to her management position, held the position of Assistant Professor of Radiologic Sciences at Quinnipiac College and Miami-Dade Community College.

Dr. Towers is currently Professor and Vice Chair of the Department of Obstetrics & Gynecology at University of Tennessee Medical Center Knoxville in the Division of Maternal-Fetal Medicine. He is still clinically active managing numerous high-risk pregnancies. He is also actively involved in research with over 90 publications in major medical journals. Though his research has spanned many areas in obstetrics, he has primary interests in drugs in pregnancy, infections in pregnancy, fetal heart monitoring, bleeding in pregnancy, and fetal lung maturity.

He has authored a book for consumers regarding the safety of over-the-counter medications that are used in treating the common cold entitled "I'm Pregnant & I Have a Cold – Are Over-the-Counter Drugs Safe to Use?" published by RBC Press, Inc. He is also one of the new Editors of the reference book for clinical care providers entitled "Drugs in Pregnancy and Lactation, published by Wolters & Kluwer.

