

Calcium requirements for bone growth in Canadian boys and girls during adolescence

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Adequate dietary intake during the growth period is critical for bone mineral accretion. In 1997, an adequate intake (AI) of 1300 mg/d Ca was set for North American adolescents aged 9–18 years based on best available data. We determined bone Ca accrual values from age 9 to 18 years taking into account sex and maturity. Furthermore, we used the accrual data to estimate adolescents' Ca requirements. Total body bone mineral content (TBBMC) of eighty-five boys and sixty-seven girls participating in the Saskatchewan Paediatric Bone Mineral Accrual Study were used to determine annual TBBMC accumulation over the pubertal growth period. Using a similar factorial approach as the AI, we estimated Ca requirements of adolescent boys and girls for two age groups: 9–13 and 14–18 years. Between 9 and 18 years, boys accrued 198.8 (SD 74.5) g bone mineral content (BMC) per year, equivalent to 175.4 (SD 65.7) mg Ca per d with the maximum BMC accrual of 335.9 g from age 13 to 14 years. Girls had 138.1 (SD 64.2) g BMC per year, equalling 121.8 (SD 56.6) mg Ca per d with the maximum annual BMC accrual of 266.0 g from age 12 to 13 years. Differences were observed between both sex and age groups with respect to Ca needs: boys and girls aged 9–13 years would require 1000–1100 mg/d Ca, and from age 14 to 18 years, the mean Ca requirements would be relatively stable at 1000 mg/d for girls but would rise to 1200 mg/d for boys.

Calcium requirements: Bone mineral accrual: Adolescence

The development of peak bone mass during the growing years is considered an important determinant for future risk of osteoporosis in later life^(1–3). An adequate Ca intake during the growth period therefore may be critical in maximising bone mineral potential. The importance of Ca for skeletal growth has led to the setting of a North American Dietary Reference Intake (DRI) adequate intake level of Ca for adolescents aged 9–18 years, 1300 mg/d from a range of 1100–1600 mg/d based on available evidence at that time⁽⁴⁾. However, in 1997, the lack of sufficient longitudinal Ca accrual data for boys and girls during the 10 years of adolescence meant the expert panel was unable to estimate Ca requirements related to either sex differences or the effects of maturation both of which are known to impact Ca accrual⁽⁴⁾.

To derive the adequate intake for Ca, the DRI panel on Ca used three major approaches. These included (1) Ca balance studies of subjects consuming variable amounts of Ca, (2) clinical trials on adolescents investigating the response of changes in bone mineral content/density to varying Ca intakes, and (3) a factorial model approach^(4,5). Non-linear regression equations were used to determine the Ca intake required to achieve a desirable retention of Ca (282 mg/d for boys and 212 mg/d for girls) with a plateau balance from balance studies conducted in Caucasian girls aged 11–14 years⁽⁴⁾. Evidence from randomised trials in children and adolescents revealed additional intake of Ca in habitual intake of about 900 mg/d

positively affects bone mineral accretion, particularly during the pre-pubertal stage. However, the effect is not maintained post intervention⁽⁴⁾. In the factorial approach, Ca requirements were estimated based on combining Ca retention and Ca loss via various routes (skin, urine and faecal) by apparently healthy individuals, while considering the absorption fraction of Ca⁽⁴⁾. The values for Ca retention were calculated to be 212 mg/d for girls and 282 mg/d for boys. These were based upon a cross-sectional analysis of bone mineral accrual during the 2 years surrounding the age of peak bone mineral content accrual in 115 girls and 113 boys⁽⁵⁾. For boys, peak bone mineral content (BMC) accrual occurred at 14.5 years of age; whereas for girls, peak BMC accrual occurred earlier, at 13.0 years of age. It has been suggested that applying these particular 2-year retention values for Ca likely overestimates the requirement throughout the whole adolescent period, i.e. from 9 to 18 years. Using Ca balance data in adult males (aged 28.2 (SD 7.7) years, *n* 82) and females (aged 47.0 (SD 18.5) years, *n* 73), lower Ca requirement of 741 mg/d (where Ca balance is neutral) has been estimated for adult males and females compared to previous estimates⁽⁶⁾. No estimate of Ca requirement for adolescents (9–18 years) has been reported recently. We now present longitudinal data covering the same age span, 9–18 years of age and report the average accumulation of Ca during these years in Caucasian Canadian boys and girls⁽⁴⁾.

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Methods

Study participants and design

The data are taken from subjects participating in the University of Saskatchewan's Paediatric Bone Mineral Accrual Study^(5,7-9). The study used a mixed longitudinal design incorporating cohorts at 8 years of age. The study was initiated in 1991, when 228 boys (113) and girls (115) aged 8–15 years were recruited (220 were dual-energy X-ray absorptiometry scanned). From 1992 to 1993 an additional 31-, 8- and 9-year-old subjects were recruited. The age range of the sample was 12–21 after 6 years of follow up (1997). Bone mineral was measured annually until 1997 at which time 197 individuals had been repeatedly measured on more than one occasion. As the relative size of the overlapping cohorts remained the same, it was possible to estimate a 14-year developmental pattern (8–20 years) from 7 years of data collection. For the present analysis, we used data in DRI age range for adolescence (9–18 years). Subjects were included who had a measure of biological age at peak height velocity (PHV) and continuous measures of BMC accrual for at least two or more consecutive time points; 152 participants (eighty-five boys and sixty-seven girls) were eligible. Eligible children were Caucasian and had no history of chronic disease or chronic medication use; no medical conditions, allergies or medications known to influence bone metabolism or Ca balance. They were recruited from two elementary schools in middle-class neighbourhoods in Saskatoon, Saskatchewan Canada. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the University of Saskatchewan Advisory Committee on Ethics in Human Experimentation. Written informed consent was obtained from all the subjects as well as parent/guardians.

Age

A decimal value for chronological age was determined by subtracting the date of birth from the date of measurement⁽¹⁰⁾. Chronological age groups were formed by using 1-year intervals where, for example, the 9.49–10.49-year-old participants would be considered 10 years of age.

Dietary calcium intake

Food intake was assessed via serial 24-h recalls conducted both at the participating schools and in the hospital at the time of the bone scans. The target number of recalls was three recalls/year collected in different seasons. Approximately, 10% of recalls were discarded for being implausible (below 4.18MJ or above 20.92MJ). All days of the week, except Friday and Saturday were included. To obtain Ca intake, food intake from the 24-h recalls was analysed using a nutritional assessment software package (NUTS Nutritional Assessment System, version 3.7 Quilchena Consulting Ltd, Victoria, BC, Canada). Ca supplement use was included in Ca intake data when supplement use was considered consistent. To obtain usual intake, intake of Ca from serial 24-h recalls was averaged for each year of study (Table 1)⁽⁸⁾.

Table 1. Total body bone mineral content (TBBMC), height, weight and calcium intake of adolescent boys (B)* and girls (G)† (Mean values and standard deviations)

| Age (years) | n | | TBBMC (g) | | | Height (cm) | | | Weight (kg) | | | Ca intake (mg/d) | | | | | |
|-------------|----|----|-----------|-------|--------|-------------|-----|-------|-------------|------|------|------------------|------|------|-----|------|-----|
| | B | G | Mean | SD | | B | SD | | B | SD | | B | SD | | | | |
| 8 | 6 | 18 | 797.3 | 72.2 | 790.5 | 178.7 | 6.3 | 132.9 | 7.0 | 28.7 | 4.9 | 36.0 | 17.4 | 1045 | 287 | 1066 | 393 |
| 9 | 19 | 34 | 932.5 | 102.6 | 889.8 | 225.8 | 4.5 | 137.9 | 8.4 | 32.4 | 5.1 | 32.3 | 8.4 | 1116 | 358 | 1100 | 420 |
| 10 | 32 | 53 | 1046.5 | 148.0 | 1002.3 | 234.5 | 5.9 | 142.3 | 8.1 | 35.3 | 5.8 | 35.6 | 8.3 | 1043 | 337 | 1004 | 369 |
| 11 | 53 | 65 | 1191.1 | 169.6 | 1166.2 | 297.6 | 6.2 | 149.2 | 8.7 | 39.2 | 7.8 | 40.5 | 10.8 | 1050 | 506 | 982 | 296 |
| 12 | 75 | 78 | 1365.9 | 224.3 | 1381.2 | 322.7 | 6.7 | 155.2 | 8.3 | 44.4 | 8.4 | 46.0 | 10.8 | 1126 | 416 | 997 | 428 |
| 13 | 88 | 92 | 1597.6 | 307.4 | 1647.2 | 342.6 | 7.7 | 160.5 | 7.4 | 50.4 | 9.5 | 52.1 | 11.1 | 1164 | 449 | 993 | 433 |
| 14 | 89 | 95 | 1933.5 | 399.2 | 1833.2 | 324.9 | 8.6 | 163.2 | 6.4 | 57.1 | 10.4 | 56.0 | 11.1 | 1352 | 689 | 993 | 466 |
| 15 | 79 | 87 | 2230.1 | 409.5 | 1954.9 | 267.1 | 7.6 | 164.3 | 5.7 | 62.2 | 11.4 | 58.9 | 11.1 | 1327 | 592 | 910 | 427 |
| 16 | 66 | 61 | 2497.4 | 373.2 | 2030.8 | 272.3 | 6.8 | 165.5 | 5.6 | 68.8 | 10.2 | 60.6 | 11.5 | 1514 | 736 | 878 | 418 |
| 17 | 51 | 45 | 2659.6 | 391.7 | 2086.8 | 293.2 | 7.3 | 165.8 | 6.3 | 72.2 | 13.4 | 63.9 | 12.5 | 1644 | 923 | 880 | 464 |
| 18 | 36 | 34 | 2785.5 | 424.2 | 2171.2 | 339.0 | 7.8 | 165.8 | 6.5 | 76.1 | 13.0 | 66.9 | 13.6 | 1370 | 684 | 968 | 456 |

* Cohort included a total of seventy boys.

† Cohort included a total of sixty-eight girls.

Bone measurements

Bone measurements were obtained by annual dual-energy X-ray absorptiometry scans of the whole body. They were carried out by one of two experienced operators using a Hologic QDR 2000 (Hologic, Waltham, MA, USA) in the array mode using enhanced global software version 7.10. To minimise operator-related variability, the same qualified person analysed all whole body scans, using enhanced software version 5.67A. In our laboratory, *in vivo* short-term reproducibility for total body BMC is 0.60%. A Victoreen Ion Chamber Survey Meter (Model 450p) measured entrance radiation dose. When this surface dose was corrected for body attenuation, subject age and type and volume of tissue being irradiated, the effective dose equivalent was less than 1mrem. Measurements are presented for Total body bone mineral content (TBBMC), unadjusted for body size, at defined age points. Annual Ca retention (g/year) and daily Ca retention (mg/d) were derived by assuming that 32.2% Ca in bone mineral content⁽¹¹⁾.

Anthropometric measurements

Anthropometric measurements were taken at 6-month intervals by trained personnel following a standard protocol⁽⁷⁾. Standing heights were recorded without shoes as stretch stature to 0.1 cm using a wall mounted stadiometer. Body mass was measured to 0.01 kg on a calibrated electronic scale.

Analysis

By plotting TBBMC values over time (age in years), distance and velocity curves were generated (GraphPad PRISM 4, GraphPad Software Inc., La Jolla, CA, USA; www.graphpad.com) in order to find TBBMC at each discrete age. Data are presented as means and standard deviations. Sex differences in TBBMC values at each age were tested using Student's *t* test. α was set to a value of 0.05.

We used the same factorial approach for Ca requirements of adolescents as DRI report on Ca (Ca requirements = (Ca needs + Ca losses)/38%)⁽⁴⁾. In this method, we added Ca needs for growth to Ca losses via urine, faeces and sweat and adjusting the results for absorption (38%). Ca needs (Ca accretion) were obtained from our longitudinal data for boys and girls in age groups 9–13 and 14–18 years. We used the same values for Ca loss that DRI panel used (Faecal Ca, 112 and 108 mg/d in girls and boys respectively; sweat loss, 55 mg/d in boys)⁽⁴⁾. However, when recent data were available for Ca loss, we used them^(12,13). For girls, we used Ca sweat loss values from data reported by Palacios *et al.*⁽¹²⁾ (51 mg/d). For urinary excretion, recent values taken from Braun *et al.*⁽¹³⁾ (106 and 85 mg/d in girls and boys respectively). These data were provided by the authors of that study.

Results

Not every subject completed all 7 years of data collection. However, data were overlapping and it can be seen that TBBMC of the subjects from age 8 through to age 18 years increased by 3.5 times in boys and 2.7 times in girls (Table 1). In our cohort at ages 8 and 9 years, boys and girls began adolescence with similar TBBMC, yet by 14 years of age boys had more TBBMC, were taller and had higher Ca intake than girls ($P < 0.01$). As shown in Table 2, boys accrued more TBBMC during their peak years (ages 14–16 years) than girls during their peak years (ages 12–14 years); in boys, net accrual through adolescence was 31% greater than in girls. However, Ca retention per height (mg/d per cm) varied over adolescence (Fig. 1). The peak Ca accrual per unit height was achieved at the age of PHV velocity in both sexes.

Using the same factorial approach as DRI report on Ca, we estimated Ca retention for the whole adolescence age range of 9–18 years as well as for two subgroups, younger adolescents aged 9–13 years and older adolescents aged 14–18 years, for boys and girls separately. For Ca retention we used values

Table 2. Bone mineral content retention (g/year) calculated from total body bone mineral content (TBBMC), calcium retention (g/year)*, calcium retention (mg/d)† of adolescent boys and girls of age 9–18 years

| Age (years) | Boys | | | | | Girls | | | | |
|-------------|----------|-----------|-----------------|-----------------------|---------------------|----------|-----------|-----------------|-----------------------|---------------------|
| | <i>n</i> | TBBMC (g) | Net accrual (g) | Ca retention/year (g) | Ca retention/d (mg) | <i>n</i> | TBBMC (g) | Net accrual (g) | Ca retention/year (g) | Ca retention/d (mg) |
| 8 | 6 | 797.3 | – | – | – | 18 | 790.5 | – | – | – |
| 9 | 19 | 932.5 | 135.2 | 43.5 | 119.3 | 34 | 889.8 | 99.4 | 32.0 | 87.7 |
| 10 | 32 | 1046.5 | 114.0 | 36.7 | 100.6 | 53 | 1002.3 | 112.5 | 36.2 | 99.3 |
| 11 | 53 | 1191.1 | 144.5 | 46.5 | 127.5 | 65 | 1166.2 | 163.8 | 52.8 | 144.5 |
| 12 | 75 | 1365.9 | 174.8 | 56.3 | 154.2 | 78 | 1381.2 | 215.1 | 69.2 | 189.7 |
| 13 | 88 | 1597.6 | 231.7 | 74.6 | 204.4 | 92 | 1647.2 | 266.0 | 85.7 | 234.7 |
| 14 | 89 | 1933.5 | 335.9 | 108.2 | 296.3 | 95 | 1833.2 | 186.0 | 59.9 | 164.1 |
| 15 | 79 | 2230.1 | 296.6 | 95.5 | 261.7 | 86 | 1954.9 | 121.6 | 39.2 | 107.3 |
| 16 | 66 | 2497.4 | 267.3 | 86.1 | 235.8 | 61 | 2030.8 | 75.9 | 24.4 | 67.0 |
| 17 | 51 | 2659.6 | 162.2 | 52.2 | 143.1 | 45 | 2086.8 | 56.1 | 18.1 | 49.5 |
| 18 | 36 | 2785.5 | 125.9 | 40.5 | 111.1 | 34 | 2171.2 | 84.3 | 27.2 | 74.4 |
| Mean | – | 1730.6 | 198.8 | 64.0 | 175.4 | – | 1541.3 | 138.1 | 44.5 | 121.8 |
| SD | – | 726.1 | 78.6 | 25.3 | 69.3 | – | 514.4 | 67.6 | 21.8 | 59.7 |

* Calcium retention (g/year) obtained and daily calcium retention (mg/d) was derived by assuming 32.2% calcium in bone mineral content.

† Calcium retention (mg/d) obtained by converting calcium retention values from g/year to mg/d.

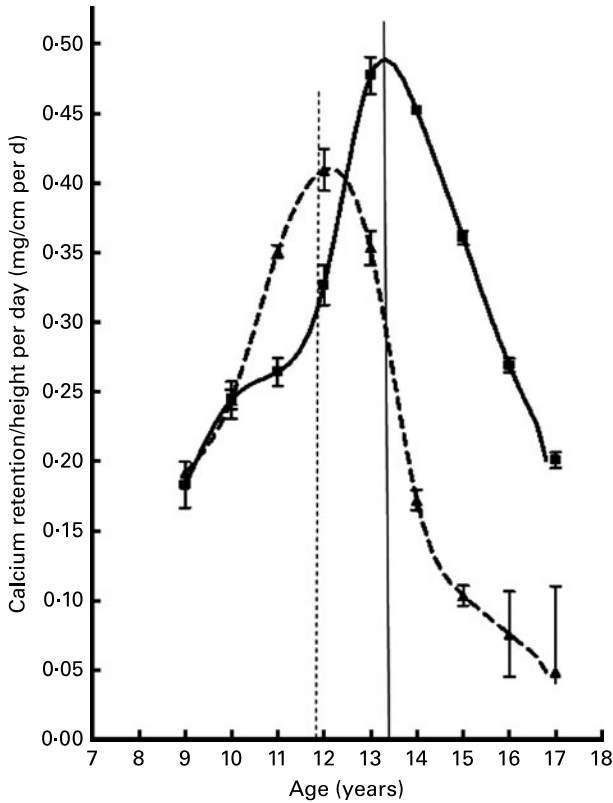


Fig. 1. Calcium retention (mg/d) per centimetre height in boys and girls during adolescence. Peak height velocity was achieved at age 11.8 years in girls and 13.5 years in boys. ■, Male; ▲, female.

from Table 2. The resulting calculations, summarised in Table 3, show differences from those values calculated in 1997⁽⁴⁾. For adolescents aged 9–13 years, the difference in the estimation of Ca requirements for boys and girls is 81 mg (1024 and 1105 mg in boys and girls, respectively). For adolescents aged 14–18 years, there is a marked difference in the estimation of Ca requirements for boys and girls; the value for older girls decreases below 1000 mg, while that for older boys increases to 1205 mg. None of these estimates approaches the values calculated in the 1997 DRI report on Ca, of 1300 mg for girls and 1500 mg for boys⁽⁴⁾.

Discussion

Using Ca accrual throughout the complete age span (9–18 years) of the DRI life stage category of ‘adolescence’⁽⁴⁾ in the calculation of mean Ca requirements for boys and girls gave estimates of 1113 mg (approximately 1100 mg) and 1026 mg (approximately 1000 mg) respectively. These are lower than those previously reported⁽⁵⁾ of 392 mg for boys and 250 mg for girls in which only cross-sectional data from 2 years about the age of PHV were used⁽⁵⁾. The DRI panel for Ca used desirable Ca retention rather than optimal in its factorial approach. Using the subgroups of adolescence (9–13 and 14–18 years), mean Ca requirements for younger girls and boys adolescents would be similar (1000–1100 mg) but then diverged in the older age group, to less than 1000 mg for girls and more than 1200 mg for boys.

Although before puberty no substantial sex difference has been reported in bone mass of the axial or appendicular skeleton, a sex difference in bone mass becomes expressed during puberty^(14,15). In addition to hormonal variation, this difference appears to be the result of a more prolonged bone maturation period in boys than in girls^(14,15). In adolescent girls, puberty starts earlier than boys; the gain in bone mass declines rapidly after menarche, and no considerable gains are observed even 2 years later in some bone sites⁽¹⁴⁾. In adolescent boys, bone mineral accrual accelerates, particularly from 13 to 17 years⁽¹⁴⁾. In our cohort, the age of PHV, as an indicator of maturity, occurred at ages 11.8 and 13.4 years in girls and boys, respectively⁽⁵⁾. Girls achieved their peak bone mineral content velocity some 8 months later at age of 12.54 years and boys achieved 9 months later at age of 14.05 years⁽⁵⁾. Our data suggest that Ca requirement estimations should be based on age subgroups (9–13 and 14–18 years), as shown in Table 3, and this is more compatible with biological needs of Ca according to sex difference in timing and pattern of bone and body growth in boys and girls (Table 2).

Our calculation of Ca requirements using the factorial method described in the DRI report⁽⁴⁾, assumes that every other component is valid for the entire adolescence age range. Only limited evidence from well-designed balance studies were available to the DRI panel in 1997. Urinary Ca loss for girls in the original factorial calculation (106 mg)

Table 3. Comparison of factorial calculations for determining calcium requirements during adolescence (age 9–18 years) and calcium requirements during peak calcium accretion in white adolescents

| Factorial criteria* | Females | | | | Males | | | |
|-------------------------|----------------------------------|-------------------|-------------------|--------------------|----------------------------------|-------------------|-------------------|--------------------|
| | During peak Ca accretion† (mg/d) | 9–18 years (mg/d) | 9–13 years (mg/d) | 14–18 years (mg/d) | During peak Ca accretion† (mg/d) | 9–18 years (mg/d) | 9–13 years (mg/d) | 14–18 years (mg/d) |
| Ca accretion | 212‡ | 121 | 151 | 92 | 282§ | 175 | 141 | 210 |
| Urinary losses | 106 | 106 | 106 | 106 | 127 | 127 | 127 | 127 |
| Endogenous faecal Ca | 112 | 112 | 112 | 112 | 108 | 108 | 108 | 108 |
| Sweat losses | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| Total | 485 | 394 | 424 | 365 | 572 | 465 | 431 | 500 |
| Absorption (%) | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 |
| Adjusted for absorption | 1276 | 1037 | 1116 | 961 | 1505 | 1224 | 1134 | 1316 |

* Criteria listed in Tables 3–4 of Institute of Medicine⁽⁴⁾.
 † Values taken from Tables 3–4 of Institute of Medicine⁽⁴⁾.
 ‡ Age 13 (SD 1.0) years (Hund & Johnson⁽⁶⁾).
 § Age 14.5 (SD 1.0) years (Hund & Johnson⁽⁶⁾)

was derived from two studies: white girls 11–14 years⁽¹⁴⁾ and 12.5–14.5 years^(4,16). A study by Tylavsky *et al.*⁽¹⁷⁾ provides an estimate of urinary Ca excretion for girls at the lower end of the adolescent range (10 years of age) of 68–99 mg, the lower value seen when fruit and vegetable consumption was greater than three servings per day⁽¹⁷⁾. However, at the higher end of the adolescent range (17–18 years of age), urinary Ca excretion would be expected to be higher than the midpoint of adolescence, as adult girls have a higher excretion than peri-pubertal girls⁽¹⁶⁾. A recent Ca balance study conducted by Braun *et al.*⁽¹³⁾ reported lower urinary Ca excretion with similar Ca intake in boys than in girls who were matched for sexual maturity. Endogenous faecal losses of girls used in the factorial calculation were based on subjects consuming a Ca diet of 1330 mg⁽¹⁸⁾ and was similar to that estimated for several adolescent boys on 500–700 mg Ca diets⁽¹⁹⁾. Sweat losses of 55 mg in boys were extrapolated⁽²⁰⁾ from adult values of 60 mg/d⁽²¹⁾. In girls, we used the sweat loss values of 51 mg reported by Palacios *et al.*⁽¹²⁾ in white girls. We used newly available values on Ca losses either due to the superior sample characteristics or better analytical approaches. Finally, in the factorial calculation, a value of 38% was used as the estimate of Ca absorption efficiency. This value was determined from a controlled metabolic study of 11–14 year-old girls given 1330 mg Ca per d⁽¹⁸⁾. In the absence of recent reliable data on Ca absorption efficiency during growth, we used the original value used in DRI factorial method. The value may be an overestimate as it was derived during the time of peak bone mineral accrual for girls, hence Ca need was greatest. On the other hand, it may underestimate Ca absorption efficiency at a lower (i.e. < 1330 mg) Ca intake and in boys^(22,12). Ca absorption efficacy is affected by vitamin D status. We did not measure vitamin D status of our subjects; however, sub-optimal vitamin D status has been reported in Canadian children and adolescents^(23,24). While all of these values are subjected to further refinement due to age and body size as well as adjustment for Ca intake, the value for Ca accrual is the largest component of the factorial equation. We determined Ca accrual differently in this analysis than we reported previously as the purpose then was to determine the age at, and the value for, peak bone mineral accrual^(5,9). We initially found Ca retention using a cross-sectional approach, and these data were used in the DRI factorial calculation for adolescent Ca requirement⁽⁴⁾. We then determined peak Ca accrual using a longitudinal analysis⁽⁹⁾ by finding each subject's peak bone mineral content velocity. The latter analysis found a retention that was approximately 30% higher than the cross-sectional approach. In the current analysis, we found Ca retention using longitudinal data and made our calculations based on chronological rather than biological age. Because the DRI life stage of adolescence begins before the onset of puberty and ends after puberty, then calculations using biological age are not necessary.

The Ca accrual values in Table 2 are based on a sample of Caucasian subjects. Therefore, it is not surprising our data are similar but not identical to those in Danish children⁽²⁵⁾. Using their cross-sectional data of BMC accrual over ages 8.5–18.5 years (boys, 171 g/year; girls, 152 g/year) and calculating Ca requirements from Ca accrual (boys, 151 mg/d; girls, 134 mg/year), the resulting Ca requirements are approximately 1100 mg for both boys and girls

(after rounding). One difference in these datasets may be Ca intake. Our cohort, particularly in the younger age range, has a reasonably good Ca intake (Table 1); however, as subjects age through adolescence, boys increase Ca intake while girls show a reduction (Table 1). Some of the decline in Ca intake may be due to under-reporting that appears to be greater in older adolescent girls than younger girls or boys, based on comparison of energy intake to estimated energy need⁽²⁶⁾. Ca intake of participants in our cohort seemed to be comparable with values reported by Kalkwarf *et al.*⁽²⁷⁾ in a longitudinal study of 1554 healthy children (761 boys, 793 girls) aged 6–16 years of all ethnicities except for boys aged 13–16 years (Table 1). They reported Ca intake of 1098 (SD 603) mg/d and 1119 (SD 712) mg/d for non-black boys at age groups of 9–12 and 13–16 years, respectively. The corresponding values for girls at age groups 9–12 and 13–16 years were 885 (SD 527) mg/d and 875 (SD 556) mg/d⁽²⁷⁾. Difference in dietary assessment method (FFQ in their study) might be responsible for partial dissimilarity. The ages of PHV of girls and boys in our cohort were similar to the Tanner stage 3 (breast) in 12.0 (SD 1.4) years of girls and Tanner stage 4 (testis) in 13.8 (SD 1.2) years in the study by Kalkwarf *et al.*⁽²⁷⁾. Consequently, TBBMC of boys and girls in our cohort were located between 50 and 90 TBBMC percentile of non-black boys and girls in corresponding chronological ages in Kalkwarf *et al.*'s⁽²⁷⁾ reference values. This may reflect the generalisability of our values to non-black adolescents.

Braun *et al.*⁽¹³⁾ in a 3-week metabolic balance studies of thirty-one boys aged 12–15 years suggested that more Ca retention in boys than in girls does not necessarily mean that Ca requirements for boys and girls should be different. They justify that a higher Ca absorption efficacy and lower Ca excretion in boys explain why there is no need for sex specific recommendation⁽¹³⁾. The explanation of Braun's *et al.* is based on the balanced studies that they have conducted in boys and girls who were in Tanner pubertal stages (3.5 and 3.7 in boys and girls, respectively). Biological difference exists in boys and girls in bone mineral accrual during growth with boys having more time to lay down mineral mass in their bones (14–17 years), while a sharp decline exists in girls' bone mass accumulation after starting the menstruation period^(14,15). By splitting the whole age range of 9–18 years to two age groups: 9–13 and 14–18 years, we have age and sex-specific values for Ca retention for adolescent that takes to account the biological difference in time and tempo of maturation in boys and girls.

In summary, we provide new data on Ca accrual during the whole age range of adolescence (9–18 years), which demonstrates the sex difference in time and pattern of Ca retention during adolescence. We are, however, unable to provide estimates of variability of Ca retention. One of the unique aspects of our data is estimating mean Ca requirements for adolescents using a factorial approach, where Ca retention data are obtained from longitudinal measurements in participants of different ages all in the same timeframe. In contrast to the 1997 DRI report on Ca, which used Ca accrual during peak Ca accretion over only the pubertal growth spurt, we use Ca retention data from age 9 to 18 years. In the former situation, an adequate intake of 1300 mg was chosen for the whole range of adolescence in both sexes. In the latter, we put forth an

estimated mean requirement of 1100 mg for boys and girls from age 9 to 13 years. For the age range of 14–18 years we estimated daily Ca intake of 1200 mg for boys and 1000 mg for girls. The biological differences due to sex in time and tempo of growth spurt have been considered in our calculations of Ca requirements.

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