What's hip in diet and osteoporosis?

By Karl Michaëlsson, Åke Bruce and Sverker Ljunghall

Abstract

Many nutritional causes of osteoporosis have been suggested, but the one that has been and that is still most debated is the possible role of a low calcium intake. In our analysis of published papers we have found convincing evidence, mostly from several clinical trials completed in the last few years, that an increase in the current Nordic calcium recommendations for post-menopausal women should lead to decreased bone loss among these women in the future, although the effect is probably modest. We therefore recommend a calcium intake level above 1,200 mg/day for women over the age of 50 years. We have also found compelling evidence of a need for vitamin D supplementation among elderly individuals not regularly spending time out of doors. Further research in the area of diet and osteoporosis is strongly needed.

Introduction

Throughout adult life bone tissue continuously undergoes a remodelling process during which old brittle bone is renewed. Approximately 10% of the bone is changed each year, with a greater rate of change in trabecular than in cortical bone. Disturbances in the remodelling of bone can lead to bone diseases, and in osteoporosis the absolute amount of bone decreases with each remodelling cycle. Osteoporosis is a truly multifactorial disease, but although one of its riskfactors, calcium intake, has been widely investigated, studies on other nutrients have been sparse. The clinical manifestation of osteoporosis is the osteoporotic fracture, occurring after minor trauma and typically located at the hip, distal forearm or spine. The highest incidence rates of osteoporotic fractures are found in the Scandinavian countries (1) and it is estimated that the life-time risk for 50-year old women is at least 50% (2).

Calcium is not only essential for bone strength but also acts as a regulator of cellular activity in all organs of the body. The serum concentration of calcium is therefore normally kept constant within a narrow range. The main regulators of the calcium homeostatic process are parathyroid hormone (PTH) and vitamin D. In the skeleton 1,000-1,400 g of calcium is incorporated from the time of birth to skeletal maturity in the twenties (3). Approximately 200-250 mg of calcium is lost every day in the urine, faeces and sweat in an adult individual (4). To avoid a net loss of calcium it is therefore

essential to absorb this amount of calcium from the intestine (Figure 1). Calcium is absorbed from the gut both passively and through an active process partly regulated by vitamin D (4). The proportion of the ingested calcium intake that is absorbed in the intestine also depends on age, the calcium content of the food and the food composition (5). The absorptive capacity of calcium can range from 15 to 75% (4), and among post-menopausal women the normal absorption amounts to 20-30% (6,7). Oestrogen enhances the intestinal absorption of calcium (8).

In this survey we have reviewed recently published articles in the field of diet and osteoporosis and have made some comments on methodological aspects of the different studies which might explain the different results. We have focused especially on a number of controlled studies on calcium supplementation in post-menopausal women, since the results of recent studies have necessitated an amendment to the new Nordic nutrition recommendations. The recently establish-

ed Nordic recommendation for calcium is 800 mg for adults of both sexes and 900 mg for the ages between 11 and 20 years (9). The daily recommended calcium intake varies widely between countries and scientists. For adult women the recommendation ranges from 500 mg (4) to 1,500 mg/day (10). Even the higher level of recommendation is low in an evolutionary perspective of the human race (11). The same calcium recommendations cannot be made for all countries, since the calcium absorptive capacity and calcium losses vary considerably between different populations.

Childhood and adolescence

Theoretically, by increasing the bone mass during growth (peak bone mass) a reserve of bone that will reduce the risk of osteoporotic fractures can be built up (Figure 2). In several studies attempts have been made to answer the question as to whether a higher peak bone mass can be achieved by an increased calcium intake, but the results are conflicting. Only a few well

Figure 1. Daily fluxes of calcium in an adult with net calcium balance.

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Table 1. Randomised, controlled studies on the effects of calcium supplementation on BMD and BMC. Children and pre-menopausal women.

Ref. no.	Country	Number, sex and mean age at start	Mean calcium intake before/ suppl. dose	Duration of study	Method	Site
22	Pennsylvania, USA	94 girls, 11.9±0.5 years	980 mg/500 mg	18 months	Dual-energy x-ray absorptiometry, BMD, BMC	Lumbar spine Total body
23	Indiana, USA	45 monozygotic twins of both sexes 10 years, range 6-14 years	900 mg/1,000 mg	3 years	Dual-photon absorptiometry, BMD	Radius (2 sites), Prox femur (3sites), Lumbar spine
24	Utah, USA	48 girls, 11±1 years	730 mg/ suppl. with dairies to a total mean Ca intake of 1,400 mg	12 months	Dual-energy x-ray absorptiometry, BMD, BMC	Lumbar spine Total body
25	Switzerland	144 girls, 7-9 years	900 mg/850 mg by calcium fortified foods	12 months	Dual-energy x-ray absorptiometry, BMD, BMC	Radius (2 sites), Femur (3sites), Lumbar spine
32	Netherlands	49 women, pre-menopausal, age?	1,000 mg/1,000 or 2,000 mg	3 years	Metacarpal cortical thickness by radiographs Dual-photon absorptiometry, BMD	Metacarpals Lumbar spine

BMD Bone mineral density; BMC Bone mineral content

Result according to the original report

Ref (22): Calcium supplementation for a group of 12-year-old girls resulted in significant gains in total body and spine BMD.

Ref (23): In prepubertal children whose average dietary intake of calcium approximated the recommended daily allowance, calcium supplementation enhanced the rate of increased BMD.

Ref (24): Supplemented group had significantly greater increases in BMD at lumbar spine and in total body mineral.

Ref (25): In girls with a normal calcium intake below 880 mg/day – calcium fortified foods can enhance bone modeling and increase statural height.

Ref (32): Calcium supplementation substantially reduces cortical and trabecular bone loss in the years immediately preceding menopause.

designed studies have been performed among children. In balance studies of dietary calcium intake, *Matkovic* et al have found that 1,200-1,600 mg calcium/day is required for optimal skeletal growth and to avoid a negative calcium balance (12-14). The results from a number of *observational* studies in young people have differed; some have shown a positive association between calcium intake and bone density (15-19), whereas others have not confirmed this finding (20,21).

A few more reliable and convincing *randomised* trials have been performed (Table 1). An 18-month long placebo-controlled randomised investigation was carried out among girls with a mean age of 12 years, and the dietary calcium intake was estimated to be 960 mg/day (22). The active treatment was 500 mg of supplemental calcium/day. The authors found that treatment with calcium increased the bone mineral density both in the spine and in the total body compared with placebo. This study may be criticised for its short treatment duration and thus for not taking into account the slow adaptation of the remodelling process to an anti-resorptive regimen. A likewise placebo-controlled trial but with twice the treatment duration has been undertaken in the USA among

monozygotic twins with a mean age of 10 years (23). Their average habitual dietary calcium intake was calculated to be 900 mg/day and the active treatment constituted of 1,000 mg of calcium/day. The bone density of the lumbar spine and forearm, but not of the femoral neck, increased more in the actively treated group than in the placebo-treated group. This difference between the groups was only observed among the pre-pubertal children and the difference was not significant one year after cessation of the treatment, i.e. the higher bone mass was not maintained when the calcium treatment was withdrawn. In another American randomised study of 11-year-old girls, half of the children were given milk supplementation up to a total calcium intake of over 1,200 mg/day and the other half remained on their normal diet containing a mean of 700 mg calcium/day (24). In the high-calcium group the bone density of the lumbar spine was 10% higher than that in the control group when the study ended after one year. In a recently published double-blind placebo-controlled trial in 144 pre-pubertal girls, the effect of calcium-fortified foods was investigated (25). The median calcium intake was 880 mg/day and the girls were supplemented

for one year either with foods giving an extra calcium intake of 850 mg/day or with placebo. The girls with a habitual calcium intake below the median increased their bone density and bone mass as well as their bone area and statural height compared with placebo, whereas these effects were not observed among the girls with a higher habitual calcium intake. Despite the fact that several of the presented studies indicate a beneficial effect of increased calcium intake on bone mass, the effects are insufficient to motivate revision of the current calcium recommendations for children.

Pre-menopausal women

The intestinal absorptive capacity of calcium in adult pre-menopausal women is estimated to be 30-35%, with relatively small extra-intestinal losses of calcium. According to calculations from balance studies, an intake of 600 mg calcium/day is required to reach zero balance (8). In observational studies on pre-menopausal women a positive association between calcium intake and bone density has been found (26,27), but in other studies with a comparable design these results have not been confirmed (28,29). In several studies attempts have been made to estimate

Table 2. Randomised, controlled studies on the effects of calcium supplementation on BMD and BMC. Post-menopausal women.

Ref. no.	Country	Number and age	Mean calcium intake before/ suppl. dose	Duration of study	Method	Site
55	Denmark	43, 51 years, early post-menopausal	not stated/ 2,000 mg	2 years	Single- and dual photon absorptiometry, BMC, BMD	Proximal and distal forearm
56	New York, USA	118, 52 years, 3-6 years post-menopausal	480 mg/ suppl. to a total calcium intake of 1,700 mg	3 years	Gamma neutron activation, TBC, Single- and dual photon absorptiometry, BMD	Total body, Spine Total body Distal radius Spine Femur (3 sites)
57	Boston, USA	301, 54.5 and 59.9 years	280 mg or 520 mg/ 500 mg	2 years	Dual-photon scanner, BMD	Spine Femoral neck Radius
58	New Zealand	122, 58±5 years	750 mg/ 1,000 mg	2 years	Single-photon scanner, BMD Dual-energy x-ray absorptiometry, BMD	Whole body Lumbar spine Femur (3 sites)
65	New Zealand	78, see ref 58	700 mg/ 1,000 mg	4 years	Dual-energy x-ray absorptiometry, BMD	Whole body Lumbar spine, Femur (3 sites)
59	W. Australia	120, 58±4 years	800 mg/ 1,000 mg	2 years	Forearm bone densitometry, BMD	Forearm (3 sites)
60	France	56, 84±6 years	510 mg/ 1,200 mg	18 months	Dual-energy x-ray absorptiometry, BMD	Femur (4 sites)
61	Switzerland	93, 72±0.6 years	675 mg/ 800 mg	18 months	Dual-photon absorptiometry, BMD	Femur (2 sites) Lumbar spine
62	Netherlands	295, 46-55 years	1,150 mg/ 1,150 mg	2 years	Dual-photon absorptiometry, BMD Metacarpal cortical thickness by radiographs	Lumbar spine Metacarpals
63	Wisconsin, USA	169, 35-65 years	680 mg/ 1 500 mg	4 years	Single-photon absorptiometry, BMC and width	Radius, ulna and humerus
64	W. Australia	168, 62±5 years	800 mg/ 1 000 mg	2 years	Dual-energy x-ray absorptiometry, BMD	Lumbar spine, Femur (4 sites), Tibia (2 sites)
66	W. Australia	84, 67 years, range 64-74 years	950 mg/ 1 000 mg	4 years	Dual-energy x-ray absorptiometry, BMD tibia (3 sites)	Lumbar spine, Femur (4 sites),

BMD Bone mineral density; BMC Bone mineral content; TBC Total body calcium

Result according to abstract etc. in original report

Ref (55): Data suggest that calcium supplements is not as effective as oestrogen therapy for the prevention of early post-menopausal bone loss but can have minor effects on cortical bone loss.

Ref (56): Although less effective than oestrogen-progesterone-calcium; calcium augmentation alone significantly retards bone loss from the femoral neck and improves calcium balance.

Ref (57): Healthy older post-menopausal. women with a daily calcium intake <400 mg can significantly reduce bone loss by increasing their calcium intake to 800 mg/day.

Ref (58): Calcium supplementation had a similar positive effect whether dietary calcium intake was above or below the mean value for the group.

Ref (65): Calcium supplementation produces a sustained reduction in the rate of loss of total body BMD in healthy post-menopausal women.

Ref (59): Bone loss at the distal forearm site was significantly lower in the exercise-calcium group compared to the control and exercise groups

Ref (60): BMD + 2.7% in supplemented group and -4.6% in control group.

Ref (61): BMD changes in calcium supplemented women statistically significantly different from placebo in one femur site.

Ref (62): The effect of calcium supplementation on lumbar spine bone loss was significant in the first year, but not in the second. Calcium supplementation did not have a significant effect on metacarpal cortical bone loss.

Ref (63): Calcium supplementation counteracted a large portion of the additional bone loss attributable to menopause in this population.

Ref (64): Calcium supplementation completely prevents bone loss at some areas of the important hip site in elderly women more than 10 years past the menopause. It is less effective at the ankle site and no overall bone loss occurred at the spine site.

Ref (66): Calcium supplementation produces a sustained reduction in the rate of bone loss at the ankle and hip sites in elderly post-menopausal women.

retrospectively dietary calcium intakes at different ages and in general it has been observed that a low life-time calcium intake predicts a low bone density (27,30,31). Studies of this type, however, are prone to information bias. In a Dutch interventional study (Table 1) it was found that a supplement of 1,000 or 2,000 mg

calcium/day totally inhibited bone loss with age in pre-menopausal women (32).

Post-menopausal women

Several intestinal absorption and balance studies have shown an increased calcium requirement after the menopause. These investigations have indicated a need for

1,500 mg calcium/day to avoid a negative calcium balance (8,33,34). It has been difficult in *observational* studies among early post-menopausal women, within 5 years after the menopause, to detect any substantial positive effect of increasing dietary calcium intake on the bone mass (35-39), and the associations found were

in general weaker than among older women. A proposed reason for the difficulty in detecting such a relationship is the dominating effect of the decline in oestrogen production after the menopause, which leads to an annual decrease in bone mass of 3-5% (Figure 2), overwhelming the effects of other riskfactors during these years (40).

In older women the *Study of Osteoporotic Fractures* (SOF) has been the major observational investigation, with a prospective design and an outstanding power ($n \approx 9,000$), but with selected participants, which can affect the external validity of the study. In that study dietary calcium intake showed a positive association with the bone density of the femoral neck, but a much weaker association with that at the trabecular sites of the distal radius and the lumbar spine (41,42). These positive relationships between calcium intake and bone mineral density have not been confirmed in other studies (43-45) with smaller numbers of participants. In a study of the influence of dietary calcium intake on bone density with longitudinal dietary assessment, we compared bone density values between a group of women with an estimated mean calcium intake of 1,600 mg/day and two other groups, one with a mean calcium intake of 500 mg/day and one with an intake level of around 1,000 mg/day (46). We found higher bone density among the women in the high calcium group than in those in the intermediate and low calcium groups. The difference in bone density between the latter two groups was small. The bone density values in the high calcium group, adjusted for possible confounding factors, were comparable to those in women 10-20 years younger. Few post-menopausal Swedish women seem to have a dietary calcium intake of over 1,500 mg/day (47) and if this is the level that has to be reached for a substantial positive effect on the skeleton in older women, as indicated by our study, this may explain why it has been difficult to detect the effect of calcium on bone mass in smaller observational studies.

An association between a high calcium intake and a low fracture risk has also been difficult to establish in prospective observational studies. Only in one (48) of all the reviewed prospective investigations (48-53) was such an association found. As in the bone density studies, this lack of relationship between calcium intake and fracture risk may be due to the fact that few study participants reached a calcium intake above the zero balance level and they were too few to affect the results of the studies. Several retrospective studies have lead to the conclusion that a high calcium

intake has a preventive effect on osteoporotic fractures, but with this study design there is a risk of introducing recall bias (54).

The randomised trials among post-menopausal women are more reliable in the attempt to establish the optimal calcium intake for prevention of osteoporosis, since they avoid the many possibilities of confounding and bias that can occur with an observational study design.

In this review we will discuss these studies in detail, since their results are important for the formulation of future calcium recommendations for post-menopausal women and thus will also be relevant for various nutritional policy measures for increasing calcium intake. We have tried to identify all well-controlled trials indexed in common databases. We have not attempted to identify unpublished negative trials or randomised investigations in which calcium supplementation has played a subordinate part in trials focused for example, on the effect of hormone replacement therapy or physical exercise. Ten controlled trials in women have thus been identified (Table 2), all published during the last decade (55-64). All these trials are consistent in their results and the message is convincingly clear: that women receiving supplemental calcium show retarded bone loss compared with those receiving placebo. The settings are a number of developed countries (USA, Denmark, France, Netherlands, Australia, Switzerland and New Zealand) and the participating women are all of Caucasian origin. All participating women have undergone a natural menopause. In one survey the subjects are divided into peri-menopausal and early and late post-menopausal, respectively (62). Only the last two groups are considered in our discussion. In many of the investigations there is a considerable variation in age among the subjects but there is no attempt in the analyses to stratify the results according to age. This could be a methodological weakness, since there is no compelling evidence that the effect of calcium supplementation is evenly distributed throughout the post-menopausal life-span. The randomisation procedure seems to have been done properly in the studies, but there is in general no random allocation of the subjects into the studies, they are all selected volunteers. Some of the studies also include women with manifest osteoporosis, but they are analysed separately and the results for these particular subjects are not included in our review.

In two of the studies the number of subjects averaged 300 (57,62) and in five studies exceeded 100 (56,58,59,63,64).

Figure 2. Schematic variation of bone mineral density with age and sex.

The duration of intervention and follow-up was four years in three studies (63,65,66) and three years in one study (56).

Information on the women's habitual dietary calcium intake is usually meagre and is even lacking in one study (55). In general the estimation of the dietary calcium intake was based on some days of food recording at the initiation of the trial and the main purpose was probably to show that the intake was similar in controls and supplemented women. Only two of the investigations provide further information concerning energy and/or protein intake (63,64).

The supplemented doses of calcium ranged from 500-2,000 mg/day. Only one study had two dosage levels (1,000 and 2,000 mg/day) (62) and in three of the surveys two different types of supplemental calcium, with the same amount of elemental calcium, were used (57,61, 64). In two trials (56,61) all participants were vitamin D replete and in one survey only those allocated to active treatment also received vitamin D₃ supplementation (60).

The compliance to treatment among the subjects has not been well investigated. In several of the studies urinary calcium was measured, but this only showed that there was a difference in calcium intake between actively and placebo-treated women. We may thus conclude that it is hard to establish the exact calcium intake, both in controls and in calcium-supplemented women. Further, there is a wide variation in the estimated habitual calcium intake among the study subjects, from 500 mg/day in the study by Chapuy et al (60) to 1150 mg/day in that by Elders et al (62), and taken together with the differences in supplemented calcium dose it is difficult to establish any threshold effects in a meta-analysis.

Comparisons between the studies are further complicated by the fact that the different surveys use different measurement sites and different methods of bone

measurement, and also by the use of either bone mass or bone density, or both, for the outcome. In three of the reports results from total body measurements are given (55,56,58), with separate results for the arms, legs and trunk in addition in the last report by Reid et al (58,65). In all of these three surveys a clearly reduced bone loss was found in those who received 1,000-2,000 mg of supplemental calcium/day. Seven of the reports provide data from measurements of the lumbar spine (L2-L4 region) (55-58,61,62,64), and in all except two of these studies (55,61), a positive effect on the spine with active treatment was found. Despite a non-measurable effect on spinal bone density, the prevalence of spine fractures was lowered in the supplemented group in the study by Chevalley et al (61). Data from different parts of the femur, mainly the proximal region, are presented in five of the studies (56-57,60,65,66) and they all consistently show retarded bone loss as an effect of supplements. Six of the reports describe results from measurements of the forearm and the authors found a generally small positive effect of calcium increment on the forearm bone mineral density/bone mass.

The very large study by Chapuy et al (60,75) was primarily designed to investigate the fracture-preventive effect of a combination of vitamin D₃ and calcium, and bone measurements were only performed in a small proportion of the subjects. In the hip fracture rate, the main target, the authors found an impressive 43% reduction and the total number of non-vertebral fractures was reduced by 32% (60). In the much smaller study by Reid et al (65) a total of two fractures were found in the group with active treatment, compared with seven fractures in the placebo group ($P=0.04$).

In a recently published three-year long randomised placebo-controlled trial (67), a group of 70-year-old women received calcium supplementation to a total intake of over 2 g/day and were compared with a placebo group with a estimated calcium intake of 800 mg/day. A comparison was also made with a reference group of adult pre-menopausal women with a mean age of 30 years and with a mean habitual calcium intake of 900 mg/day. The high calcium intake completely reversed the age-dependent increase in PTH levels in the actively treated group and the mean PTH levels in this group were comparable to those in the reference group of the young females.

From this review of post-menopausal women, it is evident that despite the heterogeneity of the study designs all trials showed a positive effect of calcium supplementation on bone mass or bone

density after two years of treatment. We find the results consistent and also in accordance with the findings in several epidemiological studies, and it is therefore suggested that they be taken into account when making new nutrient recommendations, even though an exact optimal level of calcium intake is difficult to establish. A cautious interpretation of the results indicates that the daily recommendations for post-menopausal women should be increased to 1,200 mg/day, at least at the ages between 50 and 70 years. A footnote has been added regarding the Nordic recommended intake of calcium in women above the age of 61 years, stating: "Supplementation with 500-1,000 mg/day may possibly to some degree delay bone loss" (9).

Men

Few published papers have dealt with bone mineral density and calcium intake in adult men. In an Australian observational study on men with a mean age of 44 years, a clear positive association was found between dietary calcium intake and bone density in both the lumbar spine and femoral neck (68). In a British retrospective case-control study of hip fracture, a protective effect of a dietary calcium intake of more than 1,000 mg/day was found among men, but not among women (69). The risk of a hip fracture was reduced by 50% in men with a calcium intake of over 1,000 mg/day compared with men with a calcium intake below 400 mg/day in a cohort study. To our knowledge no randomised investigation has been performed in men in which the effect of calcium supplements on bone density has been analysed independently of vitamin D intake. Thus there is a great need for further studies of diet and osteoporosis in men.

Other nutrients

The capacity of the body to produce vitamin D decreases with age, which means that the dietary intake of vitamin D is of more importance among the elderly. Vitamin D deficiency is common in elderly persons (70), especially in those who are institutionalised (71). Polymorphisms of the vitamin D receptor have also gained much interest in recent osteoporotic research (72), but the results are conflicting (73). An annual injection of vitamin D in institutionalised elderly persons prevented fractures of the extremities in a Finnish study (74), and in the large French randomised study (60,75) the fracture rate declined with a combined supplemental daily intake of 1.2 g calcium and 800 IU vitamin D₃. The design of this investigation, however, precluded determination of

the independent effects of these two nutrients. Lips et al (76) supplemented free living Dutch elderly persons with 400 IU vitamin D₃ without any addition of calcium in a placebo-controlled trial and found no fracture-preventive effect of the treatment, although the study could suffice a lack of power. The same amount of vitamin D₃ has been found both to reduce the PTH level and to increase the bone mineral density (77).

A high dietary protein intake, as is common in the developed countries, increases the urinary excretion of calcium, and this has been suggested as a cause of bone loss (78). A high protein intake has been examined as a riskfactor for fracture in the Nurses' Health Study and a slightly increased risk was observed for forearm fractures but not for hip fractures for women who consumed more than 95 g protein/day compared with those who consumed less than 68 g/day (79), however, in a study in post-menopausal women a high protein intake was not associated with bone density (80). The high protein intake together with other factors in the Western diet can cause slight metabolic acidosis, which in turn will cause a negative calcium balance and also increased bone resorption (81,82). The negative calcium balance associated with this type of diet can be reversed with bicarbonate supplementation (81,83). A high salt intake has also been suggested as a possible cause of bone loss by resulting, in parallel with a high protein intake, in increased urinary excretion of calcium (84). A typical western diet contains approximately 5 g sodium/day and for every gram of sodium intake the urinary loss of calcium increases by 10-30 mg. Free fatty acids from ingested fat can together with calcium form soap in the gut and thus impair calcium absorption. In two cross-sectional studies fat consumption was found to be negatively associated with the bone density of the lumbar spine (45,80) and in another, observational study a daily fat intake of more than 25 g *versus* an intake below this level increased the fracture risk (85). A high fibre content of the diet could also, theoretically, impair calcium absorption (86), which could lead to an increased risk for osteoporotic fractures (53). The relations between osteoporosis and the dietary intake of magnesium, phosphorous, potassium and several trace minerals are uncertain (87). Slightly higher bone density values have been observed in areas with a high content of fluoride in the drinking water (88). Fluoride stimulates osteoblastic activity, and treatment with low doses can both increase bone density and reduce fracture rates (89-91). A high

dietary intake of iron, estimated to be 13 mg/day, *versus* an estimated intake below 9 mg/day has been claimed to be a risk-factor for hip fracture (53), and a high iron content in bone is inversely correlated to the bone mass both in humans and animals (92-94). High doses of vitamin A lead to spontaneous fractures in rodents (95) and it is known that vitamin A stimulates osteoclasts and induces bone resorption (96). This could be of clinical importance, since we have found that a high dietary vitamin A intake of approximately more than 1.5 mg/day is associated with an increased risk of hip fracture and also with low bone density (97). A certain minimum amount of vitamin C (≈ 15 mg/day) is required in the diet to prevent scurvy, but high doses have caused demineralisation of the skeleton in animals (98-101) and an estimated intake by a questionnaire of 95 mg vitamin C each day compared to an intake below 42 mg/day are also related to an increased risk for hip fracture in women (53). Alcoholism is associated with an increased risk of fractures and low bone mass (5,102) but individuals with a modest alcohol intake have higher bone density values than total abstainers (42,103,104). Caffeine increases the urinary excretion of calcium (105-108), but it is calculated that one cup of coffee only raises the urinary losses of calcium by 5-10 mg. However, an intake of more than two cups of coffee each day has been reported to be associated with a slightly increased risk of hip fracture (52,109), but this result was not confirmed in our Swedish prospective hip fracture study (53). The possible negative effect of two cups of coffee each day on bone density can be off-set by drinking one glass of milk/day (110).

A problem with interpreting scattered and variable data on relations between individual nutrients and say (in this case) bone mineral data is the fact that statistically significant findings are highlighted while non significant (negative) findings normally are not reported in conclusions and abstracts. In order to evaluate the findings reviewed above, the entire epidemiological literature has to be scrutinised. Also the meaning of "high" and "low" intakes differ depending on national dietary habits, methods etc. Moreover, although a high intake of many foods and nutrients is associated with a low bone mass and an increased fracture risk, clinically more important could be the high prevalence of malnutrition among elderly individuals, with the associated susceptibility to low bone mass and fractures (111,112). Dietary supplementation of the elderly after a hip fracture can improve postoperative rehabilitation (113).

Conclusions

Calcium is the most extensively investigated nutrient in relation to osteoporosis. In children, adolescents, men and pre-menopausal women there are indications that an increased dietary intake of calcium above current recommendations will also lead to gains in bone density and bone mass, but the studies to date are insufficient to justify a revision of the requirements.

Women of ages 50-70 years should be recommended an intake of calcium above 1,200 mg/day. It is possible, but not convincingly established, that this recommendation also should be adopted by older women. In persons with osteoporosis, we recommend a calcium supplement of 500-1,000 mg/day, with the higher dose for those individuals with a low habitual intake of dairy products. Prophylactic supplementation with vitamin D should be given to all institutionalised elderly persons who do not regularly spend time out-of-doors. This is emphasised in the new Nordic nutrition recommendations, according to which all persons older than 61 years should have a vitamin D₃ intake of 10 mg (400 IU)/day. Osteoporosis in persons over the age of 70 strengthens the indication for vitamin D supplementation, with a daily dose of 800 IU. To facilitate administration and minimise the costs, vitamin D can be given in the form of a weekly or monthly dose. Several other nutrients have been associated with osteoporosis, but we have to await further research before specific recommendations can be made. A high intake of salt is probably negative for the skeleton and should be avoided.

Low weight and weight loss are the strongest riskfactors for osteoporosis. Malnutrition is common among patients with osteoporotic fractures and dietary advice and food supplementation are essential strategies for an improved rehabilitation.

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