17 • Calcium

17.1 Introduction

Calcium is the fifth most abundant element in the human body, with approximately 1000 g present in adults. It plays a key role in skeletal mineralization, as well as a wide range of biologic functions. Nearly all (99%) of this is in the skeleton. The remainder is in the teeth (0.6%), the soft tissues (0.6%), the plasma (0.03%) and the extracellular fluid (0.06%). Calcium is an essential element that is only available to the body through dietary sources.

17.2 Functions

Calcium plays a key role in a wide range of biologic functions, either in the form of its free ion or bound complexes. One of the most important functions as bound calcium is to provide a "structural role" in providing rigidity (structure and strength) to the skeleton. This function is provided by a form of calcium phosphate that is generally known as hydroxyapatite [Ca^{10} $(OH)^2(PO^4)^6$] crystals which are embedded in collagen fibrils. In bone, calcium serves two main purposes: it provides skeletal strength and, concurrently, provides a dynamic store to maintain the intra- and extracellular calcium pools (Munro, 2010).

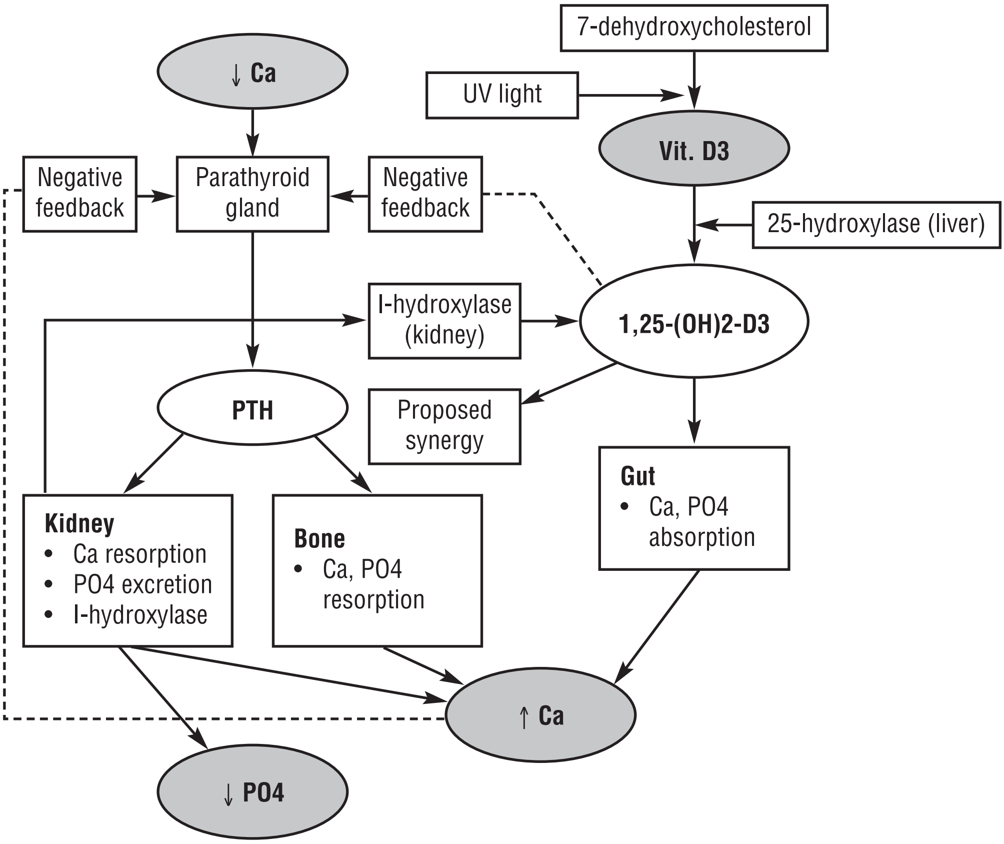
Calcium ions on the surface of bone can interact with ions in body fluids and act like a large ion exchanger. These properties are important in relation to the role of bone as a reserve of calcium to help maintain a constant concentration of blood calcium. Blood calcium is responsible for a wide range of essential functions, including extra-and intracellular signaling, nerve impulse transmission, and muscle contraction (Campbell 1990; Bootman *et al.,* 2001). Serum calcium ranges from 2.2 to 2.6 mmol/l in healthy subjects. It comprises free ions (51%), protein-bound complexes (40%), and ionic complexes (9%). The concentration of serum ionized calcium is tightly maintained within a physiologic range of 1.10 to 1.35 mmol/L to avoid calcium toxicity. Nonionized calcium is bound to a variety of proteins and anions in both the extra- and intracellular pools. The main calcium binding proteins include albumin and globulin in serum and calmodulin and other calcium-binding proteins in the cell. The major ionic complexes in serum are calcium phosphate, calcium carbonate, and calcium oxalate.

17.3 Metabolism

Calcium requirement is dependent on the state of calcium metabolism, which is regulated by three main mechanisms: intestinal absorption, renal reabsorption, and bone turnover. These in turn are regulated by a set of interacting hormones, including parathyroid hormone (PTH), 1,25-dihydroxyvitamin D ($1,25(OH)^2D$), ionized calcium itself, and their corresponding receptors in the gut, kidney, and bone.

A decrease in serum calcium inactivates the calcium receptors in the parathyroid glands to increase PTH secretion, which acts on the PTH receptor in the kidney to increase tubular calcium reabsorption, and in bone to increase net bone resorption. The increased PTH also stimulates the kidney to increase secretion of $1,25(OH)^2D$, which activates the vitamin D receptor in gut to increase calcium absorption, in the parathyroid glands to decrease PTH secretion, and bone to increase resorption. With a rise in serum calcium, these actions are reversed, and the integrated hormonal response reduces serum calcium. Together, these negative feedback mechanisms help to maintain total serum calcium levels in healthy individuals within a relatively narrow physiologic range of 10%.

A schematic diagram of calcium homeostasis can be seen below.



Source: Garth FE (2016). http://emedicine.medscape.com/article/874690-overview (accessed 10/3/17)

Dietary intake and absorption provide sufficient calcium to maintain healthy body stores. Absorption occurs mostly in the duodenum and the jejunum. Calcium absorption is a function of active transport that is controlled by 1-25(OH)^{2}D, which is particularly important at low calcium intakes, and passive diffusion, which dominates at high calcium intakes (Bronner, 2009). Typically, at normal calcium intake, 1-25(OH)^{2}D-dependent transport accounts for the majority of absorption, whereas as little as 8 to 23% of overall calcium absorption is caused by passive diffusion (McCormick, 2002). The rate of paracellular calcium uptake is considered non-saturable, while transcellular transport can be upregulated under conditions of low calcium intake. Recent evidence suggests that paracellular calcium transport is also regulated, at least in part, by 1-25(OH)^2 vitamin D (Christakos, 2012). Since a concentration gradient is not a prerequisite for this process, transcellular transport accounts for most of the absorption of calcium at low and moderate intake levels.

Calcium is excreted in urine, feces, and body tissues and fluids, such as sweat. Calcium excretion in the urine is a function of the balance between the calcium load filtered by the kidneys and the efficiency of reabsorption from the renal tubules. Most of the calcium (-98%) is reabsorbed by either passive or active processes occurring at four sites in the kidney, each contributing to maintaining neutral calcium balance. The majority of the filtered calcium (-70%) is reabsorbed passively in the proximal tubule and the remaining 30% actively in the ascending loop of Henle, the distal tubule, and collecting duct (Munro, 2010).

High intakes of sodium increase urinary calcium excretion. In contrast, adding more potassium to a high-sodium diet might help decrease calcium excretion, particularly in postmenopausal women (Sellmeyer *et al.,* 2002). Studies on human subjects have shown that calcium (Ca) can inhibit iron (Fe) absorption. Both minerals bind to a transporter on the surface of intestinal absorptive cells, but whereas non-haem iron enters the cells this way, calcium hinders further entry of the iron. This effect is mainly relevant when calcium and iron supplements are taken together. However, a thorough review of studies on humans in which Ca intake was substantially increased for long periods shows no changes in hematological measures or indicators of iron status. Thus, the inhibitory effect may be of short duration and there also may be compensatory mechanisms (Lönnerdal 2010; Lynch, 2000).

17.4 Sources

Dietary calcium comes from food sources associated with dairy products, other foods such as vegetables and cereals, foods fortified with inorganic or organic calcium, and from dietary supplements containing calcium.

Other than milk and dairy products, calcium-rich foods in the Malaysian diet can be obtained from fish with edible bones such as canned sardines and anchovies, beans and bean products including yellow dhal, *tofu* and *tempeh* (fermented soybeans), locally processed foods such as shrimp paste, *cincaluk* and *budu*, as well as vegetables like spinach, watercress, mustard leaves, *cekur manis,* tapioca leaves, *kai-lan* and broccoli (Tee *et al.,* 1997). Currently, food manufacturers in Malaysia have also made available in the market calcium fortified products such as high-calcium milk, yogurt, breakfast cereals, biscuits and even rice. Table 17.1 below shows calcium content of local foods in Malaysia.

Table 17.1: Calcium content of foods

Food	mg/100g
Milk and milk products	
High-calcium milk powder	2000
Skimmed milk powder	1169
Low fat cheese	489
Low Fat Milk	132
Low-fat yoghurt	127
Full-cream milk	109
Meat, fish, poultry, legumes, nuts	
Ikan bilis (dried without head & entrails)	500
Sardine (canned)	234
Almonds	222
Cooked dhal	171
Tofu	135
Tempeh	69
Mussels	62
Baked beans	40
Soybean milk	20
Vegetables	
Watercress (sai-yong coy)	200
Kale, Chinese (kai lan coy)	179
Mustard green (sawi),	138
Spinach	69
Calcium fortified products	
High-calcium soybean milk	180
Enriched bread	167
Orange juice (calcium fortified)	146

Ref: Tee *et al.* (1997)

Bioavailability of calcium from plant foods however can be affected by calcium chelators such as oxalate and phytate. Oxalic acids are found in high amounts in plant foods such as spinach, chocolate or cocoa products and in lesser quantities in dried beans, sweet potato, tea infusion, wheat germ, kale, okra and soybean products. However, a clinical study in humans has shown that calcium absorption from low-oxalate high calcium dark green vegetables from the kale species is comparable to milk (Heaney & Weaver, 1990). The authors concluded that the bioavailability from other *Brassica* family vegetables such as broccoli, mustard green, Chinese kale *(kai lan)* and cabbage can be considered as good as milk.

17.5 Deficiencies

Indicators of dietary calcium intakes include calcium balance (i.e., calcium accretion, retention, and loss) which can be measured using stable isotopes techniques. However, bone mineral density can be considered as surrogate marker of fracture risk and calcium status.

Inadequate intake, poor calcium absorption and excessive calcium losses contribute to reduced mineralization of bone. A reduction in absorbed calcium causes serum ionized calcium concentration to decline. This stimulates the parathyroid hormone (PTH) that will act in one of three ways to increase and maintain the level of serum calcium. The parathyroid hormone can increase the production of calcitriol (1,25-dihydroxycholecalciferol), which in turn increases calcium absorption through active transport in the gut and tubular reabsorption in the kidneys. Bone resorption may also increase leading to more calcium being released from the bone. Thus, PTH maintains normal circulating calcium concentration during calcium deprivation. It is noted nonetheless; this is done at the expense of skeletal mass.

Since more than 99% of body Ca is present in the skeleton, an adequate Ca intake during the growth period may be critical in maximizing bone mineral content. Once calcium intake is adequate to prevent rickets (disordered organization of the cartilage matrix) or osteomalacia (defective bone mineralization), provision of additional calcium may increase bone density by affecting bone turnover and the size of the remodeling space. A systematic review concluded that increased calcium/dairy intake significantly increases total body and lumbar spine bone mineral content in children with low baseline intakes (Huncharek *et al.,* 2008).

Chronic calcium deficiency due to inadequate intake or poor intestinal absorption is one of the causes of reduced bone mass and osteoporosis. Osteoporosis is defined as a skeletal disease characterized by reduced bone mass, increased bone fragility and susceptibility to fracture (WHO, 1994). The clinical and public health impact of osteoporosis stems from its association with fractures of the hip, spine and forearm.

There is a dearth of information on the incidence of hip fractures in Malaysia. The Kuala Lumpur Hospital (HKL) had reported the incidence of hip fractures in 1981 as 0.49 per 1,000 and the rate increased to 0.70 per 1,000 in 1989 (Lee, Sidhu & Pan 1993). In that report, the investigators also reported ethnic differences in admissions for hip fractures in HKL, in that Chinese accounted for 58% followed by Indians (27%) and Malays (15%). In 2001, hip fracture incidence from hospital records was reported to be the highest among Chinese (men 94/100,000, women 220/100,000) followed by Indians (men 98/100,000, women 204/100,000) and Malays (men 27/100,000, women 43 /100 000) (Lau *et al.,* 2001). The most recent data reported that the incidence of hip fractures in Malaysia ranges from 10/100,000 population from age 50 years old to 510/100, 000 populations at age above 75 years old with a sharp increase at age 65 years and above. Similarly, the Chinese had the highest incidence of hip fractures compared to the Malays and Indians. Chinese women accounted for 44.8% of hip fractures. (Lee & Khir, 2007).

Cross sectional surveys in Malaysia often report low calcium intakes among various population. The median intake of calcium among Malaysians was reported to be 353 mg (men 374 mg; women 333 mg) by the Malaysian Adult Nutrition Survey (Institute of Public Health 2014). The SEANUTS study reported that more than one-third did not achieve the Malaysian RNI in 2005 for calcium in children aged 6 months to 12 years (Poh *et al.,* 2013).

Systematic reviews published on the effects of calcium in health and disease showed that in general, low calcium intake is not associated with higher risk of many non-skeletal conditions (Chung *et al.,* 2009; Uusi-Rasi1 et al. 2013). Among hypertensive adults, calcium supplementation (400 to 2000 mg/d) lowered systolic, but not diastolic, blood pressure by a small but statistically significant amount (2 to 4 mm Hg). For body weight, despite a wide range of calcium intakes (from supplements or from dairy and nondairy sources) across the calcium trials, the randomized controlled trials were fairly consistent in finding no significant effect of increased calcium intake on body weight.

There was also no overall effect of calcium intake on cancers, although for breast cancer, subgroup analyses in four cohort studies consistently found that calcium intake in the range of 780 to 1750 mg/d in premenopausal women was associated with a decreased risk for breast cancer. However, no RCTs of calcium supplementation to prevent breast cancer in premenopausal women have been published. For prostate cancer, three of four cohort studies found significant associations between higher calcium intake (>1500 or >2000 mg/day) and increased risk of prostate cancer, compared to men consuming lower amount of calcium (500-1000 mg/day).

On cardiovascular health, six cohort studies of calcium intake suggest that in populations at relatively increased risk of stroke and with relatively low dietary calcium intake (i.e., in East Asia), lower levels of calcium intake under about 700 mg/day are associated with higher risk of stroke. This association, however, was not replicated in Europe or the US, and one Finnish study found a possible association of increased risk of stroke in men with calcium intakes above 1000 mg.

On immunologic disorders; and pregnancy-related outcomes including preeclampsia, there were either few studies or findings were inconsistent.

17.6 Factors affecting calcium requirement

The body’s need for calcium relative to skeletal growth and remodeling varies by life stage. The major physiological activities include bone accretion during skeletal growth and maintenance of bone mass after growth is completed. Infancy through late adolescence periods are characterized by positive calcium balance due to enhanced bone formation. After puberty and throughout most of adulthood, bone formation and resorption are balanced. During this period, bone mass is consolidated, and calcium requirements are relatively stable. Later in life, menopause and age-related bone loss lead to a net loss of calcium due to enhanced bone resorption.

During pregnancy, the foetal need for calcium is met by maternal physiological changes, primarily through increased calcium absorption. Calcium is actively transported across the placenta from mother to foetus, an essential activity to mineralizing the fetal skeleton. Intestinal calcium absorption of the mother doubles in pregnancy (Kovacs, 2005). In teenage pregnancy, whose skeleton is still growing, pregnancy could theoretically reduce peak bone mass and increase the long-term risk of osteoporosis.

Human breast milk is the sole dietary source of calcium to the infant and most of the calcium present in milk was derived from the maternal skeleton. Maternal bone resorption is markedly up-regulated (Specker et al. 1994; Kalkwarf et al. 1997), and it appears that maternal BMD can decline 5 to 10 percent during the 2-to 6-month time period of exclusive breastfeeding. However, it normally returns to baseline during the 6 to 12 months post-weaning (Kalkwarf, 1999). Thus, in the long term, a history of lactation does not appear to increase the risk of low BMD or osteoporosis. The normal loss of BMD during lactation and the post-lactation recovery occurs in adolescents as well (Chantry *et al.,* 2004).

Protein intake stimulates acid release in the stomach, and this, in turn, enhances calcium absorption. However, it has long been known that protein also increases urinary calcium excretion. It is estimated that for every gram of protein metabolized, urinary excretion of calcium increases by 50% or 0.025 mmol calcium taken out. Nevertheless, while protein intake appears to increase urinary calcium excretion, the effect of protein on calcium retention is controversial. While several observational and clinical studies have shown that a higher protein intake (84 to 152 g/day) was positively associated with change in femoral neck and spine BMD (Shapese & Sukumar 2010), other epidemiological studies suggest that high protein diets reduce bone mass; this has been attributed to a higher acid load, leading to a buffering response by the skeleton and greater urinary calcium excretion. A meta-analysis (Darling *et al.,* 2009) concluded that there is a small benefit of protein for bone health, but the benefit may not necessarily translate into reduced fracture risk in the long term. IOM (2011) has not adjusted calcium requirement based on protein intake.

High intakes of sodium increase urinary calcium excretion. In contrast, adding more potassium to a high-sodium diet might help decrease calcium excretion, particularly in postmenopausal women (Sellmeyer *et al.,* 2002). However, available evidence does not warrant different calcium intake requirements for individuals according to their salt consumption.

Caffeine from coffee and tea modestly increases calcium excretion and reduces absorption (Heaney & Recker 1982; Bergman *et al.,* 1990). Two studies have indicated that caffeine intake (two to three or more cups of coffee per day) will result in bone loss, but only in individuals with low milk or low total calcium intake (Barrett-Connor *et al.*1994; Harris & Dawson-Hughes, 1994). The addition of milk into coffee could ameliorate the adverse effect of caffeine.

High dietary intake of phosphorus gives rise to high blood phosphate levels which in turn, reduce the formation of calcitriol in the kidneys, reduce blood calcium and lead to elevated levels of PTH that may be detrimental on bone mineral content. Several observational studies have suggested that the consumption of carbonated soft drinks with high levels of phosphate is associated with reduced bone mass and increased fracture risk, but this is more likely due to the displacement of milk with the carbonated drinks, rather than the phosphorous itself (Heaney & Rafferty, 2001).

Some epidemiological evidence suggests that vegetarians had higher bone loss than omnivores due to the limited quantities of protein, calcium, and phosphorus in their diet (Weaver *et al.,* 1999). In a study of the Seven-Day Adventists (SDAs), however, no significant relationships or trends were found between early or current dietary intake and bone mineral content in that population.

Lacto-ovo vegetarians should be able to obtain adequate calcium intake from milk and milk products. Vegans who eat only plant-based diet may have challenges meeting calcium requirements and should be aware that the bioavailability of calcium may be lower due to plant constituents that can impede calcium absorption.

17.7 Setting requirements and recommended intakes of calcium

Calcium requirements are best derived from balance studies, which is a careful measurement of calcium absorbed and calcium losses across a range of calcium intakes. The intake which provides just enough absorbed calcium to meet losses (zero balance) is then derived and set as the mean calcium requirement of an adult. In children, adolescence and pregnancy, the factorial approach is used to estimate calcium requirement because these groups need to be in positive calcium balance.

The main reference in arriving at this revised recommended intake for calcium for Malaysians is the updated Institute of Medicine, USA (IOM) DRI recommendations in 2011 and the existing FAO/WHO (2002) reference. No other regional RNIs nor updated FAO/WHO data are available at this point in time. There are no known local studies on calcium requirements of communities but several local studies on calcium intake, bone mineral density and calcium supplementation conducted locally has been published (Chee *et al.* 2002; Chee *et al.* 2003; Esra *et al.* 2014; Suriawati *et al.* 2016).

Infants

The optimal source of calcium during the first year of life is human milk. No evidence shows that exceeding the calcium intake of the exclusively breastfed term infant during the first 6 months of life or the intake of the breastfed infant supplemented with solid foods during the second 6 months of life is beneficial to achieving long-term increases in bone mineralization. Calcium requirements for infants are presumed to be met by human milk (IOM, 1997). There are no functional criteria for calcium status that reflect response to calcium intake in infants

(IOM, 1997). According to IOM (2011), data are not sufficient to establish an estimated average requirement (EAR) for infants 0 to 6 and 7 to 12 months of age, and therefore adequate intake (AIs) have been developed based on the available evidence.

Based on infant weighing studies, a reasonable average amount of breast milk consumed is 780 mL/day. The average level of calcium within a liter of breast milk is 259 mg (± 59 mg). It is therefore estimated that the intake of calcium for infants fed exclusively human milk is 202 mg/day (IOM, 2011).

The daily increment of calcium in the skeleton in the first 2 years of life is about 100 mg/day. The urinary calcium loss is about 10 mg/day. Therefore, infants need to absorb about 120 mg of calcium per day for normal growth. Absorption of calcium is assumed to be 60% from human breast milk, while that from infant formula is lower at 40%. It is estimated therefore breastfed infants with an intake of about 202 mg/day would be able to meet the required amount of absorbed calcium of 120 mg, and formula fed babies would require an intake of 250 mg/day of calcium (IOM, 2011).

Based on the above, the proposed AI for infants (0-6 months) who are exclusively breastfed is set at 200 mg calcium/day. Similarly, for formula-fed babies, the AI amount is set higher at 250 mg calcium/day.

As intake of solid foods increases for infants aged 6-12 months, calcium intake from breast milk decreases. There is also lower calcium concentration of breast milk at 6 to 12 months of lactation. Hence, calcium requirement for this age group is expected to be derived increasingly from solid foods. IOM (2011) had proposed the AI for infants 6-12 months to be 260 mg calcium/day.

The figure is derived by assuming that mean human milk intake during the second 6 months of life would be lower at 600 ml/day (Dewey *et al.,* 1984). The calcium concentration in the milk is assumed to be 200 mg/L (Atkinson *et al.,*1995) hence the infant would consume 120 mg/day of calcium. The estimated calcium intake from solid food was assumed to be 140 mg /day and this gives a total of 260 mg/day.

AI for infants

0 - 6 months	**breast fed**	**200 mg/day**
	formula fed	**250 mg/day**
7 - 12 months		**260 mg/day**

Children and adolescents

The amount of calcium that is accumulated in young children is mainly for bone growth. Several studies among Asian children in Hong Kong showed that those with habitually higher calcium intakes during the first 5 years of life had significantly higher bone mineral content (Lee *et al.,* 1993) than in children with lower calcium intakes of less than 400 mg/day. Lee & Leung (1995) also showed that amongst 7-year old Hong Kong Chinese children who habitually consume a low calcium diet (280 mg/day), gains in radial bone density (3.1 % more than controls) were seen when supplemented with 300 mg/day calcium carbonate for 18 months. No local studies exist for measuring bone calcium accretion in young children.

The IOM (2011) recommendation provided scientific data measuring calcium balance and hence, derive estimated total intake needed for bone accrual across several age groups. For children aged 1- 3 years old, Lynch *et al.* (2007) suggested a target average calcium retention level of 142 mg/day, consistent with the growth needs of this life stage group. Through the factorial method, a calcium intake of 474 mg/day is estimated to meet this need. An estimated EAR was, established as 500 mg of calcium per day, rounded from 474 mg/day. An assumption specified by Lynch et al. (2007) is that an additional 30 percent calcium retention would meet the needs of 97.5 percent of this age group. This results in an estimated RNI for calcium of 700 mg/day calcium for this age-group.

Similarly, for children aged 4 to 8 years old, Abrams *et al.* (1999) and Ames *et al.* (1999) estimated that the total intake of 800 mg would be needed for bone accrual. Again, the assumption that another approximately 30 percent is needed to cover about 97.5 percent of the population- the RNI value for calcium would be 1,000 mg/day for this age group.

Most research in children regarding optimal calcium intakes has been directed toward 9- to 18-year-olds - the efficiency of calcium absorption is increased during puberty, and most bone mineralization occurs. This is the period of growth spurts and the attainment of 'peak bone mass'. Achieving a higher peak bone mass is considered a better approach for prevention of osteoporosis.

Data from studies on calcium balance in this age-group have provided bone calcium accretion levels for children and adolescents ranging from 92 to 210 mg/day (Vatanparast *et al.,* 2010). Average bone calcium accretion was included in the factorial method, and the intake levels can be estimated as ranging between 961-1116 mg/day in females and 1200-1300 mg/day in males. IOM (2011) interpolated an estimated mean need for calcium for boys and girls of 1,100 mg/day with rounding, a value approximately at the midpoint between the two groups. Hence, the RNI is recommended to be set at 1300 mg/day to cover 97.5 percent of the population aged 9 to 18 years old.

RNI for children & adolescents

1 - 3 years	**700 mg/day**
4 - 6 years	**1000 mg/day**
7 - 9 years	**1000 mg/day**

RNI for adolescents

10 - 12 years	**1,300 mg/day**
13 - 16 years	**1300 mg/day**
16 - 19 years	**1300 mg/day**

Adults

After peak bone mass attainment, bone formation and resorption is balanced during adulthood. Bone mass density is relatively stable between ages 20-50, and hence there are relatively few intervention studies on the role of calcium during young and middle adulthood.

FAO/WHO (2002) recommended 750 mg/day for populations with animal protein intake of 20-40 g/day. IOM (2011) cited a study which provides the only evidence for calcium balance studies at this life stage groups. Based on a series of controlled calcium balance studies, they have established an EAR calcium intake level of 741 mg/day to maintain neutral calcium balance, which is rounded to 800 mg/day. Hence, IOM has set the RNI for calcium for this age-group at 1000 mg/day. Based on these considerations, the proposed RNI for calcium for adults aged 19 to 50 years in women and men is revised to 1000 mg/day.

The natural process of bone loss begins to manifest itself in the older age group. It begins earlier for women than for men as a result of the onset of menopause, which usually occurs when women reach 50 to 55 years of age. By the time both men and women have reached 70 or more years of age, they will be experiencing bone loss. Menopause is also associated with a rise in excretion of obligatory calcium or fasting urine of about 20 mg-40-mg daily.

Women 51 through 70 years of age are considered separately from men. Although it is evident that calcium intake does not prevent bone loss during the first few years of menopause, there is the question of whether or to what extent calcium intake can mitigate the loss of bone during and immediately following the onset of menopause. Several studies including a local study of milk supplementation among Malaysian postmenopausal women with 1200 mg calcium per day has been shown to reduce rate of bone loss (Chee *et al.,* 2003).

Available balance data indicate that the EAR for women aged over 51 is 1000 mg/day and 800 mg for men. (IOM, 2011). Therefore, the RNI for calcium is set at 1200 mg/day for women aged 51 years and above and 1000 mg for men.

RNI for adults

20 - 39 years	**1000 mg**
40 - 49 years	**1000 mg**
50-59 years	**1200 mg (women); 1000 mg (men)**
≥60 years	**1200 mg (women); 1000 mg (men)**

Pregnancy & Lactation

The foetal need for calcium is met by maternal physiological changes, primarily through increased calcium absorption. There is still a debate whether the calcium required for foetal bone mineralization can be obtained with no detectable mobilization of maternal bone. Nevertheless, IOM (2011) reported that the EAR for non-pregnant women and adolescents is appropriate for pregnant women and adolescents based on the randomized controlled trials (RCTs) of calcium supplementation during pregnancy that reveal no evidence that additional calcium intake beyond normal non-pregnant requirements has any benefit to mother or foetus (Koo *et al.* 1999; Jarjou *et al.* 2010). Hence the RNI for non-lactating pregnant women and adolescent are at 1000 and 1300 mg/day, respectively.

Post-lactation maternal bone mineral is restored without consistent evidence that higher calcium intake is required, as based on two RCTs (Cross *et al.* 1995; Prentice *et al.* 1995). There is no evidence that calcium intake in lactating women and adolescents should be increased above that of non-lactating women and no additional amount was provided (IOM, 2011). The calcium RNI for lactating women is set at 1000 mg/day and lactating adolescents at 1300 mg/day.

RNI for pregnancy & lactation

13 - 19 years	**1300 mg/day**
20 - 49 years	**1000 mg/day**

Discussions on revised RNI for Malaysia

The previous recommended dietary intakes for calcium (NCCFN, 2005) were lower than the current recommended calcium intake for Malaysian infants, but higher for adolescents, younger adults, pregnant and lactating mothers. This is in light of revised data from IOM (2011) based on studies on calcium balance across different age-groups.

17.8 Tolerable upper intake levels

Calcium levels in the body are very closely controlled so that excessive accumulation in blood or tissues arising from over consumption is unknown. Abnormally high calcium concentrations may occur but usually secondary to diseases such as bone cancer, hyperthyroidism and hyperparathyroidism. The efficiency of calcium absorption decreases with intake, thereby providing the body with a protective mechanism to lessen the chances of calcium intoxication.

The common effects of excessive calcium intakes are kidney stones (nephrolithiasis), milk-alkali syndrome and interaction of calcium with absorption of other essential minerals such as iron, zinc, magnesium and phosphorous. Calcification of vascular tissues has been reported with high calcium intake however, the reports are based on individuals with compromised kidney function. No link has been clearly established for a general population. Similarly, there is no conclusive evidence that the intake of calcium per se in the range of 1000 to 1200 mg/day can be associated with cardiovascular events (IOM, 2011). IOM (2011) had established a tolerable upper level (UL) according to age groups. The calcium tolerable upper intake levels by life stages is shown in Table 17.2.

Table 17.2: Calcium Tolerable Upper Intake Levels by Life Stages

Life Stage Group	UL (mg)
Infants	
0-6 months	1000
6-12 months	1500
Children, adolescents & adults	
1-3 years	2500
4- 8 years	2500
9-13 years	3000
14-18 years	3000
19-30 years	2500
31-50 years	2500
51-70 years	2000
>70 years	2000
Pregnancy & lactation	
14-18 years	3000
19-50 years	2500

Source: IOM (2011).

17.9 Research recommendations

The following priority areas of research are recommended:

1. Nationally representative data on calcium intakes of various population groups such as children, adolescents, adults and elderly.

2. Content of calcium in local foods and absorption efficiency, especially from non-dairy foods.

3. Studies on the effects of increased calcium intakes on skeletal mass and bone loss. In adolescents, it is important to determine to what extent increased calcium intake can influence peak bone mass formation in conjunction with other nutrients and physical activity level.

4. Calcium balance studies on various age and ethnic groups to determine optimal recommendations of calcium intake.

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Appendix 17.1 Comparison of recommended intake for calcium: RNI Malaysia (2017), RNI Malaysia (2005), RNI of IOM (2011) and RNI of FAO/WHO (2004)

Malaysia (2017)		Malaysia (2005)		IOM (2011)		FAO/WHO (2004)	
Age group	**RNI (mg/day)**	**Age group**	**RNI (mg/day)**	**Age group**	**RNI (mg/day)**	**Age group**	**RNI (mg/day)**
Infants		**Infants**		**Infants**	**AI**	**Infants**	
0 - 5 months	200(BF)	0 - 5 months	300 (BF)	0 - 6 months	200(BF)	0 - 6 months	300 (bf)
	250(FF)		400 (FF)		250 (FF)		
6 - 11 months	260	6 - 11 months	400	6 - 12 months	260	7 - 11 months	400 (ff)
Children		**Children**		**Children**		**Children**	
1 - 3 years	700	1 - 3 years	500	1 - 3 years	700	1 - 3 years	500
4 - 6 years	1000	4 - 6 years	600	4 - 8 years	1000	4 - 6 years	600
7 - 9 years	1000	7 - 9 years	700			7 - 9 years	700
Boys		**Boys**		**Boys**		**Boys**	
10 - 12 years	1,300	10 - 12 years	1,000	9 - 18 years	1,300	10 - 18 years	1,300
13 - 15 years	1,300	13 - 15 years	1,000				
16 - 18 years	1,300	16 - 18 years	1,000				
Girls		**Girls**		**Girls**		**Girls**	
10 - 12 years	1,300	10 - 12 years	1,000	9 - 18 years	1,300	10 - 18 years	1,300
13 - 15 years	1,300	13 - 15 years	1,000				
16 - 18 years	1,300	16 - 18 years	1,000				
Men		**Men**		**Men**		**Men**	
19 - 29 years	1,000	19 - 29 years	800	19 - 50 years	1000	19 - 65 years	1,000
30 - 50 years	1,000	30 - 50 years	1,000			> 65 years	1,300
51 - 59 years	1,000	51 - 59 years	1,000	51 - 70 years	1,000		
60 - 65 years	1,000	60 - 65 years	1,000	> 70 years	1,000		
≥ 60 years	1,000	≥ 60 years	1,000				

Malaysia (2017)		Malaysia (2005)		IOM (2011)		FAO/WHO (2004)	
Age group	RNI (mg/day)	Age group	RNI (mg/day)	Age group	RNI (mg/day)	Age group	RNI (mg/day)
Women		**Women**		**Women**		**Women**	
20 - 39 years	1,000	19 - 50 years	800	19 - 50 years	1,000	19 - 50 years	1,000
40 - 49 years	1,000	51 - 65 years	1,000			51 - 65 years	1,300
50 - 59 years	1,200	> 65 years	1,000	51 - 70 years	1,200	> 65 years	1,300
≥ 60 years	1,200			> 70 years	1,200		
Pregnancy		**Pregnancy**		**Pregnancy**		**Pregnancy**	
13 - 19 years	1,300						
1st trimester	1,000	1st trimester	1,000	14 - 18 years	1,300	1st trimester	1,000
2nd trimester	1,000	2nd trimester	1,000	19 - 50 years	1000	2nd trimester	1,000
3rd trimester	1,000	3rd trimester	1,000			3rd trimester	1,200
Lactation		**Lactation**		**Lactation**		**Lactation**	
13 - 19 years	1,300						
0 - 3 months	1,000	0 - 3 months	1,000	14 - 18 years	1,300	0 - 3 months	1,000
4 - 6 months	1,000	4 - 6 months	1,000			4 - 6 months	1,000
7 - 12 months	1,000	7 - 12 months	1,000	19 - 50 years	1000	7 - 12 months	1,000

BF=breast fed FF=formula fed