CHANGING THE FACE OF OSTEOPOROSIS

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A THESIS

Presented to the Department of Biology
and the Honors College of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Bachelor of Arts

May 1998

Approved: [redacted]

V. Pat Lombardi

An Abstract of the Thesis of

Sarah Marie Hollopeter for the degree of Bachelor of Arts
in the Department of Biology to be taken May 1998

Title: CHANGING THE FACE OF OSTEOPOROSIS

Approved: [redacted]
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Osteoporosis, a bone deteriorating disease, is often referred to as a silent disease because it typically goes unnoticed and untreated until it is too late. Although its hidden and slow route of action has given it this title, the number of victims suffering from this widespread disease are staggering. It afflicts an estimated 25 million Americans, 80% of whom are women. With the elderly population growing rapidly, and few ways to detect and effectively fight osteoporosis in medical practice, it appears that osteoporosis may be one of the major epidemics of the 21st century.

However, recent scientific studies on the life cycles of bone tissue have revealed a window of opportunity in the fight against osteoporosis. These studies suggest that although osteoporosis has always been treated as a geriatric disease, it is now time to view it as having a strong pediatric component. In fact, osteoporosis is now being referred to as a pediatric disease by many individuals in the

scientific community. With this recent insight, it is now time to attack this disease with a novel approach. If osteoporosis begins in adolescence, we must redirect our energy and resources at preventing the onset of this debilitating disease by focusing on the youth in our communities. It is time to change the face of osteoporosis.

ACKNOWLEDGMENTS

I am continually amazed with certain faculty members on this campus. Dr. Lombardi has taken the time from his hectic schedule of balancing teaching, research, and raising a family to aid me in this thesis. I truly appreciate that I had the opportunity to have him as an advisor, as well as an instructor. I also owe a warm thank you to Annie Dochnahl for her advise and encouraging words. She has also been a highly valued instructor in my undergraduate education and for my Honors College Thesis. Both Dr. Lombardi and Annie Dochnahl accepted my request for their help as advisors without really knowing what they were committing themselves to. I will certainly not forget their time and generosity, and it humbles me to know that I can't properly return this favor.

DEDICATION

I would like to dedicate my hard work and time spent on this Honors College Thesis to my grandmother, Maxine Spitler. Despite her shrinking frame that currently just reaches five feet with her shoes on, her strength continues to amaze me. I hope that as I grow old, I will be as young at heart as she remains to this day.

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CHAPTER 1

INTRODUCTION

Every year, hundreds of thousands of men and women are surprised to learn that they are victims of a silent, degenerative bone disease called osteoporosis. Osteoporosis afflicts an estimated 25 million Americans, 80% of whom are women. One in two post-menopausal caucasian women will experience an osteoporotic fracture in her remaining lifetime. In fact, the lifetime risk for a woman to incur an osteoporotic hip fracture is greater than her combined lifetime risk of breast, ovarian, and endometrial cancer. The risk of suffering from osteoporosis also exceeds the risk of heart disease for women over the age of 50 and more people will break their hips each year than sustain a stroke. [2]

The actual number of people that are directly affected by osteoporosis are truly amazing. Most people in their teenage and college age years have come across the haunting silhouettes of older women hunched over and walking painfully. These are common associations and images of osteoporosis.

A young adult, for example, would never associate themselves or their daily habits with an elderly disease like osteoporosis. However there has been a recent surge in the appearance of extensive studies on bone mass and bone density in a wide range of young adults, indicating some novel ideas about how best to prevent bone loss. Instead of focusing on the bone loss that naturally occurs with the aging process, it is now being suggested that the entire life cycle of bone tissue be considered.

A much more important component in determining an individuals bone health during their elderly years appears to be a person's peak bone mass following puberty. Various types of behaviors that affect an adolescent's peak bone mass can be used as a major determinant of whether or not an individual is at risk for developing osteoporosis almost forty to sixty years later in life. These studies indicate that we have been focusing on the wrong years in a person's lifetime to truly prevent osteoporosis.

At several places throughout recent literature on bone health, words like, "osteoporosis" and "pediatric behavior," occur in the same sentence. How could this be, though, when most of the medical care system and the public health programs still present osteoporosis as a disease of the elderly? This Honors Thesis assesses the current research pertaining to osteoporosis and specifically the possible effects of an individual's adolescent bone mass in determining their future bone health. Included is a complete and concise review of the scientific literature suggesting that osteoporosis has a pedantic link, which naturally leads to the demand of a novel and preventative approach. In the hopes that this information is not solely destined to a life on the shelf of the Robert D. Clark Honors College Library, several offers to present this knowledge to students on this college campus, to parents in this community, and most importantly, to adolescents in the surrounding public schools have been made, during the corse of this thesis project. Finally, a model for an education based preventative approach in the public shcools is provided.

CHAPTER 2

PYSIOLOGY OF BONE

To understand the mechanisms behind osteoporosis and in order to explain how it has become recognized as a pediatric disorder, it is primarily important to examine how bone is formed and maintained in the human body. Two hundred and six individual bones make up the human skeletal system and serve a vast array of crucial functions in the body. Five main functions that are associated with the skeletal system, are support, protection of vital internal organs, locomotion, manufacture of blood cells, and storage of calcium and phosphate ions. Ions are small particles that carry an electrical charge. [6]

Humans have an axial skeleton, which supports the main body axis and includes the bones in the skull, the ribs, sternum, and the vertebra. Humans also have an appendicular skeleton, which supports the appendages and includes all of the bones in the arms and legs. Together, the axial and appendicular skeleton make up the 206 individual bones in the humans body. [11]

The two types of skeletal tissue in bone are cortical bone and trabecular bone. Cortical bone, commonly called compact bone, is more densely packed and includes approximately 80% of all skeletal tissue. On the other hand, trabecular bone, also called spongy bone, is much more sensitive to the aging process and is mainly concentrated in the spine and at the end of long bones. As the relative proportion of trabecular bone increases at certain sites in the skeleton, so does the incidence of fractures from osteoporosis. [6]

Our bones are a marvelous achievement of evolutionary engineering. By serving so many various functions in the body, bone must have the perfect balance of highly specific characteristics. For example, to allow quick movement and support, bones must be both light and solid. Even further, bone has to allow for flexibility to ensure that it does not shatter, but rather bend and change shape in response to strong forces. Most importantly, however, bone must correspond with the environment inside and outside of the body, in order to quickly adapt to the body's needs and to properly serve its various roles. [9]

In order to understand how bones are able to accomplish what appears to be so many different and competing roles, it is crucial to first recognize the structure and the components of bone tissue. Bone is comprised of a combination of matrix and mineral. Overlapping fibers of collagen, a stringy protein, arrange to form the soft bone matrix and spaces in the bone. Crystals of calcium, phosphorus, and water fill these spaces within the matrix. The matrix allows the bone tissue to bend rather than shatter under force, while the mineral crystals provide the bone with its strength. The soft matrix is deposited first and then the minerals are added, in a process known as mineralization or calcification. [9]

The living and working cells in the bones

It is crucial to note, nevertheless, that bone tissue is not merely a combination of matrix and minerals. Bone is a living tissue that undergoes a specific life cycle and contains living cells that are embedded throughout the matrix. The three types of bone cells involved in the bone's life cycle are osteoblasts, osteoclasts, and osteocytes. [6]

Osteoblasts are responsible for forming the bone matrix, while osteoclasts break down calcified bone in a process known as resorption. As the bone matrix formed by the osteoblasts becomes mineralized, the osteoblasts get buried by the surrounding matrix. These entrapped osteoblasts, are now referred to as the third type of bone cells, called osteocytes. Although these cells lose their ability to build new bone matrix they begin to regulate the calcium exchange between the bone and the blood. [9]

Almost all bone tissue is organized into individual units called osteons. Osteon bone units run parallel along the long axis of bones. Each osteon consists of a central canal containing a blood vessel and layers of concentrically arranged lamellae. Llamellae are simply layers of embedded osteocytes in the bone matrix that they deposited around themselves, while formerly acting as osteoblasts. Osteoblasts are found along the outter surface of the bone and connect with the layers of entrapped osteocytes to form an interconnecting cell network. This network of cells is responsible for communicating and tranfering material between the minealized bone and the blood vessels in the central canals. [6]

Bone is a highly organized tissue and although its three cell types may first appear simplistic, bone is actually a highly complicated tissue. However, to briefly summarize, osteoblasts are the bone-building cells, osteoclasts are the cells responsible for resorption, and osteocytes regulate calcium exchange between bone tissue and the extracellular matrix. [6]

Bone in a constant state of flux: Growth, modeling, and remodeling

Bone was originally regarded as a permanently fixed structure. However, bone is now being viewed as a shifting organ that is continually undergoing adaptive activities. In fact, throughout life, bone is in a constant state of flux. This dynamic condition involves the three processes of growth, modeling, and remodeling. During a person's life span, a single process may dominate the other two at specific times, or all three operations may function concurrently at times. [5] No single bone cell type can accomplish any of the skeletal adaptation processes without the help of the other bone cells. All three types of bone cells work together to allow bone thickness and length to increase during growth, bone strength to adapt to use during modeling, and bone resorption to occur during remodeling.

In the human body, growth is marked by a net synthesis of proteins which involves lengthening of the long bones and an increase in the number and size of cells throughout the body. The activity of growth, in direct relation to bone, is defined as the enlargement of the entire skeleton. It is important to point out that growth is not a constant process throughout a person's lifetime. In addition, there are several different considerations responsible for triggering skeletal growth, which include hormonal, genetic, and environmental factors. [6]

Children exhibit a postnatal growth spurt, in the two years following birth and a pubertal growth spurt during adolescence. (Figure 1) During puberty, there is a remarkable acceleration in linear growth that occurs because of the lengthening of the long bones. The pubertal growth spurt begins at approximately the age of thirteen in boys and the age of eleven in most girls. Although the exact mechanisms that are accountable for this growth spurt are not entirely understood, scientists do know several factors that are involved in determining various characteristics of this growth period. [11]

It appears that the timing and the length of the pubertal growth spurt are controlled by the release of growth hormones and sex hormones. Growth hormones are able to promote bone growth in both length and thickness. For bones to grow in length, growth hormones promote the proliferation of cartilage at each end of a bone. This cartilage containing region at the ends of bones are known as the growth plates or more specifically the epiphyseal plates. Growth hormone causes the epiphyseal plates to expand outward, towards the distal ends of the bone.

As the epiphyseal cartilage stretches outward, the diaphysis, or the uniform shaft that runs along the main length of the bone expands to replace the old epiphyseal cartilage with newly formed bone tissue. Even during growth, osteoblasts must cooperate with osteoclasts to ensure that bone lengthens properly. Osteoblasts work to deposit new bone while osteoclasts break down the old cartilage cells that previously defined the location of the growth plate. [11]

As bone also grows in thickness, new bone is added on top of the already existing bone to its outer surface. As the osteoblasts, or bone-building cells, begin to deposit new bone on the outer surface, osteoclasts, or the bone-breaking cells, dissolve the bone tissue along the inner shaft of the bone. The tissue that runs down the center of the bone's shaft is called marrow. This marrow cavity is responsible for yet another of bone's crucial functions, the production of blood cells. It is important that as bone grows in thickness on its outer surface, that the marrow cavity is enlarged to keep pace with the increasing circumference of the bone shaft. [6]

Growth hormone is able to continue to stimulate the lengthening of the long bones as long as the epiphyseal plate remains cartilaginous or open. However, at the end of adolescence, under the influence of the sex hormones, these growth plates completely ossify or close. [6] Therefore, bones can no longer respond to growth hormones and grow in length. Clearly, the growth process of bone represents a crucial period in bone's life cycle and is significantly controlled by a person's genetic factors for growth hormones and sex hormones. However, it is important to remember the influence of other factors such as adequate diet and freedom from chronic disease and extreme stress, in determining the potential of the growth process, in addition to the other two bone operations, discussed next.

The second process, bone modeling, alters the shape and mass of the bones in response to mechanical loading factors, such as weight-bearing physical activities. Bone strength can be improved through modeling by adding mass and improving the internal structure at various locations in the skeleton. Although this activity can occur at any time in a person's life, the ability of bone to adapt to loading factors is much higher during growth than following maturity. Maturity in humans, is associated with the cessation of skeletal growth. [5]

The final skeletal process, remodeling, although present at a young age, is the dominant bone operation that modifies shape and mass in adults. One of the primary purposes of remodeling is to replace fatigued bone tissue, which has become damaged over the years with new bone tissue. [5] Remodeling occurs when osteoclasts are signaled by microfractures to break down and dissolve deteriorated and worn bone. These osteoclastic cells will eventually die and leave a small hole in the bone structure. Following this, osteoblasts will appear and begin to lay down new bone matrix which can eventually become calcified and strong. [9] (Figure 2)

The bone remodeling cycle last from 4 months to as long as one year, at any particular site within bone tissue. In an adult human, 10% to 30% of the entire skeleton is replaced by the remodeling process every year! [9] However, this mechanism of continuous recycling of bone tissue does more than replace worn bone tissue with a new structure. In addition, the process of remodeling allows the body an available storage source of calcium, one of the body's most important chemical ions.

Calcium balance in the body

Any valid discussion of bone cycles, bone function, and bone diseases must include a strong understanding and appreciation for calcium balance in the body. Calcium plays a crucial role in a long list of important activities throughout the body. Approximately 99% of the body's calcium is in the stored crystalline form within the skeleton and teeth. Of the remaining 1% of calcium, around 0.9% is located inside the cells and only 0.1% of the total calcium of the body is found in the fluid outside of cells, known as the extracellular fluid. Only this free circulating calcium in the fluid between cells is biologically active and must be kept at a precise level. [6]

The small amount of free moving calcium found in the extracellular fluid plays a vital role in numerous activities that are essential for basic survival. Cells are the building blocks of life and they have evolved a form of communication based on the movement of ions such as calcium. The inside of a cell and the its surroundings communicate with one another by exchanging these ions. Therefore, a cell's functions rely on having a precise amount of calcium on either side of its membrane. For example, nerve cells form a network of communicating lines that innervate the entire body and transmit signals between the brain and the rest of the body. Even the smallest variations in the calcium content in the extracellular fluid can have an extreme effect on the sensitivity of nerve cells and their ability to transmit important information to the brain. Calcium is also necessary for muscle contraction, including the pumping of the heart. [6]

As well, calcium is responsible for signaling little vesicles or capsules within the cell to travel to the cell membrane and empty it's cargo to the outside of the cell. This little highway of vesicle transport is the method used between cells to communicate with one another. Without a specific amount of available calcium, these vesicles would remain motionless on their highway systems and freeze up all communication between cells. In addition, the intercellular cement that holds certain cells together is maintained by calcium. Finally, blood clotting occurs through a cascade of several steps, many of which rely on the presence of calcium. [6] Clearly, the body relies on a careful balance of available calcium in the extracellular fluid.

Although the amount of free floating calcium is minute compared to the body's total calcium content, this free circulating calcium content is one of the most significant balances and messengers in the entire body. It must be kept at a specific level and any deviation from this set point means sudden catastrophe to the body. This level is so important that the body has evolved to be ready at any moment to tear down its stored source of calcium in order to maintain the availability of calcium in the extracellular fluid. [9]

Besides providing support, protection, and a lever arm, our bones act as ready source of calcium for the body and the recent discovery of bone remodeling accounts for the bones ability to quickly release calcium from its structure. This proves just how important the balance of calcium in the fluid inside and outside the cells is if the body will maintain this balance at the expense of breaking down its supporting framework. Dr. John Aloia an active researcher in bone health describes the role of bones similar to that of banks. "Bone is the skeletal 'bank' from which calcium may be 'withdrawn' for homeostasis if needed. The skeletal bank is always open. It is like a cash machine where you can withdraw or deposit money 24 hours a day" [9].

It is evident that the process of bone remodeling has evolved to serve numerous functions. This process, nevertheless, has not evolved without its imperfections. Over time, the process of remodeling results in a net loss of bone, as new bone never completely replaces the bone that has been resorbed. It is this process that serves us in so many ways that is also responsible for the decrease in bone mineral that accompanies aging, thus resulting in osteoporosis.

Who wins: osteoblasts vs osteoclasts?

The question that remains now, is how does bone accomplish all of these competing functions, while at the same time, maintain its own structure and strength? More specifically, how do the osteoblasts and osteoclasts find a balance or are they able to find a balance?

Bone tissue is very much like a battle field. The osteoblasts fight to build-up new bone structure, while the osteoclasts fight to break apart bone tissue. Although they have the complete opposite functions, it is important that both cell types find a middle ground and a balance between one another. As is the case with most things in life, though, there are exceptions and subsequently, times when a perfect balance does not occur. Sometimes the osteoblasts conquer and at other times, they are clearly defeated by the osteoclasts.

The complete life cycle of bone, which is comprised of coupling the bone formation process to bone resorption or breakdown is not fully understood, although it is constantly being performed. Growth, modeling, and remodeling, the three processes of bone's life cycle described previously, can be characterized according to the interactions and who dominates between the osteoblasts and osteoclasts. This can even be further characterized by the overall bone loss or bone gain that occurs in order to determine the total bone mass of the skeleton, at any given time.

Observing the overall changes in skeletal bone mass is a clear way to compare bone loss versus bone gain and serves as a useful tool in understanding the health of bone tissue. There are two key stages of bone mass in a human's lifetime, characterized by large changes in the individual's skeletal bone mass. The first phase results in a net gain of bone mass, due to the clear domination of bone gain over bone loss that occurs during this time. The second key period in an individual's bone mass occurs after menopause in females and approximately a decade later in males as humans begin to age. Unfortunately, this stage results in a clear net loss of bone mass, as the osteoclasts continue to operate while the osteoblasts lag behind. [6] (Figure 3)

<u>The osteoblasts dominate: peak bone mass</u>

From infancy through young adulthood, up to sometimes 30 years of age, the activity of bone formation predominates, as a whole, over bone resorption. This results in a steady accumulation of bone mass during the first 2 and sometimes 3 decades of life. Therefore, the turnover rate of bone tissue and skeletal calcium varies with age, being maximal during infancy to adolescence but decreasing in adults. During the adolescent growth spurt, young people accumulate their peak bone mass. [7]

The peak bone mass is defined as the highest level of bone mass achieved as a result of skeletal growth. The establishment of a maximum level of bone mineral content during the growing years, when the process of modeling is also superimposed on growth, is absolutely crucial when considering lifelong skeletal health. This represents an opportune time because the osteoblasts have a window of time when they are able to outwork the osteoclasts. [4]

The osteoclasts dominate: osteoporosis

An additional time when a human's bone mass is changing very rapidly due to an imbalance between the activity of osteoclasts and osteoblasts occurs later in life. When the osteoclasts outwork the osteoblasts, less bone tissue is formed than resorbed. The bone becomes weak, porous and vulnerable to fracture at these sites. This is the event that leads to the condition known as osteoporosis, literally meaning porous bone (Figure 4). The spine, hip and wrist bones are especially susceptible since they have a large amount of trabecular bone, also known as spongy bone, which is more responsive to the remodeling process. (Figure 5) In other words, as people age and they are less able to absorb calcium for a number of reasons, it is the bone in the hip, spine, and wrists, that is broken down in order to supply the body with the much needed calcium.

A common analogy can be drawn between bone and a bank account. The skeletal bank is always open for withdraws and deposits. Unfortunately, the number of withdraws over a life time begin to exceed the number of deposits and the skeleton becomes susceptible to fracture with the loss of bone. Osteoclasts eventually win out over the activity of osteoblasts.

In fact, low bone mass is the most important factor for osteoporotic bone. Bone loss with advancing age is a universal phenomenon present in almost every population studied and the rate of bone loss seems to be equal among different populations. Bone loss does, however, begin earlier and proceed more rapidly in females than in males, with an accelerated phase in postmenopausal years. This accelerated bone loss in females is attributed to the loss of estrogen function. [4] Regardless, bone mineral loss is a normal consequence of aging, however, osteoporosis is not. Unfortunately, the methods used to currently detect and treat osteoporosis promote the idea of accepting that this disease is inevitable.

CHAPTER 3

OSTEOPOROSIS: THE CURRENT DEFINITION, DIAGNOSIS, AND TREATMENT

Osteoporosis has become almost a household word, still, most people cannot define osteoporosis. Osteoporosis is a condition in which the amount of bone tissue is so low that the bones easily fracture in response to even minimal forces. A person with osteoporosis can fracture a wrist or hip from a fall on the ice or receive a broken rib from an affectionate hug. In fact, the amount of bone tissue may be so low that a person fractures a vertebrae by simply carrying the weight of the body. Osteoporosis literally means, porous bone, because of the reduction and subsequent gaps in bone tissue of individuals with the disease. [2]

This simple definition may seem clear and easily understood, however, the detection and diagnosis of osteoporosis does not rely on a clinical definition, like that above. Osteoporosis is defined by the medical field based on the results of a measurement of bone mineral density count greater than 2.0 standard deviations below peak bone mass of young adults. There are several major problems associated with this definition and with the detection of bone mineral density.

One major problem with the disease is that a blood pressure cuff can be used to easily measure blood pressure and blood can be quickly drawn to check cholesterol levels, but a simple office-based test for detecting osteoporosis does not exist. [2] The best method today to show low bone mass appears to be dual energy x-ray absorptiometry (DEXA), a test that costs about $150 to $200 and is often not covered by insurance plans. To further complicate the matter, densitometry units are not standardized across manufacturers, and different machines measure different non-comparable anatomical sites. [2]

In addition, there has been very little agreement on which measurement, bone mass, bone density or even bone mineral content, is more accurate in determining one's overall bone health. Quantitative information about the skeleton and skeletal development is provided by the bone mass or bone mineral content measurement. Whereas, bone density provides a more qualitative measurement and accounts for size differences. For example, women in general have a lower bone mineral content or bone mass than men, because their skeletons are anatomically smaller. [2]

Although there has been work to utilize less expensive and less complicated methods to assess bone health as an alternative to the costly DEXA measurements, one example being the measure of calcium excretion in the urine, these methods have not proven reliable. [2]

This alone, is probably a major contributor to why this disease goes unchecked and undetected in most people until a fracture occurs. Unlike other silent diseases such as heart disease and cancer, osteoporosis does not command a lot of attention, in the area of prevention and screening. The medical field does not wait for a stroke to screen for or treat high blood pressure, yet they simply do not confront bone loss until people sustain a fracture. [1]

Although the current medical field has been unable to address the obvious need to prevent osteoporosis, it has had to treat a vast number of people as a result of the disease. Annually, osteoporosis accounts for 1.3 million debilitating fractures, mostly of the weight-bearing hip and spine. Even more dramatic, the first-year mortality rate for hip fractures ranges from 14% to 31%, and 25% of the survivors move to long-term care facilities. These bone fractures currently cost the nation $10 to $12 billion a year. [1]

According to the U.S. census, there will be more than 100 million people over the age of 55 years in America by the middle of the next century. [4] The cost of bone fractures in this increasing population could well be $62 billion in the year 2020. [2] As a result, many scientists and health care workers are predicting osteoporosis to be the epidemic of the 21st century.

Despite all the money and resources that the medical community is currently pouring into treating these fractures, half of all women who fracture a hip will never walk again without assistance, experts claim. Nevertheless, the burden of osteoporosis goes far beyond fractures. Women diagnosed with osteoporosis report that it affects almost every aspect of their lives. Among the most frequent complaints associated with this disease are difficulty playing with grandchildren, traveling, finding clothes that fit, poor self-image, and chronic fatigue. [1]

In this dismal picture, there have been some recent efforts to develop medications to treat the bone loss associated with osteoporosis. However, there are many problems with these drugs because there still does not exist a cost effective way to accurately diagnosis those people who require the medication. In addition, these drugs are expensive and have added harmful side effects, like an increased risk of breast cancer. This risk is often enough to keep women from taking the drugs because they would prefer to accept the threat of osteoporosis over the risk of breast cancer. [3]

These facts create a haunting image of an older woman and this image hardly fits into the ideal world where a man an woman should stand tall together as equals, from birth until death. Osteoporosis does not need to be a normal part of aging, as some health care workers may tell their older patients. Unfortunately, though, there is clearly a gap between the number of those people affected by osteoporosis and the attention that is given to preventing its threat. It appears that it is time to change the face of osteoporosis. It should no longer be viewed as a silent disease.

Physicians and scientists are finally accepting that although the process of remodeling is absolutely necessary and useful in a number of ways, its failings are unavoidable. This does not mean that osteoporosis is inevitable. Let us not forget the other two important skeletal processes: growth and modeling. At last, it appears that scientists are getting closer to understanding how to prevent osteoporosis, by looking not at the elderly, but at the youth. More specifically, some scientists are pointing their attentions not at the stage of significant bone loss that occurs with age, but at stage of significant bone gain during puberty. It is time to truly evalute the implications of peak bone mass.

CHAPTER 4

PREVENTION

Two determinants have been advanced to explain the cause of dangerously low bone mineral density in some older members of the population: excessive bone loss during aging and failure to attain a sufficiently high bone mineral content during the years of growth. Leading researchers of bone health claim that it is quite obvious that the main determinants of osteoporosis are the peak bone mass level reached at skeletal maturity and the subsequent rate of bone loss throughout the life [4]. Although most osteoporotic fractures occur in elderly people, the risk of osteoporosis may be profoundly affected by events in early life. Not until recently, have scientists begun to evaluate the factors that determine a person's maximum level of bone mineral content, known as peak bone mass.

There is still some controversy surrounding the specifics as to the age when peak bone mineral content is attained at different sites in the skeleton. It is apparent, however, that peak bone mass is acquired before the age of 30, with approximately 90% achieved by the age of 17. [5] In fact, at most skeletal sites, peak bone mass is reached by 18 years of age and at some of these sites, bone loss begins immediately after the age of 18. [4] (Figure 6) In addition, there are differences in the timing of peak bone mass between males and females, due to the fact that the onset of sexual maturation occurs earlier in females. [5]

Physical activity

Although the attainment of peak bone mass seems to be affected to some extent by genetic factors, most studies indicate that at least 50% or more of the determining factors may be environmental. [10] Several studies, in addition to the research conducted by Dr. Taaffe, indicate the effects of mechanical loading and physical activity on bone mineralization during growth. [14, 15, 16] Although there are gaps in our understanding of the exact role of physical activity in attaining peak bone mass during growth, data indicates that there is certainly a strong relationship between the two. [5]

One such model of this relationship, are childhood activities that preferentially stress one side of the body over the other. These types of activities provide a unique example for examining the effects of activity and use on the growing skeleton. For example, in Little League baseball players from 8 to 19 years of age, there was a significantly greater bone mass and bone mineral content found in their dominant arms. This was also found to be true with female tennis players and elite squash players from the same age group. In fact, when participation in the activity began at the start of puberty and continued throughout this stage, there was a significantly larger side-to-side difference, averaging around 22%, found between the bone mass of the dominant arm compared to the nondominant arm. [17] It is this type of difference in peak bone mass that can make the distinction of maintaining a bone mass above the fracture threshold later in life. [7, 18, 19]

Calcium intake

In addition to the effects of physical activity during puberty, it appears that the attainment of a maximum peak bone mass further depends on an optimal calcium balance. Studies conducted to determine calcium's influence on bone mineral content have indicated a strong positive relationship between calcium intake and bone mass. [4]

The most accurate studies of adolescence reveal that it is likely that variations in calcium nutrition early in life may account for 5% to 10% differences in peak bone mass, following puberty. Although these numbers do not seem impressive, it is small percentages in peak bone mass such as these that make the crucial differences later in life. In fact, such a difference of 5% to 10% in peak bone mass probably accounts to more that 50% of the difference in the risk of hip fractures rates later in life. [4]

Besides calcium intake affecting the calcium balance and bone mineral content in the body, the ability to absorb calcium is also a significant factor. Urinary calcium content was revealed to have a negative influence on bone mass. A reliable determinant of calcium retention in the body is urinary excretion. This measurement, along with the level of calcium intake, can indicate the calcium balance in the body and its ability to absorb calcium so that a proper amount of calcium can be deposited into the bones.

Unfortunately, calcium in not easily absorbed in the small intestines and requires the activity of an activated form of vitamin D. This further complicates calcium balance because in order for vitamin D to aid in calcium absorption, it has to become activated in a process that also requires several steps and the help of numerous organs. Vitamin D can either be produced in the skin by UV light or ingested in the diet, however, it still requires activation steps in the liver and kidney before it can play a role in the calcium balance of the body. [6] The complex mechanism of calcium balance further involves the control of the parathyroid and thyroid endocrine organs, located in the neck. [13] (Figure 7)

Calcium intake does affect the ability to reach a maximum peak bone mass, although there are several other factors, such as vitamin D, smoking, alcohol, protein and sodium intake, and caffeine. [12] Nevertheless, variations in calcium nutrition alone, in the early years of life, account for a 5 to10% difference in peak adult bone mass. This difference may seem quite small but it translates to as much as 50% of the difference in hip fracture rates later in life. [4]

Physical activity, calcium intake, and vitamin D all powerfully influence bone health, particularly during growing years. These environmental factors, including exercise and diet, are obviously of interest because they are susceptible to intervention. If women, however, are to prevent or delay the development of osteoporosis in later life, then prevention should begin decades before menopause. [10]

Education

A major component of prevention is education, yet few researchers have even evaluated what young people in the second decade of life know about osteoporosis. Researchers have not bothered to assess adolescents' beliefs about the disease, and to what extent they practice preventive behaviors, such as adequate calcium intake and regular physical activity. This type of information, would assist health care professionals and educators in developing educational programs for this age group. [8]

Only 7% of undergraduate women report getting sufficient osteoprotective exercise and dietary calcium. The majority of young women believe that osteoporosis is significantly less likely to develop in them than either heart disease or breast cancer. This is contrary to the harsh reality that today's young women have up to a 50% chance of being affected by this disease. Statistics show that heart disease will develop in 33% of women and breast cancer will develop in approximately 11% of women. [8] The difference between reality and what young women perceive to be the greatest health risk may be a result of the years of public health campaigns concerning heart disease and breast cancer.

Data suggests that educational institutions and health care providers have either missed the opportunity to distribute information concerning osteoporosis to young people or that this information has not been retained by them. It is also possible that although physicians are aware of osteoporosis prevention, they may not integrate this message into their practice due to difficulties or because their practice focuses on treatment rather than preventative medicine. Similarly, schools have not seen it as their role to educate students about this particular health concern. [8]

The increasing teenage population must be targeted as the risk group for osteoporosis. The U.S. Bureau of Census is expecting the population of teenagers to significantly increase in the near future.

In the next decade, according the census, the teen population will grow at nearly twice the rate of the overall population. Even further, it is expected to reach 30.8 million at its peak in 2015.

Research reveals the importance of early prevention and the development and evaluation of a comprehensive, population-wide educational program should be used to educate young women about the risk factors for osteoporosis. It is absolutely necessary that preventative strategies be implemented, as early as grade school and continuing through high school, in an effort to increase the peak bone mass of this age group if an epidemic of osteoporosis is to be avoided. This preventative strategy should focus on promoting the importance of adequate calcium intake as a strong component of a proper diet and regular, yet varied exercise programs. This once silent disease of the elderly is clearly a pediatric condition that should be treated as such. [4]

Prevention model for public schools

The following curriculum model is in the format suggested and utilized as apart of the Oregon Educational Act for the 21st Century by the Oregon Department of Education. The Common Curriculum Goals what public schools should offer in a comprehensive K-12 curriculum. The subsequent benchmarks are the more specific descriptions and expectations for individual grade levels. In the following curriculum model, the overall subject area is bone health.

The subject area of bone health has been divided into three categories that most significantly impact an individual's bone health, including calcium intake, growth and development, and physical activity. For each of the three crucial categories, there are benchmark standards set for the grade levels of elementary, middle, and high school. Following the flow chart of curriculum standards, there are suggested activities to aid teacher's in reaching these goals. It is important to note that the following curriculum model would be best utilized with a joint participation and contribution from the separate subject areas of science, health education, and physical education.

Curriculum Goals	Elementary School Benchmark	Middle School Benchmark	High School Benchmark
Calcium Intake: (as apart of a healthy diet) Understand and analyze the role of a healthy diet, specifically calcium intake, on the health and strength of bones.	Identify common foods containing calcium.	Construct a sample healthy diet containing an adequate amount of calcium.	Classify and evaluate their own dietary intake values based on a three to five day period.
Growth and Development: Understand the key concepts of growth and development and their relationship to lifetime bone health and overall wellness.	Recognize and describe the process of growth and development in a variety of organisms, including humans.	Explain the process of growth and development in bones.	Describe and analyze the effects of critical periods during the process of growth and development. Define osteoporosis.
Physical Fitness: Identify and apply various fitness activities that promote stong bones. Demonstrate a physically active lifestyle.	Identify and explore various physical activities and recognize some of the organized teams associated with various physical activities.	Actively participate in a physical education classroom.	Demonstrate an independent pursuit of a regular schedule of physical activity. Classify physical activities according to their target muscles and bones. Demonstrate an understanding of the need for variety in physical activity.

SUGGESTED ACTIVITIES FOR ELEMENTARY SCHOOL

1.) CALCIUM INTAKE: As a part of a healthy diet

Provide students with list of calcium rich foods. Ask students to take the list home and check off those foods that are contained in their own kitchens. They should be encouraged to also take the list and accompany their parents the next time they go grocery shopping. Students could check off the foods in their grocery cart that contain calcium. An emphasis should be placed on the variety of foods that contain calcium.

2.) GROWTH AND DEVELOPMENT:

Conduct an activity in which students are asked to classify animal and human pictures according to the stages of life, including, newborn, childhood, adolescence, adulthood, and elderly.

On a narrow piece of paper, that can be easily rolled up and stored away, record each students height at the beginning of the school year and three more times throughout the course of the year. This activity allows the students to observe their own growth and development.

Ask each student to bring an old white t-shirt to class. Provide a stencil or a sample diagram of an outline of the underlying bone structure, heart, and lungs of the chest. Each student can draw these structures on the front of their t-shirts, coloring in the heart and lungs. An emphasis should be made on the protective role of bones.

3.) PHYSICAL FITNESS:

Start certain days of the week with an organized stretching routine, followed by jumping jacks. This brief activity should only take five to ten minutes and can be conducted on a single day of the week or throughout the entire week. Music is always a great tool to get kids moving.

SUGGESTED ACTIVITIES FOR MIDDLE SCHOOL

1.) CALCIUM INTAKE: As a part of a healthy diet

Construct a sample healthy diet for a three day period, with a calcium rich source included in every meal.

Demonstrate the effects of a poor diet on bone strength with the following model:

Materials: Several chicken bones
Vinegar
Milk

Place several chicken bones in a glass containing vinegar and the other chicken bones in a glass containing milk. Throughout the course of a week, observe the effects of acid, on the strength and flexibility of bones. Allow students to bend and break the bones from the milk glass and the vinegar glass and ask them to compare and contrast the results.

2.) GROWTH AND DEVELOPMENT:

Either in the context of the Health Education classroom or the Science classroom, explain to the students the process of growth and remodeling that occurs in bones. Obtain cross sectional slides of normal, healthy bone structure and osteoporotic bone. Have the students compare and contrast the structure of the two types of bone.

3.) PHYSICAL FITNESS:

Before each new activity in the Physical Education classroom. discuss the area of the body that the activity targets. In addition. discuss how this activity is utilized and important to all age groups. from childhood through adulthood. The importance of bone health should be mentioned, in addition to the health of the heart and lungs.

SUGGESTED ACTIVITIES FOR HIGH SCHOOL

1.) CALCIUM INTAKE: As a part of a healthy diet.

Assign students to record their three to five day dietary intake. Requiring them to record specific information, including time of intake, location, amount, and a description of the food. Ask students to subsequently evaluate their own diets and pick a dietary behavior that they feel deserves alterations. Ask students to set an achievable and realistic goal in order to achieve their desired behavior change. Finally, students should be assigned to write occasional journal entries in order to monitor the progress of their behavior change. It should be emphasized that students choose a realistic behavior change that could become a lifetime alteration. Remember to emphasize the link between osteoporosis and a healthy diet during these early years. This activity may be most appropriate for the Health Education classroom.

2.) GROWTH AND DEVELOPMENT:

Within the environment of a Life Science, Biology, or Physiology classroom, present certain diseases that are associated or directly result from disrupted or improper growth and development. Osteoporosis should be presented and discussed in the context of growth and development in bones.

3.) PHYSICAL EDUCATION:

In the context of the Physical Education classroom, before starting a new activity, discuss the benefits of the exercise and ask students to discuss why, where, and when they could participate in the various activities, outside of the school and later in life. Once again, osteoporosis should be highlighted as being linked to a person's physical activity level.

* OTHER CLASS ACTIVITIES:

Bulletin boards in any classroom and at any grade level are an effective way to introduce or remind the students of how best to prevent osteoporosis. Osteoporosis can also be mentioned in math class in the context of evaluating the slopes of lines. Students could demonstrate the importance of the rate of bone loss and bone gain and graph these differences. The physics classroom supplies yet another opportunity in the context of density. Different abilities to withstand force by varying structures could be highlighted as an example of how important strong bones are to an person's health.

As an attempt to administer the curriculum model and suggested activities listed above, letters were sent to 17 different public schools in Eugene, at the high school and junior high level, explaining the importance of early intervention to prevent osteoporosis and offering to give a brief presentation with handouts on the subject matter. Of the 17 letters, two health instructors responded to the offer. Presentations and activites were conducted upon these requests and proved to be successful in producing interests among the students and teachers.

The limited response could be due to the fact that teachers in the public school are extremely busy and it may be that osteoporosis is still associated as being a disease of the elderly. However, in addition to offering presentations and possible acitivities among the public schools, an extensive presentation on bone health was given to the Peer Health Educators, at the Student Health Center on campus, so that they might be able to use the information in their own lives, but also able to dissipate it to others. During this presentation and others conducted throughout the community, handouts on easy tips to follow in order to build and maintain strong bones. (Figures 8, 9, 10, and 11) An extensive folder of articles on the topic of bone health and how to prevent osteoporosis was also submitted to the Peer Health Education Office.

CHAPTER 5

SUMMARY AND CONCLUSIONS

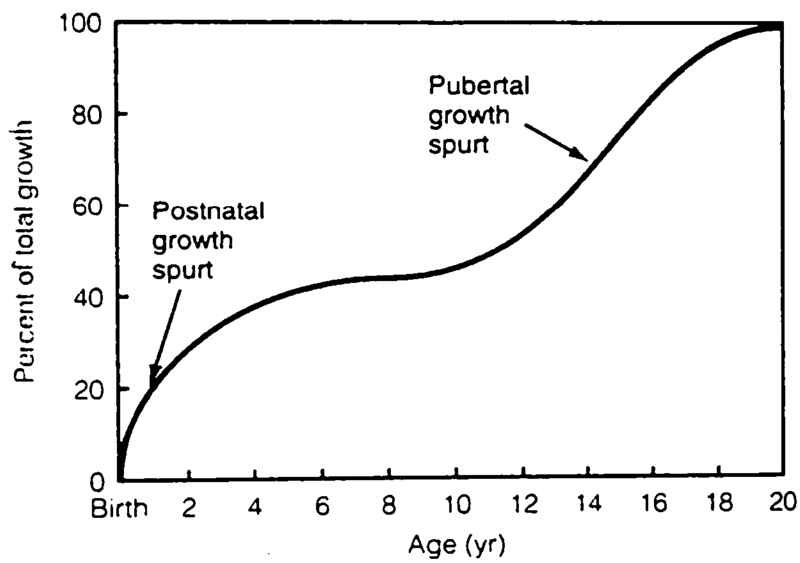
Based on the overwhelming evidence, we can no longer allow osteoporosis to be a silent disease, but more importantly, we can no longer view it as a disease of solely the elderly population. It begins at a young age and therefore deserves attention at a young age. If scientists have discovered important information on how to prevent the ills of osteoporosis, the effected age group has the right to know this information.

The subject of osteoporosis needs to be incorporated into the health, science, and physical education classrooms in public schools, starting at the elementary level and continued throughout the high shcool years. For a preventative approach to be succussful, it will require a joint and unified effort amoung the teachers in all three classrooms listed above. Activities that spur student's interests and encourage hands on experience should be incorporated into the lesson plans. In addition, activites should encourage participation of the parents and family members of the students. This will help ensure a common environment, inside and outside of the schools. These activities should all emphasize the importance of maintaining a healthy diet and exercise program throughout a lifetime.

There are certainly questions remaining that concern the various specifics involved in bone's life cycle and the exact mechanism of the calcium balance. It could be a complete picture of all the factors that potentially influence an individual's bone strength and peak bone mass will never be reached. However, the research reviewed in this thesis provides compelling evidence for the support and initiation of a pediatric approach to prevent the risks of osteoporosis. It is time to change the face of osteoporosis.

Figure 1

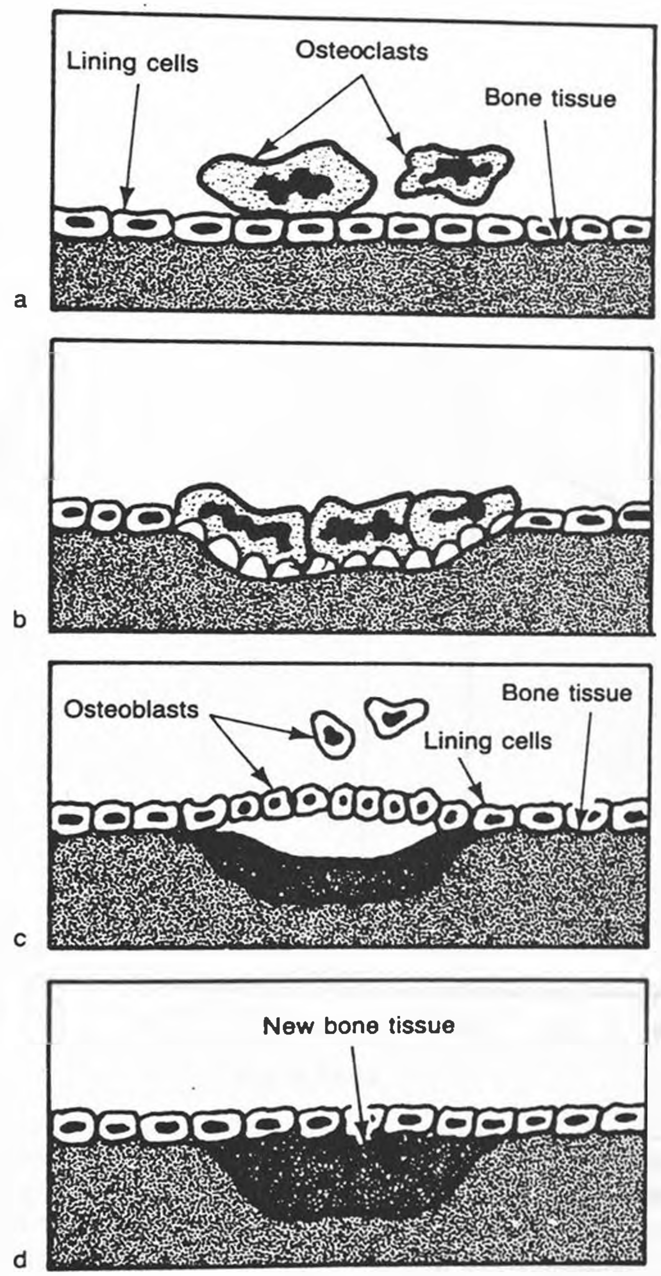
The Normal Growth Curve for Humans



Source: Sherwood. Lauralee. *Human Physiology: From Cells to Systems*, 3rd ed: Wadsworth Publishing Company. ITP. 1997: 644

Figure 2

The Bone Remodeling Cycle

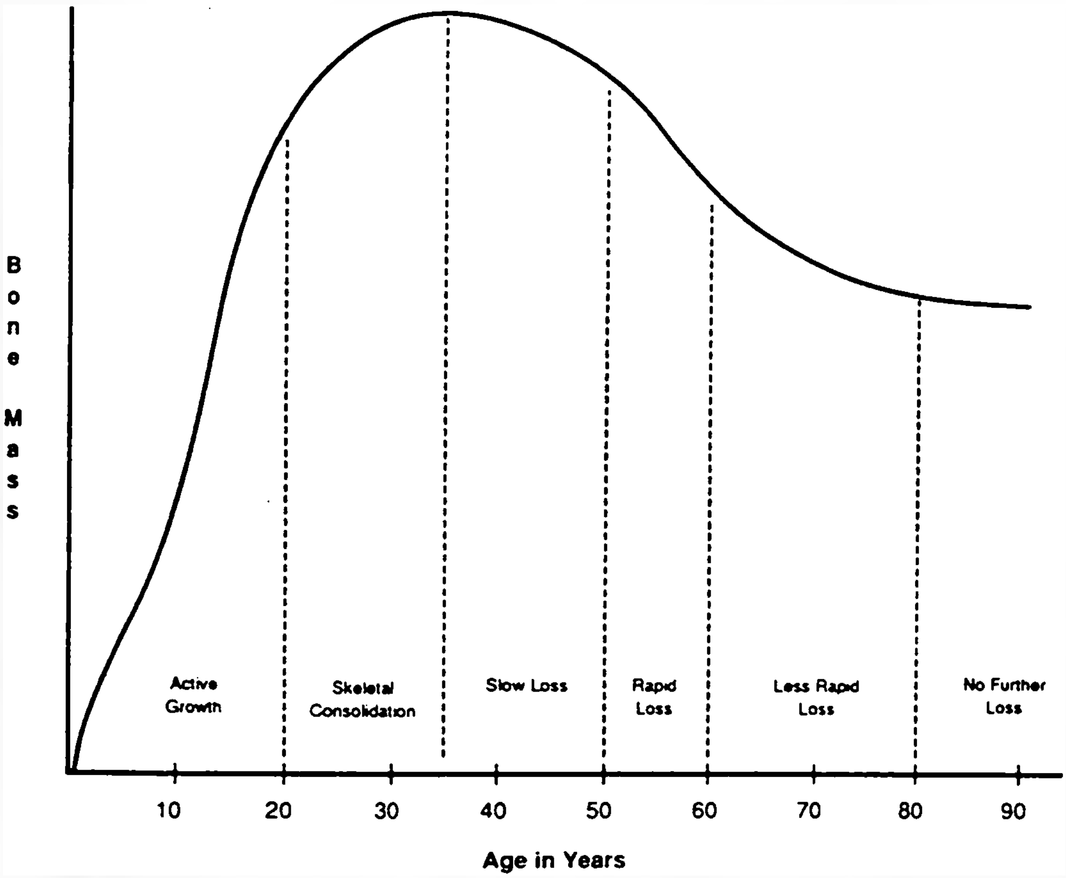


Bone remodeling cycle. Remodeling occurs when osteoclasts are activated (a) and dissolve bone (b). Osteoblasts later appear and fill the cavity with bone matrix which is then mineralized (c). The new bone is then in a quiescent phase (d).

Source: Aloia, John, F. *Osteoporosis: A Guide to Prevention and Treatment.* Champaign, Illinois: Leisure Press, 1989: 13

Figure 3

The Stages of Bone Mass

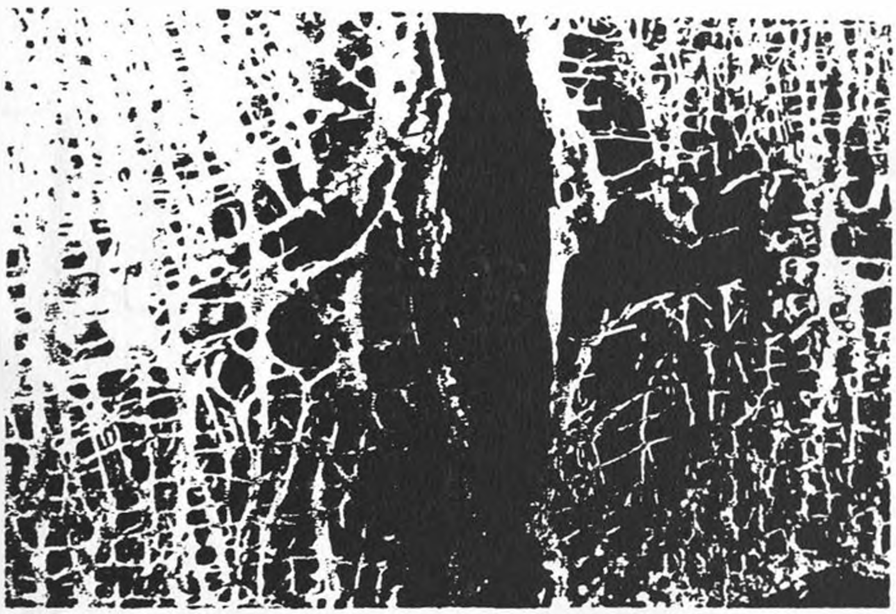


Stages of bone mass in the life cycle of a woman. Following completion of growth there is another phase of an increase in bone mass at the end of which peak bone mass is attained. This is followed by a slow rate of loss that accelerates following menopause.

Source: Aloia, John, F. *Osteoporosis: A Guide to Prevention and Treatment*. Champaign, Illinois: Leisure Press, 1989: 20

Figure 4

A Thinning of the Bone Matrix

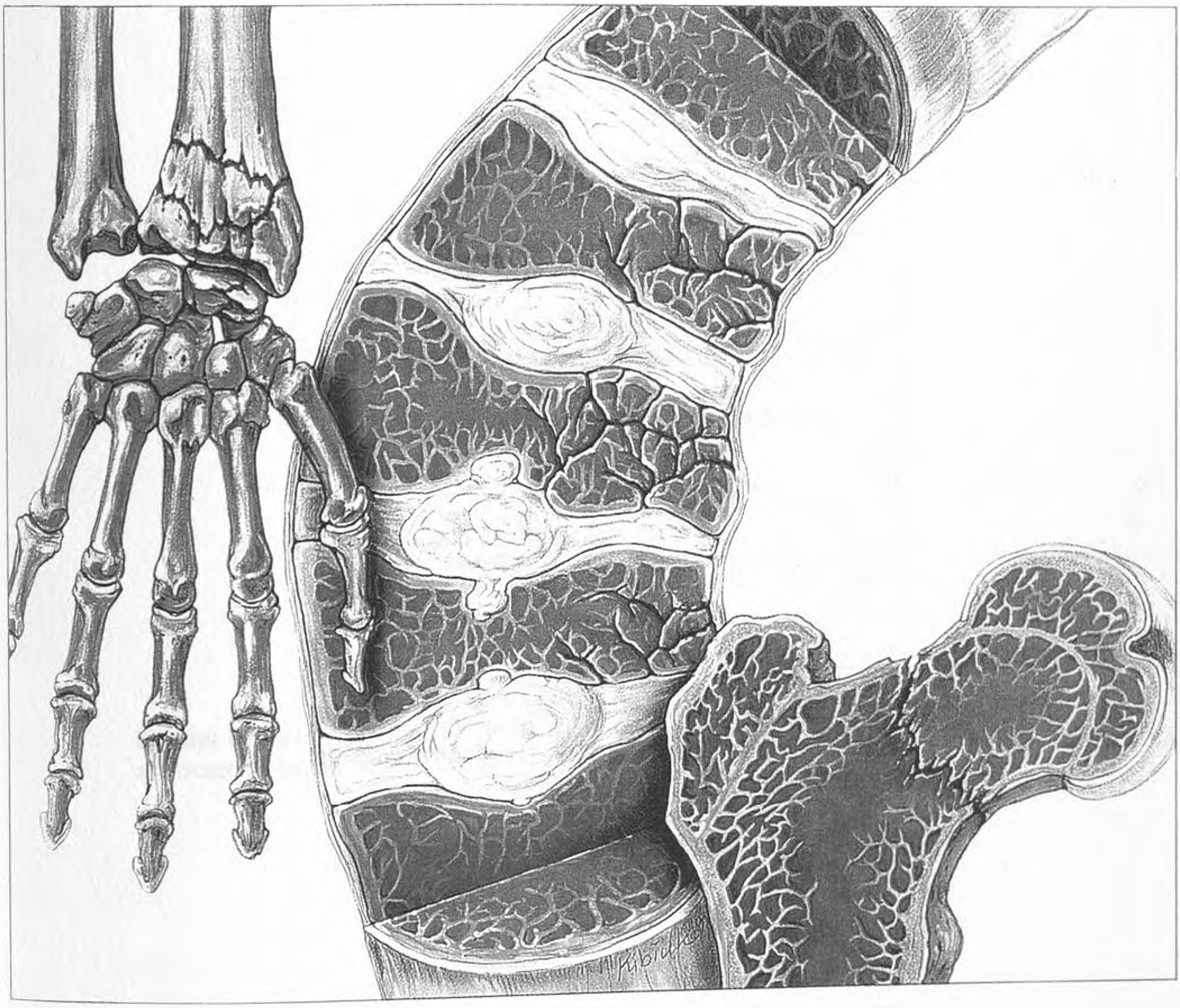


Normal bone [B] shows a thicketlike meshwork of fibers, but an osteoporotic bone [C] has thinner fibers and many holes.

Source: Postlethwait, John H. and Hopson, Janet. L. *The Nature of Life, 3rd ed.* New York: McGraw-Hill, Inc., 1995: 740.

Figure 5

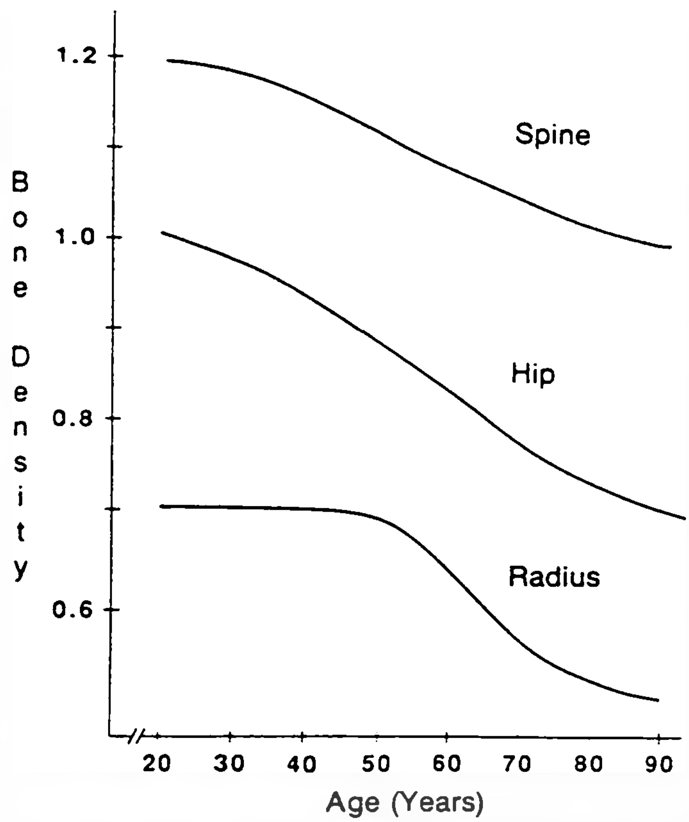
Susceptible Sites for Osteoporotic Fractures



Source: Siris, Ethel S. and Schussheim, Debra H. Osteoporosis: assessing your patient's risk. *Women's Health in Primary Care:* Vol 1. February 1998: 101.

Figure 6

Loss of Bone Density with Age

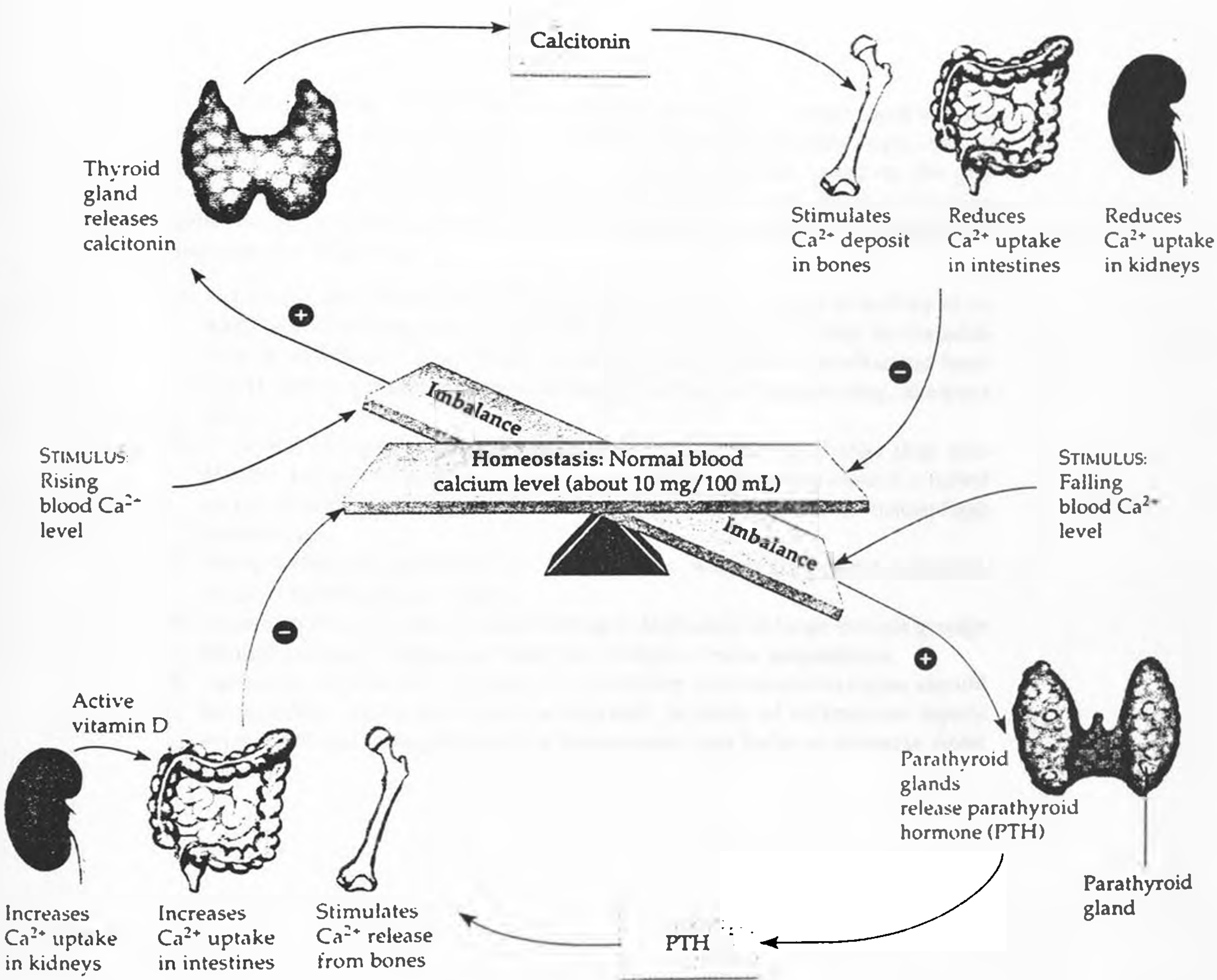


Loss of bone density with age. Note that bone loss begins before menopause from the spine and hip whereas the greatest amount of bone is lost from the radius after menopause.

Source: Aloia, John F. Osteoporosis: *A Guide to Prevention and Treatment*. Champaign, Illinois: Leisure Press, 1989: 22

Figure 7

Calcium Balance: A Complex System



Source: Campbell. Neil A. *Biology, 4th ed.* New York: The Benjamin/Cummings Publishing Company. 1996: 928.

Figure 8

Suggestions for Exercising to Optimize Bone Health

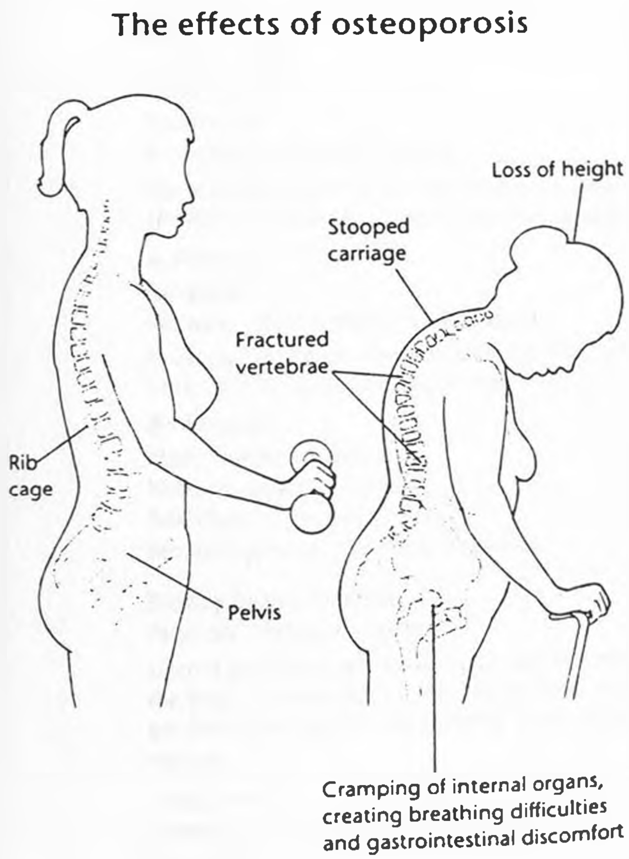
Although there remain many questions about the complicated mechanisms controlling bone mineral accretion during the growing years, it is still possible to offer some prudent advice to young people, based on the preceding review of bone-related research in children and adolescents. Suggestions for optimizing bone mineral acquisition during the growing years include the following:

1. A person should make a lifelong commitment to physical activity at an early age. Growing bones respond to weight-bearing activity by the addition of new bone. The ability to adapt to increases in mechanical loading is much greater in the growing, than in the nongrowing, skeleton [96].
2. A variety of vigorous daily activities of short duration is better than prolonged repetitive activity. Activities should be diverse to ensure a varied strain distribution on bone, and they should be vigorous to ensure high strain rates.
3. Weight-bearing activities are better than weight-supported activities, such as swimming or cycling.
4. Activities that increase muscle strength and work all large muscle groups should be encouraged, as these can enhance bone acquisition.
5. As much as possible, periods of immobility and immobilization should be avoided; when this is not achievable because of sickness or injury, even brief daily weight-bearing movements can help to conserve bone mineral.

Source: Bailey, Donald A., Faulkner, Robert A., and McKay, Heather A. Growth, Physical Activity, and Bone Mineral Acquisition. *Exercise and Sports Sciences Reviews*. Vol. 24. 1996: 258.

Figure 9

Bone Health Handout



<u>Good Bone Building Exercises</u>

~Aerobics
~Jogging
~Walking/Hiking
~Baseball
~Soccer
~Frisbee
~Tennis
~Basketball
~Weight lifting

Source: Carlson, Karen J., Eisenstat, Stephanie A., and Ziporyn, Terra. *The Harvard Guide to Women's Health.* Cambridge: Harvard University Press, 1996: 444.

Figure 10

Boost Your Calcium Intake

Best and Worst Calcium Sources

Some of the top sources of this important nutrient are listed here as well as a couple that just don't deliver.

Food	Portion	Calcium (mg.)
A+ Sources		
Nonfat yogurt	1 cup	452
Skim milk	1 cup	302
Buttermilk	1 cup	285
Part-skim mozzarella cheese	1 oz.	181
Dairy products are by far the richest in calcium, and that calcium is also easily absorbed by the body. Depend on them to achieve recommended calcium intake.		
A Sources		
Sardines	6	275
Salmon, pink, canned (with bones)	3 oz.	181
Good supplementary calcium sources. They're high in calcium because of the tiny bones, but sardines can also be high in fat.		
B+ Sources		
Pinto beans, cooked	½ cup	118
Kale, chopped, cooked	½ cup	86
Bok choy, shredded, cooked	½ cup	79
Mustard greens, chopped, cooked	½ cup	52
Kidney beans, cooked	½ cup	43
Broccoli, chopped, cooked	½ cup	36
Greens and beans are moderately high in calcium, and that calcium is available to the body. Unfortunately, you'd have to eat mounds of them to meet the daily calcium levels that experts recommend. Depend on them as supplementary calcium sources.		
Figs, dried	6	161
Almonds, toasted, unblanched	1 oz.	76
Hazelnuts	1 oz.	55
Brazil nuts	1 oz.	50
Prunes, dried	5	22
Like greens and beans, nuts and dried fruits are good as a supplementary source of calcium, but you'd have to cover your plate with them to meet daily requirements. Also, nuts are high in fat, and dried fruits are loaded with calories.		
F Sources		
Spinach, cooked	½ cup	122
Ground beef, lean, cooked	3 oz.	8
Spinach is high in oxalate, which makes its calcium unavailable to the body. Meats have insignificant calcium content.		

Source: Felton, John. *Prevention's Food and Nutrition.* Pennsylvania: Rodale Press, 1993: 154-155.

Figure 11

Boost Your Calcium Intake

Amounts that Protect Best

For best results in preventing osteoporosis, the National Osteoporosis Foundation suggests these daily intakes of calcium.

Age/Condition	Calcium (mg.)
1–10	800
11–24	1,200
25–50	1,000
Pregnant women	1,200
Lactating women	1,200
Premenopausal women	1,000
Postmenopausal women	
If taking hormone replacement therapy	1,000
If not taking hormone replacement therapy	1,500
51+	1,000

Ten Quick Tips to Boost Your Calcium Intake

1. Choose frozen yogurt, ice milk or puddings made with low-fat or skim milk for dessert.
2. Sprinkle Parmesan or Romano cheese on soups, salads, vegetables and popcorn.
3. Use low-fat or skim milk instead of water in canned soups and oatmeal and during baking.
4. Use plain yogurt in place of mayonnaise in salad dressing and other recipes.
5. Add a slice of cheese to sandwiches, or melt some on toast, English muffins or bagels.
6. Add one or two tablespoons of nonfat dry milk to hot cereals, stews, casseroles, meat loaf or mashed potatoes.
7. Use farmer's cheese, ricotta cheese or cottage cheese as a sandwich or toast spread.
8. Try tofu in place of beef or chicken in stir-fry recipes, or add it to soups and salads.
9. Choose broccoli, collards, kale, bok choy or turnip greens.
10. Have low-fat milk shakes instead of soft drinks.

Source: Felton, John. *Prevention's Food and Nutrition.* Pennsylvania: Rodale Press, 1993: 154-155.

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