

# Invest in your bones

How diet, life styles and genetics  
affect bone development in young people

Jean-Philippe Bonjour, M.D.

Professor of Medicine, Division of Bone Diseases – WHO Collaborating Center for Osteoporosis  
University Hospital of Geneva, Switzerland, Member of IOF Committee of Scientific Advisers



International Osteoporosis Foundation

## ■ What is fact, what is fiction?

A foreword by Pierre D. Delmas, M.D., PhD, President, International Osteoporosis Foundation

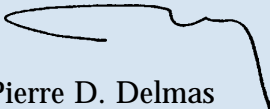
Osteoporosis affects one in three women and one in eight men during their lives. Most people who suffer from the disease are in the last third of their lives, generally 50 or older. It is therefore appropriate that a considerable amount of research effort goes into finding new diagnosis and treatment options for people with osteoporosis.

However wherever I speak to public gatherings, people ask me about the issue of prevention. I'm asked if children take certain precautions, eat certain foods, live in a certain way, can they avoid osteoporosis later on in life? My answer is always 'yes, up to a point'.

It is simplistic, and wrong, to say that if a child drinks plenty of milk she or he will not get osteoporosis as an adult. Many other factors enter into the equation – especially whether the child has inherited a genetic tendency to osteoporosis from the mother. But certain life style changes can dramatically improve, or hinder, the development of strong bones, which can, in turn affect the likelihood of a person developing osteoporosis and breaking a bone later in life. This report, written by Jean-Philippe Bonjour, one of the world's leading experts in the field, presents the facts and addresses the fallacies.

IOF's more than 120 member societies around the world give increasing attention to the question of education. I urge you to look at the new section on the IOF website ([www.osteofound.org](http://www.osteofound.org)) – IOF Bone Education Resource Center – which is dedicated to the imaginative education programs of our members.

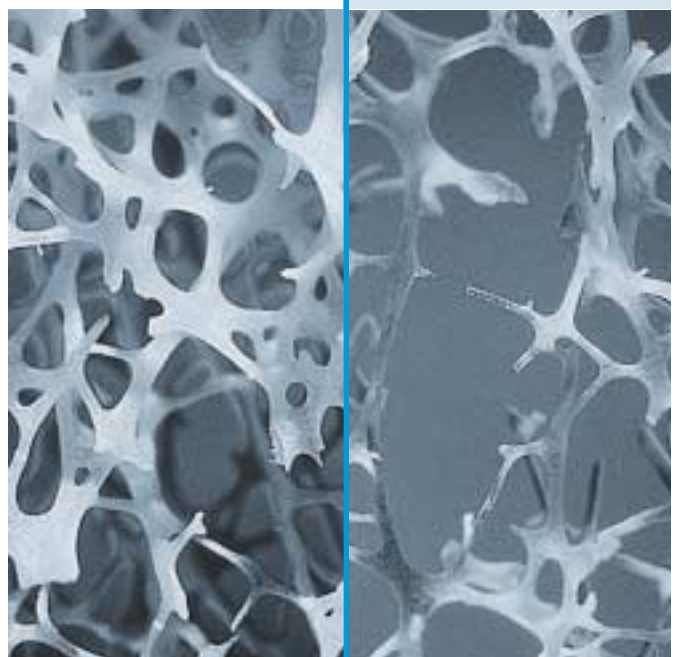
You can, and should, invest in your bones.



Pierre D. Delmas

### What is osteoporosis?

Osteoporosis is a disease characterised by low bone density and the deterioration of bone tissue. As the bones become more porous and fragile, the risk of fractures is greatly increased. The loss of bone occurs "silently" and progressively. Often there are no symptoms until the first fracture occurs.



Healthy bone

Osteoporotic bone

Courtesy of NOS, U.K.

Jean-Philippe Bonjour, M.D.

Professor of Medicine, Division of Bone Diseases  
WHO Collaborating Center for Osteoporosis  
University Hospital of Geneva, Switzerland,  
Member of IOF Committee of Scientific Advisers



# Invest in your bones

How diet, life styles and genetics affect bone development in young people

## ■ Introduction

The world is facing an osteoporosis epidemic.

Every 30 seconds, someone in the European Community has a fracture as a result of osteoporosis. The number of hip fractures (actually a fracture of the head of the femur in the thigh) is expected to double in the next 20 years due to increasing population and increased life expectancy. According to Gro Harlem Brundtland, director general of the World Health Organization, the greatest increase in osteoporosis will take place in the developing world.

Obviously osteoporosis is widespread, and as the world's population ages, more and more people will suffer from this debilitating, and sometimes fatal, disease.

Therefore it is essential to develop a worldwide strategy for osteoporosis management and prevention. But the general public poorly understands whether osteoporosis can be prevented. One of the best preventive measures to avoid later-in-life osteoporotic fractures is to build up the strongest bones possible during childhood and adolescence. Healthy adults generally reach their peak bone mass by age 20. It is estimated that a 10% increase of peak bone mass reduces the risk of an osteoporotic fracture during adult life by 50%.

Thus, an efficient way of preventing osteoporotic fractures occurring in the second half of life is to build up the strongest bones possible during the juvenile periods when rapid bone growth occurs, thereby achieving maximum bone mass by the end of the teen years.



It is estimated that a 10% increase of peak bone mass reduces the risk of an osteoporotic fracture during adult life by 50%.

## ■ Is there a key age at which bone development takes place?

During puberty, bone mass in the spine and hip increases by approximately five times.

Bones are living tissue, and the skeleton grows continually from birth to the end of the teen years, reaching a maximum strength and size around the age of 20. Some ages are particularly important for accelerated growth of the skeleton.

The first period of rapid bone growth occurs from birth to two years. A second period of rapid bone growth corresponds to the years of puberty, when sexual maturation takes place, roughly from age 11 to 14 in girls

and 13 to 17 in boys. During puberty, the speed of building up bones in the spine and hip increases by approximately five times.

In girls, the bone tissue accumulated during the ages 11 to 13 approximately equals the amount of bone lost during the 30 years following menopause. However, preventive measures should not be concentrated only on these periods of accelerated bone growth. Indeed the skeleton appears to respond quite well to changes in the intake of calcium or in the degree of physical activity during the years preceding the period of sexual maturation.

During growth the gain in bone mineral mass is mainly due to an increase in bone size with very little change in bone density, i.e. in the amount of bone tissue within the bones. Just because a child is growing tall, this does not mean that his or her bone mass is growing at a sufficient rate.



In girls, the bone tissue accumulated during the ages 11 to 13 approximately equals the amount lost during the 30 years following menopause.



The first period of rapid bone growth occurs from birth to two years.

From birth to the onset of puberty, bone mineral mass is the same in girls as in boys. During puberty bone mass increases more in boys than in girls.



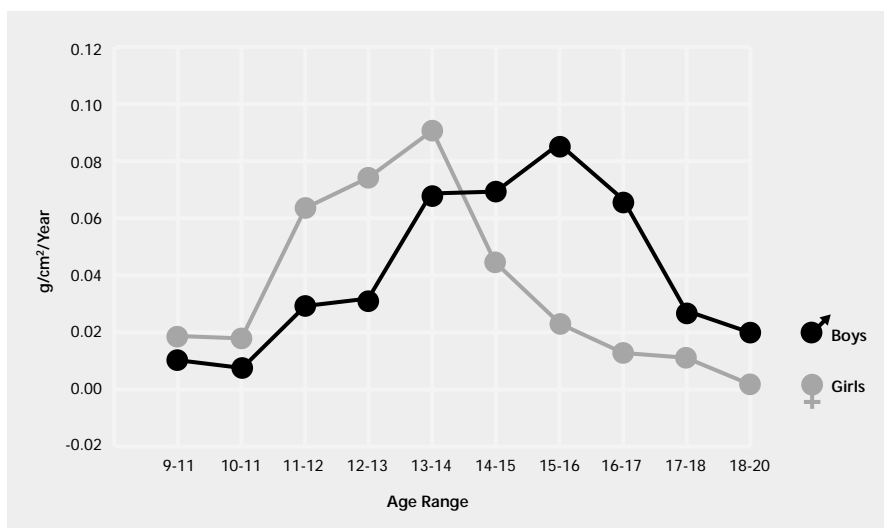
## ■ What role does gender play in bone growth?

From birth to the onset of the sexual maturation, the bone mineral mass at any given age is the same in girls as in boys. During puberty bone mass increases more in boys than in girls.

This difference appears to be mainly due to a more prolonged period of accelerated growth in males than in

females, resulting in a larger increase in bone size and thickness of the cortical shell of the bones.

Note that from birth to the end of the growth period there is no gender difference in the density of the spongy bone which is found beneath the harder cortical shell.



### The key ages for bone growth

Bone mineral mass gain in the spine increases five-fold during pubertal maturation or between the ages 11-14 in girls and from 13-17 in boys.

From Theintz et al., *J. Clin. Endocrinol. Metab.* 75, 1060-1065 (1992)

## ■ What proportion of bone mass comes from genetics, what proportion from life style?

Many factors can influence bone mineral mass accumulation from foetal life to the end of the teen years, and thus account for the marked difference of peak bone mass between individuals. At the end of puberty, in healthy individuals of the same sex, same age and having the same height, the difference in the amount of bone contained in the lumbar spine can vary by a factor of two. For example, one sexually mature, 165 cm tall girl might have 10 grams of bone mineral in one lumbar vertebrae while a physically similar girl of the same age might have 20 grams. Why does this surprisingly large variation exist? Certainly it is due to genetics as well as life style determinants, such as nutrition, physical activity and risk factors (see below), but the relative importance of each variable is unclear.

Comparison either between parents and children or between monozygotic and dizygotic twins suggest that genetics accounts for 60 to 80% of the variability in individual peak bone mass. The hereditary transmission of bone mass is very likely dependent upon several genes which have not been yet identified, but which are being intensively searched for in several research centers

throughout the world. However, environmental factors such as nutrition and exercise may be underestimated when calculating the role of genetics.

The "milk-displacement effect": Girls who are soft-drink drinkers consume almost one-fifth less calcium than nonconsumers of soft drinks.



## ■ What is the influence of diet?

### Calcium

Calcium is essential for healthy bone development, and increasing the calcium intake in children and adolescents increases bone growth. The benefit of increasing the calcium intake is greater in the shaft of the long bones in arms and legs than in the spine. The skeleton appears to be more responsive to calcium supplementation before the onset of puberty than after puberty has started. Milk and other dairy products are the most abundant source of calcium. Are children getting enough calcium? Increasingly they are not, and in some countries there is widespread concern about the decrease in the consumption of dairy products.

### What is the reason for this decrease?

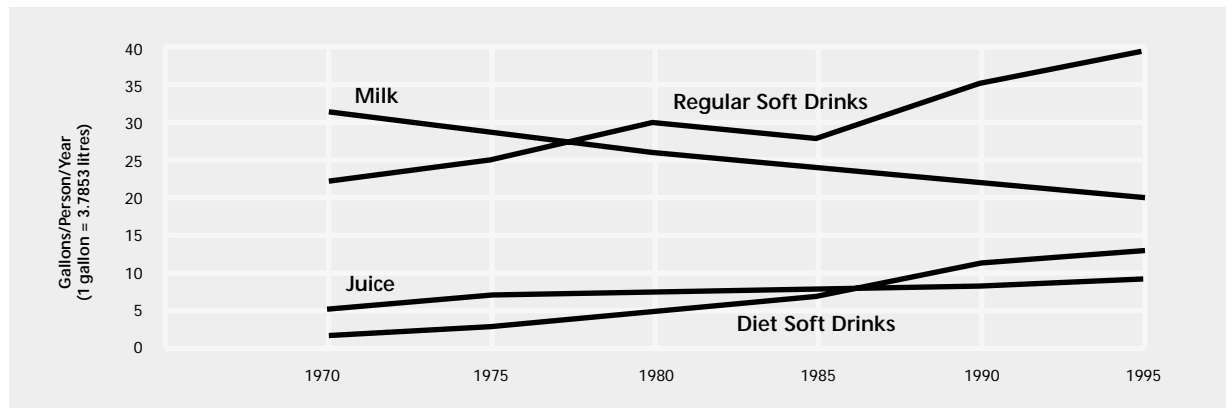
This trend may be related to the fact that many children do not have a proper breakfast, with its traditional variety of calcium-rich foods. The reasons are an increasingly fast-paced life and the independent life styles of different people in a family. Also, children increasingly drink soft drinks during meals and snacks instead of milk products. Another factor is that many children, particularly teenage girls, believe that dairy products are

high in fat content and that eating too many dairy products will lead to obesity. Of course this is related to a perception, particularly among girls, that skinny is beautiful. Besides being of debatable aesthetics, an obsession with thinness can lead to eating disorders, such as anorexia, which can in turn damage a girl's skeleton. Eating disorders often are associated with cessation of menstrual periods, with a corresponding decrease in estrogen levels. Since estrogen in girls is essential in growing bone tissue, a girl who suffers amenorrhea (an unnatural cessation of menstruation not due to pregnancy) is likely to suffer reduced bone growth. For those who refuse or cannot consume dairy products there are available alternatives such as calcium-enriched foods which can be prescribed by dieticians or pediatricians.

### Vitamin D

Vitamin D is essential for bone growth and health at all ages, because vitamin D helps the body absorb ingested calcium and to deposit the calcium, with phosphate, into the skeleton. One natural source of vitamin D is exposure to sunshine.

## Milk consumption falls, soft drinks zoom



These figures from the USA show that in 1970 there was far more milk than regular soft drinks in the food supply. By 1995 soft drinks had surged ahead. Why is this a problem for bone health? The negative influence of soft drinks on the acquisition of peak bone mass is probably related to the associated low consumption of calcium-rich beverages, the so-called "milk-displacement effect".

Currently, teenage American girls consume only 60% of the recommended amount of calcium, and girls who are soft-drink drinkers consume almost one-fifth less calcium than nonconsumers of soft drinks.

*From United States Department of Agriculture, Economic Research Service Statistical Bulletin No 939, 1997*

Regardless of the recommended daily allowance, many children do not take in enough calcium to build strong bones.

### Calcium content of some common foods

Food	Portion	Calcium (mg)
Cheddar cheese	100 g	800
Milk, semi-skimmed	500 ml	663
Milk, full cream	500 ml	638
Yoghurt	125 g	225
Muesli	55 g	110
Canned sardines in oil	100 g	550
Broccoli	100 g	100
Spinach	100 g	130
Dried figs	100 g	280

## How much calcium is enough?

Most experts agree that calcium intake should be increased during the most important years of bone growth – particularly the pre-teen and teenage years. Nevertheless, there is little agreement by national experts as to how much calcium is recommended.

The recommended range for toddlers (1-3 years) ranges from 350mg per day in the UK up to 500 mg per day in the USA and Canada. For children 7 to 10 years old, the recommended daily requirement varies from 550 mg in the UK to 1300 mg in the United States and Canada. Recommendations for girls 15-18 range from 800 mg in the UK to 1200mg in France and 1300mg in Canada and the USA, and for boys 15-18 the range varies from 900mg in the Nordic countries to 1300 mg in Canada and the USA.



When exposure to natural sunlight is insufficient (for example, when babies are kept indoors), it is essential to supplement infants with approximately 400 I.U. of vitamin D per day. A failure to ensure a normal supply of vitamin D, either by sunshine exposure or by oral supplementation, may jeopardize the building up of strong bones.

### Proteins

In addition to calcium, protein plays a key role in bone mass acquisition. During growth, under-nutrition, including insufficient caloric intake and protein, can severely impair bone development. Low protein intake can be detrimental for skeletal integrity by lowering

both the production and action of a growth factor, IGF-1, which enhances bone formation. In addition this growth factor stimulates both the intestinal absorption of the bone mineral elements, calcium and phosphate, via an increase in the renal production of calcitriol, the hormonal form of vitamin D. Therefore, during growth and pubertal maturation, an impaired production and/or action of IGF-1 due to a low protein intake may result in reduced bone development. This is why we find a positive correlation between protein intake and bone mass gain in children.

## ■ What is the influence of sport and exercise?

Young bones respond more to exercise than do adult bones.

The most effective exercise is weight-bearing exercise – walking, gymnastics, aerobics, ball games, competitive sports, dancing – and children and adolescents who exercise regularly show significant increase in bone mass.

Interestingly, the increased bone mass that results from intense physical activity, training for competitive sports, during childhood and adolescence is maintained in young adults even after training slows down or ceases completely.

Too much exercise, particularly among girls, can harm bone growth, particularly when intensive physical activity is accompanied by loss of body weight and reduced

sexual hormone production that leads to the cessation of menstruation. Obviously, most young people do not engage in intense physical activity at a high competitive level. So how much exercise is enough?

Moderate exercise programs in schools increase the bone mass gain of children. It is still not clear which moderate exercises are most effective for developing bone at different sites of the skeleton.

On the one hand it is certain that bone, like muscle, can become stronger in response to more or less moderate physical stress. On the other hand, the increasing attraction of television, video games or surfing on the internet promotes a sedentary life style which does not favor the optimal development of bone mass and strength during childhood and adolescence.



Children and adolescents who exercise regularly show significant increase in bone mass.



A sedentary life style does not favour the optimal development of bone mass and strength.

## ■ What is the impact of smoking, coffee, soft drinks?

### **Tobacco**

Over the last ten years tobacco use among adolescents has increased substantially in several countries, particularly in female teenagers. Smoking may affect the attainment of peak bone mass, particularly when it is associated with other health risk behavior such as inadequate nutrition and low physical activity. However, the greatest concern is the fact that cigarette use during adolescence increases the risk of continued and heavy smoking during adulthood. In adult female smokers bone mineral mass is reduced and the risk of hip fractures is increased. The same increased risk also exists in men. Therefore, avoiding tobacco use during adolescence is an efficient way of reducing the risk of osteoporotic fractures as well as preventing other health problems in later life..

### **Alcohol**

There is little information on the influence of alcohol on peak bone mass attainment in young people. In adult men and women excessive alcohol consumption is associated with a decrease in bone formation. Hence, it can be predicted that alcohol will also exert a negative effect on bone mass development during adolescence.

### **Coffee**

There is no evidence that caffeine consumed in a reasonable amount impairs bone mass acquisition during adolescence.

### **Soft drinks**

It has been suggested that low peak bone mass results from the excessive consumption of soft drinks because of the high phosphate content of carbonated cola beverages. There is no scientific evidence that supports this claim. However, soft drinks are not necessarily good for bone health, and any negative influence of soft drinks on the acquisition of peak bone mass is probably related to the associated low consumption of calcium-rich beverages, the so-called “milk-displacement effect”.

### **Body weight and bone health**

Excessive leanness in adolescence leads to a low peak bone mass. It is not clear whether obesity during childhood and adolescence either impairs or favors bone mass gain.



Erika Goodman, a lead dancer with the Joffrey Ballet in New York, was described by a critic as "a treasure of her generation." Due to her self-imposed anorexia as a young dancer, her bone growth was affected and she now suffers severe osteoporosis. Erika, now 54, says.

"The really perverse irony of this is that what has been taken away from me are my legs."

Many girls struggle to stay skinny in order to participate in dance, competitive sports and to emulate an emaciated self-image perpetrated by the fashion industry. Besides being of debatable aesthetics, an obsession with thinness can lead to eating disorders such as anorexia which can in turn damage a girl's skeleton.

## ■ What other research needs to be done?

In order to establish scientifically based recommendations, additional research is needed on the impact of nutrition and physical activity on peak bone mass and strength. Particularly it will be important to determine, by

well-designed interventional studies carried out at various ages during childhood and adolescence with a follow-up period till the end of skeletal development, the most efficient ways to increase peak bone mass and strength.

## ■ Conclusion and recommendations

The prevention of osteoporosis begins with optimal bone mass acquisition during growth. Factors which limit this acquisition result in a reduced peak bone mass, which in turn is an important determinant of the risk of osteoporotic fracture in later life. Several non-genetic factors, particularly nutrition, physical activity, and sun exposure can influence substantially the gain of bone mass during childhood and adolescence. Despite a certain number of uncertainties which need more research, there is enough evidence from studies on bone development in children and adolescents so that the following recommendations for bone growth in children and adolescents can be made :

- ensure an adequate calcium intake which meets the relevant dietary recommendations in the country or region concerned

- avoid undernutrition and protein malnutrition
- maintain an adequate supply of vitamin D through sufficient exposure to the sun or oral supplementation
- increase the general level of physical activity
- avoid smoking
- educate adolescents about the risk of high alcohol consumption

Each country or region should develop its own strategy in order to translate these general recommendations into specific actions adapted to the local cultural and economic conditions.

## ■ Further Reading

Bonjour J.-P. and Rizzoli R. (2001). Bone acquisition in adolescence. In "Osteoporosis, Second Edition" (Marcus R., Feldman D., and Kelsey J., eds), pp. 621-638. San Diego: Academic Press. • Rizzoli R., Bonjour J.P. and Ferrari S.L. (2001). Osteoporosis, genetics and hormones. *J. Mol. Endocrinol.* 26:79-94. • Seeman E. (2001). The effects of tobacco and alcohol use on bone. In "Osteoporosis, Second Edition" (Marcus R., Feldman D. and Kelsey J., eds), pp. 771-794. San Diego: Academic Press. • Specker B., Namgung R., and Tsang R.C. (2001). Bone mineral acquisition in utero, during infancy and throughout childhood. In "Osteoporosis, Second Edition" (Marcus R., Feldman D., and Kelsey J., eds), pp. 599-620. San Diego: Academic Press.



**International Osteoporosis Foundation**

The International Osteoporosis Foundation (IOF), with over 120 member societies from around the world, supports the worldwide effort to educate people about bone health.

**IOF's Mission**

- To support national societies in order to maximize their effectiveness
- To increase awareness and understanding of osteoporosis
- To motivate people to take action and to prevent, diagnose, and treat osteoporosis

The theme of World Osteoporosis Day, October 20, 2001, is Invest in Your Bones-Education. For more information about World Osteoporosis Day and the wide range of materials available from IOF (including videos, press materials, the Bone Education Resource Center, and the One Minute Risk Test), please contact:

**IOF**

5 Rue Perdtemps  
1260 Nyon  
Switzerland  
Tel: +41 22 994-0100  
Email: [info@osteofound.org](mailto:info@osteofound.org)  
Website: [www.osteofound.org](http://www.osteofound.org)

An increasing number of schools worldwide teach bone education. See the IOF Bone Education Resource Center, at [www.osteofound.org](http://www.osteofound.org), for examples of some of the imaginative education programs run by IOF member societies.

The publication of this report was made possible by a partial unrestricted grant from NESTLE SA.

In partnership with:  
International Council of Nurses

Bone & Joint Decade

Editorial adviser / Paul Spencer Sochaczewski  
Production supervisor / Laura Misteli  
Designer / Claudio Bernardis

“The truth is that osteoporosis is a silent epidemic. Its foundation is laid in the early years of childhood, but manifests itself later in life. Prevention begins early on, particularly among young girls who face greater risk as they grow older. It begins with highlighting the need to know about preserving our bones in the early years of bone formation.”

Queen Rania of Jordan  
IOF Patron  
Worldwide Conference of Osteoporosis  
Patient Societies  
Naples, Italy, May 27, 2001

