New Reference Values for Calcium

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Key Words

Calcium · Nutrient intake · Reference value

Abstract

The nutrition societies of Germany, Austria and Switzerland are the joint editors of the 'reference values for nutrient intake'. They have revised the reference values for the intake of calcium and published them in June 2013. The reference values for the calcium intake for infants are derived from the calcium content of breast milk. For infants from 4 to <12 months of age, the calcium intake from solid foods is included in addition to the calcium intake from breast milk. Thus, the reference values for infants are estimated values; they are 220 mg/day for infants to <4 months and 330 mg/day for infants from 4 to <12 months of age. As a parameter for determining the calcium requirement in children and adolescents, calcium retention is taken into account. The average requirement is calculated by the factorial method. A balanced calcium metabolism is calculated based upon calcium balance studies and used as a parameter for the determination of the calcium requirement in adults. On the basis of the average requirement, recommended calcium intake levels for children, adolescents and adults are derived. Depending on age, the recommended calcium intake ranges between 600 mg/day for children aged 1 to <4 years and 1,200 mg/day for adolescents aged 13 to <19 years; for adults, it is 1,000 mg/day.

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Introduction

The D-A-CH 'reference values for nutrient intake' are jointly issued by the nutrition societies of Germany, Austria and Switzerland [the abbreviation D-A-CH arises from the initial letters of the common country identification for the countries Germany (D), Austria (A) and Switzerland (CH)] [1]. Currently, the 'reference values for nutrient intake' are being revised. Following vitamin D [2], calcium is the second nutrient that has been revised [1].

Reference Values for the Intake of Calcium

Infants

Breast milk is considered to be the optimal diet for infants [3, 4]. Therefore, the reference value for the intake of calcium for infants is derived from the calcium content of breast milk.

A fully breastfed infant gets 220 mg of calcium per day from drinking 750 ml of breast milk [5, 6]. At an absorption rate of 60% [7, 8], 130 mg of calcium is absorbed. In view of the fact that no calcium deficiency has been found

The German Nutrition Society initiated a working group for editing the reference values for calcium. The expert group consisted of H. Heseker, E. Leschik-Bonnet, J. Linseisen, H. Przyrembel, P. Stehle, D. Strohm, and A. Zittermann.

in fully breastfed infants with a good vitamin D supply [9], the estimated value for calcium intake for breastfed infants at the age of <4 months is set to 220 mg calcium (table 1).

Along with the introduction of solid foods, the daily calcium intake increases, and thus, calcium retention is higher as well [10]. The intake of calcium from solid foods is about 140 mg per day [11]. An infant aged 4–12 months drinks about 650 ml per day [6]. Thus, the additional intake of calcium from breast milk is 190 mg per day. Therefore, the estimated value for the calcium intake from breast milk and solid foods for infants at the age of 4 to <12 months is 330 mg per day (table 1).

Children

Calcium retention is taken into account as a parameter for determining the calcium requirement in children and adolescents.

In the age group of the 1- to <4-year-olds, according to Lynch et al. [12], 140 mg of calcium per day are retained for their growth needs. According to the calculation with the factorial method¹ and a calculated absorption rate of 45.6%, the average requirement for calcium is 474 mg/day (table 2). To cover the requirement in 97.5% of this population group, 20% are added, which is about the 2-fold standard deviation. This procedure is also applied for the derivation of the reference values for the intake of calcium for all other age groups of children and adolescents. The calculation results in a recommended intake of 600 mg calcium per day for 1- to <4-year-old children (table 1).

Children aged 4 to <7 years retain about 120 mg calcium per day [14]. According to the calculation with the factorial method and an assumed absorption rate of 38%, the average requirement for calcium is 629 mg/day (table 2). After adding 20%, the recommended intake is set to 750 mg calcium per day for 4- to <7-year-old children (table 1).

Children aged 7 to <10 years may already be in the late prepubescent phase and have to retain about 140–160 mg of calcium per day for optimal bone growth [11, 15, 16]. According to the calculation with the factorial method and an assumed absorption rate of 38%, the average requirement for calcium is 776 mg/day (table 2). After adding 20%, the recommended intake is set to 900 mg calcium per day for children of this age group (table 1).

¹ The factorial method calculates the sum of the estimated losses of calcium (through urine, sweat and endogenous fecal losses) and of the estimated or calculated calcium storage and adjusts for the respective calcium absorption rate to calculate the desirable calcium intake [13].

Table 1. Reference values for calcium intake (recommended intake) [1]

Age	Calcium, mg/day
Infants	
0 to <4 months ^a	220
4 to <12 months ^b	330
Children	
1 to <4 years	600
4 to <7 years	750
7 to <10 years	900
10 to <13 years	1,100
13 to <15 years	1,200
Adolescents and adults	
15 to <19 years	1,200
19 to <65 years	1,000
65 years and older	1,000
Pregnant women ^c	1,000
Lactating women ^d	1,000

^a Estimated value for breastfed infants. ^b Estimated value for the calcium intake from breast milk and solid foods. ^c Pregnant women <19 years old 1,200 mg. ^d Lactating women <19 years old 1,200 mg.

Children from 10 Years of Age and Adolescents

Vatanparast et al. [20] used data from 85 boys and 67 girls aged 9–18 years in Canada to determine their calcium requirement. Girls and boys aged 10 to <13 years retain 151 and 141 mg calcium per day, respectively, according to Vatanparast et al. [20]. Because a higher absorption rate has to be expected during rapid growth than during slower growth [23, 24], and due to the earlier onset of the pubertal growth spurt in girls than in boys, in girls of this age group, an absorption rate of 42% is assumed. The absorption rate in boys of this age group is 38% [19]. According to the calculation with the factorial method, the average requirement in girls and boys is about 900 mg calcium per day (table 2). After adding 20%, the recommended intake for girls and boys at the age of 10 to <13 years is 1,100 mg calcium per day (table 1).

According to Vatanparast et al. [20], girls and boys at the age of 13 to <19 years retain 92 and 210 mg calcium per day, respectively. Other studies also showed that calcium retention in boys aged 12–15 years is higher than in girls of the same age at the same calcium intake [23, 24]. The higher calcium retention in boys than in girls was attained through lower urinary excretion and a higher calcium absorption rate [24].

According to the calculations with the factorial method, a calculated absorption rate of 38% in girls [19] and a

Table 2. Calculation of the average calcium requirement in children and adolescents according to the factorial method

Age, years/gender	Average calcium accretion, mg/day	Urinary calcium losses, mg/day	Endogenous fecal calcium losses, mg/day	Sweat calcium losses, mg/day	Total calcium needed, mg/day (sum of the figures in columns 1–4)	Calcium absorption, %	Average calcium requirement, mg/day
1 to <4, male/female	142 ^a	37 ^b	37 ^c	–	216	45.6 ^a	474
4 to <7, male/female	124 ^d	45 ^b	40 ^c	30 ^b	239	38 ^e	629
7 to <10, male/female	150 ^f	55 ^b	50 ^c	40 ^b	295	38 ^e	776
10 to <13, female	151 ^g	94 ^h	79 ⁱ	53 ^j	377	42 ^k	898
10 to <13, male	141 ^g	67 ^h	82 ⁱ	55 ^b	345	38 ^e	908
13 to <19, female	92 ^g	100 ^h	100 ⁱ	53 ^j	345	38 ^e	908
13 to <19, male	210 ^g	75 ^h	100 ⁱ	55 ^b	440	42 ^k	1,048

^a Lynch et al. [12]. ^b Weaver [17], adjusted to age where necessary. ^c Mean value from Weaver [17] and calculation according to Abrams et al. [18], adjusted to age where necessary. ^d Ames et al. [14]. ^e An absorption rate of 38% is assumed based on Wastney et al. [19]. ^f Assumption from Abrams et al. [15] and the Institute of Medicine [11] as well as from the fact that children in the late prepubescent phase have to retain a little more calcium per day for optimal bone growth than the next younger age group [16].

^g Vatanparast et al. [20]. ^h Abrams et al. [21], adjusted to age where necessary. ⁱ Mean value from Weaver [17] and calculation according to Abrams et al. [18, 21], adjusted to age where necessary. ^j Mean value from Weaver [17] and Palacios et al. [22]. ^k According to Jackman et al. [23] and Braun et al. [24], during the pubertal growth period, the rate of calcium absorption is increased at the same calcium intake; therefore, an absorption rate of 42% is assumed during rapid pubertal growth.

higher assumed absorption rate of 42% in boys due to rapid pubertal growth, the average requirement in girls and boys is 908 and 1,048 mg/day, respectively (table 2). After adding 20%, the recommended intake for girls and boys at the age of 13 to <19 years is 1,200 mg calcium per day (table 1).

Adults <65 Years of Age

The point in life when peak bone mass is reached varies between different bones and joints and also between different individuals (at the end of adolescence or possibly only in the 3rd decade of life) [25–27]. According to Barger-Lux et al. [28], bone mass still increases by 0.28% per year in women at the age of 20–30 years. An intake of >800 mg calcium per day does not result in an additional increase in bone mass [29]. After reaching peak bone mass, an age-dependent annual loss of bone mass of about 1% occurs in both genders [30].

Bone is subject to constant formation and breakdown. To preserve bone mass, it is necessary to maintain both muscle mass and calcium balance. Calcium balance is taken into account as a parameter for deriving the calcium requirement in adults <51 years old. On the basis of calcium balance studies with a total of 73 women at the age of 20–75 years (mean age 47) and 82 men at the age of 19–64 years (mean age 28), Hunt and Johnson [31] determined that a mean calcium intake of 741 mg/day at an average absorption of 25% is required for cal-

cium balance, independent of age and gender. This corresponds to the average requirement. Considering the variation in the requirement in the population by adding 30%, the recommended intake for adults <65 years is set to 1,000 mg calcium per day (table 1).

Some observational studies showed a positive association between the intake of calcium and bone density in premenopausal women [32, 33]. In these studies, physical activity was included as a factor influencing bone density. Data regarding vitamin D supply were not available, and therefore, the validity of the results is limited. In men, it was mainly not possible to confirm such an association [34–36].

The loss of bone mass, and hence a negative calcium balance, is associated with aging (especially with the loss of muscle mass with age) and occurs earlier and more abruptly in women than in men due to the menopause [37]. Adequate calcium intake can reduce the loss of bone mass but cannot prevent it [11]. A meta-analysis by Tang et al. [38] of 29 randomized controlled intervention studies in women at the age of 50–85 years showed a lower bone density loss at a calcium intake of 1,200 mg/day compared with a lower calcium intake. However, this meta-analysis could not show any dose-response relationship, as in most of the studies, a calcium supplement of 1,200 mg/day was administered, and the total intake of calcium (intake from foods and supplements) was not recorded. Furthermore, this meta-analysis included both

studies that investigated calcium intake alone and studies that investigated calcium intake in combination with vitamin D. However, the individual studies with the administration of calcium alone also showed positive effects (reduced loss) on bone density.

Because there is no clear evidence that a calcium intake of more than 1,000 mg provides additional benefit regarding bone health in this age group, the recommended intake for women >50 years old is not higher than that either.

Adults >65 Years of Age

For the age group of 65 years and older, the risk of fracture is taken into account as a parameter to derive the reference value. The meta-analysis by Tang et al. [38] demonstrated a lower bone density loss and a reduced risk of fracture with a supplementation of 1,200 mg calcium per day (in combination with vitamin D). A subsequent intervention study also showed that supplementation with 1,200 mg calcium per day and an additional calcium intake of about 900 mg/day from foods reduced the risk of fracture [39].

In contrast, other studies including a meta-analysis did not detect a preventive effect of a calcium intake of >1,000 mg/day regarding fractures [40–44].

The mentioned studies could not detect any dose-response relationship between the calcium intake and the risk of fracture. There is no clear evidence that a calcium intake of >1,000 mg provides additional benefit regarding the bone health of adults >65 years old. Thus, to derive the reference value for adults >65 years of age, the derivation of the reference values for adults <65 years old is used, and the recommended intake for men and women >65 years old is set to 1,000 mg calcium per day as well.

The reference values for the intake of calcium require a good vitamin D supply [25(OH)D serum concentration of ≥ 50 nmol/l] in all age groups. Especially for the age group >65 years, it was shown that particularly the combination of a calcium intake corresponding to the recommended intake and a good vitamin D supply lowers the risk of fracture [45].

Pregnancy and Lactation

The fetal calcium requirement reaches its maximum during the 3rd trimester and is mainly covered by an increased rate of calcium absorption during pregnancy [46]. Calcium absorption doubles during pregnancy [47–49]. In pregnant women, not only the intestinal calcium absorption is higher, but also the glomerular filtration rate of the kidneys and along with that, the renal calcium

excretion is increased. During late pregnancy, bone resorption is also enhanced. These gestational changes are temporary adaptations that usually are not associated with an increased risk of osteoporosis [50, 51].

In randomized controlled intervention studies, no benefit of an additional calcium intake which exceeded the recommended intake for non-pregnant adolescents and adults was detected [52]. According to these data, the requirement during pregnancy does not differ from the requirement in non-pregnant adolescents and adults, and therefore, the recommended intake for pregnant adolescents <19 years old is set to 1,200 mg calcium per day and for pregnant women 19 years and older to 1,000 mg calcium per day (table 1).

During lactation, the calcium for the infant's requirement is extracted from the mother's bones [53, 54]. However, an increased calcium intake during lactation neither reduces calcium release from maternal bone [53, 55–58] nor influences breast milk calcium concentration [59]. Thus, the recommended calcium intake for breastfeeding women is the same as for other adolescents and adults. The recommended calcium intake for breastfeeding mothers <19 years old is 1,200 mg/day and for breastfeeding mothers >19 years old is 1,000 mg/day (table 1).

After weaning, the hormone-related (hypoestrogenemia) loss of bone density during lactation [60] is compensated with a calcium intake equal to the reference value [54, 61], so that breastfeeding is not associated with a higher risk of osteoporosis [51, 62, 63].

Ensuring a Sufficient Calcium Supply

It is possible to ensure a sufficient supply of calcium with a high intake of foods with a naturally high calcium content. For a diet rich in calcium, especially milk and dairy products are recommended, not only because of their high calcium content and the quantity that is consumed, but also because of their absorption-promoting properties discussed in the literature. Mineral waters with a calcium content of >150 mg calcium per liter are also suitable. Due to their low energy density, various types of vegetables with a calcium content of >80 mg per 100 g are particularly suitable for a diet rich in calcium [5]. Broccoli in particular can contribute to a sufficient calcium supply because of its low oxalate content and possibly other absorption-promoting properties [84]. Calcium intake should be distributed among several meals throughout the day, because this increases the intestinal calcium absorption rate.

Industrially manufactured infant milk has a higher calcium content than breast milk. In the European Union, the allowed range is between 33 and 91 mg per 100 ml, with an energy value of 65 kcal per 100 ml of the infant milk [64]. This is accompanied by a lower calcium absorption rate from industrially manufactured infant milk than from breast milk [9]. However, due to the higher calcium content, a sufficient supply of calcium can be ensured in infants fed with infant milk formulas.

Other Preventive Aspects

In addition to the preventive effects of a good calcium supply on bone health that were taken into account to derive the reference values, other preventive aspects are dis-

cussed. They are briefly described in the following by citing recent studies including meta-analysis, but without performing an evidence judgment based on a systematic literature research.

A high calcium intake (calcium from supplements and from dairy products) is associated with preventive effects regarding obesity [65, 66], hypertension [67, 68] and serum lipid concentrations [69–71] which in turn influence the risk of coronary heart disease. Due to the controversial results of the studies regarding the association between calcium supplementation and the risk of coronary heart disease [72–79], further research is needed [80–82].

The preventive effects of calcium on the risk of cancer are not fully understood either. In particular, an inverse association with the risk of colorectal cancer is discussed [83].

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