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Editorial

It is well known that calcium and vitamin D have essential roles in maintaining good health and nutritional well-being throughout the life cycle. In fact, one of the first things that most schoolchildren learn about vitamins and minerals is just how important calcium and vitamin D are for building and maintaining strong bones. However, while skeletal health is still the centre of much of the interest in these nutrients, recent research has provided fascinating insights into a wide range of nutritional and health issues associated with them.

Inadequate dietary calcium is associated with a number of common chronic medical disorders worldwide, such as osteoporosis, cardiovascular diseases, diabetes and hypertensive disorders of pregnancy, obesity and colon cancer. Inadequate vitamin D is associated with bone abnormalities, such as rickets, and with a decrease in the body's ability to absorb calcium. Osteoporosis, in particular, is a major public health problem in many countries and is one of the most significant causes of long-term disability in older people, especially older women.

One of the outcomes of recent research on the role of calcium in physical development and health is an increasing recognition of the complex interaction among various nutrients and other biologically active compounds in foods. While further research is needed to understand these relationships better, it is clear that a varied, balanced diet and regular physical exercise are fundamental to controlling some of the diseases associated with low levels of calcium intake.

To understand better the complex roles of calcium and vitamin D, FAO, the World Health Organization and Italian authorities sponsored the First World Congress on Calcium and Vitamin D in Human Life in Rome, Italy in October 1996. Scientists from around the world discussed ways to improve intakes of these nutrients among all population groups and to promote proper growth during infancy, childhood and adolescence. They emphasized the importance of adequate amounts of vitamin D and the need for foods rich in calcium as the best way to ensure adequate intakes and help prevent such disorders as poor bone formation, poor growth and loss of bone mass.

Several of the participants in the congress have contributed articles to this issue of *Food, Nutrition and Agriculture*. The experts view calcium and vitamin D from an evolutionary perspective and review the history of scientific inquiry about these nutrients. The importance of calcium throughout each stage of life is explained. Authors point to the value of physical exercise to enable individuals to benefit fully from adequate calcium intakes. They demonstrate the need to weigh carefully all factors in establishing public health policies that encourage the consumption of specific nutrients and modifications in the food supply.

It is hoped that readers will find this issue of *Food, Nutrition and Agriculture* a useful source of information on means of reducing the risk of disease, improving nutritional status and enhancing well-being among all people throughout the world.

♦

Il est bien connu que le calcium et la vitamine D jouent un rôle fondamental dans le maintien de la santé et du bien-être nutritionnel tout au long de la vie. De fait, l'une des premières notions que la plupart des enfants apprennent à l'école concernant les vitamines et les minéraux est l'importance de la vitamine D et du calcium pour la constitution des os et leur maintien en bon état. Bien que la santé osseuse soit aujourd'hui encore la raison principale de l'intérêt porté au calcium et à la vitamine D, des recherches récentes ont fourni des informations du plus haut intérêt sur divers aspects de la santé et de la nutrition liés à ces nutriments.

On observe dans le monde entier qu'un certain nombre de troubles chroniques et fréquents, tels que l'ostéoporose, les maladies cardiovasculaires, le diabète et les troubles d'hypertension chez la femme enceinte, l'obésité et le cancer du côlon, proviennent d'une carence en calcium dans l'alimentation tandis qu'une mauvaise ossification (rachitisme, par exemple) et une diminution de la capacité du corps à absorber le calcium traduisent une carence en vitamine D. Dans de nombreux pays, l'ostéoporose, en particulier, est l'un des plus grands problèmes de santé publique et l'une des premières causes d'invalidité de longue durée chez les personnes âgées, tout particulièrement chez les femmes.

Les nouvelles recherches sur le rôle du calcium dans le développement du corps humain et la santé font de plus en plus souvent ressortir l'interaction complexe de divers nutriments et d'autres composants ayant une activité biologique dans les aliments. Des recherches plus approfondies sont nécessaires pour mieux appréhender cette interaction, mais il est d'ores et déjà clair qu'une alimentation bien équilibrée et diversifiée, ainsi que la pratique régulière d'une activité physique, sont essentielles pour réduire le risque de certaines maladies provoquées par de faibles apports calciques.

En octobre 1996, la FAO, l'Organisation mondiale de la santé et les autorités italiennes ont parrainé, à Rome, le Premier Congrès mondial sur le rôle du calcium et de la vitamine D dans la vie humaine, afin de mieux comprendre le rôle complexe du

calcium et de la vitamine D. Les scientifiques venus du monde entier ont examiné les possibilités d'augmenter les apports en calcium et en vitamine D des divers groupes de population et de favoriser ainsi la bonne croissance des nourrissons, des enfants et des adolescents. Ils ont souligné l'importance d'apports suffisants en vitamine D et en aliments riches en calcium si l'on veut éviter des problèmes tels qu'une ossification insuffisante, une mauvaise croissance ou une perte de la masse osseuse.

Certaines personnes ayant participé au Congrès ont contribué, sous forme d'articles, à ce numéro de la revue *Alimentation, nutrition et agriculture.* Ces spécialistes étudient le calcium et la vitamine D dans une perspective évolutive et retracent l'historique de la recherche scientifique en la matière. Ils expliquent le rôle que joue le calcium à chaque étape de la vie et insistent sur l'importance de l'activité physique pour profiter pleinement d'un apport suffisant en calcium. Les auteurs montrent enfin qu'il faut prendre en considération toutes les conséquences avant de mettre en œuvre des politiques de santé publique préconisant la consommation de certains nutriments et des modifications de l'approvisionnement alimentaire.

Nous espérons que les lecteurs trouverons dans ce numéro de *Alimentation, nutrition et agriculture* des informations utiles pour réduire les risques de maladie, améliorer le niveau nutritionnel et promouvoir le bien-être de tous.

♦

Es bien sabido que el calcio y la vitamina D contribuyen de manera esencial a mantener la buena salud y el bienestar nutricional en el curso de la vida. De hecho, una de las primeras cosas que aprenden casi todos los escolares sobre las vitaminas y los minerales es la importancia del calcio y la vitamina D para la formación y el mantenimiento de unos huesos fuertes. Sin embargo, aunque gran parte del interés por estos nutrientes sigue centrándose en su importancia para el buen estado de los huesos, recientes investigaciones han arrojado interesantes resultados sobre una amplia variedad de cuestiones nutricionales y sanitarias relacionadas con ellos.

La insuficiencia de calcio alimentario está asociada con diversos trastornos comunes y crónicos en todo el mundo, como la osteoporosis, las enfermedades cardiovasculares, la diabetes y los trastornos hipertensivos del embarazo, la obesidad y el cáncer de colon. La insuficiencia de vitamina D está asociada con anomalías óseas, como el raquitismo, y con un descenso de la capacidad del organismo para absorber el calcio. La osteoporosis, en particular, es un importante problema de salud pública en muchos países y una de las principales causas de invalidez de larga duración en personas ancianas, especialmente mujeres.

Uno de los resultados de investigaciones recientes sobre la función del calcio en el desarrollo físico y la salud ha sido el creciente reconocimiento de la compleja interacción entre diversos nutrientes y otros componentes biológicamente activos de los alimentos. Aunque son necesarias más investigaciones para comprender mejor estas relaciones, es evidente que comer alimentos variados, mantener una alimentación equilibrada y realizar habitualmente ejercicio físico son factores fundamentales para combatir algunas de las enfermedades asociadas con bajos niveles de ingestión de calcio.

Para comprender mejor la compleja función del calcio y la vitamina D, la FAO, la Organización Mundial de la Salud y las autoridades italianas patrocinaron el Primer Congreso Mundial sobre el Calcio y la Vitamina D en la Vida Humana, que se celebró en Roma, Italia, en octubre de 1996. Científicos procedentes de todo el mundo examinaron medios para mejorar las ingestas de estos nutrientes en todos los grupos de población y para promover un crecimiento adecuado durante la lactancia, la niñez y la adolescencia. Subrayaron la importancia de recibir cantidades suficientes de vitamina D y la necesidad de alimentos ricos en calcio como el mejor modo para asegurar ingestas adecuadas y evitar trastornos tales como la formación defectuosa de los huesos y la pérdida de masa ósea.

Varios de los participantes en el Congreso han colaborado en el presente número de *Alimentación, Nutrición y Agricultura.* Los expertos estudian el calcio y la vitamina D desde una perspectiva evolutiva y pasan revista a la historia de la investigación científica sobre estos nutrientes. También se explica la importancia del calcio en cada una de las etapas de la vida. Los autores señalan la importancia de que las personas realicen ejercicio físico para que puedan aprovechar plenamente el calcio que ingieren. También demuestran la necesidad de sopesar cuidadosamente todos los factores al establecer políticas de salud pública que fomenten el consumo de determinados nutrientes y la modificación del suministro alimentario.

Confiamos en que el presente número de *Alimentación, Nutrición y Agricultura* será de utilidad para los lectores y les informará sobre los medios para reducir el riesgo de enfermedades, mejorar el estado nutricional y promover el bienestar de la población en todo el mundo. ♦

The roles of calcium and vitamin D in skeletal health: an evolutionary perspective

R.P. Heaney
Robert P. Heaney is John A. Creighton University Professor, Creighton University, Omaha, Nebraska, United States.

Hominid evolution took place in an environment (equatorial East Africa) that provided a superabundance of both calcium and vitamin D, the first in available foods and the second through conversion of 7-dehydrocholesterol to pre-vitamin D in the skin, a reaction catalysed by the intense solar ultraviolet (UV) radiation. Seemingly as a consequence, the evolving human physiology incorporated provisions to prevent the potential of toxic excesses of both nutrients. For vitamin D the protection was of two sorts: skin pigmentation absorbed the critical UV wavelengths and thereby limited dermal synthesis of cholecalciferol; and slow delivery of vitamin D from the skin into the bloodstream left surplus vitamin in the skin, where continuing sun exposure led to its photolytic degradation to inert compounds. For calcium, the adaptation consisted of very inefficient calcium absorption, together with poor to absent systemic conservation. The latter is reflected in unregulated dermal calcium losses, a high sensitivity of renal obligatory calcium loss to other nutrients in the diet and relatively high quantities of calcium in the digestive secretions.

Today, chimpanzees in the original hominid habitat have diets with calcium nutrient densities in the range of 2 to 2.5 mmol per 100 kcal, and hunter-gatherer humans in Africa, South America and New Guinea still have diets very nearly as high in calcium (1.75 to 2 mmol per 100 kcal) (Eaton and Nelson, 1991). With energy expenditure of 3 000 kcal per day (a fairly conservative estimate for a contemporary human doing physical work), such diets would provide substantially in excess of 50 mmol of calcium per day. By contrast, median intake in women in North America and in many European countries today is under 15 mmol per day.

Two factors altered the primitive situation: the migration of humans from Africa to higher latitudes and the adoption of agriculture. The first reduced environmental vitamin D availability, and the second, the calcium content of the diet.

MIGRATION AND THE VITAMIN D SYSTEM

The vitamin D system began its evolutionary adaptation much earlier than the calcium system. Long before the adoption of agriculture and a settled mode of existence, waves of humans left East Africa and populated higher latitudes. Since, with the exception of oily fish, available foods did not provide significant quantities of vitamin D, these populations lost most or all of their skin pigmentation and thereby improved their production of vitamin D to compensate for the lower solar UV radiation at the higher latitudes. Rickets and osteomalacia, still common today in dark-skinned immigrants to northern Europe and North America, would presumably have placed nomadic tribes at a severe reproductive disadvantage (rickets being a disorder of the pre-reproductive years); thus the evolution of reduced skin pigmentation must have occurred relatively rapidly. Still, it should be noted that the evolutionary trend of decreasing skin pigmentation with increasing latitude has manifest limits. At far northern and southern latitudes, the angle of the sun during most of the year is so low, even at noon, that effectively no UV radiation reaches the surface of the earth. Thus, the further north one lives, the greater the dependence on food (or, today, pharmaceutical) sources of vitamin D.

Calcium, by contrast, would still have been abundant in the food of hunter-gatherer nomads in Europe and Asia. Leafy greens, nuts, roots, tubers and the other foods in a typical hunter-gatherer's diet tend to be quite calcium rich. Indeed, the annual rack of antlers produced by deer species in northern latitudes is testimony to the environmental abundance of calcium.

DEVELOPMENT OF AGRICULTURE AND THE CALCIUM SYSTEM

The paleolithic high calcium intake probably prevailed for the human race as long as humans followed a hunter-gatherer economy, that is until about 10000 BC in the Fertile Crescent and until perhaps no more than 2 000 to 3 000 years ago in the Western Hemisphere. Thus the number of elapsed generations from the shift to an agriculture-based economy has not been sufficient to permit substantial evolutionary change in calcium physiology.

The adoption of agriculture, mandated in part by population pressures, would have meant a substantial fall in the calcium content of the diet, since cereals have very

low calcium density. Foraging would still have provided some roots and tubers, but their contribution to the diet would have been limited by the fact that agriculture required the community to be relatively settled, thus limiting the range over which they could roam for food. However, even in early farming communities calcium intake was probably not as low as the composition of the cereal grains might suggest. In the Fertile Crescent, for example, there is abundant evidence that limestone mortars and querns were used for the processing of cereal grains (Molleson, 1994). Grinding of grains would have contributed substantial quantities of calcium carbonate to the resulting flour; thus the product may be thought of as the first known fortified food. With the development of metallurgy and the ability to fabricate harder and harder millstones (mostly silicon-based, rather than calcium-based), this source of calcium was gradually lost.

From the Iron Age to the present there were even fewer generations to permit human physiologies to adapt to the reduction in calcium intake. Furthermore, the principal skeletal consequence of a low calcium diet, osteoporosis, is a disease of the post-reproductive years; therefore calcium deficiency would give affected populations a less severe reproductive disadvantage than environmental vitamin D deficiency.

CALCIUM AND VITAMIN D REQUIREMENTS

It has been understood for over a century (even since before vitamin D was identified) that absence of vitamin D produces manifest disease. It was less clear, at least until recently, that low calcium intakes had any untoward consequences. Clearly, the fact that calcium intake was high under primitive conditions does not mean, in its own right, that people need that much or that the requirement today is higher than the amount contemporary diets provide. In fact, until quite recently, significant components of the scientific community were of the opinion that there was, for all practical purposes, no calcium deficiency disease in humans and, correspondingly, that there was, effectively, no calcium requirement (Kanis and Passmore, 1989). In other words, it was held that even the relatively restricted calcium intakes of contemporary industrialized nations provided sufficient calcium to meet the needs of almost everyone. That position is no longer tenable.

In the early days of nutritional science, requirements were estimated by determining the intakes of populations in which particular deficiency diseases were and were not prevalent; the requirement was defined as the lowest intake prevailing in populations with low occurrence rates of the deficiency state. The criteria for recognition of deficiency in the early years of the twentieth century were necessarily crude, and the understanding of the biochemistry of the vitamins very rudimentary at best. Much more sensitive and specific criteria have been established in recent years, and it has become clear that mere absence of clinically apparent disease is not the same thing as health. Thus requirements today are increasingly being defined on the basis of the intake required to maintain optimal functioning of the systems in which the nutrients operate.

Factors influencing calcium requirements

Calcium occupies a nearly unique position among the essential nutrients. Like many of the vitamins and trace minerals, it has key roles in signal transduction and catalytic protein activation at the most fundamental levels of cell biology. Furthermore, a constantly maintained concentration of calcium ions in the extracellular fluid (ECF) is critical for optimal functioning of the neuromuscular and blood coagulation systems, among others. These roles are so critical to life, both of the cell and of the organism itself, that systems have evolved for extraordinarily tight regulation of ECF calcium ion concentration.

Aquatic vertebrates had two mechanisms to buffer calcium ion concentration: transfer of ions across the gill membrane and transfer of ions in and out of bone. The first predominated, with the calcium-rich external aquatic environment serving both as the reserve (to be called upon in situations of need) and the sink (to be used for disposal of excess). As vertebrate evolution progressed to life outside a supporting aquatic medium, the bone mechanism assumed increased importance. It was now the only source and sink for buffering ECF calcium ion concentrations, and at the same time it provided the internal structural rigidity needed for locomotion and gravity-resisting activity. With the exception of energy (stores of which serve as thermal insulation), calcium is the only nutrient known for which the reserve has acquired a function in its own right, distinct from its fundamental metabolic role. In brief, humans walk about on their calcium reserve.

In adult humans, total body calcium amounts to about 400 mmol per kilogram, of which less than 0.1 percent is in the critical ECF compartment. Thus, the reserve is vast relative to the metabolic pool of the nutrient, and for all practical purposes metabolic calcium deficiency probably never exists, at least not as a nutritional disorder. However, because of the structural significance of the nutrient reserve, i.e. of the skeleton, it follows that any decrease in the size of the reserve relative to the genetically determined optimum will result in a corresponding decrease in bone strength.

Thus, unlike requirements for all other nutrients, the requirement for calcium relates not to maintenance of the metabolic function of the nutrient, but to the maintenance of an optimal reserve and the support of the reserve's function.

Small fluctuations around the optimum reserve size have no practical structural significance, but protracted, unbalanced withdrawals from the skeletal reserves produce inescapable structural consequences. It is now quite clear that this occurrence explains the rapid bone loss and at least some of the skeletal fragility of the elderly (Chapuy *et al.*, 1992; McKane *et al.*, 1996). Because the effect of unbalanced withdrawals from the calcium reserve accumulates over many years, the frequency of osteoporotic fractures tends to rise with age.

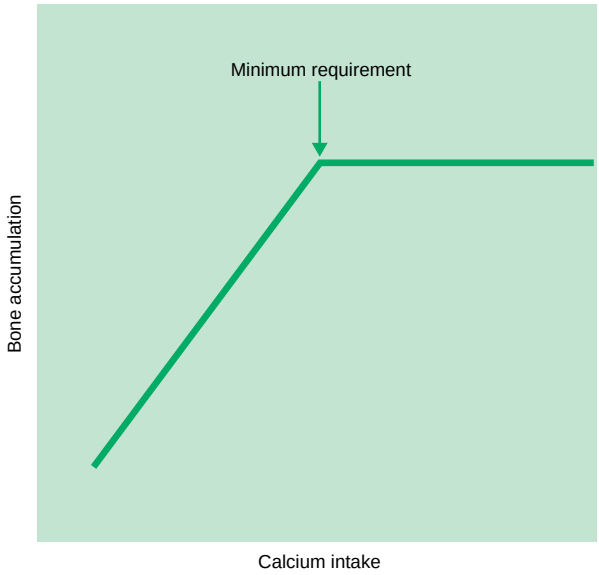
It must be stressed that reduced bone mass is not the only factor in osteoporotic fragility, and low calcium intake is not the only factor causing reduced bone mass. Osteoporotic fractures are complex phenomena involving not just intrinsic bone strength or fragility, but age-related neuromuscular changes that determine both the frequency and types of falls, as well as other critical factors. All these factors increase in intensity with age.

Calcium is virtually unique among nutrients in a second sense: the relationship between the size of the reserve and the environmental availability of the nutrient is asymmetric. (By contrast, energy, the fat-soluble vitamins and many trace minerals exhibit symmetrical reserve behaviour, i.e. their reserves can expand as well as shrink, virtually without limit.) In the face of environmental calcium shortage, the organism cannot build or maintain an optimal reserve; but in the face of surplus, the size of the reserve is completely determined not by the diet but by non-nutritional forces. Because ECF calcium concentration is rigidly regulated at levels equal to only about half the calcium and phosphate solubility product (Ca × P), excess absorbed calcium is spilled into the urine, not accumulated as calcific deposits. Bone mineralization requires active metabolic work. In brief, calcium is stored not as such, but as bone tissue, i.e. a composite of a protein matrix encrusted with mineral crystals. This composite is laid down as a result of cell-based activity, which, in turn, is determined by the combined effects of genetics and mechanical usage.

The importance of mechanical loading for optimal bone health is now well recognized. Bone, in essentially all vertebrates studied to date, has a density that permits bending of about 0.1 to 0.15 percent under the kinds of loads routinely imposed upon it by the organism. More massive bone is stiffer, bends less and is recognized by the organism as excessively heavy. As a consequence, some of the excess bone is removed in an ongoing remodelling process until the stiffness reaches the evolutionary optimal figure of 0.1 to 0.15 percent bending. Conversely, bone that bends more than the reference amount is recognized as flimsy, and the organism attempts to strengthen it by adding more bone through the normal remodelling. A surplus of calcium will not prevent the downward remodelling of excessively massive bone, but calcium deficiency will prevent the strengthening of flimsy bone.

Because of the asymmetric relationship between nutrient intake and the size of the reserve, calcium functions as a "threshold" or "plateau" nutrient, illustrated schematically in Figure 1. At suboptimal intakes the size of the reserve, i.e. the ability of the organism to store calcium as bone tissue, is limited by the intake of the nutrient. But above the quantity of bone determined as optimal for genetic and mechanical purposes, further increases in intake are not stored. As already noted, humans can store fat and fat-soluble vitamins virtually without limit, i.e. to the point of producing disease and/or toxicity. Calcium, however, can only be stored as bone, and increasing calcium intake beyond the amount that produces the optimal bone mass will not result in more bone, any more than increasing iron intake beyond the amount that produces the optimal haemoglobin mass will result in more blood. The requirement for such a nutrient can be visualized as the intake at, or just above, the knee of the curve in Figure 1.

Figure 2 shows the operation of this system from experiments in growing rats. Femur calcium content is seen to be a rising linear function of intake at low intake levels, but it does not change further above a threshold intake value. This behaviour is easy to demonstrate and understand in such animal models, particularly during growth. However, if body retention of calcium is substituted for bone mass in the figure, then the figure works for humans as well and, more important, for all ages. The concept leads to an approach to defining the calcium requirement based on maximal calcium retention. The calcium retention that is maximal will, of course, be quite different for different life stages. It should be positive during growth and pregnancy, stable during most of the adult years and probably somewhat negative during the declining years of life (as the skeleton adapts to the reduced mechanical loading associated with ageing). Whatever the retention value may be (positive, zero or negative), it is maximal with respect to intake when further increase in steady-state intake produces no further increase in retention. This approach has now been formally adopted in the United States for estimation of recommended calcium intakes (United States National Academy of Sciences, 1997).



Note: Below the threshold or plateau, bone accumulation is a linear function of intake (the ascending line); in other words, the amount of bone that can be accumulated is limited by the amount of calcium ingested. Above the threshold (the horizontal line), bone accumulation is limited by other factors and is no longer related to changes in calcium intake.
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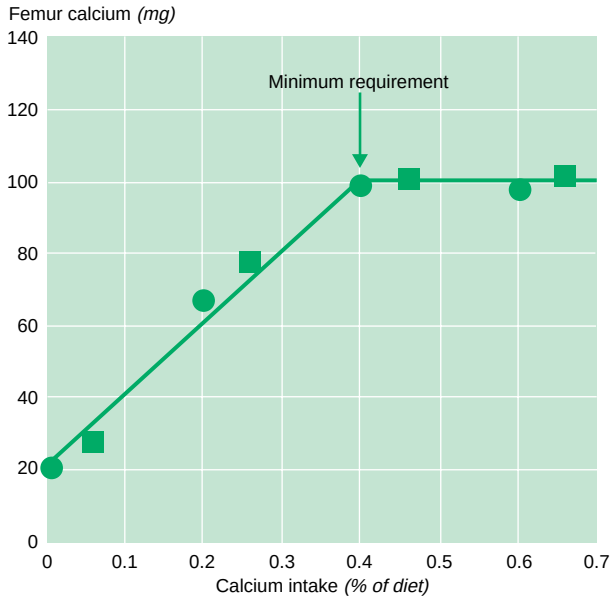
1
Theoretical relationship of bone accumulation to calcium intake



Source: Redrawn from data in Forbes *et al.*, 1979.
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2
Data from two experiments in growing rats, showing how bone accumulation exhibits a threshold pattern

Recommended calcium intakes in the United States and Canada

Life stage *(years of age)*	Recommended intake[a] *(mmol/day)*
4-8	20
9-13	32.5
14-18	32.5
19-30	25
31-50	25
51-70	30
>70	30

[a]Average requirements for the ages concerned.
Source: Data from United States National Academy of Sciences, 1997.

Average requirements for individuals living in the United States and Canada estimated using this criterion are given in the Table. (NB: recommended dietary allowances [RDAs] will be approximately 20 percent higher than the values in the Table.)

It should be stressed that there are important genetic and environmental influences on these average requirements, which will result in substantial differences both in the requirement for various national or ethnic groups and in the relationship of calcium intake to fracture risk.

The genetic influences, briefly, include such factors as bone architecture and geometry (e.g. hip axis length, vertebral cross-section) which have important effects on the structural properties of the bone and corresponding effects on fracture risk. Thus, while the basic relationship between bone mass and fracture risk and between bone mass and calcium intake is the same in Asians and Caucasians (Hu *et al.*, 1993), Asians have about half the hip fracture rate of Caucasians (Lau *et al.*, 1991), probably mainly because of a genetically shorter hip axis length (Cummings *et al.*, 1994). Ignorance of the importance of these structural features has led in the past to the erroneous conclusion that calcium intake was not related to fracture risk.

There are also important differences in responsiveness of bone to the hormones that mediate the function of bone as the body's calcium nutrient reserve. Blacks, with substantially heavier skeletons than Caucasians or Asians, both absorb and retain calcium more efficiently than Caucasians (Abrams *et al.*, 1995), probably as a consequence of somewhat reduced skeletal responsiveness to the action of parathyroid hormone. In other words, in the face of exogenous deficiency, the bone reserves are slightly less readily available, resulting in higher secretion of parathyroid hormone and better intestinal absorption and urinary retention (both also effects of parathyroid hormone). Thus, blacks have stronger skeletons than Caucasians, despite generally lower calcium intakes. Each racial group exhibits the same basic relationship between bone mass and calcium intake, only the equilibrium values are different.

The environmental influences on the calcium requirement include such factors as other constituents of the diet and the degree of mechanical loading imposed upon the skeleton in everyday life. As has already been noted, because calcium was a surfeit nutrient in the primitive environment, there was no need for evolving hominid physiology to develop means of conserving calcium. This lack is expressed in a unique sensitivity of the calcium economy to other constituents of the diet. Urinary calcium losses, for example, rise with both sodium intake (by 0.5 to 1 mmol of calcium per 100 mmol of sodium) and protein intake (by 0.025 mmol of calcium per gram of protein ingested) (Nordin *et al*., 1993; Heaney, 1996). At protein and sodium intakes typical of the industrialized nations, these effects result in average obligatory urinary calcium loss of 2 to 3 mmol per day, and in some individuals the loss is substantially greater. This effect would create no problem in the face of calcium surfeit, but it can be severely limiting in individuals with low calcium intakes, since the influence of these other nutrients restricts the ability of the organism to reduce calcium losses.

It is likely that the acid-ash residue of a high-meat diet has a similar effect, since substitution of chloride by organic anions in various diets has been shown to reduce urinary calcium loss dramatically (Berkelhammer, Wood and Sitrin, 1988; Sebastian *et al*., 1994). It is sometimes mistakenly said that there is a difference in this regard between animal and vegetable proteins, but the protein *per se* is probably not responsible for any difference that may exist. Rather, adequate protein from both sources will have approximately the same content of sulphur-containing amino acids (which become oxidized to sulphate). Instead, any difference would result from the different content of organic anions in vegetable and meat sources. (Incidentally, dairy products, though animal products, are alkaline-ash, rather than acid-ash, foods.)

These considerations mean that the calcium requirement, i.e. the intake necessary to reach the plateau of Figure 1, is substantially influenced by other constituents of the diet. Because net absorption of an increment in calcium intake is only about 10 percent, and because even the resulting small absorptive increase in ECF calcium concentration will cause some of that absorbed increment to be spilled into the urine, changes in obligatory losses through the skin and kidney are amplified by a factor of about 20-fold in their effect on the requirement. Thus, at low sodium and low protein intakes, the requirement may be as low as 12.5 mmol per day, whereas for typical Western diets, the requirement may be as high as 50 mmol per day. Therefore, the recommendations produced for North America are specifically intended to describe the requirement for individuals in the population there, and should not automatically be extrapolated to other population groups.

Factors influencing vitamin D requirements

The vitamin D requirement has been exceedingly difficult to define. The requirement was once defined by the absence of rickets and/or osteomalacia, which are now recognized to be manifestations of extreme deficiency. Lesser degrees of inadequacy (termed "insufficiency" in current jargon) limit the ability of the organism to adapt to low calcium intake with an appropriate increase in calcium absorption efficiency, and thus aggravate the prevailing low calcium intakes of many populations. In addition, it is likely that at high calcium intakes there is very little active transport of calcium mediated by vitamin D, but at low calcium intakes vitamin D is essential for the induction of a calcium-binding transport protein in the intestinal mucosa which enhances calcium extraction from the digestate. Thus the vitamin D requirement may in part be inversely related to prevailing calcium intakes.

Defining the requirement is complicated further by the fact that some fraction of the daily need is typically met from solar exposure, even in northern latitudes, and total body production from this source has never been adequately quantified.

One approach to estimating the requirement, useful with many other nutrients, is to determine the input required to offset daily consumption, utilization and loss of the nutrient. In an experiment involving persons living on atomic submarines who were deprived of all solar exposure for many months at a time, levels of serum 25-hydroxyvitamin D [25(OH)D] were maintained constant at oral intakes of 600 IU (15 µg) per day (Holick, 1994). This is three times the 1989 RDA for vitamin D in the United States (United States National Academy of Sciences, 1989). In the 1997 United States recommendations, the 1989 recommendation of 200 IU (5 µg) is maintained for young adults, who are likely to have substantial amounts of solar exposure, but for people in the middle and older age groups the recommendation has been raised to 400 and 600 IU per day, respectively, reflecting the fact that skin vitamin D synthesis declines with age and that solar exposure of the skin frequently declines as well (United States National Academy of Sciences, 1997).

A second approach to determining the vitamin D requirement is based on the determination of the level of serum 25(OH)D that is required to maintain optimal functioning of the calcium economy. It is well recognized that in northern Europe and North America serum 25(OH)D levels decline in late winter and early spring and reach an

annual peak in late summer and early fall (Webb, Kline and Holick, 1988; Salamone *et al.*, 1993). It was once thought that these changes reflected only changes in the size of the vitamin D reserve. However, it now seems clear that 25(OH)D levels below 80 to 110 nmol per litre in late winter or early spring (or, for that matter, at any time of year) result in increased release of parathyroid hormone, increased serum alkaline phosphatase, increased bone remodelling and decreased bone mass (Dawson-Hughes *et al.*, 1991; 1997; Rosen *et al.*, 1994). These changes are a clear indication that extraction efficiency of calcium from the diet declines at low serum 25(OH)D levels, and that the body is therefore forced to draw upon the skeletal reserves. Because these seasonal responses can be abolished by maintaining the serum 25(OH)D level in the range of 80 to 110 nmol per litre or higher (Dawson-Hughes *et al.*, 1991; 1997; Rosen *et al.*, 1994), the vitamin D requirement can be defined as the daily intake and/or production that results in such a serum 25(OH)D level.

Unfortunately, the precise relationship between daily input of vitamin D and serum 25(OH)D levels has not yet been adequately worked out. Nevertheless, clinical experience in the United States and Canada with therapeutic use of oral 25(OH)D indicates that doses in the range of 10 to 20 µg per day result in serum 25(OH)D levels in the desired range. If it is assumed that quantitative, steady-state conversion of vitamin D to 25(OH)D takes place on a mole-to-mole basis under physiological conditions, it follows that the requirement for vitamin D would be in the same range (effectively the requirement put forth by the United States National Academy of Sciences).

Incidentally, it is worth noting that young adults in North America typically have 25(OH)D levels well above 100 nmol per litre, and that seasonal outdoor workers frequently have levels above 150 nmol per litre at the end of the summer. Such levels are not known to be associated with toxicity or even perceptible physiological effects. Hence, maintaining a serum 25(OH)D level above 80 nmol per litre would seem to be safe as well as optimal.

CONCLUSION

Nutrition is only one component of skeletal health and fracture risk. The nutrients that are most important in this regard are protein, calcium, vitamin D, copper, zinc and ascorbic acid. Of these, calcium and vitamin D are the nutrients most likely to be limiting in the industrialized nations. The optimal calcium intake in the industrialized, northern nations, given existing dietary patterns, is probably in the range of 30 to 40 mmol per day. Because of the major influence of both environmental and genetic factors on the calcium requirement, there can be no single requirement for the world population. At least as far as skeletal health is concerned, the calcium requirement will usually be lower for blacks than for Asians and Caucasians. Since both salt and protein increase obligatory calcium losses, estimation of the calcium requirement must take into consideration other constituents of the diet. Finally, vitamin D should be provided in sufficient quantity to optimize the physiological control of the calcium economy. In brief, sun, food and/or supplements should combine to produce a year-round serum 25(OH)D level above 80 nmol per litre. ♦

REFERENCES

Abrams, S.A., O'Brien, K.O., Liang, L.K. & Stuff, J.E. 1995. Differences in calcium absorption and kinetics between black and white girls aged 5-16 years. *J. Bone Miner. Res.*, 10: 829-833.

Berkelhammer, C.H., Wood, R.J. & Sitrin, M.D. 1988. Acetate and hypercalciuria during total parenteral nutrition. *Am. J. Clin. Nutr.*, 48: 1482-1489.

Chapuy, M.C., Arlot, M.E., Duboeuf, F., Brun, J., Crouzet, B., Arnaud, S., Delmas, P.D. & Meunier, P.J. 1992. Vitamin D_3 and calcium to prevent hip fractures in elderly women. *N. Engl. J. Med.*, 327: 1637-1642.

Cummings, S.R., Cauley, J.A., Palermo, L., Ross, P.D., Wasnich, R.D., Black, D. & Faulkner, K.G. 1994. Racial differences in hip axis lengths might explain racial differences in rates of hip fracture. *Osteoporosis Int.*, 4: 226-229.

Dawson-Hughes, B., Dallal, G.E., Krall, E.A., Harris, S., Sokoll, L.J. & Falconer, G. 1991. Effect of vitamin D supplementation on wintertime and overall bone loss in healthy postmenopausal women. *Ann. Intern. Med.*, 115: 505-512.

Dawson-Hughes, B., Harris, S.S., Krall, E.A. & Dallal, G.E. 1997. Effect of calcium and vitamin D supplementation on bone density in men and women 65 years of age or older. *N. Engl. J. Med.*, 337: 670-676.

Eaton, S.B. & Nelson, D.A. 1991. Calcium in evolutionary perspective. *Am. J. Clin. Nutr.*, 54: 281S-287S.

Forbes, R.M., Weingartner, K.E., Parker, H.M., Bell, R.R. & Erdman, J.W. Jr. 1979. Bioavailability to rats of zinc, magnesium and calcium in casein-, egg- and soy protein containing diets. *J. Nutr.*, 109: 1652-1660.

Heaney, R.P. 1996. Nutrition and risk for osteoporosis. *In* R. Marcus, D. Feldman & J. Kelsey, eds. *Osteoporosis*, p. 483-505. San Diego, California, USA, Academic Press.

Holick, M.F. 1994. Vitamin D – new horizons for the 21st century (McCollum Award Lecture 1994). *Am. J. Clin. Nutr.*, 60: 619-630.

Hu, J.-F., Zhao, X.-H., Jia, J.-B., Parpia, B. & Campbell, T.C. 1993. Dietary calcium and bone density among middle-aged and elderly women in China. *Am. J. Clin. Nutr.*, 58: 219-227.

Kanis, J.A. & Passmore, R. 1989. Calcium supplementation of the diet – I and II. *Br. Med. J.*, 298: 137-140, 205-208.

Lau, E.M.C., Cooper, C., Donnan, S. & Barker, D.J.P. 1991. Incidence and risk factors for hip fractures in Hong Kong Chinese. *In* C. Christiansen & K. Overgaard, eds. *Osteoporosis 1990*, p. 66-70. Copenhagen, Denmark, Osteopress ApS.

McKane, W.R., Khosla, S., Egan, K.S., Robins, S.P., Burritt, M.F. & Riggs, B.L. 1996. Role of calcium intake in modulating age-related increases in parathyroid function and bone resorption. *J. Clin. Endocrinol. Metab.*, 81: 1699-1703.

Molleson, T. 1994. The eloquent bones of Abu Hureyra. *Sci. Am.*, 271: 70-75.

Nordin, B.E.C., Need, A.G., Morris, H.A. & Horowitz, M. 1993. The nature and significance of the relationship between urinary sodium and urinary calcium in women. *J. Nutr.*, 123: 1615-1622.

Rosen, C.J., Morrison, A., Zhou, H., Storm, D., Hunter, S.J., Musgrave, K., Chen, T. & Holick, M.F. 1994. Elderly women in northern New England exhibit seasonal changes in bone mineral density and calciotropic hormones. *Bone Miner.*, 25: 83-92.

Salamone, L.M., Dallal, G.E., Zantos, D., Makrauer, F. & Dawson-Hughes, B. 1993. Contributions of vitamin D intake and seasonal sunlight exposure to plasma 25-hydroxyvitamin D concentration in elderly women. *Am. J. Clin. Nutr.*, 58: 80-86.

Sebastian, A., Harris, S.T., Ottaway, J.H., Todd, K.M. & Morris, R.C. Jr. 1994. Improved mineral balance and skeletal metabolism in postmenopausal women treated with potassium bicarbonate. *N. Engl. J. Med.*, 330: 1776-1781.

United States National Academy of Sciences, Food and Nutrition Board. 1989. *Recommended dietary allowances.* Washington, DC, USA, National Academy Press. 10th ed.

United States National Academy of Sciences, Food and Nutrition Board. 1997. *Dietary reference intakes for calcium, magnesium, phosphorus, vitamin D, and fluoride.* Washington, DC, USA, National Academy Press.

Webb, A.R., Kline, L. & Holick, M.F. 1988. Influence of season and latitude on the cutaneous synthesis of vitamin D_3: exposure to winter sunlight in Boston and Edmonton will not promote vitamin D_3 synthesis in human skin. *J. Clin. Endocrinol. Metab.*, 67: 373-378. ◆

Summary/Résumé/Resumen

The roles of calcium and vitamin D in skeletal health: an evolutionary perspective

Because hominid evolution took place in an environment with an abundance of calcium and vitamin D, human physiology prevents toxic excesses of both nutrients. In the case of calcium, the protection consists of inefficient calcium absorption and poor systemic conservation. For vitamin D, the protection was provided by skin pigmentation and slow delivery of the vitamin from the skin into the bloodstream. With the migration of humans out of Africa to higher latitudes, the availability of vitamin D was reduced, and this resulted in evolutionary adaptation of the vitamin D system. The adoption of agriculture and a cereal-based diet lowered calcium intakes, but this occurred too recently to permit substantial change in calcium physiology.

Calcium plays key roles in signal transduction and catalytic protein activation at the most fundamental levels of cell biology, and a constantly maintained concentration of calcium ions in the extracellular fluid (ECF) is critical for optimal functioning of the neuromuscular and blood coagulation systems, among others. These roles are so critical to life that systems have evolved for extraordinarily tight regulation of ECF calcium ion concentration. However, less than 0.1 percent of total body calcium is in the ECF. The vast reserve is stored in the skeleton, where it has acquired a structural role. Thus the requirement for calcium relates not to maintenance of its metabolic function, but to the maintenance of an optimal reserve – the skeleton – and to supporting the skeleton's function. Protracted, unbalanced withdrawals from the skeletal reserves produce inescapable structural consequences.

Vitamin D inadequacy limits the body's ability to adapt to low calcium intake with an appropriate increase in calcium absorption efficiency, and thus aggravate the prevailing low calcium intakes of many populations. The vitamin D requirement may in part be inversely related to prevailing calcium intakes. Defining the requirement is complicated because some of the daily need is met from solar exposure, and total body production from this source has never been adequately quantified. The vitamin D requirement is also based on the determination of the level of serum 25(OH)D which is required to maintain optimal functioning of the calcium economy.

The nutrients that are most important for skeletal health are protein, calcium, vitamin D, copper, zinc and ascorbic acid. Of these, calcium and vitamin D are most likely to be limiting in the industrialized nations. The optimal calcium intake in these countries, given existing dietary patterns, is probably in the range of 30 to 40 mmol per day. Because of the major influence of both environmental and genetic factors on the calcium requirement, there can be no single calcium requirement for the world population.

Rôle du calcium et de la vitamine D dans la santé du squelette: une perspective évolutive

L'évolution humaine s'est déroulée dans un environnement riche en calcium et en vitamine D, et c'est pourquoi la physiologie humaine empêche l'assimilation d'excès toxiques de ces deux éléments. En ce qui concerne le calcium, la protection consiste en une absorption peu efficace et une faible assimilation du calcium. Pour la vitamine D, la protection est assurée par la pigmentation cutanée et par la lenteur du passage de la vitamine de la peau dans le sang. La migration des hommes depuis l'Afrique vers des latitudes plus élevées a réduit la disponibilité de vitamine D, ce qui a entraîné, lors de l'évolution humaine, une adaptation du système d'absorption de cette substance. L'avènement de l'agriculture et un régime à base de céréales pauvre en calcium se sont traduits par une baisse des apports en calcium.

Le calcium joue des rôles essentiels dans la transduction des signaux et l'activation catalytique des protéines aux niveaux les plus fondamentaux de la biologie cellulaire, et une concentration constante d'ions de calcium dans le liquide extracellulaire (LEC) est fondamentale pour un fonctionnement optimal de certains systèmes tels que le système neuromusculaire et celui de la coagulation du sang. Ces fonctions sont si vitales que les systèmes ont évolué pour permettre une régulation extrêmement fine de la concentration d'ions de calcium. Toutefois, moins de 0,1 pour cent du calcium corporel se trouve dans le LEC. La très grande réserve est stockée dans le squelette, où il joue un rôle structurel. Ainsi, le calcium ne sert pas à assurer la fonction métabolique du nutriment, mais à entretenir une réserve optimale dans le squelette et à permettre son fonctionnement. Une mise à contribution prolongée et excessive des réserves du squelette aura des conséquences structurelles inévitables.

L'insuffisance de vitamine D limite la capacité du corps à compenser un faible apport en calcium par une meilleure efficacité d'absorption, ce qui aggrave les carences observées dans de nombreuses

populations. Les besoins en vitamine D peuvent être, en partie, inversement proportionnels aux apports en calcium. Ces besoins sont difficiles à estimer car une partie des besoins journaliers sont satisfaits par l'irradiation solaire et il n'a jamais été possible de préciser la quantité totale de vitamine D que l'organisme tire de cette source. Les besoins en vitamine D sont par ailleurs fondés sur la détermination du taux sérique 25(OH)D nécessaire pour maintenir le fonctionnement optimal de l'équilibre calcique.

Les protéines, le calcium, la vitamine D, le cuivre, le zinc et l'acide ascorbique sont les nutriments les plus importants pour assurer la santé du squelette. Parmi ces substances, le calcium et la vitamine D sont celles qui font probablement le plus défaut dans les pays industrialisés. L'apport optimal en calcium dans ces pays, compte tenu de leurs habitudes alimentaires, se situe probablement aux alentours de 30-40 mmoles/jour. On ne peut définir les besoins en calcium de manière uniforme pour l'ensemble de la population mondiale car ils dépendent considérablement de facteurs d'ordre génétique et environnementaux.

Las funciones del calcio y de la vitamina D en la salud del esqueleto: una perspectiva evolutiva

Dado que la evolución de los homínidos tuvo lugar en un entorno en el que abundaban el calcio y la vitamina D, la fisiología humana evita que la ingesta excesiva de ambos nutrientes tenga efectos tóxicos. En el caso del calcio, la protección consiste en una absorción ineficiente y una escasa conservación sistémica de este elemento. En lo que respecta a la vitamina D, la protección consistió en la pigmentación cutánea y la lenta liberación de esta vitamina de la piel y su paso al torrente sanguíneo. La migración de seres humanos procedentes de Africa a latitudes superiores redujo la disponibilidad de vitamina D, mientras que la adopción de una agricultura basada en los cereales rebajó el contenido de calcio en la alimentación.

El calcio tiene una importancia decisiva en la transducción de señales y la activación catalítica de las proteínas en los niveles más fundamentales de la biología celular, mientras que el mantenimiento de una concentración constante de iones de calcio en el líquido extracelular es fundamental para el funcionamiento óptimo de los sistemas neuromuscular y de coagulación de la sangre, entre otros. Estas funciones son tan esenciales para la vida que los sistemas han evolucionado de manera que la concentración de iones de calcio en el líquido extracelular está regulada con extraordinaria precisión. Sin embargo, menos del 0,1 por ciento del calcio total del organismo se encuentra en el líquido extracelular. La mayor parte de la reserva se encuentra en el esqueleto, donde ha adquirido una función estructural. Las necesidades de calcio no guardan, por consiguiente, relación con el mantenimiento de la función metabólica del nutriente, sino con la conservación de una reserva óptima, es decir el esqueleto, y con el apoyo a su función. Un recurso prolongado y excesivo a las reservas óseas tiene inevitablemente consecuencias estructurales.

La insuficiencia de vitamina D limita la capacidad del organismo para adaptarse a una ingesta baja de calcio aumentando oportunamente la eficiencia de la absorción de éste, lo cual agrava la baja ingesta de calcio predominante en muchas poblaciones. Las necesidades de vitamina D pueden estar en parte inversamente relacionadas con la ingesta de calcio. Es complicado determinar la cantidad de vitamina D que se requiere, porque las necesidades diarias se cubren en parte con la exposición a los rayos del sol y nunca se ha cuantificado debidamente la producción total del organismo a partir de esta fuente. La definición de las necesidades de vitamina D se basa asimismo en la determinación del nivel de suero 25(OH)D que se requiere para mantener un funcionamiento óptimo de la economía del calcio.

Los nutrientes más importantes para el buen estado de los huesos son las proteínas, el calcio, la vitamina D, el cobre, el zinc y el ácido ascórbico. De ellos, el calcio y la vitamina D son los que más probabilidades tienen de producir efectos limitativos en los países industrializados. Teniendo en cuenta los hábitos alimentarios existentes en esos países, la ingesta óptima de calcio oscila probablemente entre 30 y 40 mmol/día. Dado que los factores ambientales y genéticos influyen considerablemente sobre las necesidades de calcio, no es posible establecer una cantidad única para las necesidades de calcio de la población mundial. ♦

Calcium in health and disease

B.E.C. Nordin
B.E. Christopher Nordin is Professor in the Division of Clinical Biochemistry, Institute of Medical and Veterinary Science, Department of Pathology at the University of Adelaide, South Australia, Australia.

Calcium is an essential but controversial nutrient: there is no consensus on the level of human calcium requirement or the significance of calcium deficiency. The explanation for this must be sought in the history of calcium research since Pommer (1885) first established the difference between osteoporosis and osteomalacia. Pommer showed that rickets and osteomalacia represented a failure to mineralize new bone as it was being formed, leading ultimately to a calcium deficit in the bony tissue itself, whereas osteoporosis was a deficit of whole bone tissue without change in its mineral content. Not long afterwards, Miwa and Stoeltzner (1898) demonstrated that calcium deficiency caused osteoporosis, not osteomalacia, in experimental adult animals. It was Mellanby (1918) who finally identified vitamin D as the factor that prevented and cured rickets. Soon after that, Telfer (1926) showed that vitamin D deficiency led to malabsorption of calcium. From this it was assumed that vitamin D deficiency and calcium deficiency must have the same metabolic consequences. Accepting the concept that both calcium and vitamin D deficiencies led to rickets or osteomalacia, Albright *et al.* (1938) invoked a new pathogenetic mechanism – failure of new bone formation because of sex hormone deficiency and/or negative nitrogen balance – to explain postmenopausal and other forms of osteoporosis.

This paradigm prevailed for a generation until a seminal paper from Sweden (Carlsson and Lindquist, 1955) showed that vitamin D not only regulated calcium absorption but also independently regulated plasma calcium homeostasis. This made it possible to distinguish vitamin D deficiency from calcium deficiency (Nordin, 1960) and allowed the re-emergence of the concept (Hess, 1929) that calcium deficiency led to osteoporosis and vitamin D deficiency to osteomalacia. Although this concept is increasingly accepted in theory, there is in practice no consensus about the contribution of calcium deficiency to clinical osteoporosis or about the reality of a calcium requirement in humans (Kanis and Passmore, 1989). Clearly the menopause is associated with a rise in bone breakdown rather than a fall in bone formation (Young and Nordin, 1967; Gallagher, Young and Nordin, 1972; Stepan *et al.*, 1987; Nordin and Polley, 1987; Prince *et al.*, 1995). The current issue is whether oestrogens inhibit bone resorption directly or whether they operate through the calcium economy; it is no longer maintained that they promote bone formation. In the meantime, Albright and colleagues' original ideas about osteoporosis survive in relation to corticosteroid-induced osteoporosis and perhaps as part of the explanation for age-related osteoporosis, particularly in men.

PHYSIOLOGY

Calcium is an essential nutrient accounting for about 2 percent of body weight, ranking fifth after oxygen, carbon, hydrogen and nitrogen. Nearly 99 percent of the body's calcium (1 200 g or 30 mol) is stored in the skeleton; the remainder is in the teeth and soft tissues (each containing 7 g or 175 mmol) and the extracellular fluid (ECF) (1 g or 25 mmol) (Nordin, 1976). Calcium comprises 25 percent of the dry weight of the skeleton and circulates in the ECF at a concentration of 6 to 7 mg per 100 ml (1.5 to 1.75 mmol per litre). The total calcium concentration within cells is comparable to that in the extracellular water, but the free calcium concentration is about 10^4 times lower (Robertson, 1988).

The most obvious function of calcium is to provide rigidity to the skeleton by virtue of the insoluble salts it forms with phosphoric acid. Primitive exoskeletons (such as shells) are composed of calcium carbonate formed in seawater, which is high in calcium but low in phosphorus. Fish endoskeletons may be composed of cartilage or bone. All mammalian skeletons are composed of true bone in which rigidity is provided by a particularly insoluble calcium salt analogous to the mineral hydroxyapatite [$Ca_{10}(OH)_2(PO_4)_6$] but containing also a small component of calcium carbonate (Termine and Posner, 1967).

The calcium salts do more than provide rigidity to the skeleton; they also constitute a very large reservoir of calcium for the maintenance of the (ionized) calcium concentration in the extracellular water at or very close to 4.8 mg per 100 ml (1.2 mmol per litre). The protection of this critical concentration by parathyroid hormone and vitamin D reflects the vital role that calcium plays in the neuromuscular system, in regulation of the heart, in

enzyme-mediated reactions and in many other metabolic processes. Since only about 1 g (25 mmol) of calcium normally circulates in the ECF, the skeleton can maintain the extracellular ionized calcium against external calcium deprivation for years before it suffers significant damage. It is important to recall that as calcium is removed from bone, the matrix is also resorbed; this is why the result is osteoporosis rather than osteomalacia.

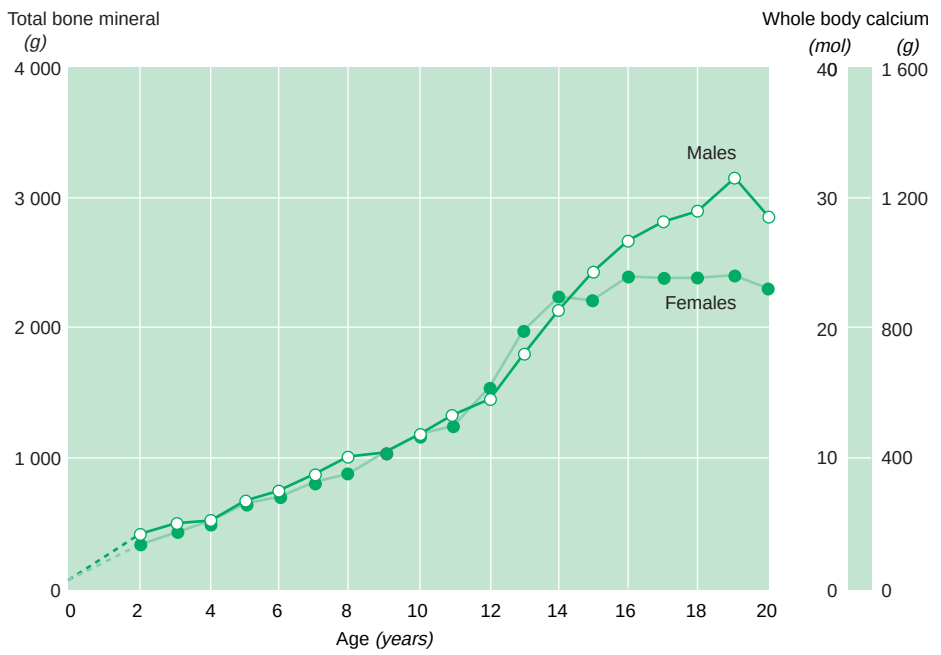
BONE GROWTH AND DECAY

Calcium enters the body through the gastro-intestinal tract, is absorbed mainly in the upper small intestine and is excreted via the bowel, kidneys and skin. During skeletal growth and maturation, i.e. until the age of the early twenties in humans, calcium accumulates in the skeleton at an average rate of 150 mg a day (Figure 1). During maturity, the body – and therefore the skeleton – is more or less in calcium equilibrium. From the age of about 50 in men and from the menopause in women, bone balance becomes negative and bone is lost from all skeletal sites (Figure 2). This bone loss is associated with a marked rise in fracture rates, starting with non-hip fractures in women after the menopause but leading to rising hip fracture rates in both sexes (Figures 3 and 4). The cause of the bone loss associated with menopause and ageing is uncertain. This paper looks at this question, particularly in relation to the body's calcium economy.

THE CALCIUM ECONOMY

Regulation of the calcium economy is somewhat more complex than that of other minerals such as sodium, potassium, phosphorus and magnesium (Marshall, Nordin and Speed, 1976). These other minerals are primarily regulated by a relatively simple homeostatic system in which variations in input modify the concentration in the ECF, which in turn modifies the urinary loss; as input rises or falls, the ECF concentration follows suit, and so does urinary excretion, until a new equilibrium is established at which input and output are equal. This account is of course an oversimplification, but it represents the essential feature of these systems.

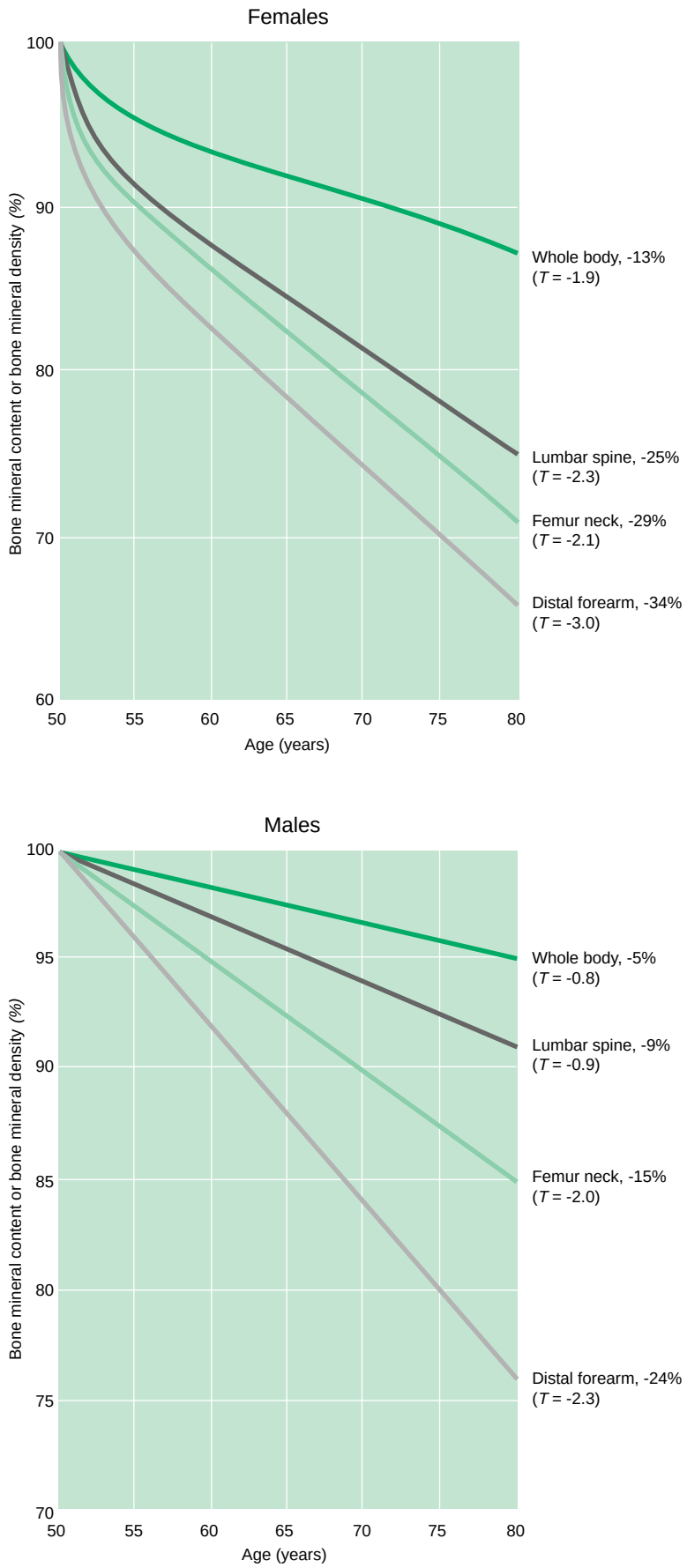
The calcium system contains a similar component but differs from the others in that the concentration of (ionized) calcium in the ECF is more vigorously defended, presumably because it is critical to so many physiological functions. Although it is true that raising calcium input raises ECF and urine calcium and therefore tends to equilibrium, the converse process (lowering of ECF and urine calcium when input falls) is limited by the intervention of parathyroid hormone secretion when the ionized calcium approaches the lower limit of the normal range. The result is the maintenance of the ECF ionized calcium and thus of calcium excretion via the kidneys and the bowel. The immediate effect of this parathyroid response is to increase renal tubular resorption of calcium



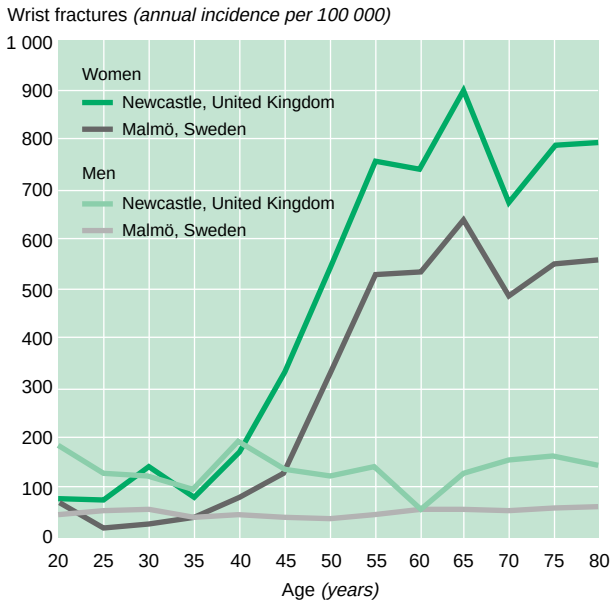
Source: J. Zanchetta, unpublished Norland bone densitometry data.
Note: Densitometry data are normally expressed in total bone mineral terms (left axis), whereas nutritionists normally consider the body content of elemental calcium (right axis). Bone mineral contains approximately 40 percent calcium.

1
Accumulation of total bone mineral and whole body calcium in boys and girls as a function of age

2
Percentage loss of bone at four different sites as a function of age in men and women

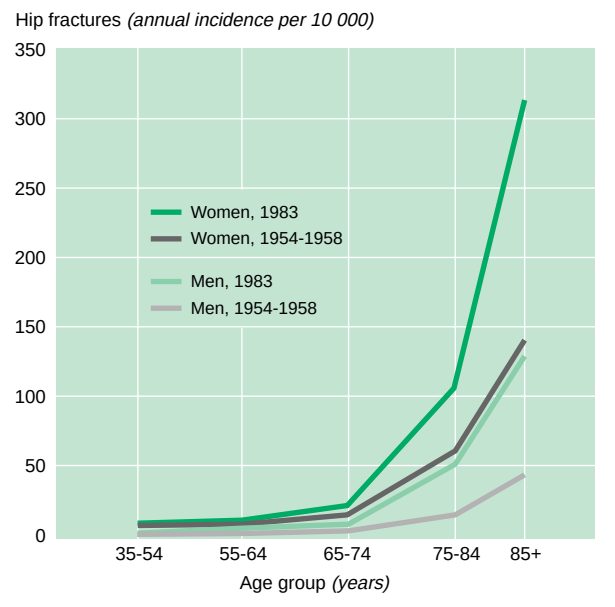


Source: Calculated from Wahner and Fogelman, 1994.



Source: **Miller and Grimley Evans, 1985.**

3
Wrist fracture rates as a function of age in men and women in two European cities



Source: **Calculated from Boyce and Vessey, 1985.**

4
Hip fracture rates as a function of age in men and women in Oxford, United Kingdom, 1954 to 1958 and 1983 (note the apparent increase in hip fracture rates between the 1950s and 1983)

(and so to conserve calcium) and to stimulate the synthesis of calcitriol [$1,25(OH)_2D_3$] in the kidneys to promote calcium absorption. If these mechanisms are insufficient to maintain the concentration of ionized calcium, parathyroid hormone secretion rises and increases bone resorption. This is the response of the organism to calcium deprivation, and it leads sooner or later to osteoporosis in experimental animals (Nordin, 1960). Osteoporosis can also be produced experimentally by oophorectomy, but the magnitude of the effect depends on the calcium intake (Hodgkinson *et al.*, 1978; Shen *et al.*, 1995) and can be amplified by sodium feeding, which increases the obligatory calcium loss (Goulding and Campbell, 1983). Since oestrogen insufficiency is regarded as the most important single risk factor for osteoporosis – at least in women – it is important to establish whether the negative calcium balance that follows the menopause is the cause or the result of the bone loss. This question requires consideration of the calcium requirement and therefore of the relationship among calcium intake, absorption and excretion.

Intake

Calcium consumption varies greatly worldwide, ranging from 800 mg per day or more in industrialized countries to 200 to 300 mg in some developing countries (FAO, 1991) (Table 1). The differences are mainly due to variation in the intake of dairy products, which are the richest sources of calcium. In countries where milk is scarce, calcium may be obtained from certain cereals, notably millets. Despite this large variation in calcium consumption, there is no evidence that osteoporosis is more common in developing than in industrialized countries – rather the reverse. In fact, the prevalence of hip fracture, as measured by mortality from fractures in the elderly (Eddy, 1972), is positively rather than negatively related to calcium intake (Figure 5). This paradox, and evidence of adaptation to low calcium intakes in Norwegian male prisoners (Malm, 1958), led a 1960 FAO/WHO Expert Committee to recommend a calcium allowance of only 500 mg (FAO, 1962). This recommendation is now being seriously questioned if not abandoned as the influence of other dietary constituents becomes increasingly apparent (Nordin *et al.*, 1996).

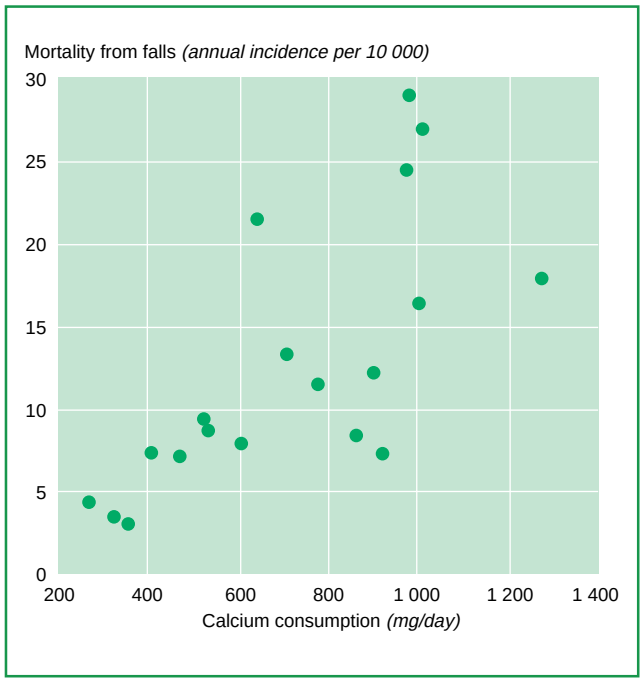
Absorption

Calcium is absorbed from the small intestine by a saturable active transport system with a diffusion component (Wilkinson, 1976; Marshall, 1976; Bronner, 1987; Heaney, Saville and Recker, 1975) (Figure 6). At low calcium intakes, most calcium travels by the active pathway, but as intake rises, the amount transported by diffusion (6 percent of

TABLE 1
Food consumption, latitude, hip fractures and standard of living in 19 countries

Country	Calcium consumption[a] *(mg/day)*	Animal protein[a] *(g/day)*	Latitude of capital city *(degrees N or S)*	Mortality from falls in women over age 75[b] *(per 10 000)*	Gross domestic product (purchasing power)[c] *(US$ per caput)*
Japan	354	52.2	19.2	2.9	21 140
Jamaica	319	27.5	17.6	3.4	3 400
Guatemala	262	7.6	14.5	4.3	3 440
Chile	466	27.1	33.0	7.2	8 890
Brazil	406	24.5	16.5	7.4	5 400
Australia	921	65.7	35.1	7.4	18 120
Argentina	603	63.6	34.4	7.9	8 720
United Kingdom	855	53.0	51.3	8.5	17 970
Ecuador	529	22.3	1.0	8.7	4 190
Colombia	519	25.6	4.4	9.3	5 330
New Zealand	771	70.2	41.2	11.6	15 870
Canada	898	62.7	45.3	12.4	19 960
Israel	704	55.1	32.1	13.4	15 300
Netherlands	997	64.7	52.2	16.6	18 750
Finland	1 267	61.6	60.1	18.0	16 150
Italy	637	57.3	41.5	21.6	18 460
France	969	76.1	48.5	24.6	19 670
Norway	1 002	64.7	59.6	27.0	20 210
Denmark	974	66.2	55.5	29.0	19 880

[a]FAO, 1991.
[b]WHO, 1990-1995.
[c]World Bank, 1996.



5
Mortality from falls in women over age 75 as a function of calcium consumption in the countries in Table 1

intake) gradually becomes dominant. In the calcium intake range of 500 to 1 000 mg (12.5 to 25 mmol), active transport is the main component, but at higher intakes (e.g. when calcium supplements are taken), the additional calcium is mainly absorbed by diffusion. It follows that true fractional calcium absorption is inversely related to calcium intake and falls from about 70 percent for very low intakes to 10 percent or less for high intakes (Nordin and Marshall, 1988). However, there is always loss of calcium in the faeces from the digestive juices (endogenous faecal calcium), and it follows that the net calcium absorbed (the difference between calcium intake and faecal calcium) is negative at zero intake, becomes zero when intake matches endogenous loss and then increases with intake, rapidly at first and then more slowly. This relationship [based on 212 calcium balances in 84 normal Western subjects (Marshall, Nordin and Speed, 1976)] is shown in Figure 6; the equation is: $y = [491x/(287 + x)] + 0.06x - 206$ mg, where y represents net absorbed calcium and x represents intake (Nordin and Marshall, 1988).

The principal regulator of calcium absorption is vitamin D [generally derived from the effect of sunlight on the skin (Holick, 1995)] in the form of its two active metabolites, 25-hydroxyvitamin D (calcidiol) and 1,25-dihydroxyvitamin D (calcitriol) (Holick, 1995), acting almost certainly on the active transport component. It would therefore be expected that the absorption line in Figure 6 would move up or down with vitamin D status (see below).

Excretion

Apart from the loss of calcium through the bowel, the principal routes of calcium excretion are via the kidneys and the skin. In normal individuals in zero calcium balance, calcium excreted via the skin and urine must equal net calcium absorbed. The slope of urinary calcium (y) to dietary calcium (x) in normal Western subjects is:

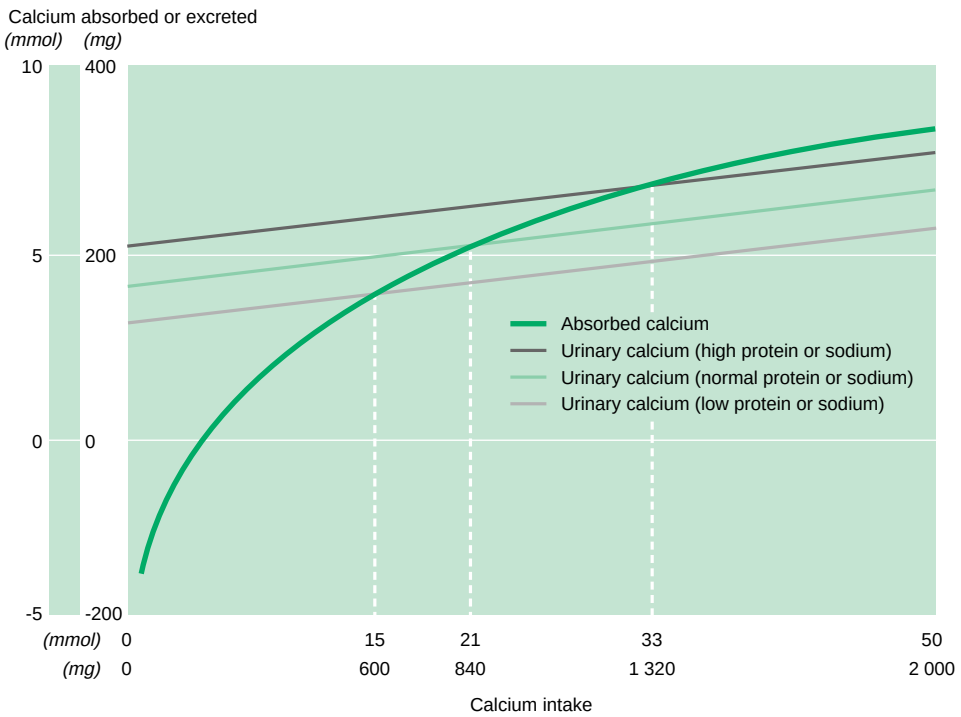
$y = 0.051x + 128$ mg per day (Nordin and Marshall, 1988). However, skin loss of some 40 mg (1 mmol) per day (Charles *et al.*, 1983) also needs to be taken into account. If this skin loss is assumed to be independent of intake, it can be added to the urine calcium component, and the equation of skin plus urine calcium to intake becomes $y = 0.051x + 168$ mg per day, as represented by the central excretion line in Figure 6. It must be emphasized that this relationship is based on Western data. Urine calcium is closely related to phosphate and sodium excretion, and variation from an average Western diet will move the urine calcium line up or down as indicated in Figure 6 and discussed below.

Calcium requirement

The mean calcium intake at which urine plus skin calcium equals net absorbed calcium can be taken as the calcium requirement of adults. As calculated by Nordin and Marshall (1988) from 212 Western calcium balances, this requirement amounts to about 840 mg (21 mmol) daily (Figure 6). It is clear that calcium consumption in most developing countries falls well short of this value (Table 1), which would lead to the conclusion either that the values derived from balance studies are misleading and do not take sufficient account of adaptation (which was the view of the FAO/WHO Expert Committee) or that there are special circumstances that reduce the calcium requirement of poorer nations. The reduction could be related to reduced calcium excretion and/or increased calcium absorption.

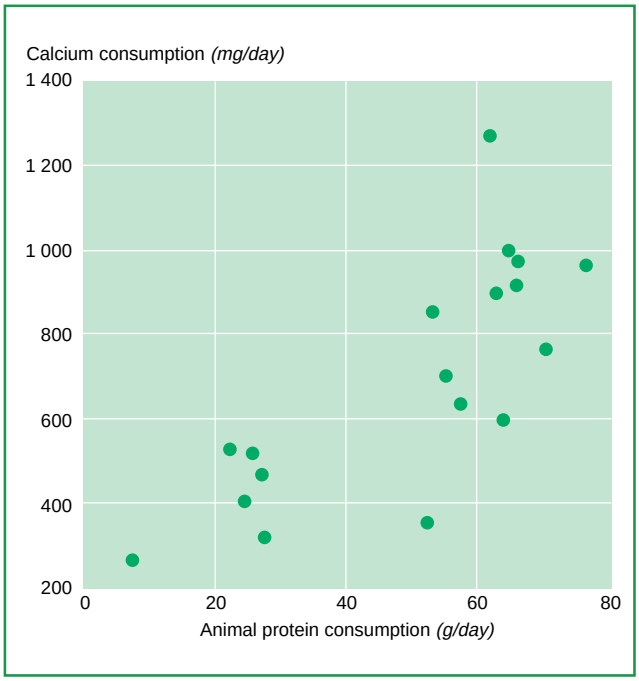
Reduced calcium excretion. At least two factors modify urine calcium at any given calcium intake: dietary protein and sodium. A positive relationship between urine calcium and protein (particularly animal protein) intake has been well documented (Linkswiler *et al.*, 1981; Margen *et al.*, 1974) and is probably due to the complexing of calcium by phosphate in the renal tubules. This explains the significant correlation between urine calcium and phosphate in normal subjects on free diets (Nordin and Polley, 1987), but the quantitative relation between protein intake and urine calcium has not been precisely defined. However, in one small study (Nordin *et al.*, 1996) in which calcium intake was held constant, raising the animal protein intake from 40 to 80 g increased the urine calcium by 40 mg (1 mmol) in six postmenopausal women. If this relationship operates at all calcium intakes (which is not certain), the addition of 40 g of animal protein to a basal intake of 60 g would double the calcium requirement. Conversely, reducing the animal protein intake from 60 to 20 g would be expected to reduce the calcium requirement from 840 to 480 mg per day (21 to 12 mmol) (Figure 6). Since animal protein and calcium intakes are strongly related (Table 1 and Figure 7), populations that have low calcium intakes may be at least

6
Calcium absorbed and excreted as a function of calcium intake in normal subjects



Note: The intercept of the excretion and absorption lines represents the calcium requirement, as shown by the interrupted lines.

7
Relation between calcium and protein consumption in the countries in Table 1



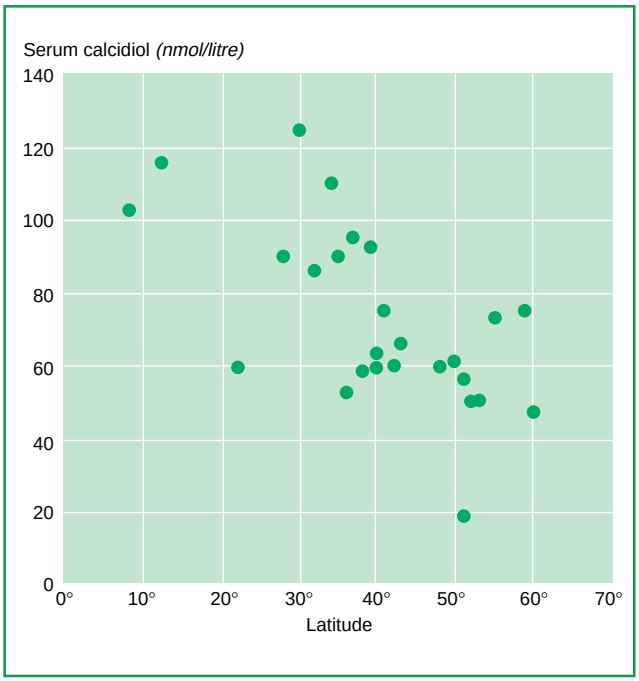
partially protected from negative calcium balance by their low protein consumption.

Urine calcium is also greatly influenced by sodium intake, because of competition between calcium and sodium ions for renal tubular resorption; 2.3 g of sodium (100 mmol) results in excretion of 1 mmol of calcium (40 mg) in the urine (Nordin and Polley, 1987; Nordin *et al.*, 1996; Goulding, 1981; Nordin *et al.*, 1993; Nordin and Need, 1994). Varying the sodium intake by this amount therefore has the same effect on urine calcium as 40 g of animal protein (Figure 6). It is likely that these two effects are additive (since the mechanisms are different) and that populations on low sodium and low protein intakes would have even lower calcium requirements, but sodium data from poorer countries are scanty (Intersalt Cooperative Research Group, 1988). In hot climates, there may also be loss of sodium in sweat, which would tend to divert sodium from the urine and reduce renal calcium excretion and therefore the calcium requirement. However, this effect might be offset by greater losses of calcium in sweat (Klesges *et al.*, 1996), which would have the opposite effect. This is relatively unexplored territory.

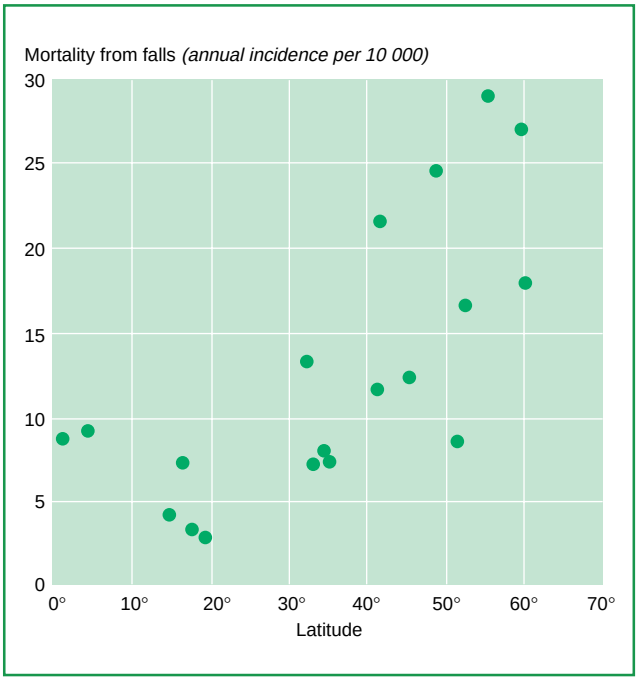
Increased calcium absorption. Higher calcium absorption must also lower the calcium requirement. Since calcium absorption is a function of the serum calcitriol level (Morris *et al.*, 1991), and since the serum concentration of its precursor calcidiol is a function of latitude (because of the angle of incidence of the sun's rays) (Table 2 and Figure 8), it is very likely, although unproven, that calcium absorption also falls with latitude. However, serum calcidiol is also a function of racial factors (skin

TABLE 2
Latitude and vitamin D status in 27 cities

City	Latitude *(degrees N or S)*	Serum calcidiol *(nmol/litre)*	Reference
Recife, Brazil	8	103	Linhares *et al.*, 1984
Curaçao, Netherlands Antilles	12	116	Dubbelman *et al.*, 1993
Hong Kong SAR, China	22	60	Pun *et al.*, 1990
Brisbane, Australia	28	90	Personal communication
Houston, USA	30	125	Breslau *et al.*, 1982
Perth, Australia	32	86	Personal communication
Sydney, Australia	34	110	Personal communication
Adelaide, Australia	35	90	Personal communication
Buenos Aires, Argentina	36	53	Personal communication
Melbourne, Australia	37	95	Personal communication
Saint Louis, USA	38	58	Villareal *et al.*, 1991
Baltimore, USA	39	92	Sherman, Hollis & Tobin, 1990
Indianapolis, USA	40	60	Personal communication
Philadelphia, USA	40	63	Matsuoka *et al.*, 1995
Madrid, Spain	40	59	Moreiras *et al.*, 1992
Omaha, USA	41	75	Personal communication
New York, USA	42	60	Meier, 1991
Hobart, Australia	43	66	Personal communication
Paris, France	48	60	Chapuy, Durr & Chapuy, 1983
Brussels, Belgium	50	61	Bouillon *et al.*, 1987
Cardiff, UK	51	56	Compston *et al.*, 1981
London, UK	51	18	Corless *et al.*, 1985
Groningen, Netherlands	52	50	Dubbelman *et al.*, 1993
Leeds, UK	53	50	Personal communication
Copenhagen, Denmark	55	73	Hartwell, Riis & Christiansen, 1990
Oslo, Norway	59	75	Falch, Oftebro & Haug, 1987
Helsinki, Finland	60	47	Von Knorring *et al.*, 1982



8
Relation between serum calcidiol and latitude in the cities in Table 2



9
Mortality from falls in women over age 75 as a function of latitude in the countries in Table 1

pigmentation) (Matsuoka *et al.*, 1995), social habits and climate (exposure to sunlight) (van der Wielen *et al.*, 1995), diet (McKenna, 1992) and age (Baker, Peacock and Nordin, 1980; MacLaughlin and Holick, 1985), all of which contribute to the scattered pattern in Figure 8. Hip fracture rates (inferred from mortality from falls in the elderly) are also a positive function of latitude (Figure 9) and are thus more closely related to vitamin D status than to wealth or animal protein intake (Table 1). Moreover, low vitamin D status is a well-documented feature of hip fracture cases in the West (Aaron *et al.*, 1974; Baker *et al.*, 1979; Lips *et al.*, 1982; Morris *et al.*, 1984), and the risk of hip fracture was significantly reduced by vitamin D with calcium in a controlled study in France (latitude 48º) (Chapuy *et al.*, 1992). Vitamin D supplementation was also shown to inhibit bone loss in a controlled study of elderly women in Leeds, United Kingdom (latitude 53º) (Nordin *et al.*, 1985).

MENOPAUSE

Although the above account may offer a possible explanation for the apparent differences in calcium requirement and hip fracture rates among nations, it leaves the important role of the menopause unexplained. The menopause is associated with a rise in obligatory calcium excretion (Young and Nordin, 1967; Gallagher, Young and Nordin, 1972; Stepan *et al.*, 1987; Nordin and Polley, 1987; Prince *et al.*, 1995) and a probable decrease in calcium absorption (Heaney *et al.*, 1989; Nordin, 1997) which are commonly attributed to a cytokine-induced increase in bone resorption secondary to oestrogen deficiency (Manolagas *et al.*, 1993; Pacifici, 1996). This aspect tends to separate postmenopausal bone loss from the rest and to imply a need for hormones or other expensive treatment regimens. However, it can be argued that menopausal bone loss results from an increase in calcium requirement and can be managed accordingly. The increase in calcium loss at the menopause is some 20 to 40 mg (0.5 to 1.0 mmol) (Young and Nordin, 1967; Gallagher, Young and Nordin, 1972; Stepan *et al.*, 1987; Nordin and Polley, 1987; Prince *et al.*, 1995), which is comparable to the salt and protein effects described above and shown in Figure 6.

This argument, fully reviewed elsewhere (Nordin, 1997), relies on the experimental evidence that ovariectomy-induced osteoporosis in experimental animals is modifed by calcium and sodium intake (Hodgkinson *et al.*, 1978; Shen *et al.*, 1995; Goulding and Campbell, 1983) and on physiological evidence that the increase in calcium excretion in women at the menopause is due to a renal calcium "leak" (Nordin *et al.*, 1991; Nordin *et al.*, 1994) rather than to an overflow of calcium lost from the skeleton by a primary process. This paradigm is supported by 20 prospective bone density trials in which mean bone loss was close to zero in 855 calcium-treated postmenopausal women and highly significant in 625 controls ($P < 0.001$) (Nordin, 1997). Although treatment with calcium is not quite as effective as treatment with oestrogen [which produces a small gain of bone (Prince *et al.*, 1991;

Christiansen and Riis, 1990), which was not seen in the calcium trials], this may be because oestrogens simultaneously lower urinary calcium (Gallagher and Nordin, 1973; Reginster *et al.*, 1993; Prince, 1994; Selby *et al.*, 1985) and improve calcium absorption (Civitelli *et al.*, 1988; Horowitz *et al.*, 1993), thus having a greater effect than simple calcium supplementation. This issue is not yet resolved, but the old paradigm is changing, and the concept that menopausal bone loss is (at least in part) secondary to an increase in calcium requirement is gaining support. Recent consensus conferences (United States National Institutes of Health, 1994; American Journal of Medicine, 1993) have recommended a calcium allowance of 1 500 mg for postmenopausal women, without however explicitly stating that postmenopausal osteoporosis is, or could be, caused by calcium deficiency.

CONCLUSIONS

It is remarkable that there should be so much controversy over the roles of calcium and vitamin D in human nutrition in general and in osteoporosis in particular, given that both are acknowledged to be essential nutrients. Classical work on rickets and osteomalacia casts a long shadow. No sooner have osteomalacia and osteoporosis been satisfactorily distinguished than evidence of their overlapping aetiologies becomes apparent. The theses put forward in this paper are that primary negative calcium balance is the major, but not the only, cause of osteoporosis; that such a negative balance may be the result of inadequate calcium intake, low calcium absorption or high calcium excretion; that low calcium absorption may be the result of moderate vitamin D insufficiency; and that high calcium excretion may be due to dietary factors (such as protein and sodium intakes) or to hormonal effects (such as oestrogen deficiency). Seen in this light, the worldwide pattern of osteoporosis becomes comprehensible, but carefully targeted fieldwork – exemplified by studies on the relationship between calcium intake and bone density in the Gambia (Prentice, 1994) – will be required to fill in the picture. ♦

REFERENCES

Aaron, J.E., Gallagher, J.C., Anderson, J., Stasiak, L., Longton, E.B. & Nordin, B.E.C. 1974. Frequency of osteomalacia and osteoporosis in fractures of the proximal femur. *Lancet*, 2: 229-233.

Albright, F., Bloomberg, E., Drake, T. & Sulkowitch, H.W. 1938. A comparison of the effects of A.T.10 (dihydrotachysterol) and vitamin D on calcium and phosphorus metabolism in hypoparathyroidism. *J. Clin. Invest.*, 17: 317-329.

American Journal of Medicine. 1993. Consensus development conference: diagnosis, prophylaxis, and treatment of osteoporosis. 94: 646-650.

Baker, M.R., McDonnell, H., Peacock, M. & Nordin, B.E.C. 1979. Plasma 25-hydroxy vitamin D concentrations in patients with fractures of the femoral neck. *Br. Med. J.*, 1: 589.

Baker, M.R., Peacock, M. & Nordin, B.E.C. 1980. The decline in vitamin D status with age. *Age Ageing*, 9: 249-252.

Bouillon, R.A., Auwerx, J.H., Lissens, W.D. & Pelemans, W.K. 1987. Vitamin D status in the elderly: seasonal substrate deficiency causes 1,25-dihydroxycholecalciferol deficiency. *Am. J. Clin. Nutr.*, 45: 755-763.

Boyce, W.J. & Vessey, M.P. 1985 Rising incidence of fracture of the proximal femur. *Lancet*, 2: 150-151.

Breslau, N.A., McGuire, J.L., Zerwekh, J.E. & Pak, C.Y.C. 1982. The role of dietary sodium on renal excretion and intestinal absorption of calcium and on vitamin D metabolism. *J. Clin. Endocrinol. Metab.*, 55: 369-373.

Bronner, F. 1987. Intestinal calcium absorption: mechanisms and applications. *J. Nutr.*, 11: 1347-1352.

Carlsson, A. & Lindquist, B. 1955. A comparison of the intestinal and skeletal effect of vitamin D in relation to dosage. *Acta Physiol. Scand.*, 35: 53-55.

Chapuy, M.C., Arlot, M.E., Duboeuf, F., Brun, J., Crouzet, B., Arnaud, S., Delmas, P.D. & Meunier, P.J. 1992. Vitamin D_3 and calcium to prevent hip fractures in elderly women. *N. Engl. J. Med.*, 327: 1637-1642.

Chapuy, M.-C., Durr, F. & Chapuy, P. 1983. Age-related changes in parathyroid hormone and 25 hydroxycholecalciferol levels. *J. Gerontol.*, 38: 19-22.

Charles, P., Taagehoj, F., Jensen, L., Mosekilde, L. & Hansen, H.H. 1983. Calcium metabolism evaluated by Ca^{47} kinetics: estimation of dermal calcium loss. *Clin. Sci.*, 65: 415-422.

Christiansen, C. & Riis, B.J. 1990. 17β-Estradiol and continuous norethisterone: a unique treatment for established osteoporosis in elderly women. *J. Clin. Endocrinol. Metab.*, 71: 836-841.

Civitelli, R., Agnusdei, D., Nardi, P., Zacchei, F., Avioli, L.V. & Gennari, C. 1988. Effects of one-year treatment with estrogens on bone mass, intestinal calcium absorption, and 25-hydroxyvitamin D-1α-hydroxylase reserve in postmenopausal osteoporosis. *Calcif. Tissue Int.*, 42: 77-86.

Compston, J.E., Vedi, S., Merrett, A.L., Clemens, T.L., O'Riordan, J.L.H. & Woodhead, J.S. 1981. Privational and malabsorption metabolic bone disease: plasma vitamin D metabolic concentrations and their relationship to quantitative bone histology. *Metab. Bone Dis. Rel. Res.*, 3: 165-170.

Corless, D., Dawson, E., Fraser, F., Ellis, M., Evans, S.J., Perry, J.D., Reisner, C., Silver, C.P., Beer, M., Boucher, B.J. *et al.* 1985. Do vitamin D supplements improve the physical capabilities of elderly hospital patients? *Age Ageing*, 14: 76-84.

Dubbelman, R., Jonxis, J.H.P., Muskiet, F.A.J. & Saleh, A.E.C. 1993. Age-dependent vitamin D status and vertebral condition of white women living in Curaçao (the Netherlands Antilles) as compared with their counterparts in the Netherlands. *Am. J. Clin. Nutr.*, 58: 106-109.

Eddy, T.P. 1972. Deaths from domestic falls and fractures. *Br. J. Prev. Soc. Med.*, 26: 173-179.

Falch, J.A., Oftebro, H. & Haug, E. 1987. Early postmenopausal bone loss is not associated with a decrease in circulating levels of 25-hydroxyvitamin D, or vitamin D-binding protein. *J. Clin. Endocrinol. Metab.*, 64: 836-841.

FAO. 1962. *Calcium requirements.* Report of an FAO/WHO Expert Group. FAO Nutrition Meetings Report Series No. 30. Rome.

FAO. 1991. *Production Yearbook 1990*, Vol. 44. Rome.

Gallagher, J.C. & Nordin, B.E.C. 1973. Oestrogens and calcium metabolism. *In* P.A. van Keep & C. Lauritzen, eds. *Ageing and estrogens: frontiers of hormone research*, Vol. 2, p. 98-117. Basel, Switzerland, Karger.

Gallagher, J.C., Young, M.M. & Nordin, B.E.C. 1972. Effects of artificial menopause on plasma and urine calcium and phosphate. *Clin. Endocrinol.*, 1: 57-64.

Goulding, A. 1981. Fasting urinary sodium/creatinine in relation to calcium/creatinine and hydroxyproline/creatinine in a general population of women. *N.Z. Med. J.*, 93: 294-297.

Goulding, A. & Campbell, D. 1983. Dietary NaCl loads promote calciuria and bone loss in adult oophorectomized rats consuming a low calcium diet. *J. Nutr.*, 113: 1409-1414.

Hartwell, D., Riis, B.J. & Christiansen, C. 1990. Comparison of vitamin D metabolism in early healthy and late osteoporotic postmenopausal women. *Calcif. Tissue Int.*, 47: 332-337.

Heaney, R.P., Recker, R.R., Stegman, M.R. & Moy, A.J. 1989. Calcium absorption in women: relationships to calcium intake, estrogen status, and age. *J. Bone Miner. Res.*, 4: 469-475.

Heaney, R.P., Saville, P.D. & Recker, R.R. 1975. Calcium absorption as a function of calcium intake. *J. Lab. Clin. Med.*, 85: 881-890.

Hess, A.F. 1929. *Rickets, including osteomalacia and tetany*. London, UK, Lea & Febiger.

Hodgkinson, A., Aaron, J.E., Horsman, A., McLachlan, M.S.F. & Nordin, B.E.C. 1978. Effect of oophorectomy and calcium deprivation on bone mass in the rat. *Clin. Sci. Mol. Med.*, 54: 439-446.

Holick, M.F. 1995. Vitamin D: photobiology, metabolism, and clinical applications. *In* L.J. DeGroot, ed. *Endocrinology*, p. 990-1014. Philadelphia, Pennsylvania, USA, W.B. Saunders. 3rd ed.

Horowitz, M., Wishart, J.M., Need, A.G., Morris, H.A. & Nordin, B.E.C. 1993. Effects of norethisterone on bone related biochemical variables and forearm bone mineral in postmenopausal osteoporosis. *Clin. Endocrinol.*, 39: 1-5.

Intersalt Cooperative Research Group. 1988. Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. *Br. Med. J.*, 297: 319-328

Kanis, J.A. & Passmore, R. 1989. Calcium supplementation of the diet. *Br. Med. J.*, 298: 137-140, 205-208.

Klesges, R.C., Ward, K.D., Shelton, M.L., Applegate, W.B., Cantler, E.D., Palmieri, G.M.A., Harmon, K. & Davis, J. 1996. Changes in bone mineral content in male athletes. *J. Am. Med. Assoc.*, 276: 226-230.

Linhares, E.R., Jones, D.A., Round, J.M. & Edwards, R.H.T. 1984. Effect of nutrition on vitamin D status: studies on healthy and poorly nourished Brazilian children. *Am. J. Clin. Nutr.*, 39: 625-630.

Linkswiler, H.M., Zemel, M.B., Hegsted, M. & Schuette, S. 1981. Protein-induced hypercalciuria. *Fed. Proc.*, 40: 2429-2433.

Lips, P., Netelenbos, J.C., Jongen, M.J., van Ginkel, F.C., Althuis, A.L., van Schaik, C.L., van der Vijgh, W.J., Vermeiden, J.P. & van der Meer, C. 1982. Histomorphometric profile and vitamin D status in patients with femoral neck fracture. *Metab. Bone. Dis. Rel. Res.*, 4: 85-93.

MacLaughlin, J. & Holick, M.F. 1985. Aging decreases the capacity of human skin to produce vitamin D_3. *J. Clin. Invest.*, 76: 1536-1538.

Malm, O.J. 1958. Calcium requirement and adaptation in adult men. *Scand. J. Clin. Lab. Invest.*, 10(Suppl. 36): 1-289.

Manolagas, S.C., Girasole, G., Passeri, G., Bellido, T., Williams, D.C. & Jilka, R.L. 1993. Estrogen, cytokines, and the control of osteoclast formation and bone resorption *in vitro* and *in vivo*. *Osteoporosis Int.*, Suppl. 1: S144-S166.

Margen, S., Chu, J.Y., Kaufman, N.A. & Calloway, D.H. 1974. Studies in calcium metabolism – I. The calciuretic effect of dietary protein. *Am. J. Clin. Nutr.*, 27: 584-589.

Marshall, D.H. 1976. Calcium and phosphate kinetics. *In* B.E.C. Nordin, ed. *Calcium, phosphate and magnesium metabolism*, p. 257-297. Edinburgh, UK, Churchill Livingstone.

Marshall, D.H., Nordin, B.E.C. & Speed, R. 1976. Calcium, phosphorus and magnesium requirement. *Proc. Nutr. Soc.*, 35: 163-173.

Matsuoka, L.Y., Wortsman, J., Chen, T.C. & Holick, M.F. 1995. Compensation for the interracial variance in the

cutaneous synthesis of vitamin D. *J. Lab. Clin. Med.*, 126(5): 452-457.

McKenna, M.J. 1992. Differences in vitamin D status between countries in young adults and the elderly. *Am. J. Med.*, 93: 69-77.

Meier, D.E., Luckey, M.M., Wallenstein, S., Clemens, T.L., Orwoll, E.S. & Waslien, C.I. 1991. Calcium, vitamin D, and parathyroid hormone status in young white and black women: association with racial differences in mass. *J. Clin. Endocrinol. Metab.*, 72: 703-710.

Mellanby, E. 1918. The part played by an "accessory factor" in the production of experimental rickets. A further demonstration of the part played by accessory food factors in the aetiology of rickets. *J. Physiol.*, 52: 11-53.

Miller, S.W.M. & Grimley Evans, J. 1985. Fractures of the distal forearm in Newcastle: an epidemiological survey. *Age Ageing*, 14: 155-158.

Miwa, S. & Stoeltzner, W. 1898. Über die bei jungen Hunden durch kälkarme Futterung enstehende Knochenerkrankung. *Beitr. Pathol. Anat.*, 24: 578.

Moreiras, O., Carbaja, A., Perea, I. & Varela-Moreiras, V. 1992. The influence of dietary intake and sunlight exposure on the vitamin D status in an elderly Spanish group. *Int. J. Vitam. Nutr. Res.*, 62(4): 303-307.

Morris, H.A., Morrison, G.W., Burr, M., Thomas, D.W. & Nordin, B.E.C. 1984. Vitamin D and femoral neck fractures in elderly South Australian women. *Med. J. Aust.*, 140: 519-521.

Morris, H.A., Need, A.G., Horowitz, M., O'Loughlin, P.D. & Nordin, B.E.C. 1991. Calcium absorption in normal and osteoporotic postmenopausal women. *Calcif. Tissue Int.*, 49: 240-243.

Nordin, B.E.C. 1960. Osteomalacia, osteoporosis and calcium deficiency. *Clin. Orthop.*, 17: 235-258.

Nordin, B.E.C. 1976. Nutritional considerations. *In* B.E.C. Nordin, ed. *Calcium, phosphate and magnesium metabolism*, p. 1-35. Edinburgh, UK, Churchill Livingstone.

Nordin, B.E.C. 1997. Calcium and osteoporosis. *Nutrition*, 13(7-8): 664-686.

Nordin, B.E.C., Baker, M.R., Horsman, A. & Peacock, M. 1985. A prospective trial of the effect of vitamin D supplementation on metacarpal bone loss in elderly women. *Am. J. Clin. Nutr.*, 42: 470-474.

Nordin, B.E.C., Horowitz, M., Need, A.G. & Morris, H.A. 1994. Renal leak of calcium in postmenopausal osteoporosis. *Clin. Endocrinol.*, 41: 41-45.

Nordin, B.E.C. & Marshall, D.H. 1988. Dietary requirements for calcium. *In* B.E.C. Nordin, ed. *Calcium in human biology*, p. 447-471. Berlin, Germany, Springer-Verlag.

Nordin, B.E.C., Morris, H.A., Need, A.G. & Horowitz, M. 1996. Dietary calcium and osteoporosis. *In* P. Pietinen, C. Nishida & N. Khaltaev, eds. *Nutrition and quality of life.* Proceedings of the 2nd WHO Symposium on Health Issues for the 21st Century, Kobe, Japan, 1993, p. 181-198. Geneva, Switzerland, World Health Organization.

Nordin, B.E.C. & Need, A.G. 1994. The effect of sodium on calcium requirement. *Adv. Nutr. Res.*, 9: 209-230.

Nordin, B.E.C., Need, A.G., Horowitz, M. & Robertson, W.G. 1991. Evidence for a renal calcium leak in postmenopausal women. *J. Clin. Endocrinol. Metab.*, 72: 401-407.

Nordin, B.E.C., Need, A.G., Morris, H.A. & Horowitz, M. 1993. The nature and significance of the relation between urine sodium and urine calcium in women. *J. Nutr.*, 123: 1615-1622.

Nordin, B.E.C & Polley, K.J. 1987. Metabolic consequences of the menopause. A cross-sectional, longitudinal, and intervention study on 557 normal postmenopausal women. *Calcif. Tissue Int.*, 41: S1-S60.

Pacifici, R. 1996. Review: Estrogen, cytokines and pathogenesis of postmenopausal osteoporosis. *J. Bone Miner. Res.*, 11: 1043-1051.

Pommer, G. 1885. *Undersuchungen uber Osteomalacie und Rachitis.* Leipzig, Germany, Vogel.

Prentice, A. 1994. Calcium intakes and bone densities of lactating women and breast-fed infants in the Gambia. *Adv. Exp. Med. Biol.*, 352: 243-255.

Prince, R.L. 1994. Counterpoint: Estrogen effects on calcitropic hormones and calcium homeostasis. *Endocr. Rev.*, 15: 301-309.

Prince, R.L., Dick, I., Devine, A., Price, R.I., Gutteridge, D.H., Kerr, D., Criddle, A., Garcia-Webb, P. & St John, A. 1995. The effects of menopause and age on calcitropic hormones: a cross-sectional study of 655 healthy women aged 35 to 90. *J. Bone Miner. Res.*, 10: 835-842.

Prince, R.L., Smith, M., Dick, I.M., Price, R.I., Webb, P.G., Henderson, N.K. & Harris, M.M. 1991. Prevention of postmenopausal osteoporosis: a comparative study of exercise, calcium supplementation and hormone-replacement therapy. *N. Engl. J. Med.*, 325: 1189-1195.

Pun, K.K., Wong, F.H., Wang, C., Lau, P., Ho, P.W., Pun, W.K., Chow, S.P., Cheng, C.L., Leong, J.C. & Young, R.T. 1990. Vitamin D status among patients with fractured neck of femur in Hong Kong. *Bone*, 11: 365-368.

Reginster, J.Y., Christiansen, C., Dequinze, B., Deroisy, R., Gaspard, U., Taquet, A.N. & Franchimont, P. 1993. Effect of transdermal 17β-estradiol and oral conjugated equine estrogens on biochemical parameters of bone resorption in natural menopause. *Calcif. Tissue Int.*, 53: 13-16.

Robertson, W.G. 1988. Chemistry and biochemistry of calcium. *In* B.E.C. Nordin, ed. *Calcium in human biology*, p. 1-26. Berlin, Germany, Springer-Verlag.

Selby, P.L., Peacock, M., Barkworth, S.A., Brown, W.B. & Taylor, G.A. 1985. Early effects of ethinyloestradiol and norethisterone treatment in postmenopausal women on bone resorption and calcium regulation hormones. *Clin. Sci.*, 69: 265-271.

Shen, V., Birchman, R., Xu, R., Lindsay, R. & Dempster, D.W. 1995. Short-term changes in histomorphometric and biochemical turnover markers and bone mineral density in estrogen- and/or dietary calcium-deficient rats. *Bone*, 16: 149-156.

Sherman, S.S., Hollis, B.W. & Tobin, J.D. 1990. Vitamin D status and related parameters in a healthy population: the effects of age, sex and season. *J. Clin. Endocrinol. Metab.*, 71: 405-413.

Stepan, J.J., Posphichal, J., Presl, J. & Pacovsky, V. 1987. Bone loss and biochemical indices of bone remodeling in surgically induced postmenopausal women. *Bone*, 8: 279-284.

Telfer, S.V. 1926. Studies in calcium and phosphorus metabolism. *Q. J. Med.*, 20: 1-6.

Termine, J.D. & Posner, A.S. 1967. Amorphous/crystalline interrelationships in bone mineral. *Calcif. Tissue Res.*, 1: 8-23.

United States National Institutes of Health. 1994. Optimal calcium intake. NIH Consensus Conference. *J. Am. Med. Assoc.*, 272: 1942-1948.

van der Wielen, R.P.J., Löwik, M.R.H., van den Berg, H., de Groot, L.C.P.G.M., Haller, J. & Moreiras, O. 1995. Serum vitamin D concentrations among elderly people in Europe. *Lancet*, 346: 207-210.

Villareal, D.T., Civitelli, R., Chines, A. & Avioli, L.V. 1991. Subclinical vitamin D deficiency in postmenopausal women with low vertebral bone mass. *J. Clin. Endocrinol. Metab.*, 72: 628-634.

Von Knorring, J., Slatis, P., Weber, T.H. & Helenius, T. 1982. Serum levels of 25-hydroxy vitamin D, 24,25-dihydroxy vitamin D and parathyroid hormone in patients with femoral neck fracture in southern Finland. *Clin. Endocrinol.*, 17: 189-194.

Wahner, H.W. & Fogelman, I. 1994. *The evaluation of osteoporosis: dual energy X-ray absorptiometry in clinical practice.* London, UK, Martin Dunitz Ltd.

Wilkinson, R. 1976. Absorption of calcium, phosphorus and magnesium. *In* B.E.C. Nordin, ed. *Calcium, phosphate and magnesium metabolism.* Edinburgh, UK, Churchill Livingstone, p. 36-112.

World Bank. 1996. *World Development Report 1996*. New York, NY, USA, Oxford University Press.

World Health Organization (WHO). 1990-1995. *World Health Statistics Annual.* Geneva, Switzerland.

Young, M.M. & Nordin, B.E.C. 1967. Effects of natural and artificial menopause on plasma and urinary calcium and phosphorus. *Lancet*, 2: 118-120. ◆

Summary/Résumé/Resumen

Calcium in health and disease

There is a remarkable amount of controversy about the roles of calcium and vitamin D in human nutrition in general and in osteoporosis in particular. This article reviews the functions of calcium in the body, highlights major findings about calcium during the past century and explains the current debates.

The calcium salts that provide rigidity to the skeleton also constitute a large reservoir for the maintenance of the calcium concentration in the body's extracellular water. The protection of this concentration by parathyroid hormone and vitamin D reflects the vital role of calcium in the neuromuscular system, in regulation of the heart, in enzyme-mediated reactions and in many other metabolic processes.

During the period of skeletal growth and maturation, i.e. until the age of the early twenties in humans, calcium accumulates in the skeleton. During maturity, the body is more or less in calcium equilibrium; from the age of about 50 years in men and from the menopause in women, bone balance becomes negative and bone is lost from all skeletal sites. This bone loss is associated with a marked rise in fracture rates. The cause of the bone loss associated with menopause and ageing is uncertain.

Calcium consumption varies greatly worldwide, ranging from 800 mg per day or more in industrialized countries to 200 to 300 mg per day in developing countries. Paradoxically, osteoporosis is more common in the industrialized countries.

The theses put forward in this paper are that primary negative calcium balance is the major, but not the only, cause of osteoporosis; that such a negative balance may be the result of inadequate calcium intake, low calcium absorption or high calcium excretion; that low calcium absorption may be the result of moderate vitamin D insufficiency; and that high calcium excretion may be correlated with dietary factors (such as protein and sodium intakes) or hormonal effects (such as oestrogen deficiency). Seen in this light, the worldwide pattern of osteoporosis becomes comprehensible, but carefully targeted field work will be required to fill in the picture.

Le rôle du calcium dans la santé et la maladie

Le rôle du calcium et de la vitamine D dans l'alimentation humaine en général, et dans l'ostéoporose en particulier, est très controversé. Le présent article examine les fonctions du calcium dans le corps, souligne les principales conclusions des recherches entreprises au cours du siècle dernier et explique les débats actuels.

Les sels de calcium, qui assurent la rigidité au squelette, constituent également un vaste réservoir destiné à maintenir la concentration du calcium dans le liquide extracellulaire (LEC) du corps. L'hormone parathyroïde et la vitamine D protègent cette concentration qui reflète le rôle vital joué par le calcium dans le système neuromusculaire, dans le fonctionnement cardiaque, dans les réactions dépendant d'une activité enzymatique et dans beaucoup d'autres processus métaboliques.

Pendant la période de croissance et de maturation du squelette (dans les 20 premières années environ), le calcium s'accumule dans le squelette. A maturité, le corps est plus ou moins en équilibre calcique; à partir de 50 ans chez l'homme, et à partir de la ménopause chez la femme, le bilan osseux devient négatif et on enregistre une perte de masse osseuse dans toutes les parties du squelette, qui se traduit par une augmentation sensible de la fréquence des fractures. Les raisons de la perte osseuse liée à la ménopause et au vieillissement ne sont pas encore bien connues.

La consommation de calcium varie considérablement dans le monde: elle se situe entre 800 mg par jour ou plus dans les pays industrialisés, et à 200-300 mg par jour dans les pays en développement. Paradoxalement, l'ostéoporose est plus fréquente dans les pays industrialisés.

Les thèses exposées dans le présent article sont les suivantes: *i)* un bilan calcique primaire négatif est la raison principale, mais non la seule, de l'ostéoporose; *ii)* ce bilan peut être dû à un apport insuffisant de calcium, à une faible absorption ou à une excrétion importante de calcium; *iii)* une faible absorption de calcium peut provenir d'une carence modérée en vitamine D; et *iv)* une excrétion importante de calcium peut être due à des facteurs alimentaires (apports protéiques et sodiques, par exemple) ou hormonaux (tels qu'une insuffisance œstrogénique). Dans ce contexte, on comprend mieux le profil mondial de l'ostéoporose, mais on n'obtiendra une image complète de la situation que si on réalise des études de terrain soigneusement ciblées.

Summary/Résumé/Resumen

El calcio en relación con la salud y la enfermedad

La función del calcio y de la vitamina D en la nutrición humana en general y en la osteoporosis en particular ha suscitado notables polémicas. En el presente artículo se examinan las funciones del calcio en el organismo, se describen las principales conclusiones de los estudios sobre el calcio realizados durante el último siglo y se exponen los debates en curso.

Las sales de calcio que proporcionan rigidez al esqueleto constituyen además una reserva muy amplia para el mantenimiento de la concentración de calcio en el agua extracelular del organismo. La hormona paratiroidea y la vitamina D protegen esta concentración, lo que evidencia la función decisiva que el calcio desempeña en el sistema neuromuscular, en la regulación cardíaca, en las reacciones en las que intervienen enzimas y en muchos otros procesos metabólicos.

El calcio se acumula en el esqueleto durante el período de crecimiento y maduración de éste, es decir hasta que el individuo tiene poco más de 20 años. Durante la edad adulta, el calcio en el organismo se mantiene en equilibrio más o menos estable; a partir de los 50 años aproximadamente en los hombres y de la menopausia en las mujeres, el equilibrio óseo se altera y en todas las partes del esqueleto se producen pérdidas óseas. Este proceso está asociado con un aumento notable del índice de fracturas. No se conoce con certeza la causa de la pérdida ósea asociada con la menopausia y el envejecimiento.

El consumo de calcio varía enormemente en el mundo, oscilando entre 800 mg/día o más en los países industrializados y 200-300 mg/día en los países en desarrollo. Paradójicamente, la osteoporosis es más frecuente en los países industrializados.

Las tesis que se formulan en el presente artículo son que la alteración del equilibrio primario del calcio es la causa principal de la osteoporosis, pero no la única; que esta alteración del equilibrio puede ser el resultado de una ingesta insuficiente, de una absorción baja o de una excreción alta de calcio; que una absorción baja de calcio puede ser el resultado de una insuficiencia moderada de vitamina D; y que una excreción alta de calcio puede deberse a factores alimentarios (como la proteína y el sodio) o a efectos hormonales (como la carencia de estrógenos). Desde esta perspectiva, la tipología de la osteoporosis a nivel mundial resulta comprensible, si bien será necesario realizar una labor sobre el terreno con objetivos cuidadosamente seleccionados para completar el cuadro. ♦

Calcium and vitamin D deficiencies: a world issue?[1]

S.A. Miller
Sanford A. Miller is Professor and Dean, Graduate School of Biomedical Sciences, University of Texas Health Science Center at San Antonio, United States.

> "I don't want to achieve immortality through my work ... I want to achieve it through not dying."
>
> Woody Allen

The search for immortality has preoccupied human society since the dawn of time. Whether it be the elixir of life or a panacea to cure all disease, the human mind continues to believe that there exists a simple way to ensure freedom from disease and maximum quality of life. Today the situation is no different, except that the quest has been intensified by continuing developments in modern biology suggesting that modification of fundamental life processes, i.e. at the genome, could cure and prevent most human ailments, including ageing. While there is some basis for this belief, an understanding of higher levels of biological organization has resulted in the life span continuing to increase throughout most human societies, albeit faster in industrialized economies than in developing ones. Paradoxically, this success has led to even greater concern among people who, having attained the possibility of long life, are afraid to lose it. Further support for this hope results from recent discoveries made in nutrition that have led the public to believe that there are simple things that will ensure a long, quality life. This belief in nutritional panaceas has become almost a dogma; as Florence King, a United States author, has said, in reference to vitamin tablets, "I swallow it, therefore it is".

Unfortunately, the tendency is to think of these outcomes in terms of single nutrients, rather than in the matrix of a complex diet; a thought process not limited to the public, but shared, unfortunately, by some of our colleagues. Thus we continue to look for the magic bullet which will provide the equivalent of the medieval panacea and elixir of life. The nature of this bullet tends to change, depending on which nutrient occupies the most lines in the newspapers. Today the principals include beta-carotene, ascorbic acid, vitamin E and, of course, calcium. Vitamin D is often included in this credo because of its association with calcium.

To a significant extent, the mushrooming interest in calcium and vitamin D is a function of the extended life span of our populations. In large measure, this has occurred because of the ability of modern medicine to control and cure most acute infectious diseases, although this has become problematic with the appearance of new pathogens. Like peeling an onion, extension of life has brought its own set of health issues, including osteoporosis, coronary artery disease, certain cancers and so on. For calcium (and vitamin D), osteoporosis is the principal, but not sole, issue. A number of publications have addressed the possible role of calcium in the prevention of disorders other than osteoporosis, such as colon cancer, hypertension and pre-eclampsia in pregnancy.

One of the outcomes of this research has been the recognition that the need for calcium is the end-point of a series of complex events. Osteoporosis, for example, has been shown to be a function of bone mass attained in the first two or three decades of life and the rate of bone loss in later years. While calcium has been shown to be supportive of ensuring optimal bone mass and delaying or reducing the rate at which bone is lost, other factors seem to play a much more important role.

Several consistent threads emerge from the data relating calcium to bone disease. First, there is a significant body of evidence suggesting that calcium intake influences bone mass and hip fracture. Second, in those studies that involve a direct comparison of the effects of oestrogen replacement and calcium supplementation on bone mass, the oestrogen effect is usually much more marked. Recent work has demonstrated that oestrogen is necessary to maintain balance between osteoclastic and osteoblastic activity in bone. With decreasing oestrogenic activity, osteoclastic apoptosis decreases, while that of the osteoblast increases. Dietary calcium supplementation will only be effective in arresting that component of bone loss that is due to inadequate calcium intake and will not have much primary influence on the profound effects of oestrogen deficiency on bone metabolism.

The role of vitamin D is more indirect, serving to increase calcium absorption without necessarily having a direct effect on bone growth. It has been argued that vitamin D has an effect only when deficient in the diet.

[1] Keynote address at the First World Congress on Calcium and Vitamin D in Human Life, held in Rome, Italy from 8 to 12 October 1996.

The data relating calcium to hypertension and colonic cancer are also complex and not well understood.

Given the probability that increased dietary calcium and vitamin D could help in reducing the incidence of osteoporosis, hypertension and so on, the other side of the coin also has to be evaluated. What are the adverse effects of increased calcium and vitamin D intake? Concern about the toxicity of high calcium intakes has been concentrated on nephrolithiasis and mild-alkali syndrome. Over the last two decades, a substantial number of papers have attempted to determine the relationship between stone formation and calcium intake. The difficulty of demonstrating this association has led to escalating doubt on the part of many investigators of the primary role of calcium in nephrolithiasis. Nevertheless, there are studies that suggest that in certain individuals, increased dietary calcium and vitamin D can lead to stone formation and, to a lesser extent, to other aspects of hypercalcification such as aortic calcification. One of the more interesting observations in these studies is that other substances, such as sodium, may play an important and direct role in the development of stones by competing with calcium for receptors in the kidney.

This brings us to a vital issue. Interaction among nutrients, "the balanced diet", has always been a theoretical dietary concept expressed more in research paradigms than in much of contemporary media dietary advice. The relationships of calcium and magnesium, calcium and phosphorus, calcium and sodium, and calcium and zinc are very well known. Recent papers suggest that calcium has an inhibitory effect on iron absorption in humans. Yet, with the exception of calcium and phosphorus, little attention is paid to these relationships when media dietary advice is developed.

The determination of calcium and vitamin D requirements is further complicated by the recognition that there may be racial and ethnic differences in calcium needs. Several recent papers have suggested that Africans have a higher bone density and therefore may be more resistant to osteoporosis even though calcium intake in Africa is substantially less than in other parts of the world. Nevertheless, to some extent, osteoporosis and other diseases associated with calcium are widespread throughout the world.

FORTIFICATION

Given the ubiquitous nature of diet-associated disorders, recommendations have been made for the widespread fortification of food with those nutrients that are believed to be deficient in human diets, or for which levels above the recommended dietary allowance (RDA) may be helpful in preventing chronic disease. Calcium has been high on the lists of nutrients recommended for fortification. There are, however, important scientific and policy issues that must be resolved before programmes for fortification can be considered. In a recent publication, Walter Mertz listed the data needs, constraints and limitations for fortification programmes. He identified five general areas: human requirements and nutritional status; bioavailability; interactions among nutrients; interactions of fortification nutrients with carrier foods; and the safe upper limits (or upper reference levels) for these nutrients. While all need to be discussed and incorporate areas of disagreement, the domain of greatest controversy is the establishment of upper reference levels or nutrient toxicity.

Although extensive experience has been attained in safety evaluations of food additives, we are far from this level of sophistication in our evaluation of the risks associated with the use of nutrients. This lag is a result of many factors, not the least of which is the general view that nutritional patterns associated with normal diets cannot represent any particular hazard to humans. While this is generally true, a substantially modified food supply which involves fortified foods, supplements and constructed and fabricated foods offers real possibilities for exceptions to this complacent view. Another important issue is that we do not fully understand the implications of modified patterns of nutrient consumption. Until recently, nutrition studies focused primarily on the impact of deficiency states. Today nutritionists are beginning to understand that the contemporary health problem is usually not classical deficiency but, rather, excess. The fortification of a food for the prevention of one chronic disease may exacerbate another. The chronic impact on health of the distortion of the diet resulting from public belief in the daily dietary revelations in the press is not well understood. With few exceptions, the data concerning nutrient safety refer to acute toxicity. What is not understood is the chronic impact of distorted nutrient patterns on such areas as metabolism, genetic expression, behaviour, immune function, physical performance and the capacity of the organism to deal with a wide spectrum of xenobiotics.

Perhaps the best approach to the problem of making appropriate policy decisions concerning issues as profoundly important as fortification is the development of appropriate models to predict the risk associated with these actions. Recently the Food and Nutrition Board of the United States National Academy of Sciences has been examining the development of such a model in attempting to establish upper reference levels for nutrient use as part of

its programme to restructure the United States RDAs. If useful information is to be provided to policy-makers for fortification programmes, not only do we have to understand the risk of not fortifying foods, we must compare that with the risk of fortification. In other words, the issue is not risk versus benefit, but rather, risk versus risk. The problem of comparing benefits in one set of units with risk in another is, at best, difficult. Risk versus risk comparisons allow the use of similar units, therefore providing for more rational and useful recommendations. Moreover, such models must also consider that nutrients do not exist in a pristine state, but rather in a complex matrix called food, containing other nutrients and non-nutrients that may have important effects on the utilization and metabolism of the nutrient. Excellent examples are the relationship between sodium and calcium in the aetiology of nephrolithiasis, and calcium and iron absorption.

Given the intricacy of the problem, what then is the standard of scientific evidence that should be used to determine when it is or is not appropriate for major public health actions, such as fortification, to be taken? In other words, we need to examine the standard for data upon which such changes will be made.

It has often been said that surety is a fundamental goal of modern science. The scientific method is assumed to provide for a system by which data and hypothesis are checked, rechecked, evaluated and re-evaluated. This constant process of pruning and rebuilding is essential for knowledge to increase and for science to advance. There is a tendency, however, for experimental scientists who are not responsible for public health issues to look for a degree of absolutism in scientific relationships that, while appropriate for evaluating an experimental hypothesis, may only serve to delay the implementation of important public health actions. This is true, I believe, because there is a dichotomy between academic science and public health science regarding the nature of the words “sufficient scientific evidence”. Generally speaking, as scientists we are trained continually to question data and hypothesis. Scientific papers are riddled with “possibles”, “probables”, “could possiblies”, phrases that are essential to the recognition that scientific “truth” is an ephemeral concept. Such “truth” almost always is as stable as the next scientific journal. When we recognize this in science and recognize it to such an extent that its philosophical premise becomes ingrained into our psyches, we are rarely able to say we believe without reservation that any proposed relationship is unequivocally demonstrated. This tentative attitude, essential to academic science, is not always an acceptable position for a public health scientist. In the collection of information concerning a public health problem, public health scientists must make what I like to call “the leap of faith”. They must believe that the data are sufficiently convincing to take a public health action, even though doubts may remain. If they delay in taking that action, they run the danger of imperilling the health of substantial numbers of people. For the academic scientist, no such compelling force exists. Any doubt is sufficient to withhold full acceptance of a relationship. This dichotomy between academic and public health science and the consequent lack of agreement on the meaning of the word “sufficient” often creates a conflict between public health scientists and the professional community and, in turn, confusion for the public.

What then should the standard of evidence be? For public health scientists the standard of evidence for any particular action varies. It depends in large measure on how potentially important the action is to maintaining the public health, as well as on the potential for a counterproductive effect to occur. In other words, if the risk of doing is considerably less than the risk of not doing, then it becomes an appropriate action for public health agencies to take. This often occurs under conditions in which the academic scientist will correctly say that the data are insufficient to support the hypothesis. There is a real possibility for this to occur in our current efforts to exploit the role of diet in the modification of chronic disease, such as in the current discussion of calcium fortification. Nevertheless, as long as the harm done by the action is low or minimal, the fact that the activity ultimately has little effect on public health does not necessarily make it an inappropriate decision at the time. On the other hand, I must offer an important caveat. The very nature of public health decisions makes it necessary that we do not overstate the potential of the actions that are promoted. What we need is rationality and moderation in this process. We must also recognize the responsibility of being as assiduous in identifying and estimating the risks of doing as we are in promoting. Moreover, implicit in such public health decisions is the belief that the option of lowest risk is taken. Thus, for nutrient modification of the diet, dietary advice is less risky than fortification which, in turn, is less risky than supplement use.

It is surprising how difficult it has been to develop widely acceptable data relating diet and chronic disease, such as calcium and osteoporosis. In spite of epidemiological and animal studies supporting many of these relationships, focused human clinical studies have often been negative or at best equivocal. There is no good explanation for this. It has become a truism in nutrition to

describe the relationship between diet and chronic disease as multifactoral in an effort to indicate its complexity. In general, however, when we describe an event as multifactoral, we mean not only that many factors are involved in its aetiology, but also that each of the factors interacts with the other dietary and non-dietary components of the environment. Although we speak of this relationship, traditional experimental designs tend to ignore it. In the case of the relationships between diet and chronic disease, it is almost certain that several factors have to vary simultaneously for a response to be observed. The metabolic and physiologic relationships among nutrients suggest this as a possibility. Equally important may be the fact that the primary disease-related factors are ubiquitous in the environment. The role of diet, then, becomes important in modulating the expression of these primary factors, rather than providing a direct effect. It is not surprising, therefore, that using traditional experimental approaches, results obtained may be less powerful than we expect. Indeed, it may be that only long-term prospective multinutrient studies are capable of exploring these relationships. Such studies are expensive and tedious and not often performed. If this hypothesis is true, then much greater emphasis must be placed on creative animal and epidemiological studies in the development of public policy. Equally important, however, it emphasizes the need for continuing research in these areas; it demands that much greater support be given to exploring the relationships between nutrients and other factors in modification of the disease process, particularly at the cellular and genetic levels.

Let us return for a moment to the issue of risk assessment for nutrients. It has not always been true that risk assessment was an acceptable way of estimating the safety of additives in food. The change in attitude of most regulatory scientists towards quantitative risk assessment came about for two reasons. First, there was increasing recognition that scientific knowledge and experience were sufficient to support the identification of hazards. Second, there was the recognition of safety as a continuous rather than a dichotomous concept. Today, for food additives, toxicologists are trying to evaluate substances or products in terms of the magnitude of the risk they impose, not simply in terms of “up or down” or “yes or no” judgements. At the same time, it is important to remember that safety, considered in this way, is a societally derived point on a continuum. Thus the concept of significant risk becomes, in part, the result of consideration of social, political and economic factors. This, in turn, influences which phenomena we intend to investigate, how hard we are to look for them and how acceptable is their occurrence. While this has become recently recognized in the evaluation of chemical food additives, it has always been true for nutrients. The modification of the nutrient pattern to maintain health has always been a complex policy issue, depending to an extent on the economics and public health policy of the countries involved. What is required now is the development of a model that would allow us to perform risk assessments independent of these policy decisions, providing risk managers objective evaluations which could then be used to develop policy.

Returning to the issue of fortification as a strategy for the prevention of chronic disease, it is important to understand that the early enrichment programmes were based upon evidence of deficiency of a nutrient in a substantial segment of the population. Throughout the years, this principal has remained the pillar of fortification policy. Decisions concerning nutrient addition were relatively simple to make in the days when frank deficiency diseases such as pellagra and rickets were widespread in the population. Certainly in the industrialized world, these diseases, fortunately, no longer afflict large masses of people. In terms of fortification, the shift from deficiency disease prevention to health promotion offers a complex realm in which the scientific data are woefully insufficient. It raises the most fundamental question as to whether fortification of foods with nutrients is the most desirable approach to health promotion or whether it is better to rely on advice to the public to improve diets or on modification of nutrient patterns in foods, for example. Scientific data with respect to these issues are few, and if the scientific community were polled it is unlikely that there would be a consensus.

We must keep in mind that when fortification is practised, several problems may arise. The loss of control over what is occurring in the total food supply is a primary threat. If random fortification or widespread use of supplements in addition to fortification should occur, it could create imbalances or excesses in the food supply. Calcium is again a case in point. Recently, based on the recommended United States dietary guidelines, the possible total dietary intake of calcium was calculated assuming that all foods known to be fortified or that had been fortified with calcium were consumed. It was estimated that, under these conditions, calcium consumption could exceed 4 g per day. Consider this in relation to the recommendation of the United States National Institutes of Health (NIH) Consensus Conference on Calcium and Osteoporosis that calcium intake should not exceed 2 g per day.

Another possibility is to put increasing pressure on the agricultural production part of the system to develop and to

distribute more widely new strains of food having nutrient patterns that are considered to be more optimal for the prevention of chronic disease. The success of agricultural research and food science and technology in providing an abundant food supply aimed at solving the problems of hunger and deficiency has led in part to a host of new issues, concerns and questions which must be addressed by appropriately directed research. Enhanced productivity is still an important worldwide goal for agriculture, but the situation today demands a changing emphasis towards greater concern for the safety and nutritional quality of the diet, rather than emphasis only on its quantity. The picture is that the optimal utilization of scientific research related to chronic diseases and its associated public health concerns requires that scientific research related to food production must be formulated with nutritional consequences in mind. In other words, as it becomes increasingly apparent that the pattern of diet and its nutritional quality play an essential role in ensuring the total quality of life, health needs will also have to be considered as a major component in food policy and planning. Health policy and agricultural policy will have to be integrated to produce national and international food policy. However, this will place further pressures on the scientific community to produce new products that are more consistent with our developing understanding of the requirements for maintaining and improving health. It is important to note that this revolution in health, nutrition and agriculture is not occurring in a national vacuum. Important nutrition-related research is being done throughout the world, and the need for international cooperation is obvious. Governments in the more developed countries must consider how best to transfer agricultural, safety and nutritional technologies to less developed regions of the world, narrowing the increasing gap between the rich and the poor and thus contributing to the peace and stability of the world.

To return to the initial question of this discussion, is there a worldwide need to increase calcium and vitamin D intake? If so, what is the best way to accomplish it? I, unfortunately, do not have the answer. It seems clear that a relationship exists between calcium and several chronic diseases. It is not clear whether this relationship is primary or indirect. For example, calcium intake is lowest in Africa, yet osteoporosis, while it exists, is of a lower incidence than in other parts of the world. On the other hand, demonstrable problems exist if intake is excessive – a paradox. Whatever recommendations are made, they must consider all aspects of the risk associated with these actions.

In any case, it is clear that the next several decades will represent a revolution in the way we grow, process and distribute food. It is also clear that it is no longer possible for us to consider separately the various components of the national food supply. We have seen nutrition, food science, food safety and agricultural policy all evolving from basically independently directed disciplines to a point where it is essential that they be integrated to produce coherent food policy. We will have to consider agricultural needs, health and nutritional needs, safety needs and food technology needs simultaneously. Only in this way can we ever develop an understanding of the entire gestalt of the problem.

It is also clear that research in these areas is on the very cutting edge of science. Many times we pass over the frontier between what we know and what we would like to know. Clearly what we need is more research directed towards better understanding of these important problems, including studies of the interrelationship of science and food policy. Unfortunately, it seems that each new scientific observation results in a compelling force to change the policies that are in place or in development. This is not surprising. Science is a destabilizing force in policy, and new science is always difficult to incorporate in the development of food policies that have inherently great inertia. Perhaps T.S. Eliot was right. In 1934, he wrote in his poem “The Rock”, “Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost in information?”. Perhaps it is inappropriate for us to try to integrate everything we know into the development of public health policy. Yet I firmly believe that if we do not use the best science available we will not fulfil our mission to ensure, to all the people in the world, health and a high quality of life. ♦

Summary/Résumé/Resumen

Calcium and vitamin D deficiencies: a world issue?

Increasing life expectancy has led to growing interest in diseases associated with the ageing process. One of the most intensely studied disorders is osteoporosis. Osteoporosis is an end result of a complex series of events in which the relative importance of dietary calcium is unclear. The literature contains many conflicting references to the efficacy of calcium supplementation or fortification in prevention and mitigation of osteoporosis. The issue is complicated by the suggestion that increased dietary calcium intake can cause a number of adverse biological effects.

While in general the trends suggest an inverse relationship between calcium intake and the incidence of osteoporosis, this relationship is not always as strong as theory predicts. In some countries, relatively low intakes of calcium do not result in high incidence of osteoporosis. Part of the explanation may be that other factors such as hormone levels and exercise may be of more importance than dietary calcium. These are not always measured, particularly in epidemiological studies. Nevertheless, it has been proposed that calcium fortification to mitigate osteoporosis be considered on a widespread basis. The development of a fortification policy must be based on rigorous criteria that embrace both positive and adverse consequences. The consideration is not of risk versus benefits, but of risk versus risk. The evaluation of calcium as a possible candidate for worldwide fortification involves most of the vital policy issues associated with diet and nutrition and requires the development of data at the frontiers of contemporary nutritional research.

Carences en calcium et vitamine D: un problème mondial?

L'accroissement de l'espérance de vie a suscité un intérêt croissant pour les maladies associées au processus de vieillissement. L'ostéoporose et le rôle du calcium dans l'alimentation sont parmi les sujets les plus étudiés. Il n'est pas étonnant que l'ostéoporose soit le résultat final d'une suite de phénomènes complexes où l'importance relative du calcium dans l'alimentation n'est pas clairement déterminée. Les publications ne s'accordent guère sur l'efficacité d'une complémentation en calcium pour prévenir et limiter les effets de l'ostéoporose. La question est d'autant plus complexe que certains affirment qu'un apport accru de calcium peut entraîner nombre d'effets négatifs.

En général, tout semble indiquer qu'il existe un rapport inverse entre apport calcique et incidence de l'ostéoporose, mais ce rapport n'est pas toujours aussi clair que ne le laisse penser la théorie. Dans certains pays, un apport relativement faible en calcium n'entraîne pas une augmentation sensible de l'ostéoporose. D'autres facteurs (secrétions hormonales ou activité physique, par exemple) joueraient un rôle plus important que le calcium dans l'alimentation. Or, ces facteurs ne sont pas toujours mesurés, notamment lors des études épidémiologiques. On propose pourtant, un peu partout dans le monde, d'enrichir les aliments en calcium pour réduire le risque de cette maladie. La mise en œuvre d'une telle politique se doit d'être fondée sur des critères rigoureux prenant en considération les conséquences à la fois positives et négatives. Car il ne s'agit pas de mesurer les risques par rapport aux avantages possibles, mais plutôt d'évaluer les risques actuels par rapport à d'autres risques éventuels. Lorsqu'on évalue le bien-fondé d'un enrichissement en calcium des produits alimentaires au niveau mondial, ce sont la plupart des questions vitales de politique touchant à l'alimentation et à la nutrition qui sont en jeu et on a besoin de nouvelles données situées aux frontières de la recherche nutritionnelle contemporaine.

¿Son las carencias de calcio y vitamina D un problema mundial?

El aumento de la esperanza de vida ha provocado un creciente interés por las enfermedades asociadas con el proceso de envejecimiento. Uno de los trastornos más estudiados ha sido la osteoporosis y la función del calcio alimentario. Esto no es de extrañar, dado que la osteoporosis es el resultado final de una serie compleja de acontecimientos en los que no está clara la importancia relativa del calcio alimentario. La bibliografía sobre este tema contiene muchas referencias contradictorias a la eficacia de la suplementación de calcio para la prevención y mitigación de la osteoporosis. La sugerencia de que una ingesta de calcio alimentario bastante próxima a los niveles propuestos en los Estados Unidos puede causar diversos efectos biológicos negativos viene a complicar aún más las cosas. Y la situación

se hace todavía más confusa cuando se contempla desde una perspectiva mundial. Aunque en general los datos existentes indican una relación inversa entre la ingesta de calcio y la incidencia de la osteoporosis, esta relación no es siempre tan clara como prevé la teoría. Así pues, en algunos países, ingestas de calcio relativamente bajas no dan lugar a un aumento considerable de la incidencia de la osteoporosis. Puede que el problema se deba en parte a que otros factores, como los niveles hormonales y el ejercicio, tal vez desempeñen una función más importante que el calcio alimentario. Estos factores no siempre se tienen en cuenta, sobre todo en los estudios epidemiológicos. Además, la osteoporosis no es la única consecuencia funcional de la carencia de calcio. No obstante, se ha propuesto que se estudie la suplementación de calcio para mitigar la osteoporosis a nivel mundial. La elaboración de una política de enriquecimiento generalizada de los alimentos deberá basarse en criterios rigurosos que tengan en cuenta las consecuencias tanto positivas como negativas. El problema no consiste en confrontar los riesgos con los beneficios, sino unos riesgos con otros. La evaluación del calcio como posible candidato para el enriquecimiento a nivel mundial implica casi todas las cuestiones decisivas de política asociadas con la alimentación y la nutrición y exige la elaboración de datos en las fronteras de la investigación nutricional contemporánea. ♦

Calcium intake levels in the United States: issues and considerations

Y.K. Park, E.A. Yetley and M.S. Calvo
Youngmee K. Park is a Special Assistant to the Director of the Office of Special Nutritionals (OSN) and the Expert Regulatory Review Scientist on dietary and nutritional assessment of the Food and Drug Administration (FDA), United States Department of Health and Human Services. Elizabeth A. Yetley is the Director of OSN. Mona S. Calvo, a member of the Clinical Research and Review Staff, is the FDA Expert Regulatory Review Scientist on calcium metabolism and related nutrients.

Calcium is a nutrient required for such essential functions as nerve conduction, muscle contraction and blood clotting. Maintenance of calcium within narrow serum and cellular levels is so important to critical biological functions that an elaborate control system has evolved for storage and release of calcium from the skeleton in response to need. Since calcium is the major mineral component of the skeleton, it also provides structural support to the body. Thus, adequate dietary intakes of calcium are critical to normal growth and development of the skeleton and teeth as well as essential physiologic functions.

During recent years calcium has received much attention, primarily because of its well-publicized relation to osteoporosis, a disabling disease which occurs late in life and more commonly affects women. Osteoporosis is characterized by low bone mass, with the internal structure of the bone eroded to the extent that even slight trauma will cause the bone to fracture easily. According to recent estimates obtained using World Health Organization (WHO) diagnostic criteria, in the United States approximately 4 million to 6 million older women and 1 million to 2 million older men have osteoporosis (Looker *et al*., 1997). Because life expectancy in the United States will soon average more than 80 years, it is anticipated that this disease will affect an even larger proportion of the United States population (Melton *et al*., 1992).

In 1994, the United States National Institutes of Health (NIH) sponsored a consensus conference on optimal calcium intake to consider in depth the levels of calcium intake that could be considered optimal not merely in terms of optimal growth, but in terms of disease prevention. The resulting consensus statement (United States National Institutes of Health, 1994) concluded that adequate calcium intake is critical to achieving optimal peak bone mass and modifies the rate of bone loss associated with ageing. The consensus panel recommended levels of calcium intakes for most age and gender subgroups even higher than the recommended dietary allowances (RDAs) used in the United States at that time (United States National Academy of Sciences, Food and Nutrition Board, 1989). More recently, the National Osteoporosis Foundation and several NIH institutes have urged the adoption of these higher dietary guidelines for calcium intake (Welton *et al*., 1995; Whiting and Wood, 1997).

This paper examines current dietary intakes of calcium by United States population groups in relation to the 1989 RDAs and the optimal calcium intake levels recommended at the 1994 Consensus Conference.[1] The objectives are to

REGULATING NUTRIENT CONTENT AND HEALTH CLAIMS ABOUT CALCIUM

The United States Food and Drug Administration (FDA) has played a part in making the public aware of the importance of adequate levels of calcium intake to delay the onset of this osteoporosis. In November 1990, the President of the United States signed into law the Nutrition Labeling and Education Act of 1990. This act mandated FDA to review available scientific information on ten nutrient-disease topic areas, including calcium and osteoporosis, and to issue regulations authorizing food manufacturers to make health claims on food packaging where appropriate. The calcium and osteoporosis health claim decision was based on the total publicly available scientific evidence and on significant scientific agreement among experts qualified by training and experience to evaluate the calcium and osteoporosis relationship. In January 1993 a regulation was finalized (United States FDA, 1993) which permits a health claim regarding calcium and osteoporosis on foods that contain at least 20 percent of the reference daily intake (RDI)[1] of calcium per standard serving (known as reference amount) if they also meet other conditions specified in the regulation. Other FDA regulations permit claims such as "good source of calcium" on foods that contain 10 to 19 percent of the RDI per reference amount and "high calcium" on foods that contain 20 percent or more.

[1] RDI is a reference standard developed by FDA for nutrition labelling purposes. The RDI for calcium is 1 000 mg.

[1] **Editor's note:** After this paper was written the Food and Nutrition Board of the United States National Academy of Sciences proposed new recommendations for calcium in 1997 (see Table given by Heaney on page 7 of this issue).

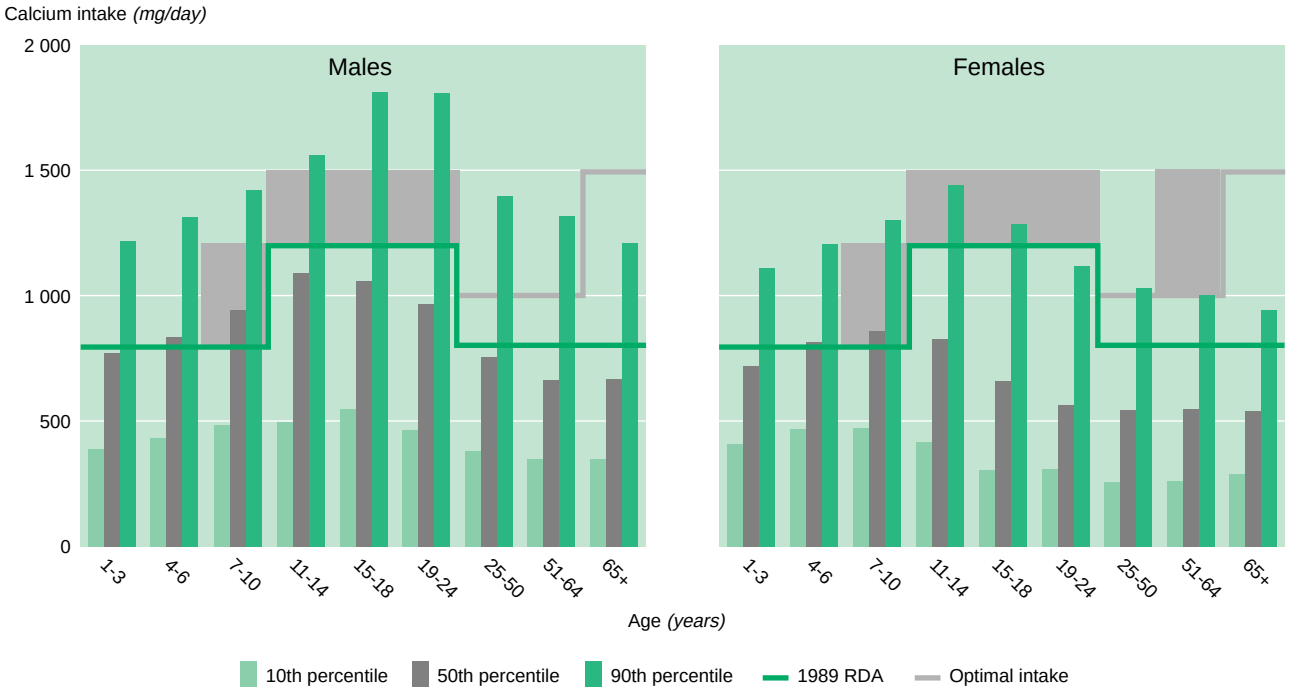
discuss some of the challenges that have been encountered in estimating calcium intake in the diverse United States population and to bring attention to several issues that need consideration in assessing nutrient intake status linked to a chronic disease in any population.

CURRENT DIETARY INTAKES OF CALCIUM IN THE UNITED STATES

Two large surveys conducted by the United States Federal Government provide nationally representative information on the kinds and amounts of foods consumed by the United States population: the Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the United States Department of Agriculture (USDA), and the National Health and Nutrition Examination Survey (NHANES), conducted by the United States Department of Health and Human Services. Data from these surveys are used to estimate nutrient intakes by United States population groups. The two surveys usually show similar results. Because CSFII provides more extensive dietary intake data than NHANES (multiple-day versus one-day, respectively), CSFII is used here to estimate current dietary intakes of calcium by United States population groups. All dietary intake estimates are based on three-day dietary intake data for persons one year of age or older. All estimates were weighted by the weighting factors provided in the survey database to represent United States population estimates.

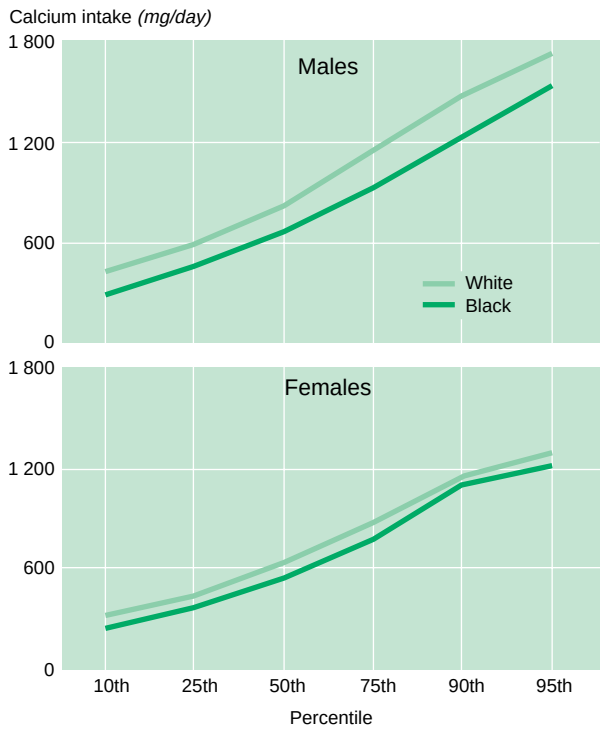
Intakes by age and gender group

Estimates of calcium intakes among males and females (divided into nine age groups and presented at the 10th, 50th and 90th percentiles) are compared with the 1989 RDAs and optimal intakes in Figure 1. The median intakes of boys and girls under 11 years of age essentially met the 1989 RDAs. Median intakes of women, particularly adolescent girls and young women, were far short of the 1989 RDAs. In contrast, median intakes of men were much closer to the 1989 RDA, ranging from 80 to 95 percent of the RDA. For all age groups and both males and females, except for women between the ages of 19 and 24 years, the 90th percentile intakes exceeded the RDA. However, a much smaller percentage of people of both genders in all age groups met the recommended optimal calcium intake level. With the exception of young children, median intakes of all age groups (both male and female) were lower than the recommended level and even the 90th percentile intakes of most adult women were short of the recommended level.



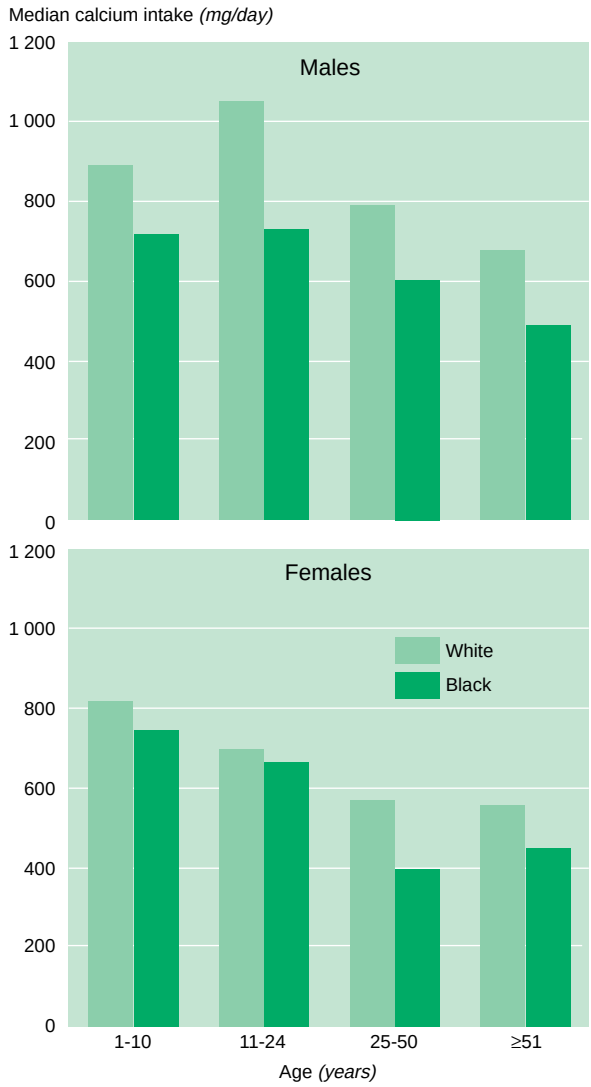
Source: Data from 1989-1991 CSFII.
Note: RDA = Recommended dietary allowances; Optimal intake = Calcium intake recommended at the 1994 optimal calcium intake consensus conference. Optimal intakes for young children are the same as RDAs. Optimal intakes for most age groups are given as a range and presented as an area.

1
Average daily intakes of calcium in the United States by age and gender (10th, 50th and 90th percentiles)



Source: Data from 1989-1991 CSFII.

2
Selected percentile average daily intakes of calcium in the United States by race and gender (excludes Hispanics)



Source: Data from 1989-1991 CSFII.

3
Median average daily intakes of calcium in the United States by race, age and gender (excludes Hispanics)

Intakes by race

For both men and women, blacks consumed less calcium than whites at all percentile levels; differences were greater for men than for women (Figure 2). For women, median intakes were lower for blacks than for whites in all age groups (Figure 3); racial differences in calcium intakes were particularly notable for women 25 years of age or older. In that age group the median intakes of black women corresponded to only about 70 to 80 percent of the median intakes of white women. The median calcium intakes of black women less than 25 years old were only slightly lower than those of white women. Similar age-related differences in median intakes were not observed in men; in all age groups, black men consumed only about 70 to 80 percent as much calcium as white men. The racial differences in calcium intakes reflect the generally lower consumption of milk and milk products by blacks (Federation of American Societies for Experimental Biology, 1995), which may be partially due to a higher prevalence of lactose intolerance among blacks.

Despite the lower calcium intakes of blacks, evidence from the third NHANES survey demonstrated significantly higher femoral density in black men and women than in whites (Looker *et al.*, 1995). There is also evidence of significantly lower hip fracture rates in blacks than in whites, particularly in women (Farmer *et al.*, 1984; Griffin *et al.*, 1992). The lower fracture rate has largely been attributed to higher peak bone mass in blacks. Racial differences in bone mass are apparent early in childhood (Luckey *et al.*, 1996; Gilsanz *et al.*, 1991), even with lower calcium intakes in black children. Other components of the diet that negatively affect bone accretion, such as inadequate protein intakes or high sodium intakes, do not appear to influence these racial differences.

Race and ethnicity are critical factors to consider in examining the adequacy of calcium intake and its specific disease association, osteoporosis. In the United States,

blacks represent a population subgroup for which genetic factors outweigh environmental influences such as diet. However, this racial difference is not necessarily universal and should be explored for each unique population.

Intakes by degree of urbanization

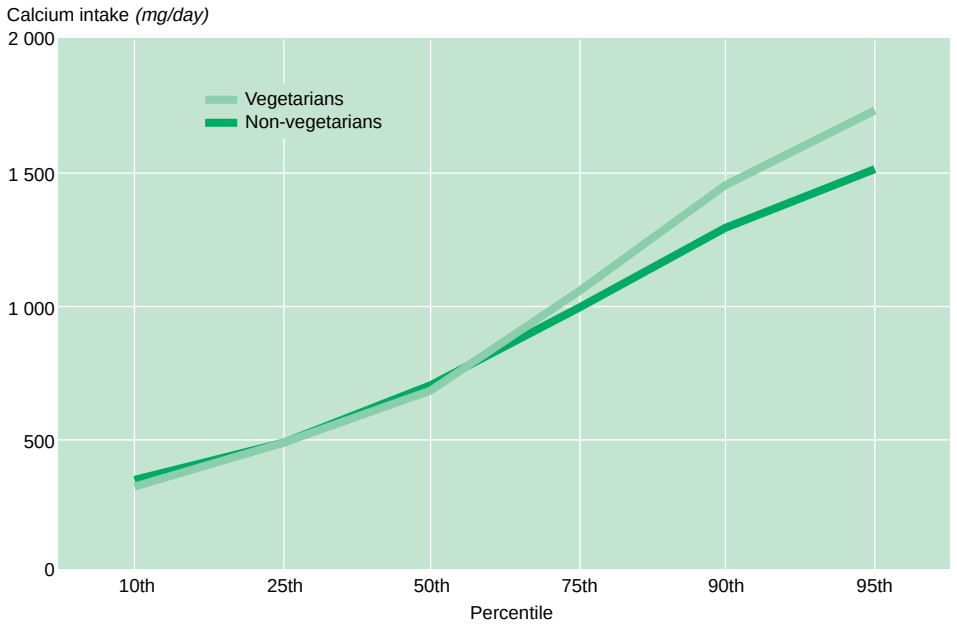
Examination of calcium intakes by degree of urbanization showed little difference among people living in city centres, suburban areas and non-metropolitan areas. This result is not surprising because in the United States, foods are shipped nationwide by large distributors. As a result, food availability is similar throughout the country, regardless of the degree of urbanization.

In developing countries calcium intakes might differ where the varieties and quantities of foods are more limited in less urbanized areas or where there is a large gap in income among people living in cities versus rural areas. Also, a possible lack of appropriate refrigeration in some rural areas of developing countries would limit the availability of the richest sources of calcium, fresh dairy foods.

Intakes of vegetarians versus non-vegetarians

USDA surveys conducted for all ages and for both males and females betweeen 1977 and 1995 show that the percentage of the United States population that is vegetarian, i.e. avoiding foods containing animal flesh, is increasing, particularly among women. It was thus of interest to analyse whether calcium intakes of vegetarians differ from those of non-vegetarians. The percentile distributions of calcium intakes among vegetarians versus non-vegetarians are shown in Figure 4. There was little difference between the two groups in the lower percentile values of intakes. For the upper percentiles, however, intakes among vegetarians were higher than those of non-vegetarians, reflecting the influence of lactovegetarians. In addition, the 1989-1991 CSFII showed that the use of vitamin and mineral supplements is more prevalent among vegetarians than among non-vegetarians (62 percent versus 38 percent, respectively). Not surprisingly, calcium intakes from supplements were higher for vegetarians than for non-vegetarians (Park *et al.*, 1997). Therefore, if calcium from supplements had been included in the calculations, the difference in intakes between the two groups would likely have been even greater.

Examination of food sources of calcium for the two groups showed that the major sources of calcium were similar for both groups: 51 to 52 percent of total calcium intakes were from milk and milk products and 25 to 27 percent from grain products. All other groups (meat, poultry and fish products; eggs and egg products; legumes, nuts and seeds; fruits and fruit products; vegetables and vegetable products; fats and oils; and sugars, sweets and beverages) contributed about 0.5 to 7.5 percent each for both vegetarians and non-vegetarians. Understandably, vegetarians obtained more calcium from legumes, nuts and seeds, fruits and fruit products and vegetables and vegetable products, whereas non-vegetarians



Source: Data from 1989-1991 CSFII.
Note: The 95th percentile value for vegetarians is potentially unreliable because of small sample size.

4
Selected percentile average daily intakes of calcium by vegetarians and non-vegetarians in the United States

obtained more calcium from meat, poultry and fish products.

The 1989-1991 CSFII also showed that vegetarians consumed about 10 g less protein per day than non-vegetarians, but that the majority of vegetarians consumed an amount equivalent to the RDA (0.8 g protein per kilogram desirable body weight for adults) or more, undoubtedly because of the wide availability in the United States of dairy products and foods of plant origin that are good sources of protein such as legumes, nuts, seeds and their products. In addition, vegetarians consumed on the average about 400 mg less sodium per day than non-vegetarians. Salt added at the table was not included in the estimates. However, the percentage of people who used salt at the table was lower for vegetarians than for non-vegetarians (50 percent versus 60 percent), which suggests that total sodium intakes including the amount used at the table would exhibit a greater difference between vegetarians and non-vegetarians. Although the differences are small, the combination of higher calcium, adequate protein and lower sodium intakes by vegetarians suggests that current dietary practices of United States vegetarians, particularly lactovegetarians, are conducive to optimal calcium absorption and retention. This may not necessarily be true for vegetarian dietary practices in other countries.

DIETARY VERSUS TOTAL CALCIUM INTAKES

The estimates of calcium intakes discussed above represent intakes from food only. They underestimate the true calcium intakes of the United States population for several reasons, as described below.

Underreporting of food intakes

Numerous studies suggest that individuals do not report their full energy intakes, i.e. food intakes, in self-reported food consumption surveys (Schoeller, 1990; Forbes, 1993). CSFII is a self-reported survey. The energy intakes reported in the 1989-1991 CSFII were substantially lower than the 1989 RDAs for energy (Crane *et al.*, 1995; Glinsmann and Park, 1995), which represent the average energy needs of individuals engaged in light to moderate physical activity with no safety margin. On the other hand, there is a prevalence of overweight in the United States; the third NHANES, conducted from 1988 to 1991, showed that 33 percent of adult men and women in the United States were overweight (Federation of American Societies for Experimental Biology, 1995). Underreporting of food intakes suggests that the calcium intakes estimated in the 1989-1991 CSFII are likely to be underestimates of the true dietary calcium intakes of the United States population.

Calcium-fortified foods

Since the authorization of nutrient content and health claims by the United States Food and Drug Administration (FDA) in 1993, many foods fortified with calcium at 10 percent of the reference daily intake (RDI) or more per serving have been introduced into the United States food supply. Informal market surveys in 1994 and 1996 showed an increasing availability of calcium-fortified foods (see Table). The majority of these products were introduced after the 1989-1991 CSFII; thus increased calcium intakes from the consumption of these fortified products were not reflected in the CSFII estimates.

Vitamin and mineral supplements

Many national surveys show that vitamin and mineral supplement use is widespread in the United States, with the proportion of users generally ranging from 35 to 40 percent of the population (Federation of American Societies for Experimental Biology, 1995). A National Health Interview Survey conducted in 1986 showed that about 20 percent of United States adults 18 years of age or older consumed supplements that contained calcium (Moss *et al.*, 1989). The same survey also showed that the potency of calcium-containing supplements varied widely (Park, Kim and Yetley, 1991). Although the median potency of products intended for consumption by adults was in a moderate range (150 to 300 mg per tablet), some products contained 600 mg or more of calcium per tablet.

Estimates of calcium intakes from the 1989-1991 CSFII do not include calcium from supplements. Using the frequency of supplement use estimated in the 1989-1991 CSFII, the median calcium potency of multinutrient supplements containing calcium and the daily dosage directions on

Examples of calcium-fortified foods commonly available in the United States[a]

Food	Amount of calcium *(mg/100 g)*
Milk	160-200
Meal replacements, milk-based	150-360
Meal replacements, fruit-based	70
Cottage cheese	170
Breakfast cereals, hot, dry	220-710
Breakfast cereals, ready to eat	270-830
Bread, light	330
Sweet bakery products	160-230
Cereal bars	540-870
Weight loss candy/bars	460-910
Apple sauce	160
Fruit juice	80-130
Fruit punch	60-130

[a] Based on an informal 1996 FDA market survey conducted in the Washington, DC metropolitan area, except for fruit punch. Some data on fruit punch came from the 1989-1991 CSFII.

single calcium supplements, it has been estimated that users of all types of supplements that contain calcium, i.e. both single and calcium-containing multinutrient supplements, would have consumed on the average about 300 mg of calcium per day from supplements.

Water

Water can be another source of calcium. The calcium content of ground and surface water used for human consumption in the United States varies widely. A two-phase survey conducted over 1989-1990 and 1991-1992 reported that the median calcium content in finished (i.e. treated for human consumption) ground and surface water ranged from 20 to 105 mg per litre and from 10 to 54 mg per litre, respectively (American Water Works Association, 1992). Estimates of calcium intakes from the 1989-1991 CSFII did not include calcium from drinking-water or water used to prepare food. As a result, calcium intake was underestimated, particularly for people who live in areas with hard water. For instance, in the midwestern United States calcium content of finished ground and surface water is typically as high as 100 and 50 mg per litre or higher, respectively (American Water Works Association, 1992).

Other sources of calcium

Drugs can also be a source of calcium. For example, some antacids (commonly used over-the-counter drugs in the United States) contain 200 to 400 mg of calcium per tablet or provide as much as 2 600 to 3 200 mg per recommended daily dosage. An analysis of data from NHANES III (unpublished) indicated that about 18 percent of United States adults 17 years of age or older use antacids in a form (tablet or capsule) that usually contains calcium.

Some prescription drugs also contain calcium, but their contributions to daily calcium intakes are likely to be minor because these medications are usually used on a short-term basis and the percentage of the population using prescription drugs containing calcium is likely to be small.

OTHER CONSIDERATIONS

Several other aspects of dietary practices should be considered in assessing calcium nutritional status.

Distribution of intakes

Studies frequently examine mean or median intakes but often fail to examine distributions of intakes within the group. People's food consumption patterns vary greatly, and as a consequence there is a wide variation in individual nutrient intake. For example, among 15- to 18-year-old girls, the lower 10 percent consumed about 300 mg or less of dietary calcium per day, while the upper 10 percent consumed more than 1 300 mg per day (Figure 1). Mean or median intakes alone are not sufficient to assess the adequacy or the safety of the calcium intakes of a population. In considering a change in public health policy, it is particularly important to examine distributions of intake to ensure that the change would favourably affect the target group (low-level consumers) while maintaining safe levels of intake for non-target groups such as upper-percentile consumers of calcium.

Nutrient interactions

Another safety aspect that should be kept in mind when fortification or supplementation programmes are under consideration is that no nutrient functions independently. The nature of the interactions with other nutrients must be defined. There is considerable evidence in experimental animals that excessive calcium intake can impair the nutritional status of other nutrients, especially magnesium, zinc and iron, but evidence in humans is not clear (Whiting and Wood, 1997). Some studies have reported deleterious effects of high calcium intakes on the nutritional status of these other minerals, while others have found no adverse effects. However, most of these clinical studies have been short term, and they have usually focused only on mineral availability or balance. More research, particularly in the form of long-term studies, is needed to determine any adverse effects of high calcium intakes on the status of other minerals in vulnerable populations.

The opposite consideration is that a number of dietary components can have an adverse impact on calcium. Western diets are typically high in protein and sodium. Low intakes of protein are associated with lower calcium absorption (Kerstetter, O'Brien and Insogna, 1997), while very high intakes of protein from animal sources are associated with higher rates of hip fracture (Abelow, Holoford and Insogna, 1992). High sodium intakes may increase the amount of calcium excreted in the urine and thereby increase the body's need for calcium (Massey and Whiting, 1996). Evaluation of protein and sodium intakes should be part of the assessment of calcium intakes in countries where protein or sodium intake are likely to be too low or excessive.

CONCLUSIONS

These efforts to estimate and evaluate calcium intakes among United States population groups illustrate a number of issues that need to be considered in evaluating national nutrition policy issues. These concerns are largely universal and should be emphasized when the intakes of any essential nutrient are estimated.

- Differences in intake among various racial and ethnic groups should be anticipated; however, they may reflect cultural preferences, as in the case of vegetarians, or genetic differences in tolerance or avoidance of specific foods such as dairy products.
- Care should be taken to resist overinterpreting the significance of estimates and their links to disease risks, and the results should be examined over the full distribution of intake, not merely in terms of means or medians.
- Surveys based on dietary recall or record reflect only the level of nutrient obtained from food. They do not account for other important sources such as vitamin and mineral supplement use, frequently used medications and drugs and water; nor do they account for the omnipresent underreporting of food intake or reflect current food fortification practices in the United States.
- Other aspects of the diet, notably those that facilitate efficient nutrient use or seriously hinder it, should be examined. Such factors as excessive sodium intake and inadequate protein intake, even with adequate intake of calcium, can have the same impact on calcium nutritional status as low calcium intake.
- Nutritional status of other nutrients could be impaired when they are consumed at low levels relative to calcium. This factor should be taken into account especially when policy decisions to raise dietary intake guidelines are being considered. ♦

REFERENCES

Abelow, B.W., Holoford, T.R. & Insogna, K.L. 1992. Cross-cultural association between dietary animal protein and hip fracture: a hypothesis. *Calcif. Tissue Int.*, 50: 14-18.

American Water Works Association. 1992. *Water industry data base: utility profiles.* Denver, Colorado, USA, American Water Works Association Research Foundation.

Crane, N.T., Wilson, D.B., Cook, D.A., Lewis, C.J., Yetley, E.A. & Rader, J.I. 1995. Evaluating food fortification options: general principles revisited with folic acid. *Am. J. Public Health*, 85: 660-666.

Farmer, M.E., White, L.R., Brody, J.A. & Bailey, K.R. 1984. Race and sex differences in hip fracture incidence. *Am. J. Public Health*, 74: 1374-1380.

Federation of American Societies for Experimental Biology, Life Sciences Research Office. 1995. *Third report on nutrition monitoring in the United States,* Vol 1. Washington, DC, USA, United States Government Printing Office.

Forbes, G.B. 1993. Diet and exercise in obese subjects: self-report versus controlled measurements. *Nutr. Rev.*, 51: 296-300.

Gilsanz, V., Roe, T.F., Stefano, M., Costen, G. & Goodman, W.G. 1991. Changes in vertebral bone density in black girls and white girls during childhood and puberty. *N. Engl. J. Med.*, 35: 1597-1600.

Glinsmann, W.H. & Park, Y.K. 1995. Perspective on the 1986 Food and Drug Administration assessment of the safety of carbohydrate sweeteners: uniform definitions and recommendations for future assessments. *Am. J. Clin. Nutr.*, 62: 161S-169S.

Griffin, M.R., Ray, W.A., Fought, R.I. & Melton, L.J. III. 1992. Black-white differences in fracture rates. *Am. J. Epidemiol.*, 136: 1378-1385.

Kerstetter, J.E., O'Brien, K.O. & Insogna, K.L. 1997. Dietary protein influences intestinal calcium absorption. *Am. J. Clin. Nutr.*, 66: 215 (Abstr.).

Looker, A.C., Orwoll, E.S., Johnston, C.C. Jr, Lindsay, R.L., Wahner, H.W., Dunn, W.L., Calvo, M.S., Harris, T.B. & Heyse, S.P. 1997. Prevalence of low femoral bone density in older U.S. adults from NHANES III. *J. Bone Miner. Res.*, 12: 1761-1768.

Looker, A.C., Wahner, H.W., Dunn, W.L., Calvo, M.S., Harris, T.B., Heyse, S.P., Johnston, C.C. Jr. & Lindsay, R.L. 1995. Proximal femur bone mineral levels of United States adults. *Osteoporosis Int.*, 5: 389-409.

Luckey, M.M., Wallenstein, S., Lapinski, R. & Meier, D.E. 1996. A prospective study of bone loss in African-American and white women – A clinical research center study. *J. Clin. Endocrinol. Metab.*, 81: 2948-2956.

Massey, L.K. & Whiting, S.J. 1996. Dietary salt, urinary calcium, and bone loss. *J. Bone Miner. Res.*, 11: 731-736.

Melton, L.J., Chrischilles, E.A., Cooper, C., Lane, A.W. & Riggs, B.L. 1992. How many women have osteoporosis? *J. Bone Miner. Res.*, 7: 1005-1010.

Moss, A.J., Levy, A.S., Kim, I. & Park, Y.K. 1989. *Use of vitamin and mineral supplements in the United States: current users, types of products, and nutrients.* Advance Data from Vital and Health Statistics of the Center for Disease Control and Prevention, National Center for Health Statistics, No. 174. Hyattsville, Maryland, USA, National Center for Health Statistics.

Park, Y.K., Calvo, M.S., Ross, S.A. & Yetley, E.A. 1997. *Sources of nutrients in the United States: food versus supplements.* Presented at the 16th International Congress of Nutrition, Montreal, Canada, 27 July - 1 August 1997 (Abstr. PT14).

Park, Y.K., Kim, I. & Yetley, E.A. 1991. Characteristics of vitamin and mineral supplement products in the United States. *Am. J. Clin. Nutr.*, 54: 750-759.

Schoeller, D.A. 1990. How accurate is self-reported dietary energy intake? *Nutr. Rev.*, 48: 373-379.

United States Food and Drug Administration (FDA). 1993. Food labeling: health claims; calcium and osteoporosis. *Fed. Regist.*, 58: 2665-2681.

United States National Academy of Sciences, Food and Nutrition Board. 1989. *Recommended dietary allowances.* Washington, DC, USA, National Academy Press. 10th ed.

United States National Institutes of Health. 1994. *Optimal calcium intake. NIH Consensus Statement,* Vol. 12, No. 4. 31 pp.

Welton, D.C., Kemper, H.C.G., Post, G.B. & van Stavern, W.A. 1995. A meta-analysis of the effect of calcium intake on bone mass in young and middle aged females and males. *J. Nutr*., 125: 2802-2813.

Whiting, S.J. & Wood, R.J. 1997. Adverse effects of high-calcium diets in humans. *Nutr. Rev.*, 55: 1-9. ◆

Summary/Résumé/Resumen

Calcium intake levels in the United States: issues and considerations

Increasing awareness of the importance of adequate calcium intake for the maintenance of bone, neuromuscular and cardiovascular health have stimulated recommendations to increase calcium intakes in the United States. Estimates of dietary calcium intakes of United States population groups have shown that the mean and median intakes of many age groups, particularly adolescent girls and adult women, are substantially lower than the 1989 recommended dietary allowances (RDAs) and the 1994 National Institutes of Health recommendations.

To increase public awareness of the importance of adequate calcium intakes, the United States Food and Drug Administration permits food manufacturers to make health claims regarding calcium and osteoporosis on food labels. Since such claims were authorized in 1993, many foods fortified with calcium, including products made from milk, cereals and fruits, have been introduced into the United States food supply. The consumption of fortified products, the use of calcium supplements and calcium from water (especially in hard-water areas) suggest that dietary surveys may underestimate calcium intakes in the United States.

A number of issues need to be considered in estimating the intakes of any essential nutrient and establishing nutrition policies. It is important to examine distributions of intake to ensure that a change in diet would benefit the target group while maintaining safe levels of intake for non-target groups. Designers of fortification or supplementation programmes should remember that no nutrient functions independently; the nature of interactions with other nutrients must be defined. Aspects of the diet that facilitate or seriously hinder efficient nutrient use should be examined. Nutrient intakes among various ethnic groups may reflect cultural preferences or genetic differences in tolerance of specific foods.

Apports en calcium aux Etats-Unis: questions et considérations

Aux Etats-Unis, on prend de plus en plus conscience de l'importance du calcium pour maintenir la santé des os et des systèmes neuromusculaire et cardiovasculaire, ce qui a conduit à l'adoption de recommandations visant à augmenter les apports calciques. Des estimations des apports alimentaires riches en calcium ont montré que les apports moyens et médians de nombreuses classes d'âge (particulièrement adolescentes et femmes) étaient nettement inférieurs aux apports alimentaires recommandés (AAR) de 1989 et aux apports préconisés par les instances nationales de la santé en 1994.

Afin de mieux informer les consommateurs des risques associés à une carence calcique, l'Office américain chargé de l'alimentation et des médicaments autorise les fabricants de produits alimentaires à attirer l'attention de la santé publique, par le biais de l'étiquetage, sur le lien existant entre ostéoporose et calcium. Depuis 1993 (année d'entrée en vigueur de cette autorisation), de nombreux aliments enrichis, y compris les produits laitiers, les céréales et les fruits, ont fait leur apparition sur le marché américain. La consommation de produits enrichis, l'utilisation de compléments en calcium et le calcium provenant de l'eau (en particulier dans les régions où l'eau est calcaire) donnent à penser que les enquêtes alimentaires sous-estiment les apports calciques aux Etats-Unis.

Un certain nombre de facteurs doivent être pris en compte lorsqu'on évalue l'apport de tout nutriment essentiel et qu'on institue des politiques de nutrition. Il est important de contrôler la répartition des apports pour s'assurer que le groupe ciblé puisse bénéficier du changement apporté à son alimentation tout en conservant un apport approprié aux groupes non ciblés. Les responsables de la conception des programmes d'enrichissement ou de complémentation devraient se rappeler du fait qu'aucun nutriment ne fonctionne indépendamment; la nature des interactions avec d'autres substances nutritives doit être définie. Les aspects de l'alimentation qui peuvent favoriser ou sérieusement entraver une meilleure utilisation d'un nutriment devraient être étudiés. Les apports nutritionnels peuvent refléter, chez divers groupes ethniques, des préférences culturelles ou des différences génétiques par rapport à la tolérance de certains aliments.

Niveles de la ingesta de calcio en los Estados Unidos: problemas y consideraciones

El reconocimiento cada vez mayor de la importancia de una ingesta suficiente de calcio para el mantenimiento del buen estado óseo, neuromuscular y cardiovascular ha alentado la formulación de recomendaciones sobre el incremento de dicha ingesta en los Estados Unidos. Las actuales ingestas media y mediana de calcio de muchos grupos de edad, en particular muchachas adolescentes y mujeres adultas, son considerablemente inferiores a los niveles dietéticos recomendados en 1989 y a las recomendaciones de los Institutos Nacionales de Salud de 1994.

Para sensibilizar al público sobre la importancia de una ingesta suficiente de calcio, la Administración de Alimentos y Medicamentos de los Estados Unidos ha autorizado a los fabricantes de alimentos a declarar las propiedades saludables del calcio para la osteoporosis. Desde que en 1993 se autorizó a declarar estas propiedades y el contenido de alimentos, se han introducido en el mercado alimentario de los Estados Unidos muchos alimentos enriquecidos con calcio. El enriquecimiento de productos a base de leche, cereales y frutas, la utilización de suplementos de calcio y el calcio contenido en el agua (especialmente en regiones donde el agua es dura) indican que es posible que en las encuestas alimentarias se subestime el nivel de la ingesta de calcio en los Estados Unidos.

Al estimar la ingesta de cualquier nutriente esencial y establecer políticas nutricionales es necesario tener en cuenta varias cuestiones. Es importante examinar la distribución de las ingestas para asegurarse de que un cambio en el régimen de alimentación beneficiaría al grupo destinatario, al tiempo que se mantendría un nivel de ingesta adecuado para los grupos restantes. Los encargados de formular programas de enriquecimiento o suplementación deben recordar que ningún nutriente actúa de modo independiente; es necesario definir la naturaleza de las interacciones con otros nutrientes. Han de examinarse los aspectos de la alimentación que facilitan un uso eficaz de los nutrientes o lo obstaculizan gravemente. Las discrepancias en las ingestas de nutrientes de diversos grupos étnicos pueden deberse a preferencias culturales o a diferencias genéticas en cuanto a la tolerancia a determinados alimentos. ◆

Calcium, micronutrients and physical activity to maximize bone mass during growth

F. Branca
Francesco Branca is Research Fellow at the National Institute of Nutrition, Rome, Italy.

A large body of evidence relates nutrition in the early stages of life to health later in life. Osteoporosis, a disease affecting several million older people worldwide, is a condition that must be prevented from childhood. Bone grows longitudinally and cross-sectionally during childhood and adolescence, with the largest accumulation of skeletal tissue (50 percent of the total mass) taking place during the adolescent growth spurt. In the third decade of life, the growth and development of the skeleton is complete. The bone consolidates: there is an increase in bone density but no increase in height. After this time, bone mass decreases progressively and becomes increasingly fragile until a threshold is reached. At this stage, fractures are very likely, even as a result of minor injuries. Having a large skeletal mass in early adulthood postpones the time in life when this threshold is reached. A 20 percent variation in the skeletal mass (corresponding to approximately 1 SD [standard deviation] of skeletal mass of the population) leads to 50 to 100 percent variation in the risk of fractures in different sites of the vertebral column (Hui, Slemenda and Johnston, 1989).

Both the formation and the subsequent maintenance of skeletal mass are determined by environmental, hormonal and genetic factors. Studies of twins have indicated that approximately 80 percent of the mass is decided by genetics (Slemenda *et al.*, 1991), while the remaining 20 percent can be manipulated with environmental interventions such as modifications of diet and physical activity. Other studies have suggested that environmental factors such as physical activity and calcium intake can each contribute 40 percent of the variance in bone density (Kelly, Eisman and Sambrook, 1990). This large discrepancy suggests that there is a considerable overlap and interaction of the different factors, since the genetic background modulates nutrient absorption and utilization and also affects muscle mass, thus indirectly influencing the level of mechanical stimulation of the bone.

CALCIUM

Intake

Approximately 70 percent of bone weight is accounted for by calcium phosphate crystals. Thus, calcium is regarded as the first nutrient to be provided to ensure optimal bone growth. Extreme calcium deprivation, experimentally induced in laboratory animals with diets containing as little as 0.3 to 0.5 mg calcium per gram of food, results in gross retardation of longitudinal growth and marked reduction of bone density. Calcium deprivation affects bone density earlier than it affects growth: in calcium-deprived rats the rate of growth declines only when bone mineral has decreased to 30 percent or less of the control values (Moore *et al.*, 1963). In cases in which infants had very low calcium intakes (below 200 mg per day) and normal vitamin D levels, there was radiographic appearance of rickets (Root, 1990). Another study compared five-year-old children in China, who had calcium intakes of less than 250 mg per day, with children of the same age in Hong Kong, who received more than twice that amount. The bone mineral content of the first group was 14 percent less and the height was 4 percent less than those of children in the second group (Lee *et al.*, 1993). Prolonged dietary deficiency of calcium has not been studied in humans; however, it is known that the bones of the malnourished are very thin and fragile (Himes, 1978).

Worldwide, there is quite a wide spectrum of calcium intakes among different populations. According to some studies, the dimensions, composition and density of bones from populations with low calcium supplies are similar to those of groups with higher calcium intake levels (Walker, 1972). Other studies show that calcium consumption during infancy and adolescence is related to bone density in adulthood (Matkovic, 1991).

Results from recent supplementation trials indicate that an increase in calcium intake leads to greater bone density. In a study of twins aged 6 to 14 years, the diet was supplemented with 1 000 mg of calcium citrate malate for three years. It was found that calcium enhanced the rate of increase in bone density (Johnston *et al.*, 1992). Research with adolescent girls involving an 18-month trial with calcium citrate supplements of 500 mg per day also led to a significant increase in total bone density (Lloyd *et al.*, 1993). In Hong Kong, a group of seven-year-old Chinese children with an initial calcium intake of approximately 500 mg per day were given elemental calcium supplements of 300 mg per

day for 18 months, and this led to a 4 percent increase in lumbar-spinal bone mineral content and a 2 percent increase in lumbar-spinal area (Lee *et al.*, 1995).

Absorption and retention

A possible explanation for this variety of findings, which is reflected in differences in the recommended dietary allowances (RDAs) for calcium, is that calcium intake is just one component of the complex dynamics regulating calcium balance. Calcium absorption is regulated by a number of dietary and individual factors. Calcium from dairy products is more available for absorption in the small intestine, but calcium from plant foods may become available for absorption in the colon (James, Branch and Southgate, 1978). Calcium absorption is enhanced when calcium is limited in the diet and is higher when the needs are greater, such as during infancy. In infants up to 50 percent of dietary calcium can be absorbed, while in adults 25 to 35 percent is absorbed (Heaney *et al.*, 1989). Protein-energy malnutrition reduces the efficiency of calcium absorption (Younoszai and Ghishan, 1979), while recovery from malnutrition can enhance calcium retention up to 87 percent (de Portela *et al.*, 1982). In addition, other factors in the diet, namely protein (Kerstetter and Allen, 1994) and sodium (Nordin and Need, 1994), impair calcium balance by increasing urinary excretion. High phosphorus intake also impairs the regulation of calcium balance in individuals with low-calcium diets (Calvo, 1994).

The list of factors affecting calcium excretion should be extended to all factors that regulate the balance between bone formation and bone resorption. In other words, calcium balance is related to the bone tissue deposited. Even when the conditions for calcium retention are favourable, the mineral may not be deposited in the bone simply because, for a number of reasons, bone is not being made. Two important factors regulating bone deposition during growth and development are micronutrient intake and physical activity.

MICRONUTRIENTS

Are diets balanced and rich enough in all the micronutrients to meet the requirements for manufacturing a sufficient amount of good-quality bone? There are questions as to whether the provision of some micronutrients is adequate worldwide. At present, there is little information about the nutrient contents of foods, let alone population intakes.

Minerals

Minerals other than calcium are involved in skeletal growth, some of them as matrix constituents, such as magnesium and fluoride, and others as components of enzymatic systems involved in matrix turnover, such as zinc, copper and manganese. Insufficient supplies of these nutrients from the diet result in reduced bone growth or in the formation of defective bone. The adequacy of the intake of these minerals should be verified if all the benefits of a good calcium intake are to be gained.

Zinc deficiency is typically characterized by the arrest of growth. The bones of zinc-deficient animals are very thin and fragile, with a marked reduction of all the cellular elements. Bone formation is depressed, while bone-resorbing cells are stimulated (Holloway *et al.*, 1996) and the concentration of parathyroid hormone, an activator of bone resorption, is increased (Roth and Kirchgessner, 1989). Marginal deficiency of zinc may be common in developing countries (Gibson, 1994), and supplementation studies indicate that the developed world might be affected as well (Sandstead, 1995).

Copper is important for the mechanical characteristics of the bone matrix; the bones of copper-deficient animals are less resistant to mechanical stress (Jonas *et al.*, 1993). In ovariectomized rats that are made copper deficient, osteoporosis progresses more quickly (Yee *et al.*, 1995).

Manganese deficiency causes reduced growth and skeletal abnormalities in animals and in humans (Fincham, van Rensburg and Maras, 1981), with decreased bone turnover.

In studies of postmenopausal women, the supplementation of a conventional low-boron diet led to a decrease of urinary calcium excretion (Nielsen *et al.*, 1987).

Fluoride is involved in the formation of hydroxyapatite crystals. In experiments, fluoride deficiency led to a delay in skeletal development in animals (Schwarz and Milne, 1972). Sodium fluoride supplements, in addition to calcium, are used as an alternative to oestrogen replacement therapy or bisphosphonate in the treatment of osteoporosis.

Vitamins

In addition to vitamin D, vitamins C and K are required for optimal bone metabolism. Vitamin C (ascorbic acid) is required for the synthesis of type I collagen, the main organic component of bone; for the subsequent extracellular modification that allows the formation of collagen cross-links; and for the synthesis of other important matrix constituents, such as glycosaminoglycans. Vitamin K is required for the synthesis of functional osteocalcin, an important structural protein of the bone matrix.

PHYSICAL ACTIVITY

The functional demand imposed on bone is a major determinant of its structural characteristics. Biomechanical studies indicate that stress applied to a skeletal segment

affects the geometry of the bone, the microarchitecture and the composition of the matrix (Carter, van der Meulen and Beaupré, 1996). Clinical studies have shown that physical activity leads to greater bone density in children and adolescents and, to a minor extent, in adults (Parfitt, 1994). Weight-bearing activities, such as walking, have a greater positive effect than non-weight-bearing activities, such as cycling and swimming (Forwood and Burr, 1993). On the other hand, bedrest and the absence of gravity experienced during space flights lead to bone loss; loss of total bone calcium may be 0.3 to 0.4 percent per month (*British Medical Journal*, 1980). Immobility during foetal development, which may result from neuromuscular diseases, leads to reduced skeleton size, with smaller bone cross-section (Rodriguez *et al.*, 1988).

A sustained level of activity leads to greater peak bone mass, as demonstrated by a 15-year longitudinal study in the Netherlands in which physical activity over time was correlated with the lumbar bone mineral density at the age of 27 years (Welten *et al.*, 1994). Interestingly, the daily intake of calcium was not correlated with peak bone mass at age 27, although it was noted that the calcium intake met the Netherlands RDA of 900 to 1 200 mg per day.

There is an important interaction between mechanical demands and the availability of nutrients to manufacture bone tissue. A meta-analysis of 16 studies carried out in postmenopausal women showed that the increase in bone density was positively related to calcium intake when calcium supplementation was accompanied by a physical exercise programme (Specker, 1996). On the other hand, when mechanical demands are low, such as during immobilization, intestinal calcium absorption is reduced (Yeh and Aloia, 1990).

IMPACT OF EXERCISE ON THE BONE MASS OF ITALIAN BOYS

At the National Institute of Nutrition in Italy, a study was carried out with 36 prepubertal boys to examine the combined effect of calcium intake and physical activity on bone mass and turnover. Twenty-six of the boys (10 ± 1.4 years of age) were involved in gymnastic training, spending about three hours per day in active games or sport and three hours in sedentary activities such as watching television or reading. The other ten boys (10.4 ± 0.6 years) spent less than one hour per day in active games or sport and more than four hours in sedentary activities.

Both groups of boys were consuming a diet adequate in calcium, although they had a calcium:phosphorus ratio below one. Controlling for height, bone area and maturational stage, it was found that the bone mineral density of the arms and legs of the sedentary boys was significantly lower than that of the active children. Time spent in weight-bearing activities was significantly related to bone density at axial and appendicular sites, and each hour of weight-bearing activity increased total bone density by 2 percent. Physical activity appeared to be more important than calcium intake in determining bone density, possibly because all the boys had adequate calcium intake (F. Branca, M. Marzia, A. Andreoli, L. Rossi, L. Callazi, S. Cianferani, S. Vitali, A. De Lorenzo and M.G. Giampietro, in preparation).

CONCLUSIONS

The available scientific evidence indicates that a sufficient amount of calcium should be provided in the diet to ensure the achievement of a peak bone mass and to allow individuals to reach their genetic potential. Frank osteopaenia during growth has been observed only at very low levels of calcium intake, below 500 mg per day, thanks to the adaptive capacity of absorption and excretion. However, higher intakes appear to be advisable. Other conditions also need to be satisfied; these include adequate intake of other nutrients needed for bone formation, such as vitamins C and K, zinc and copper, and a high mechanical demand on the skeleton through an adequate level of weight-bearing exercise. This observation leads to the general recommendation that individuals consume a balanced healthy diet, combined with physical activity, to prevent osteoporosis as well as other chronic diseases. ♦

REFERENCES

British Medical Journal. 1980. Bones in space. 280: 1288.

Calvo, M.S. 1994. The effects of high phosphorus intake on calcium homeostasis. *In* H.H. Draper, ed. *Nutrition and osteoporosis*, p. 183-207. New York, NY, USA, Plenum Press.

Carter, D.R., van der Meulen, M.C.H. & Beaupré, G.S. 1996. Skeletal development. Mechanical consequences of growth, aging and disease. *In* R. Marcus, D. Feldman & J. Kelsey, eds. *Osteoporosis*, p. 333-350. San Diego, California, USA, Academic Press.

de Portela, M.L., Zeni, S., Piazza, N. & Rio, M.E. 1982. Calcium balance in infants recovering from undernutrition. *Nutr. Rep. Int.*, 26: 1045-1051.

Fincham, J.E., van Rensburg, S.J. & Maras, W.F.O. 1981. Mseleni joint disease – a manganese deficiency? *S. Afr. Med. J.*, 60: 445-447.

Forwood, M.R. & Burr, D.B. 1993. Physical activity and bone mass: exercise in futility? *Bone Miner.*, 21: 89-112.

Gibson, R.S. 1994. Zinc nutrition in developing countries. *Nutr. Res. Rev.*, 7: 151-173.

Heaney, R.P., Recker, R.R., Stegman, M.R. & Moy, A.J. 1989. Calcium absorption in women: relationships to calcium intake, estrogen status and age. *J. Bone Miner. Res.*, 4: 469-475.

Himes, J.H. 1978. Bone growth and development in protein-calorie malnutrition. *World Rev. Nutr. Diet.*, 28: 143-187.

Holloway, W.R., Collier, F.M., Herbst, R.E., Hodge, J.M. & Nicholson, G.C. 1996. Osteoblast-mediated effects of zinc on isolated rat osteoclasts: inhibition of bone resorption and enhancement of osteoclast number. *Bone*, 19: 137-142.

Hui, S.L., Slemenda, C.W. & Johnston, C.C. 1989. Baseline measurement of bone mass predicts fracture in white women. *Ann. Intern. Med.*, 111: 355-361.

James, W.P.T., Branch, W.J. & Southgate, D.A. 1978. Calcium binding by dietary fibre. *Lancet*, 1: 638-639.

Johnston, C.C., Miller, J.Z., Slemenda, C.W., Reister, T.K., Hui, S., Christian, J.C. & Peacock, M. 1992. Calcium supplementation and increases in bone mineral density in children. *N. Engl. J. Med.*, 327: 82-87.

Jonas, J., Burns, J., Abel, E.W., Cresswell, M.J., Strain, J.J. & Paterson, C.R. 1993. Impaired mechanical strength of bone in experimental copper deficiency. *Ann. Nutr. Metab.*, 37: 245-252.

Kelly, P.J., Eisman, J.A. & Sambrook, P.N. 1990. Interaction of genetic and environmental influences on peak bone density. *Osteoporosis Int.*, 1: 56-60.

Kerstetter, J.E. & Allen, L.H. 1994. Protein intake and calcium homeostasis. *In* H.H. Draper, ed. *Nutrition and osteoporosis*, p. 167-181. New York, NY, USA, Plenum Press.

Lee, W.T.K., Leung, S.S.F., Leung, D.M.Y., Tsang, H.S.Y., Lau, J. & Cheng, J.C.Y. 1995. A randomized double-blind controlled calcium supplementation trial, and bone and height acquisition in children. *Br. J. Nutr.*, 74: 125-139.

Lee, W.T.K., Leung, S.S.F., Ng, M.Y., Wang, S.F., Xu, Y.C., Zeng, W.P. & Lau, I. 1993. Bone mineral content of two populations of Chinese children with different calcium intake. *Bone Miner.*, 23: 195-206.

Lloyd, T., Andon, M.B., Rollings, N., Martel, J.K., Landis, J.R., Demers, L.M., Eggli, D.F., Kieselhorst, K. & Kulin, H.E. 1993. Calcium supplementation and bone mineral density in adolescent girls. *J. Am. Med. Assoc.*, 270: 841-844.

Matkovic, V. 1991. Calcium metabolism and calcium requirements during skeletal modelling and consolidation. *Am. J. Clin. Nutr.*, 54: 245S-260S.

Moore, T., Impey, S.G., Martin, P.E.N. & Symonds, K.R. 1963. Meat diets. II. Effect of the age of rats on their ability to withstand the low calcium intake induced by a diet of minced beef. *J. Nutr.*, 80: 162-170.

Nielsen, F.H., Hunt, C.D., Mullen, L.M. & Hunt, J.R. 1987. Effect of dietary boron on mineral, estrogen and testosterone metabolism in postmenopausal women. *FASEB J.*, 1: 394-397.

Nordin, B.E.C. & Need, A.G. 1994. The effect of sodium on calcium requirements. *In* H.H. Draper, ed. *Nutrition and osteoporosis*, p. 209-230. New York, NY, USA, Plenum Press.

Parfitt, A.M. 1994 The two faces of growth: benefits and risk to bone integrity. *Osteoporosis Int.*, 4: 382-398.

Rodriguez, J.I., Garcia-Alix, A., Palacios, J. & Paniagua, R. 1988. Changes in long bones due to fetal immobility caused by neuromuscular disease. *J. Bone Joint Surg.*, 70A: 1052-1060.

Root, A.W. 1990. Effects of undernutrition on skeletal development, maturation and growth. *In* D.J. Simmons, ed. *Nutrition and bone development*, p. 114-130. New York, NY, USA, Oxford University Press.

Roth, H.P. & Kirchgessner, M. 1989. Influence of zinc and calcium deficiency on the concentrations of calcitonon, parathyroid hormone and 25-hydroxy-vitamin D_3 in rat serum. *J. Trace Elem. Electrolytes Health Dis.*, 3: 225-230.

Sandstead, H.H. 1995. Is zinc deficiency a public health problem? *Nutrition*, 11: 87-92.

Schwarz, K. & Milne, D.B. 1972. Fluorine requirement for growth in the rat. *Bioinorg. Chem.*, 1: 331-338.

Slemenda, C.W., Miller, J.Z., Hui, S.L., Reister, T.K. & Johnston, C.C. 1991. Role of physical activity in the development of skeletal mass in children. *J. Bone Miner. Res.*, 6(1): 1227-1233.

Specker, B.L. 1996. Evidence for an interaction between calcium intake and physical activity on changes in bone mineral density. *J. Bone Miner. Res.*, 11: 1539-1544.

Walker, A.R.P. 1972. The human requirement of calcium: should low intakes be supplemented? *Am. J. Clin. Nutr.*, 25: 518-530.

Welten, D.C., Kemper, H.G.C., Post, G.B., Van Mechelen, W., Twisk, J., Lips, P. & Teule, G. 1994. Weight-bearing activity during youth is a more important factor for peak bone mass than calcium intake. *J. Bone Miner. Res.*, 9: 1089-1095.

Yee, C.D., Kubena, K.S., Walker, M., Champney, T.H. & Sampson, H.W. 1995. The relationship of nutritional copper to the development of postmenopausal osteoporosis in rats. *Biol. Trace Elem. Res.*, 48: 1-11.

Yeh, J.K. & Aloia, J.F. 1990. Effect of physical activity on calciotropic hormones and calcium balance in rats. *Am. J. Physiol.*, 258: E263-E268.

Younoszai, M.K. & Ghishan, F.K. 1979. *In vivo* intestinal calcium absorption in infant rats: normal and growth retarded. *J. Nutr.*, 109: 573-579. ◆

Summary/Résumé/Resumen

Calcium, micronutrients and physical activity to maximize bone mass during growth

Nutrition during the early stages of life can influence an individual's health decades later. Bone growth and development are completed during the first 30 years of life, with the largest accumulation of skeletal tissue taking place during the adolescent growth spurt. Maximizing bone mass during youth can delay the loss of bone mass and reduce the risk of fracture in later years. Physical exercise and diet, in addition to genetic and hormonal factors, can influence bone density.

Research studies disagree about the effects of low calcium intakes on bone growth. The fact that calcium intake is just one component of the complex dynamics regulating calcium balance may explain the differences in research findings. Micronutrient intakes and physical activity also determine bone deposition during growth and development.

In addition to calcium, other micronutrients involved in skeletal growth include magnesium and fluoride, which are matrix constituents, and zinc, copper and manganese, which are components of enzymatic systems involved in matrix turnover. Insufficient dietary supply of these nutrients results in reduced bone growth or in the formation of defective bone.

The functional demand imposed on bone is a major determinant of its structural characteristics. At the National Institute of Nutrition in Italy, the combined effects of calcium intake and physical activity on bone mass and turnover were studied among two groups of boys. After controlling for height, bone area and stage of maturation, the bone mineral density of the arms and legs of the sedentary group was found to be significantly lower than that of the active group. Physical activity appeared to be more important than calcium intake in determining bone density, possibly because all the subjects had an adequate calcium intake. There is an important interaction between mechanical demands and the availability of nutrients to manufacture bone tissue.

Importance du calcium, des micronutriments et de l'activité physique pour maximiser la masse osseuse durant la croissance

La nutrition au cours de la prime enfance peut avoir une influence sur la santé d'un individu des décennies plus tard. La croissance et le développement osseux sont complétés durant les 30 premières années et c'est à l'adolescence, au moment de l'accélération de la croissance, que se constitue la plus grande partie du tissu osseux. Une maximalisation de la masse osseuse pendant la jeunesse peut retarder le phénomène de perte enregistré plus tard et réduire le risque de fracture chez les personnes âgées. Outre les facteurs génétiques et hormonaux, l'activité physique et l'alimentation peuvent influer sur la densité osseuse.

Les résultats des recherches donnent des avis divergents quant aux effets d'une carence en calcium sur les os car l'apport en calcium n'est qu'un des éléments d'une dynamique complexe de l'équilibre calcique. Les apports de micronutriments et l'activité physique jouent également un rôle essentiel dans l'ostéogenèse.

Outre le calcium, d'autres micronutriments ont une incidence sur le développement du squelette: le magnésium et le fluor en tant que constituants matriciels; et le zinc, le cuivre et le manganèse en tant que composants de systèmes enzymatiques associés au renouvellement de la matrice. Une disponibilité alimentaire insuffisante de ces nutriments se traduit par une diminution de la croissance osseuse et par une ossification défectueuse.

La demande fonctionnelle imposée à un os est un facteur déterminant de ses caractéristiques structurelles. En Italie, l'Institut national de la nutrition a étudié, sur deux groupes de garçons, les effets conjugués de l'apport en calcium et de l'activité physique sur la masse et le métabolisme osseux. En vérifiant la grandeur, la section osseuse et le stade de maturation, on a constaté que la densité minérale osseuse des bras et des jambes du groupe sédentaire était nettement inférieure à celle du groupe actif. L'activité physique, plus que l'apport en calcium, semble intervenir sur la densité osseuse: les sujets des deux groupes bénéficiaient en effet d'un apport calcique approprié. Il existe une interaction importante entre les contraintes mécaniques et la disponibilité de nutriments pour créer le tissu osseux.

Summary/Résumé/Resumen

Calcio, micronutrientes y actividad física para aumentar al máximo la masa ósea durante el crecimiento

La nutrición que recibe una persona durante las fases iniciales de su vida puede influir en su salud decenios más tarde. El crecimiento y desarrollo de los huesos se completa en el curso de los 30 primeros años de vida, registrándose la mayor acumulación de tejido óseo durante el estirón de la adolescencia. Aumentando al máximo la masa ósea durante la juventud, es posible retrasar la pérdida de dicha masa y reducir el riesgo de fracturas entre los ancianos. El ejercicio físico y la alimentación, además de factores genéticos y hormonales, pueden influir en la densidad ósea.

Los resultados de investigaciones relativas a los efectos de ingestas bajas de calcio sobre el crecimiento de los huesos son contradictorios. El hecho de que la ingesta de calcio sea sólo uno de los componentes de la compleja dinámica que regula el equilibrio del calcio puede explicar las diferencias en las conclusiones de las investigaciones. La ingesta de micronutrientes y la actividad física determinan también el depósito en los huesos durante el crecimiento y el desarrollo. En el crecimiento del esqueleto intervienen otros micronutrientes además del calcio: el magnesio y el flúor son componentes de la matriz; y el zinc, el cobre y el manganeso forman parte de los sistemas enzimáticos que intervienen en el ciclo metabólico de la matriz. Un suministro alimentario insuficiente de estos nutrientes se traduce en una reducción del crecimiento óseo o en la formación de huesos defectuosos.

Las exigencias funcionales impuestas a los huesos determina en gran medida sus características estructurales. En el Instituto Nacional de Nutrición de Italia, se estudiaron los efectos conjuntos de la ingesta de calcio y la actividad física sobre la masa ósea y su ciclo metabólico en dos grupos de muchachos. Controles del peso, la superficie ósea y la etapa de maduración revelaron que la densidad mineral de los huesos de los brazos y la piernas del grupo sedentario era considerablemente inferior a la del grupo activo. La actividad física era al parecer más importante que la ingesta de calcio como determinante de la densidad ósea, posiblemente porque dicha ingesta era suficiente en todos los sujetos. Existe una interacción importante entre las exigencias mecánicas y la disponibilidad de nutrientes para la elaboración del tejido óseo. ◆

NEWS

DIETARY FIBRE AND ITS ROLE IN CHRONIC DISEASE PREVENTION: HIGHLIGHTS OF THE FAO FIBRE SYMPOSIUM

At the 16th International Congress of Nutrition, held in Montreal, Canada from 27 July to 1 August 1997, FAO, with the support of an educational grant from the Kellogg Corporate Citizenship Fund, organized the FAO Scientific Symposium on Dietary Fibre and Health. The symposium was convened to honour the contributions of Alexander R.P. Walker of the South African Institute of Medical Research in Johannesburg. Walker was one of the earliest investigators to recognize the role of dietary fibre in human health and has made important contributions towards understanding fibre effects in colon cancer and coronary heart disease. The symposium was opened by John Lupien, Director of the FAO Food and Nutrition Division, who spoke briefly on the role of diet in human health. Ranjit Chandra, the president of the congress, and Victor Fulgoni of the Kellogg Company welcomed the standing-room-only crowd. Walker was unable to attend because of health reasons. However, the audience was shown a videotape in which he greeted the participants and discussed his career.

Excerpts from Walker's statement

"I certainly wish that I could have travelled to be with you because so much of my life's work has been devoted to dietary fibre and health or ill health. It is wonderful to see this type of symposium where a global food organization, a leading global food company and leading health professionals from around the world have come together to discuss the current state of the science and

NOUVELLES

LES FIBRES ALIMENTAIRES ET LEUR RÔLE DANS LA PRÉVENTION DES MALADIES CHRONIQUES: PRINCIPALES CONCLUSIONS DU COLLOQUE DE LA FAO SUR LES FIBRES

Au cours du 16e Congrès international sur la nutrition, tenu récemment à Montréal (Canada) du 27 juillet au 1er août 1997, la FAO, grâce à une subvention du Kellogg Corporate Citizenship Fund, a organisé le Colloque scientifique sur les fibres alimentaires et la santé pour rendre hommage aux contributions d'Alexander R.P. Walker de l'Institut sud-africain de recherches médicales de Johannesburg. Walker a été l'un des premiers chercheurs à reconnaître le rôle des fibres alimentaires dans la santé humaine et il a beaucoup aidé à mieux faire comprendre les effets de ces fibres sur le cancer du côlon et les maladies coronariennes. John Lupien, Directeur de la Division de l'alimentation et de la nutrition de la FAO, a inauguré le colloque et rappelé brièvement l'importance du régime alimentaire pour la santé. Ranjit Chandra, Président du Congrès et Victor Fulgoni de la société Kellogg ont accueilli les très nombreux participants. Bien que Walker n'ait pu être présent pour des raisons de santé, il a pu, par le biais d'une bande vidéo, adresser un message de bienvenue et retracer sa carrière.

Extraits du communiqué du docteur Walker

«J'aurais souhaité pouvoir être avec vous aujourd'hui car j'ai consacré une grande partie de ma vie à étudier les fibres alimentaires, la santé et la pathologie. C'est prodigieux de voir ce genre de colloque où une organisation alimentaire mondiale, une des premières sociétés alimentaires mondiales et d'éminents experts de la santé, venus de divers horizons, se trouvent réunis pour débattre de l'état actuel de la science et diffuser les conclusions de ces échanges aux populations du monde entier. Les scientifiques présentant une communication figurent parmi les chercheurs réputés dans ce domaine, et les thèmes abordés sont d'actualité,

NOTICIAS

LAS FIBRAS DIETETICAS Y SU IMPORTANCIA PARA LA PREVENCION DE ENFERMEDADES CRONICAS: RESEÑA DEL SIMPOSIO DE LA FAO SOBRE LA FIBRA DIETETICA

En el 16º Congreso Internacional de Nutrición, celebrado en Montreal, Canadá, del 27 de julio al 1 de agosto de 1977, la FAO, con la ayuda de un subsidio de educación proporcionado por la Kellogg Corporate Citizenship Fund, organizó el Simposio científico de la FAO sobre la fibra dietética y la salud. El simposio se convocó para rendir homenaje a las contribuciones de Alexander R.P. Walker, del Instituto Sudafricano de Investigación Médica de Johannesburg. El Sr. Walker fue uno de los primeros investigadores en reconocer la función de la fibra dietética en la salud humana y ha realizado importantes aportaciones a la comprensión de los efectos de la fibra en el cáncer de colon y las cardiopatías coronarias. Inauguró el simposio el Sr. John Lupien, Director de Alimentación y Nutrición de la FAO, quién habló brevemente sobre la función del régimen de alimentación en la salud humana. El Sr. Ranjit Chandra, Presidente del Congreso, y el Sr. Victor Fulgoni, de la empresa Kellogg, dieron la bienvenida al público que abarrotaba la sala. Aunque el Sr. Walker no pudo asistir por razones de salud, se proyectó una cinta de vídeo en la que saludaba a los participantes y pasaba revista a su carrera.

Extractos de la declaración del Sr. Walker

«Dado que una gran parte del trabajo que he realizado a lo largo de mi vida ha estado dedicado a la fibra dietética y su relación con la salud y la enfermedad, no cabe duda de que mi deseo habría sido estar en condiciones de viajar para poder reunirme con ustedes. Es magnífico presenciar un simposio de este tipo, en el que una organización mundial que se ocupa de la alimentación, una importante empresa alimentaria mundial y destacados profesionales de la salud de todo el mundo se han reunido para debatir el estado actual de la ciencia, y

then communicate the results to people everywhere. The presenters are among the leading researchers in this field, and the topics are very timely because of the public's increasing interest in the food they eat.

"Three decades ago, we only dreamed of what is occurring today, for governments and health organizations around the world are strongly encouraging the consumption of fibre-containing foods. Highly respected health journals regularly contain major contributions that examine how fibre works to reduce the risk of various cancers and other chronic diseases of lifestyle. Health professionals and food companies are trying to communicate to consumers on an almost regular basis the importance of dietary fibre. The timing of this occasion could not be better. The incidence of many cancers and some other diseases of lifestyle are still increasing. This is especially the case in countries where they used to be rare. These changes are alarming, and people around the world are searching for answers. We must do our best to answer them.

"We must continue to seek to learn more of the hows and whys of dietary fibre's role in disease prevention and control. We still have much to learn of how fibre works to maintain good health and reduce the risk of developing cancer and other chronic diseases. But we know that it works! FAO must continue its leadership role in working with governments to put forward guidelines and find ways to increase the consumption of fibre-containing foods. Kellogg Company must continue its historical heritage of sponsoring independent scientific fibre research and of communicating to consumers the value of fibre through its advertisements, its packaging and educational materials. And you, my good colleagues, must delve still further into the subject than I and

le public s'intéressant de plus en plus aux aliments qu'il consomme.

«Ce qui se passe aujourd'hui n'était qu'un rêve il y a 30 ans. Dans le monde entier, les pouvoirs publics et les services de santé préconisent l'intégration de produits riches en fibres dans leur alimentation. Des revues de santé, très renommées, publient périodiquement des études importantes sur la manière dont les fibres réduisent le risque de divers cancers et autres maladies chroniques liées au mode de vie. De leur côté, les experts en santé et les sociétés de produits alimentaires cherchent régulièrement à sensibiliser les consommateurs à l'importance des fibres alimentaires. Ce colloque a été programmé au bon moment. Le cancer et d'autres maladies «de civilisation» ne cessent d'augmenter, même dans les pays où ils étaient jusqu'alors rares. Ces changements sont alarmants et, dans le monde entier, on cherche des réponses. Nous devons faire tout ce qui est en notre pouvoir pour participer à cet effort.

«Il faut continuer à essayer de comprendre pourquoi et comment les fibres préviennent et enrayent la maladie. Nous avons encore beaucoup à apprendre sur la manière dont elles protègent la santé et limitent le risque de cancer et autres maladies chroniques. Mais nous savons que c'est une réalité! La FAO doit poursuivre son action catalytique en travaillant avec les instances gouvernementales pour élaborer des recommandations et trouver le moyen d'augmenter la consommation d'aliments riches en fibres. La société Kellogg doit poursuivre dans la voie sur laquelle elle s'est engagée. Depuis longtemps, en effet, elle parraine des recherches scientifiques indépendantes et informe les consommateurs de l'importance des fibres alimentaires à travers la publicité, l'emballage de ses produits et ses supports didactiques. Quant à vous, chers collègues, il vous faut approfondir mes recherches et celles de mes illustres prédécesseurs, Dennis Burkitt et Hugh Trowell, en particulier. Nous avons encore tant à apprendre et à partager avec le public! Persévérez! Continuez à comprendre

comunicar luego sus conclusiones a personas de todas partes. Los ponentes se cuentan entre los investigadores más destacados en este sector, y el tema es muy oportuno dado el creciente interés del público por los alimentos que consume.

«Hace tres decenios, lo que está ocurriendo hoy era tan sólo un sueño. Gobiernos y organizaciones que se ocupan de la salud en todo el mundo alientan vivamente el consumo de alimentos que contienen fibra. Prestigiosas revistas sanitarias publican habitualmente artículos en los que se examina la forma en que la fibra contribuye a reducir el riesgo de diversos tipos de cáncer y otras enfermedades crónicas derivadas del modo de vida. Profesionales de la salud y empresas alimentarias tratan de informar a los consumidores de manera casi sistemática sobre la importancia de la fibra dietética. Esta ocasión no podría llegar en mejor momento. La incidencia de muchos tipos de cáncer y de algunas otras enfermedades derivadas del modo de vida sigue creciendo. Esto sucede sobre todo en países donde tales enfermedades eran antes raras. Estos cambios son alarmantes, y personas de todo el mundo están buscando respuestas. Debemos hacer todo lo posible para ofrecérselas.

«Debemos seguir tratando de conocer mejor cómo y por qué contribuye la fibra dietética a prevenir y combatir enfermedades. Tenemos mucho que aprender todavía sobre el modo en que actúa la fibra para mantener la buena salud y reducir el riesgo de contraer cáncer y otras enfermedades crónicas. ¡Pero sabemos que lo hace! La FAO debe seguir desempeñando su función directiva, en colaboración con los gobiernos, para proponer directrices y encontrar medios de aumentar el consumo de alimentos que contienen fibra. La empresa Kellogg debe proseguir su trayectoria histórica de patrocinio de la investigación científica independiente sobre la fibra dietética y de información a los consumidores sobre el valor de la fibra a través de sus anuncios, sus envases y su material educativo. Y ustedes, estimados colegas, deben profundizar

my more illustrious early colleagues, notably Dennis Burkitt and Hugh Trowell, have been able to do. There is much more to be learned and shared with the public. So press on, my colleagues. Keep on making strides in understanding, even if they are not giant strides.

"I am proud of the work that I, with others, have done in this area over the past four decades. From the bottom of my heart, I appreciate the honour and recognition that you are bestowing upon me today – even in my absence. The best way to acknowledge the early pioneering work is to press on with your own endeavours."

Walker emphasized the role of dietary fibre as an essential component of a healthful diet and lifestyle. His concluding observation was, "The minimum sequelae of ageing are found only when the diet is high in fibre-containing foods".

Presentations

Michael Davidson of the Chicago Center for Clinical Research, United States, gave a general presentation on fibre types and fibre usage. He reviewed lipid lowering trials conducted with various soluble fibres and commented on new approaches to understanding the underlying mechanism, which appears to involve effects on bile acid turnover.

David Jenkins of the University of Toronto, Canada, reviewed his recent work on the hypolipidaemic effects of what he calls the "simian diet". This diet, devised to resemble the putative diet of some of humans' distant ancestors, contains nuts, plants, berries and fruit as staples, with no grains, dairy or meat products. The simian diet significantly reduced blood lipid levels and urinary C-peptide, a marker of insulin response. In order to reach some level of satiety the experimental group had to eat

et à progresser, même si ce n'est pas à pas de géant.

«Je suis fier du travail que nous avons réalisé dans ce domaine depuis 40 ans. Du fond du cœur, je vous remercie de l'honneur et de la reconnaissance que vous me témoignez aujourd'hui-même en mon absence. En continuant vos travaux, vous exprimerez de la gratitude envers ceux qui ont ouvert la voie.»

Walker a démontré que les fibres étaient une composante essentielle d'une alimentation et d'un mode de vie sains. Il a conclu ses travaux en observant que «les effets du vieillissement sont moindres lorsque l'on suit un régime alimentaire riche en fibres».

Communications

Michael Davidson, du Centre sur les recherches cliniques de Chicago (Etats-Unis), a présenté un tableau général des types de fibres et de leur usage. Il a examiné les études comparatives sur la réduction des lipides réalisées avec diverses fibres solubles et commenté de nouvelles approches visant à appréhender le mécanisme sous-jacent qui semble avoir des effets sur la synthèse des acides biliaires.

David Jenkins, de l'Université de Toronto (Canada), a fait part de ses récents travaux sur les effets hypolipémiants d'un régime qu'il a baptisé le «simian diet». Ce régime est constitué d'éléments dont, selon certains, se nourrissaient une partie des ancêtres lointains de l'homme: il se compose de noix, de plantes, de baies et de fruits, et exclut céréales et produits laitiers ou animaux. On a constaté que ce régime réduit nettement le niveau des lipides dans le sang et le peptide C présent dans l'urine, indicateur de l'activité de l'insuline. Afin d'arriver à un niveau de satiété, le groupe expérimental a dû manger constamment et une stimulation du transit intestinal et une augmentation du volume des selles ont été observées.

Michael Hill, Président de l'Organisation européenne pour la prévention du cancer, a abordé le sujet «Céréales, fibres alimentaires et cancer». Il a décrit la théorie de

en este tema más de lo que yo y los ilustres colegas que me han precedido, en particular Dennis Burkitt y Hugh Trowell, hemos podido hacer. Queda mucho por aprender y compartir con el público. Por eso insto a mis colegas a que sigan avanzando en el conocimiento, aunque los progresos no sean espectaculares.

«Estoy orgulloso de la labor que yo, junto con otras personas, hemos realizado en este sector en los cuatro últimos decenios. Aprecio de todo corazón el honor y el reconocimiento que me brindan hoy, aunque sea en mi ausencia. El mejor modo de reconocer la labor innovadora es intensificar los propios esfuerzos.» El Sr. Walker subrayó la importancia de la fibra dietética como componente esencial de un modo de vida saludable. Su observación final fue la siguiente: «Sólo cuando la dieta es rica en alimentos que contienen fibra se reducen al mínimo las secuelas del envejecimiento.»

Presentación

El Sr. Michael Davidson del Centro de Investigación Clínica de Chicago presentó los tipos de fibra y su utilización. Analizó los ensayos realizados con diversas fibras solubles para rebajar el contenido de lípidos y comentó los nuevos métodos aplicados para comprender el mecanismo básico que, al parecer, tiene efectos sobre el recambio de ácidos biliares.

El Sr. David Jenkins de la Universidad de Toronto, Canadá, presentó su reciente labor sobre los efectos hipolipidémicos de lo que denominó la «dieta símica». Esta dieta, que es similar a la que se supone que consumían los antepasados lejanos del hombre, contiene nueces, plantas, bayas y frutas, sin cereales, ni productos lácteos o cárnicos. La dieta símica reduce considerablemente el nivel de los lípidos en la sangre y del péptido C urinario, que es un indicador de la respuesta a la insulina. Para alcanzar cierto grado de saciedad, el grupo experimental tuvo que comer constantemente y había habido un aumento significativo de la actividad

constantly, and there was a significant increase in bowel activity and high output of faeces.

Michael Hill, Chairman of the European Cancer Prevention Organization, addressed the topic "Cereals, dietary fibre and cancer". He described Burkitt's hypothesis, namely, that fibre plays a protective role in colon cancer, and explained that if this could be proved it would permit a positive approach to colon cancer prevention: the recommendation to eat more fibre, rather than the negative suggestion of eating less fat. Hill reviewed the literature related to specific dietary factors and risk of colorectal cancer. Among 15 studies regarding meat and/or animal fat, about two-thirds suggest promotion of disease and the rest argue for no effect. In 19 studies on fibre, 53 percent suggest prevention and 37 percent no effect. Of 16 studies on vegetable intake, 81 percent suggest a preventive role in colon cancer and the rest show no effect. Hill discussed the difficulties of analysing dietary fibre and stated that until they are resolved it is necessary to study effects of food groups. Hill reviewed data from 58 papers on diet and colorectal cancer. Of 36 papers examining the effect of total cereal intake, 67 percent found a protective role, and of 16 papers examining the effect of cereal fibre, 82 percent showed a protective role. A recent study of FAO intake data from 26 European countries showed that cereals and vegetables offered strong protection against colon and breast cancer. Fruits and starchy roots had no effect. The data lend support to the Burkitt hypothesis.

Barbara Schneeman of the University of California-Davis, United States, discussed dietary fibre and gastro-intestinal function. She related the physical characteristics of

Burkitt selon laquelle les fibres diminueraient le risque de cancer du côlon et expliqué que si cette thèse était prouvée, la prévention de ce type de cancer pourrait s'appuyer sur un message positif: consommez plus de fibres, plutôt que négatif: mangez moins de matières grasses. Hill a ensuite analysé les publications traitant d'aliments spécifiques et du risque de cancer colorectal. Sur 15 études consacrées à la viande et/ou aux graisses animales, deux tiers environ suggèrent que ces matières favorisent le cancer colorectal et un tiers n'établit aucun lien de cause à effet. Sur 19 études portant sur les fibres, 53 pour cent indiquent que ces dernières interviennent dans la prévention de ce type de cancer et 37 pour cent qu'il n'y a aucun lien de cause à effet. Sur 16 études concernant les apports végétaux, 81 pour cent donnent à penser que ces apports jouent un rôle préventif et 19 pour cent qu'il n'y a aucun lien de cause à effet. Enfin, Hill a mentionné les difficultés rencontrées lors de l'analyse des fibres alimentaires et la nécessité d'étudier les effets de divers groupes d'aliments, en attendant la solution des problèmes. Hill a examiné les données de 58 articles établissant un lien entre le régime alimentaire et le cancer colorectal. Sur les 36 documents examinant l'effet d'un apport total de céréales, 67 pour cent parlent d'un effet protecteur des fibres céréalières et sur les 16 documents examinant l'effet des fibres céréales, 82 pour cent montrent un rôle préventif. Une récente étude sur les apports alimentaires, réalisée par la FAO dans 26 pays européens, constate que les céréales et les légumes offrent une réelle protection contre le cancer du côlon et du sein, mais que les fruits et les tubercules n'ont aucune incidence. Les données semblent ainsi étayer la thèse de Burkitt.

Barbara Schneeman de l'Université de California-Davis (Etats-Unis) a abordé la question des fibres alimentaires et de la fonction gastro-intestinale. Elle a rapporté les caractéristiques physiques des fibres aux fonctions de l'intestin grêle et du gros intestin, et en a analysé les

intestinal y una abundante producción de heces.

El Sr. Michael Hill, presidente de la Organización Europea para la Prevención del Cáncer abordó el tema de los cereales, la fiebre dietética y el cáncer. Describió la hipótesis de Burkitt de que la fibra desempeña una función protectora contra el cáncer de colon, lo que, en caso de que pudiera demostrarse, permitiría adoptar una estrategia positiva de consumir más fibra para prevenir el cáncer de colon, en lugar de la propuesta negativa de consumir menos grasa. Analizó las publicaciones sobre factores alimentarios específicos y el riesgo de cáncer colorrectal. De 15 estudios sobre la carne y las grasas animales, unos dos tercios indicaban una acción propiciatoria, mientras que los restantes sostenían la inexistencia de efectos. En el 53 por ciento de 19 estudios sobre la fibra dietética se señalaban efectos preventivos, mientras que en el 37 por ciento no se detectaban efectos. El 81 por ciento de 16 estudios sobre ingesta de hortalizas indicaban una función preventiva contra el cáncer de colon, mientras que los restantes no señalaban efecto alguno. El Sr. Hill examinó las dificultades que planteaba el análisis de la fibra dietética y declaró que, mientras no se resolvieran, sería necesario estudiar los efectos de grupos de alimentos. Al analizar datos de 58 estudios sobre alimentación y cáncer observó que en el 67 por ciento de ellos se había comprobado que la fibra de cereales ofrecía protección y el 82 por ciento demostraba la función protectora de esta fibra. Un estudio reciente de la FAO sobre ingesta de cereales y hortalizas en 26 países de Europa indica que estos tenían una importante función protectora contra el cáncer de colon y de mama, mientras que las frutas y las raíces amiláceas no tenían efectos. Estos datos apoyaban la hipótesis de Burkitt.

La Sra. Barbara Schneeman de la Universidad de California-Davis, Estados Unidos, examinó el sistema gastrointestinal y la fibra dietética, estableciendo la relación entre las características físicas de ésta y las

dietary fibre to functions in the small and large intestines. In the small intestine, fibre, owing to its water-holding capacity, adds bulk and increased viscosity to the stool, thus slowing digestion and absorption of lipid and carbohydrate, promoting nutrient absorption distally in the intestine, blunting the glycaemic response and lowering plasma cholesterol. The capacity of fibre to bind or adsorb various compounds is also associated with plasma cholesterol reduction. In the large intestine, the dispersibility of polysaccharides in water leads to their increased microbial degradation. Bulking increases the amount of material entering the large intestine, aids in laxation and provides additional substrate for the intestinal microflora. The fermentability of polysaccharides enhances growth of microflora in the large intestine and leads to an increase in the products of microbial metabolism: hydrogen, methane, carbon dioxide and short-chain fatty acids. Short-chain fatty acids are a source of energy and maintain the health of the mucosa of the large intestine. Butyrate may play a protective role in colon cancer. Understanding the effects of fibre on the gastro-intestinal tract will further knowledge of the effects of fibre on risk of disease.

Ruth Oniang'o of Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya, spoke on implications of fibre for the consumer. She reviewed briefly the epidemiological studies relating to certain types of dietary fibre and their effects on diabetes, cholesterolaemia and obesity. Oniang'o also described studies that show that consumption of a bulky diet at breakfast significantly reduces food intake at subsequent meals. She described the emphasis on

implications. Dans l'intestin grêle, la capacité de rétention d'eau, la densité et l'augmentation de la viscosité ralentissent la digestion et l'absorption des lipides et des hydrates de carbone, favorisent distalement l'absorption des nutriments dans l'intestin, diminuent l'indice glycémique, et réduisent le taux de cholestérol dans le plasma. La capacité des fibres à s'associer ou à adsorber divers composants est également liée à la diminution du cholestérol dans le plasma. Dans le côlon, l'eau distribuée de manière homogène entraîne une augmentation de la dégradation microbienne des polysaccharides. La densité accroît la quantité de matières pénétrant dans le côlon, favorise l'expulsion des matières fécales et apporte un substrat supplémentaire à la flore intestinale. La fermentation des polysaccharides favorise la croissance de la flore intestinale et entraîne un accroissement des produits du métabolisme microbien – hydrogène, méthane, gaz carbonique et acides gras à chaîne courte. Ces acides gras sont une source d'énergie et maintiennent la muqueuse du côlon en bon état. Le butyrate joue peut-être un rôle préventif dans le cancer du côlon. Une meilleure compréhension des effets des fibres sur l'appareil gastro-intestinal contribuera à approfondir nos connaissances sur les effets protecteurs des fibres contre les maladies.

Ruth Oniang'o, de l'Institut agricole et de technologie Jomo Kenyatta de Nairobi (Kenya), a parlé des implications des fibres alimentaires au niveau du consommateur. Elle a brièvement passé en revue les études épidémiologiques portant sur certains types de fibres alimentaires et leurs effets sur le diabète, la cholestérolémie et l'obésité. Oniang'o a également décrit des études indiquant que la prise d'un petit déjeuner consistant réduit nettement la quantité d'aliments prise au moment des autres repas de la journée. Elle a souligné l'importance que certains pays attachent aujourd'hui aux recommandations concernant les aliments riches en fibres. Ainsi conseille-t-on, en Australie, de

funciones de los intestinos grueso y delgado y sus repercusiones. En el intestino delgado, la capacidad de retención de agua y el incremento del volumen y de la viscocidad reducen la velocidad de la digestión y la absorción de lípidos y carbohidratos, promueven la absorción de nutrientes distalmente en el intestino, atenúan la respuesta glicémica y reducen el colesterol plasmático. La capacidad de la fibra para combinar o adsorber diversos compuestos está también asociada con la reducción del colesterol plasmático. En el intestino grueso, la dispersión en el agua se traduce en un aumento de la degradación microbiana de los polisacáridos. El incremento del volumen aumenta la cantidad de material que entra en el intestino grueso, contribuye a la laxación y proporciona un sustrato adicional para la microflora. El aumento de la fermentabilidad promueve el crecimiento de la microflora y da lugar a un incremento de los productos del metabolismo microbiano, a saber hidrógeno, metano, dióxido de carbono y ácidos grasos de cadena corta. Estos ácidos son una fuente de energía y mantienen en buen estado la mucosa del intestino grueso. El butirato puede desempeñar una función protectora contra el cáncer de colon. Comprender la acción de la fibra en el aparato digestivo permitirá conocer mejor los efectos de la fibra sobre el riesgo de enfermedades.

La Sra. Ruth Oniang'o de la Universidad Jomo Kenyatta de Agricultura y Tecnología de Nairobi, Kenya, se refirió a las repercusiones de la fibra para el consumidor. Examinó brevemente los estudios epidemiológicos relativos a determinados tipos de fibra dietética y sus efectos sobre la diabetes, la colesterolemia y la obesidad. La Sra. Oniang'o describió también estudios que muestran que el consumo de una dieta fibrosa en el desayuno reduce considerablemente la ingesta de alimentos en las comidas posteriores. Señaló la atención que se concede a los alimentos ricos en fibra en las directrices alimentarias vigentes en algunos países. Por ejemplo, en

fibre-rich foods in current dietary guidelines in a number of countries. For example, in Australia the public is advised to eat breads, whole-grain cereals and legumes; in Denmark emphasis is placed on bread, corn products, potatoes, vegetables and fruit; in France and the United States people are advised to eat wholemeal breads, vegetables, cereals, legumes and fruit; and the suggestion in the United Kingdom is to eat foods rich in fibre. Food guides for nutrition education of the general public were discussed, and here, too, emphasis is placed on cereals and other fibre-rich foods. Guidelines for developing countries are somewhat different, reflecting the already high levels of fibre intake. Oniang'o stressed the importance of addressing fibre needs within the context of a total diet approach and challenged the food industry to provide more palatable high-fibre foods. She concluded by saying that the recommendation to ingest adequate levels of dietary fibre must be part of the dietary advice for any population group.

David Kritchevsky
Scientific adviser to the symposium
Wistar Institute,
Philadelphia, Pennsylvania, USA

consommer du pain, des céréales complètes et des légumineuses; au Danemark, l'accent est mis sur le pain, les produits à base de maïs, les pommes de terre, les légumineuses et les fruits; en France et aux Etats-Unis, on recommande à la population de manger du pain complet, des légumes, des céréales, des légumes et des fruits. Au Royaume-Uni, on suggère des produits riches en fibres. Oniang'o a également mentionné les guides sur l'alimentation destinés au grand public qui, eux aussi, soulignent l'importance des céréales et d'autres produits riches en fibres. Les recommandations sont quelque peu différentes en ce qui concerne les pays en développement car les fibres occupent déjà une place importante dans le régime alimentaire. Oniang'o a enfin noté que les besoins en fibres doivent s'inscrire dans le contexte d'un régime alimentaire complet et elle a invité l'industrie alimentaire à donner un goût plus agréable aux produits à haute teneur en fibres. Elle a conclu en soulignant que les conseils diététiques donnés, quel que soit le segment de la population, doivent encourager la consommation de fibres alimentaires en quantité suffisante.

David Kritchevsky
Conseiller scientifique du symposium
Institut Wistar,
Philadelphie, Pennsylvanie, Etats-Unis

Australia se aconseja el consumo de pan, cereales de grano entero y legumbres; en Dinamarca se hace hincapié en el pan, los productos a base de maíz, la papas y las frutas y hortalizas; en Francia y en los estados Unidos, se recomienda el pan de harina integral, hortalizas, cereales, legumbres y frutas. En el Reino Unido se sugiere comer alimentos ricos en fibra. Se examinaron guías alimentarias para la educación nutricional del público en general, en las que también se hacía hincapié en los cereales y otros alimentos ricos en fibra. Las directrices para países en desarrollo son algo diferentes porque sus necesidades son también distintas debido a que la ingestión de fibra es ya elevada. La Sra. Oniang'o destacó la importancia de afrontar las necesidades de fibra en el contexto de una dieta total y exhortó a la industria alimentaria a que ofreciera alimentos ricos en fibra más apetitosos. Concluyó diciendo que la ingestión de un volumen suficiente de fibra dietética puede ser parte del asesoramiento en materia de alimentación para cualquier grupo de población.

David Kritchevsky
Consejero científico del simposio
Instituto Wistar,
Filadelfia, EE.UU.

Codex Alimentarius

The Codex Alimentarius Commission[1] is a subsidiary body of the Food and Agriculture Organization of the United Nations and the World Health Organization, with 162 member countries. It was established to formulate internationally accepted food safety standards with the aim of protecting the consumer's health and ensuring fair trade practices.

MAJOR DECISIONS ON FOOD CLAIMS, HYGIENE AND LABELLING

The Codex Alimentarius Commission held its 22nd session from 23 to 28 June in Geneva. The agenda included food safety and hygiene, food labelling and additives. Here are a few of the highlights of the meeting, attended by 444 participants from 86 countries.

Pesticide residues

FAO and WHO have been evaluating the safety of pesticide residues in foods since 1962 and establishing maximum residue limits (MRLs) to ensure that pesticides are not overused and that any residue is safe for human consumption. More than 2 500 MRLs are currently approved by the Codex Alimentarius Commission. During the June meeting, the commission deleted 315 MRLs (covering 39 pesticides) from the Codex list as being obsolete. This means that no level of residue is acceptable for those pesticides.

What is *halal*?

In view of expanding consumer demand for *halal* products (foods permitted under Islamic law) and rapidly increasing international trade in such

[1] *Codex alimentarius* is a Latin expression meaning "food code" or "food law".

La Commission du Codex Alimentarius[1] est un organe subsidiaire de l'Organisation des Nations Unies pour l'alimentation et l'agriculture et de l'Organisation mondiale de la santé. Composée de 162 pays membres, elle a été créée pour mettre au point des normes de sécurité alimentaire universellement acceptées. Ces normes visent à protéger la santé des consommateurs et à garantir des pratiques commerciales équitables.

IMPORTANTES DÉCISIONS SUR LES ALLÉGATIONS NUTRITIONNELLES, L'HYGIÈNE ALIMENTAIRE ET L'ÉTIQUETAGE

La Commission du Codex Alimentarius a tenu sa 22e session à Genève, du 23 au 28 juin 1997. L'ordre du jour de cette session couvrait l'innocuité et l'hygiène des produits alimentaires, l'étiquetage et les additifs alimentaires. On trouvera ci-dessous quelques-uns des faits saillants de la réunion à laquelle ont assisté 444 participants provenant de 86 pays.

Résidus de pesticides

La FAO et l'OMS évaluent l'innocuité des résidus de pesticides dans les produits alimentaires depuis 1962 et ont fixé des limites maximales de résidus (LMR) pour prévenir l'abus des pesticides et garantir leur innocuité pour la consommation humaine. Plus de 2 500 LMR ont ainsi été approuvées par la Commission du Codex Alimentarius. Au cours de la réunion du mois de juin, la Commission a supprimé 315 LMR (se rapportant à 39 pesticides) de la liste du Codex, devenues obsolètes. Cela signifie que les produits alimentaires ne doivent contenir aucune trace de ces pesticides.

Qu'est-ce que la nourriture *halal*?

Compte tenu de l'accroissement de la demande de produits *halal* (autorisés par la loi islamique) et de l'essor rapide que connaît le commerce

[1] *Codex alimentarius* est une expression latine signifiant «code alimentaire» ou «législation sur les produits alimentaires».

La Comisión del Codex Alimentarius[1] es un órgano auxiliar de la Organización de las Naciones Unidas para la Agricultura y la Alimentación y la Organización Mundial de la Salud, y cuenta con 162 Estados miembros. Se ha establecido para elaborar normas alimentarias internacionalmente aceptadas, destinadas a proteger la salud de los consumidores y asegurar prácticas equitativas en el comercio de los alimentos.

IMPORTANTES DECISIONES EN MATERIA DE CLASIFICACIONES DE LOS ALIMENTOS, HIGIENE Y ETIQUETAS

La Comisión del Codex Alimentarius celebró su 22ª reunión del 23 al 28 de junio de 1997 en Ginebra, con un programa que incluía la seguridad e higiene de los alimentos, las etiquetas de los alimentos y los aditivos alimentarios. He aquí algunos puntos sobresalientes de la reunión, a la que asistieron 444 participantes de 86 países.

Residuos de plagucidas

La FAO y la OMS han estado evaluando la seguridad de los residuos de plaguicidas presentes en los alimentos desde 1962, y han establecido límites máximos de residuos (LMR), a fin de asegurar que no se utilicen en exceso los plaguicidas y que los residuos que pudieran estar presentes no sean nocivos para el consumo humano. La Comisión del Codex Alimentarius actualmente aprueba más de 2 500 LMR. Durante la reunión de junio, la Comisión borró 315 LMR (que abarcaban 39 plaguicidas) de la lista del Codex, considerados obsoletos. Esto quiere decir que no se considera aceptable ningún nivel de presencia de esos plaguicidas.

¿Qué es *halal*?

En vista de la demanda creciente de parte del consumidor de productos

[1] *Codex alimentarius* es una expresión latina que significa «código alimentario» o «legislación alimentaria».

products, the commission approved new guidelines on the use of the term "*halal*". The guidelines are general to allow for minor differences of interpretation among the different Islamic schools of thought, and it is recognized that they are subject to the interpretation of the appropriate authorities of the importing countries. However, the certificate granted by the religious authorities of the exporting country should be accepted in principle by the importing country, unless justification for other specific requirements is provided.

The guidelines define the criteria for the use of the term "*halal*", lawful and unlawful sources of food and general requirements for slaughtering and processing, packaging, storage and transport of foods claimed to be *halal*. For example, the guidelines specify that the phrase "*Bismi Allah*" ("in the name of God") should be invoked immediately before the slaughter of each animal.

How low is "low fat"?

To facilitate trade in foods claimed to be "low fat", "sugar free" or "light", the commission approved new guidelines governing such claims as a supplement to the General Guidelines on Claims. For example, manufacturers can only claim that a food is "light" or reduced in energy or nutrient content if the product contains at least 25 percent less of the nutrient (which must be identified on the label) than the standard product. Manufacturers who want to export "low-fat" products must now observe an absolute measure: 3 g of fat per 100 g of food. From now on, cheese exporters may not claim their products are low fat, since they cannot meet the above criteria; they may only claim that the products contain reduced fat,

international de ces produits, la Commission a approuvé de nouvelles directives sur l'emploi du terme «*halal*». Celle-ci sont d'application générale afin de tenir compte des variations d'interprétation d'importance secondaire données par les différentes écoles de pensée islamique, et il est entendu qu'elles sont sujettes à l'interprétation des autorités des pays importateurs. Toutefois, le certificat délivré par les autorités religieuses du pays exportateur devrait en principe être accepté par le pays importateur, si aucune condition supplémentaire et justifiée n'est stipulée.

Les directives définissent les critères d'emploi du terme «*halal*», les sources licites et illicites de denrées alimentaires, les conditions générales pour l'abattage et la transformation, l'emballage, l'entreposage et le transport des aliments présentés comme des aliments *halal*. Par exemple, les directives précisent que l'expression «*Bismi Allah*» (au nom d'Allah) devrait être prononcée immédiatement avant l'abattage de chaque animal.

Aliments à faible teneur en matières grasses: quelle est la limite?

Afin de faciliter les échanges d'aliments faisant l'objet d'allégations de «faible teneur en matières grasses», «sans sucre» ou «légers», la Commission a approuvé de nouvelles directives régissant ces allégations en supplément aux Directives générales sur les allégations. Par exemple, les fabricants ne peuvent affirmer qu'un aliment est «léger» ou à teneur énergétique et en substances réduite que s'il ne contient au minimum 25 pour cent de substances nutritives en moins que le produit standard. Les fabricants qui veulent exporter des produits à faible teneur en matières grasses doivent maintenant respecter une mesure absolue: 3 g de matière grasse pour 100 g de produit. Les exportateurs de fromage ne pourront plus alléguer que leurs produits ont une faible teneur en matières grasses puisqu'ils ne peuvent respecter ce critère. Ils devront se contenter d'alléguer que leur produit contient

halal (alimentos permitidos por la ley islámica), y el rápido incremento del comercio internacional de dichos productos, la Comisión aprobó nuevas directrices para la aplicación de ese término. Estas directrices son de carácter general, a fin de acomodarse a las diferencias menores de interpretación de las diferentes corrientes islámicas, y se reconoce que están sujetas a la interpretación de las autoridades competentes de los países importadores. Sin embargo, el país importador debe aceptar en principio el certificado otorgado por las autoridades religiosas del país exportador, salvo cuando aquél proporcione una justificación relativa a otros requisitos específicos.

Las directrices mencionadas definen los criterios de aplicación del término *halal*, el origen legítimo o ilegal de los alimentos, los requisitos generales de matanza y elaboración, empaque, almacenamiento y transporte de los alimentos definidos como *halal*. Por ejemplo, las directrices especifican que la frase *Bismi Allah* («en nombre de Dios») debe invocarse inmediatamente antes de matar a cada animal.

¿Qué tan bajo es «bajo contenido de grasas»?

A fin de facilitar el comercio de alimentos definidos «de bajo contenido de grasas», «sin azúcar» o «ligeros», la Comisión aprobó nuevas directrices que regulan esas clasificaciones, como suplemento de las Directrices Generales de Clasificación. Por ejemplo, para clasificar un alimento como ligero o reducido, debe tener por lo menos 25 por ciento menos del contenido de energía o del contenido del nutriente del producto estándar. La etiqueta debe especificar esta característica. Los productores que quieran exportar productos de bajo contenido de grasas, deben observar una medida absoluta: tres gramos de grasa por cada 100 gramos del alimento. A partir de ahora, los exportadores de quesos no pueden clasificar sus productos como de bajo contenido de grasas a menos que no satisfagan los criterios antes mencionados; sólo pueden clasificarlos como de contenido reducido de grasas si tienen

that is, 25 percent less fat than the standard product.

The guidelines provide a number of definitions for the claims covered (nutrient content, comparative claims, nutrient function claims) and general requirements concerning consumer information in relation to claims. In particular, any food for which a claim is made should be labelled with a nutrient declaration, in accordance with the Codex Guidelines for Nutrition Labelling.

Food hygiene code revised

The commission approved a major revision of the code of practice regarding food hygiene so that it includes all aspects of the food chain, from production on farm to preparation in the home, concentrating on the handling, processing and distribution of food products, where most of the risks can be controlled.

The revised code, unlike previous versions, is not prescriptive in laying down design elements for factories or transport and storage facilities. Instead, it concentrates on objectives for prevention or reduced risk of contamination at each step, leaving a significant degree of flexibility for manufacturers, operators and regulatory bodies regarding how to achieve these objectives. For example, instead of requiring that stainless steel be used in flour milling plants, the code permits any construction material that does not contaminate the flour. The modifications should make the code more amenable for use in developing countries than the previous, highly prescriptive version.

Peter Lowrey
Media Support Officer,
Information Division

une quantité réduite de matières grasses, c'est-à-dire 25 pour cent de moins que le produit standard (cela devant figurer sur l'étiquette).

Les directives comportent des définitions pour les allégations prises en compte (teneur en substances nutritives, allégations comparatives, allégations en matière de valeur nutritive) et des conditions générales concernant l'information à fournir aux consommateurs. L'étiquetage de tout aliment faisant l'objet d'une allégation devrait en indiquer les éléments nutritifs, conformément aux directives du Codex concernant l'étiquetage nutritionnel.

Révision du Code d'hygiène des aliments

Dans le domaine de l'hygiène alimentaire, la Commission a approuvé une révision du Code de conduite afin qu'il incorpore tous les aspects de la chaîne alimentaire, de la production à la ferme jusqu'à la préparation des aliments chez soi, en se concentrant sur la manipulation, la transformation et la distribution des produits alimentaires, domaines dans lesquels la plupart des risques peuvent être jugulés.

Le code révisé qui, cette fois, ne prescrit pas des normes techniques devant être respectées par les usines, les services de transport et les installations d'entreposage se concentre sur les mesures nécessaires à chaque étape pour prévenir ou réduire les risques de contamination et laisse une marge de manœuvre aux fabricants, aux opérateurs et aux organismes de réglementation quant à la façon d'atteindre ces objectifs. Par exemple, au lieu d'imposer l'emploi de l'acier inoxydable dans les meuneries, le Code autorise l'emploi de tout matériau de construction ne contaminant pas la farine. Les modifications devraient rendre le Code plus facile à utiliser dans les pays en développement que l'ancienne version, très prescriptive.

Peter Lowrey
Chargé de soutien des moyens de communication,
Division de l'information

25 por ciento menos de grasas que el producto estándar.

Estas directrices ofrecen una serie de definiciones para las clasificaciones contempladas (contenido de nutrientes, clasificaciones comparativas, clasificación de funciones de los nutrientes) y de requisitos generales relativos a la información al consumidor sobre las clasificaciones. En particular, todo alimento que esté clasificado de alguna manera, debe tener en la etiqueta la declaración de sus nutrientes, de acuerdo con las Directrices del Codex en materia de especificación de los elementos nutritivos que figuran en las etiquetas.

Revisión del código de higiene de los alimentos

En materia de la higiene de los alimentos, la Comisión aprobó una revisión importante del código de prácticas, a fin de que incluya todos los aspectos de la cadena alimentaria, desde la producción en la finca hasta la preparación en casa, con especial atención a la manipulación, elaboración y distribución de los productos alimentarios, donde es posible controlar la mayor parte de los riesgos.

A diferencia de las versiones anteriores de este código, el actual no establece prescripciones en materia de elementos del diseño de las plantas procesadoras, el transporte o los almacenes. En cambio, se concentra en lo necesario en cada paso para evitar o reducir los riesgos de contaminación, y deja un considerable grado de flexibilidad a los productores u operadores y a los organismos reglamentarios para el cumplimiento de estos objetivos. Esto debe hacerlo más aceptable para su aplicación en los países en desarrollo que la versión previa del código que contenía numerosas prescripciones. Por ejemplo, en vez de exigir que se utilice acero inoxidable en las plantas de elaboración de harinas, ahora se acepta todo material de construcción que no contamine la harina.

Peter Lowrey
Oficial de apoyo a los medios de comunicación,
Dirección de Información

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Proceedings of the Workshop on Prevention and Control of Micronutrient Deficiencies in the Arab Gulf Cooperation Council Countries

FAO Regional Office for the Near East. 1997. Cairo, Egypt. 134 pp.

The Workshop on Prevention and Control of Micronutrient Deficiencies in the Arab Gulf Cooperation Council Countries was held in Kuwait from 30 June to 2 July 1996. It was organized by the FAO Regional Office for the Near East in cooperation with the Arab Nutrition Society and the Kuwait Nutrition Council. Over 20 participants from the Cooperation Council for the Arab States of the Gulf, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates were invited to attend the workshop in their personal capacities. In addition, representatives from the private sector (Kellogg Company, F. Hoffmann-La Roche Ltd and Nestlé) and a non-governmental organization (the British Nutrition Foundation) attended the workshop.

During the past three decades, the nutritional status of the populations of the Arab countries of the Gulf has improved. However, micronutrient deficiencies have been a longstanding food-related public health problem, which is spread among different population groups. The prevalence of a particular deficiency can vary considerably among different geographic locations and socio-economic groups.

The papers described in these proceedings show that the lack of adequate amounts of iron, iodine and vitamin D in the foods consumed is of special importance because these deficiencies have serious health consequences, wide geographic distribution and implications for economic stagnation. Other micronutrient deficiencies may occur, but they have not yet been investigated.

Micronutrient deficiencies in the Arab countries of the Gulf result primarily from inadequate intake of foods containing essential micronutrients and from impaired utilization, which is often associated with infections that can reduce the absorption of micronutrients and increase their metabolic consumption. Micronutrient deficiencies have a negative impact on society because they reduce working capacity, cause mental and growth retardation, reduce resistance to disease and may lead to mortality among women during pregnancy and childbirth.

The recommendations of the group call on countries to formulate and implement programmes to correct micronutrient deficiencies and to prevent their occurrence through sustainable food-based approaches that encourage dietary diversification, production and consumption of micronutrient-rich foods, food fortification and nutrition education for the public.

The publication is available free of charge from the FAO Regional Office for the Near East, PO Box 2223, Cairo, Egypt.

Samir Miladi
Regional Food and Nutrition Officer,
FAO Regional Office for the Near East

The state of food and nutrition in the Near East countries

FAO Regional Office for the Near East. 1997. Cairo, Egypt. 87 pp.
ISBN 92-855-1047-7.

Raising the levels of nutrition and standards of living of the people under the respective jurisdictions of member countries is one of the main purposes underlined in the Preamble of the FAO Constitution. An important task of FAO is to work closely with its member countries in collecting, analysing and disseminating information relating to nutrition, food and agriculture, with a view to spreading appropriate knowledge on agricultural production, food availability and other socio-economic and cultural variables.

This publication provides a succinct summary of the food and nutrition situation as well as the extent, magnitude and causes of food and nutrition problems in the countries of the Near East Region. The analysis of the food and nutrition situation takes into consideration socio-economic, cultural and environmental factors. The information and figures provided in the publication could be put to various uses, including conduct of comparative analyses, review of past trends, assessment of the present situation and identification of actions needed to achieve nutritional well-being.

The contents of the publication will be updated in the future, in light of the progress achieved and comments received. Copies can be obtained free of charge from the FAO Regional Office for the Near East, PO Box 2223, Cairo, Egypt.

Samir Miladi
Regional Food and Nutrition Officer,
FAO Regional Office for the Near East