Bone mineral changes during pregnancy and lactation: a longitudinal cohort study

Niels KOLTHOFF, Pia EIKEN, Bent KRISTENSEN and Stig Pors NIELSEN
Department of Clinical Physiology and Nuclear Medicine, Hillerød Hospital, DK-3400 Hillerød, Denmark

(Rceived 4 August/10 November 1997; accepted 26 November 1997)

1. The influence of pregnancy, lactation and weaning on bone mineral density in healthy women was investigated during a 2 year prospective study of 59 pregnant and lactating women from the 18th week of gestation.

2. Bone mineral density was measured by dual energy X-ray absorptiometry at the non-dominant radius ultra distally and more proximally in the 18th and 37th weeks of gestation, and 0, 3, 6, 12 and 18 months after delivery. Measurements of bone mineral density of the lumbar spine, the proximal femur and the whole body were performed at all dates after delivery.

3. Reappearance of menstruation after delivery averaged 6.1 months; mean lactating period was 8.7 months. During pregnancy and lactation bone mineral density tended to decrease, but different measuring sites showed different patterns of bone mineral density changes. The reduction in the ultra distal radius during pregnancy amounted to 2%, and no further changes were observed here during lactation. After delivery, reduction in mean bone mineral density was most pronounced in the spine (5.2% in 3 months), but the fall in bone mass tended to revert after resumption of menstruation. Bone mineral density was still reduced by 3.3% after 12 months in women with menstruation resumption later than 8 months after delivery. No significant reduction was observed 18 months after delivery. No association with calcium intake, weight changes or initial bone mineral density was observed. High calcium intake did not protect against bone mineral loss in the spine and the femur.

4. Thus it can be concluded that bone loss during pregnancy and lactation took place mainly from the trabecular skeleton. Resumption of menstruation tended to result in a regain of bone mass towards baseline.

INTRODUCTION

Retrospective investigations on the relation between bone mineral content (BMC) late in life and the influence of reproductive factors such as previous pregnancies, number of breast-fed children, total duration of lactation, etc. have been equivocal. Some studies have shown a direct proportionality, e.g. Fox et al. [1] showed a 1.4% increase in distal radius bone density with each additional birth in a study of 2230 postmenopausal women, while others have suggested inverse proportionality or no association, e.g. Kritz-Silverstein et al. [2]. In our cross-sectional study of non-pregnant, non-lactating Omani women with a maximum of 14 childbirths (average 5.1), we found no long-term association between multiparity and bone mass even though Omani women often breast-feed for more than 2 years and have more children than Westerners [3]. Epidemiological studies may fail to observe effects of pregnancy and breast-feeding because the bone loss might be followed by a subsequent recovery of bone mass.

Studies of markers of bone formation and bone resorption have suggested substantial biological bone activity during pregnancy and lactation. In a study of 10 long-term lactating women Zinaman et al. [4] observed that when plasma oestrogen was low, plasma osteocalcin (a marker of bone formation) and urine hydroxyproline (a marker of bone resorption) were increased, whereas reciprocal changes were noted when oestrogen levels were high. Yamaga et al. [5] followed 18 women from early pregnancy to 6 months after delivery. The biochemical markers revealed that both bone formation and bone resorption were elevated in the third trimester as well as during the puerperium, and that breast-feeding women had a significantly higher bone turnover than bottle-feeding women.

The aim of this longitudinal study was to investigate the influence of pregnancy, lactation and weaning on bone mineral density (BMD) in healthy women.

METHODS

Women investigated

Six-hundred healthy women in early pregnancy and referred for delivery were invited by mail to
participate in a study on bone mass during pregnancy and lactation. Exclusion criteria were any current condition that could affect calcium or bone metabolism, any use of relevant hormonal medication, and lactation less than 6 months before pregnancy. Fifty-nine singleton pregnant women who had healthy children at term and went through all assessments until 12 months after delivery were included in this investigation; 48 of those have been seen at the assessment 18 months after delivery.

All women were interviewed about their medical history, actual and previous physical activities (type, duration), and standing/walking habits during working hours. Calcium intake was estimated from a questionnaire adapted from Fardellone et al. [6], concerning average daily consumption of food and drink, including dairy products and calcium, mineral and vitamin supplementation. After delivery the length of lactation was registered as (i) number of months when fully breast-feeding (i.e. more than approximately 75% of the nutrition to the child coming from lactation), and (ii) number of months of any daily lactation. The date for resumption of menstruation was noted, and the number of months from delivery to the start of menstruation was calculated. The women were subdivided into three groups according to time until resumption of menstruation after delivery: group A <4.0 months, group B 4.0-7.9 months, and group C >8.0 months.

Assessments were made at the inclusion visit 18 (15-24) weeks after the last menstruation, 37 (35-39) weeks after the last menstruation (W18 and W37 respectively) and 0 (M0), 3 (M3), 6 (M6), 12 (M12), and 18 (M18) months after delivery [mean (range) 0.25 (0.0-1.4), 3.3 (2.8-4.3), 6.4 (5.6-8.4), 12.5 (11.9-14.8) and 18.6 (17.0-19.7) months after delivery respectively.

Bone mineral measurements were performed by dual energy X-ray absorptiometry with a Hologic QDR-2000 bone densitometer (Hologic Inc., Waltham, MA, U.S.A.). Lateral measurements of the lumbar spine were done in fan-beam mode (the only one available with this type of measurement for lateral scanning); all other measurements were performed in single-beam mode because of problems of accuracy and precision with the fan beam mode [7].

BMD (g/cm²) was measured at the ultra distal region (UD radius) and more proximally of the non-dominant radius (1/3 radius). After delivery supplementary measurements were performed of the lumbar spine in posterior–anterior (PA) (L2–L4) and lateral (lat) projection (L3); the right femur neck was measured in the PA projection. Lateral measurements of L3 were analysed both for the total (lat L3tot) and the mid-subregion of the vertebral body (lat L3mid). Measurements of whole-body BMC (g) and body composition [lean body mass (g) and fat mass (g)] were performed in 26 women. All measurements and analyses were done according to the Hologic operator's manual and analysed twice by one operator.

Short-time precision errors (coefficient of variation) of BMD measurements of the lumbar spine (AP and lattot), the femoral neck and the radius (UD and 1/3), estimated by repeated measurements within 2 h with intermediate repositioning, of 25 healthy, early postmenopausal women were 1.1, 4.8, 1.4, 1.7 and 1.7% respectively; the coefficients of variation of whole-body BMC, fat and lean mass measurements were 0.5, 2.1 and 0.9% respectively. The long-time precision error of BMD measurements (coefficient of variation), judged from 922 measurements of one anthropometric spine phantom (Hologic Spine Phantom 451) during the study period (January 1994–December 1996) was 0.3% (N. Kolthoff, unpublished work).

The Z-score, which is a measure of the difference between the measured value at baseline and that of age-matched peers, defined as (P-M)/S.D., where P denotes the baseline value, M is the mean value for sex- and age-matched controls, and S.D. the standard deviation of the mean value for sex- and age-matched controls, was calculated with the Hologic software, using the manufacturer's reference material.

Statistics

Assuming a linear change in BMD over time, summary statistical methods [8] were used to calculate BMD changes at all measuring sites. For each subject the change in BMD between measurements was computed using the individual number of days between measurements x 1/30 (expressed in terms of g/cm² per month), and the percentage change in BMD was calculated. The individual net changes in lumbar spine PA BMD and femoral neck BMD were further expressed as the area under the curve (AUC, mg/cm²/year). Cumulated sum (CUSUM) curves of the individual net change at assessments M3, M6, M12 and M18 were performed as the cumulated sum of AUC (mg/cm²/year), ranked according to months until resumption of menstruation after delivery. Pearson's correlation coefficient (r) was used for linear correlation analysis; two-sided one-sample Student's t-test was used for analysing means. Differences between groups were tested using one-way analysis of variance and two-sample Student's t-test (SPSS for "Windows", release 6.1; Base module).

The chosen significance limit was P = 0.01.

Laboratory tests

Blood samples were obtained for measurement of thyroid-stimulating hormone at baseline. Serum alkaline phosphatase, albumin, total calcium, albumin adjusted calcium, magnesium and phosphorus were measured at baseline, W37 and M3.

All women gave their written informed consent. The study was carried out in accordance with the
Helsinki II Declaration after approval by the State Institute of Radiation Hygiene and the local Ethics Committee.

RESULTS

Mean age (range) at inclusion was 31.9 (24.2–41.9) years, height 169 (157–189) cm, body weight 67.7 (43.4–102.2) kg, and body mass index 23.9 (16.5–38.0). Mean number of former children was 1.1 (0–4); 10 women were pregnant for the first time. All laboratory tests were within normal ranges.

Time to resumption of menstruation after delivery averaged 6.1 (range 1.0–18.0) months. The main characteristics for the women, grouped according to the number of months from delivery to resumption of menstruation, are shown in Table 1. It can be seen that there were no statistical differences between the groups except for resumption of menstruation and duration of lactation.

Three, six, nine and twelve months after delivery respectively, 92, 66, 41 and 25% of the women were lactating, and 15, 64, 78 and 93% respectively had resumed menstruation. All women had resumed their menstruation before the last assessment. The mean lactating period was 8.7 (range 0.8–18) months. Supplementary solid food was usually introduced to the infant 4–6 months post partum.

Nine women were lactating at the last assessment; two at M12 and seven at M18 respectively. The individual association between resumption of menstruation and duration of lactation is shown in Fig. 1.

The average (range) estimated daily calcium intake at inclusion was 1792 (687–4814) mg/day including calcium supplementation. No significant differences regarding calcium intake were observed between the groups (Table 1). Only six women had an estimated daily calcium intake below 1000 mg (three in group A, one in group B and two in group C), and only two of these took less than 800 mg daily [one in group A (757 mg) and one in group B (687 mg)]. Fifty-six per cent of the women (n = 33) had daily intakes of more than 1200 mg calcium from food alone; 83% (n = 49) had daily calcium intakes above 1200 mg when calcium supplementation was included. Usually, there were only minor changes in calcium intake during pregnancy and lactation.

Changes in mean body weight (S.D.) over time as a percentage of baseline body weight were W37, 114.0 (6.0); M0, 104.0 (5.9); M3, 98.5 (5.4); M6, 97.1 (5.4); M12, 95.4 (5.0); and M18, 95.9 (5.9). No significant differences were found between groups A, B and C.

Measurements of BMD at baseline

Mean values of BMD and Z-scores at baseline are shown in Table 2. The BMD values did not differ from normal reference values; mean Z-scores were close to zero and S.D. of the Z-score close to one at all measure sites. No differences in mean BMD were found between groups A, B and C at any measuring site.

Longitudinal BMD measurements

Mean BMD (S.D.) values over time of the radius (1/3 and UD), the lumbar spine PA and the femoral neck (as percentage of baseline value) are shown in Fig. 2. Large differences in magnitude and duration of the bone mineral losses are seen, with the most pronounced reduction in mean BMD in the lumbar spine. After resumption of menstruation, the fall in bone mass tended to revert in the lumbar spine and femur. In general, time until resumption of menstruation was slightly more discriminating than the duration of lactation when individual changes in BMD over time were considered, both factors being closely interrelated. The former was chosen for the

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>16</td>
<td>26</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>31.2 (24.2–35.7)</td>
<td>31.2 (25.4–40.2)</td>
<td>32.5 (24.6–41.9)</td>
<td>0.15 (NS)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169 (160–181)</td>
<td>167 (157–177)</td>
<td>171 (161–189)</td>
<td>0.14 (NS)</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>70.8 (48.1–102.2)</td>
<td>67.2 (43.4–86.4)</td>
<td>65.5 (56.4–76.0)</td>
<td>0.31 (NS)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.7 (18.9–39.0)</td>
<td>24.1 (16.5–31.9)</td>
<td>22.6 (19.8–27.5)</td>
<td>0.23 (NS)</td>
</tr>
<tr>
<td>Menarche (years)</td>
<td>14 (10–16)</td>
<td>13 (12–17)</td>
<td>14 (12–17)</td>
<td>0.47 (NS)</td>
</tr>
<tr>
<td>Parity (°)</td>
<td>0.9 (0–3)</td>
<td>1.2 (0–3)</td>
<td>1.1 (0–4)</td>
<td>0.87 (NS)</td>
</tr>
<tr>
<td>Calcium intake (mg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ suppl.</td>
<td>1624 (757–3257)</td>
<td>1223 (526–1874)</td>
<td>1299 (673–2947)</td>
<td>0.12 (NS)</td>
</tr>
<tr>
<td>+ suppl.</td>
<td>1974 (757–4057)</td>
<td>1694 (687–2446)</td>
<td>1770 (913–2947)</td>
<td>0.46 (NS)</td>
</tr>
<tr>
<td>Delivery (weeks of gestation)</td>
<td>40.5 (38.0–42.2)</td>
<td>40.7 (39.0–43.0)</td>
<td>40.4 (37.0–43.0)</td>
<td>0.90 (NS)</td>
</tr>
<tr>
<td>Resumption of menstruation (months after delivery)</td>
<td>2.3 (1.0–3.8)</td>
<td>5.3 (4.0–7.8)</td>
<td>11.0 (8.0–18.0)</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Duration of lactation (months after delivery)</td>
<td>4.8 (0.6–13.0)</td>
<td>8.8 (3.0–18.0)</td>
<td>12.2 (6.0–18.0)</td>
<td>&lt;0.00001</td>
</tr>
</tbody>
</table>
Fig. 1. Individual duration of lactation (in months) versus resumption of menstruation (in months after delivery). Group A (n = 16, ●) were menstruating after 2.3 months, group B (n = 26, ▲) after 5.3 months, and group C (n = 17, ▼) after 11.0 months on average. The regression line with 95% confidence interval is shown for each group (r = 0.67, P < 0.001, n = 59; slope 0.87, intercept 3.4). Nine women were lactating at the last assessment (three at M18 in group B, two at M12 and four at M18 in group C).

Fig. 2. Changes in BMD during and after pregnancy. ●, 1/3 radius; ▲, UD radius; ▲, lumbar spine PA; ▼, femoral neck. Mean values are expressed as a percentage of baseline value. n = 59 (n = 48 at M18). Bars represent S.D.

Table 2. BMD and coherent Z-scores at baseline. The BMD values did not differ from normal reference values: mean Z-scores were close to zero and S.D. of the Z-score close to one at all measured sites. Values are means (S.D.).

<table>
<thead>
<tr>
<th>Site</th>
<th>BMD (g/cm²)</th>
<th>Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>UD radius</td>
<td>0.422 (0.048)</td>
<td>0.27 (0.84)</td>
</tr>
<tr>
<td>1/3 radius</td>
<td>0.697 (0.045)</td>
<td>0.21 (0.77)</td>
</tr>
<tr>
<td>L2-L4 PA</td>
<td>1.074 (0.135)</td>
<td>0.01 (1.23)</td>
</tr>
<tr>
<td>Lat L3/promx</td>
<td>0.773 (0.081)</td>
<td>-0.12 (0.95)</td>
</tr>
<tr>
<td>Femur neck</td>
<td>0.862 (0.104)</td>
<td>-0.15 (1.05)</td>
</tr>
</tbody>
</table>

Later resumption of menstruation (and longer duration of lactation) was associated with larger individual net losses in BMD 1 year after delivery (r = -0.54, P < 0.01). The average individual maximum change in BMD [percentage of baseline BMD value (S.D.)] was -3.6% (2.8), -6.4% (3.7) and -9.0% (4.3) in groups A, B and C respectively, the mean of group C being significantly different from the mean of group A (P < 0.001). Twelve women had maximum BMD losses of more than 10%. All of these women had estimated daily calcium intakes of more than 1200 mg from food alone, and seven had a daily intake of more than 1600 mg of calcium, inclusive of calcium supplementation. Mean BMD at
Bone mineral changes during pregnancy and lactation

100 - 90 - 80 - 70 - 60 - 50

Baseline was similar to that of the other participants, but resumption of menstruation was observed later than 8 months after delivery in 10 of these 12 women, who lactated for an average of 13 months (only one lactated for less than 8 months).

CUSUM test

The individual net changes in lumbar spine BMD at assessments M3, M6, M12 and M18, expressed as the cumulated sum of AUC, ranked according to months until resumption of menstruation after delivery, are shown in Fig. 4.

Effect of age

No differences in baseline BMD or in BMD changes during the study were observed between women under 32 years and women over 32 years.

Lateral scanning

Mean lumbar spine lat L3mid BMD showed no significant changes in groups B and C until M3. From M6 until M12 the mean BMD in groups A and B increased by 1.4 and 2.7% per month respectively (*P < 0.01 by t-test). Large individual variations were observed.

Lumbar spine lat L3tot provided no further information; neither did any width adjusted measurements.

Femoral neck

BMD reduction averaged 5.3% during the first 6 months after delivery (Fig. 3, bottom). In groups B and C, the nadir of mean BMD was seen at M6. In...
group A, no extra bone loss was detected after M3. The mean BMD showed an average decrease of 0.3% per month from M0 to M18 ($P<0.01$ by $t$-test) in group C.

CUSUM curves for the femoral neck showed, like CUSUM curves for the lumbar spine, more negative slopes of the curves at M12 and M18 for women with resumption of menstruation later than around 9 months after delivery (greater bone loss in these women), the differences being more obvious in the lumbar spine. No signs of net bone mineral gain were observed for the femoral neck.

**Whole body**

Whole-body BMC changes as a percentage of baseline values are shown in Fig. 5. Large individual variations in lean and fat mass changes were observed over time. After M3, the fat mass was significantly lower in women with earlier resumption of menstruation ($n=9$) compared with women with earlier resumption of menstruation ($n=17$) ($P<0.01$ by $t$-test); e.g. mean (S.D.) fat mass as percentage of baseline value was 76 (13) versus 92 (12) respectively at M12. No significant differences were observed in lean body mass.

**DISCUSSION**

During pregnancy and lactation the calcium homoeostasis must adapt to large demands for calcium. The total content of calcium for an average woman is about 1000 g, 99% being located in the skeleton. A full-term infant needs 30 g of elemental calcium for full development. Two-thirds of this amount is accumulated during the last trimester of pregnancy. After delivery the calcium needs are more variable. The maternal calcium losses depend during lactation on the length of the lactation period, the breast milk calcium concentration, and the amount of breast milk produced. A daily intake of 120–250 mg of calcium by the infant seems to be normal during lactation. However, large inter-individual differences in daily breast-milk calcium concentrations and amounts have been observed with some mothers secreting more than 300 mg calcium per day [9]. The total skeletal calcium losses during pregnancy and lactation of a mother, who delivers at term and fully breast-feeds her baby for 6 months, would be in the region of 7% [(30 – 40) g/1000 g], if the skeleton were the only source of calcium.

The impact of the maternal calcium losses on the maternal skeleton is modified by other mechanisms. Pregnancy appears to be a state of positive calcium balance [10]. Kent et al. [11] detected an increase in intestinal calcium absorption capacity in late pregnancy. Increased 1,25-dihydroxyvitamin-D levels are believed to be responsible for this adaptation, but no consistent increase and no improved intestinal calcium absorption have been detected during lactation [10–12]. Kalkwarf et al. [13] concluded that lactation stimulates fractional calcium absorption and serum calcitriol, but these responses were only apparent after weaning or the resumption of menstruation.

After delivery, the high levels of oestrogen produced by the placenta disappear, and hypo-oestrogenaemia is seen within 1 week [14, 15]. Lactation is associated with high levels of prolactin [14, 15], causing a prolonged suppression of the hypothalamic–pituitary axis and amenorrhoea [16]. Recently, Sowers et al. [17] showed that high parathyroid hormone-related peptide concentrations are associated with the breast-feeding status, elevated prolactin levels and lower oestrogen levels, but negatively associated with the BMD changes in the spine and the femoral neck over time.

Prospective bone mineral studies related to pregnancy are sparse. We detected a 2% BMD reduction in the mainly trabecular 'UD radius', but no changes at all in the more proximal, compact '1/3 radius'. This is in accordance with Lamke et al. [18], who observed losses of trabecular, but not cortical bone in the forearm in 14 women. Drinkwater and Chesnut [19] observed bone losses in the radial shaft, but not in the distal part (!), and in the femoral neck, but only six subjects were measured before pregnancy and again within 6 weeks after parturition. Christiansen et al. [20] and Kent et al. [21] observed no forearm changes during pregnancy. Sowers et al. [22] did not find any significant differences between femoral neck bone mineral changes in 32 women measured before conception and again within 2 weeks after delivery compared with non-pregnant controls. Sowers et al. [23] further studied the pos-
Possible effect on spine and hip BMD of a subsequent pregnancy within 18 months after initiating lactation; no differences in changes of bone mass were found in these 25 women compared with a group of lactating, non-pregnant women. Laskey and Prentice [24] followed 12 women during and after lactation. Significant BMC reductions were seen in the spine, femoral neck and whole body during breast-feeding, but the changes were reversible and did not persist during a subsequent pregnancy, even when conception occurred during breast-feeding at the time when bone loss was still evident.

In the post partum period, our present longitudinal investigation demonstrates large and rapid mean bone mineral losses in the lumbar spine and the femoral neck. Those results are in agreement with other prospective studies conducted during lactation [23–32]. We had no non-lactating post-partum controls. Thus, the post-partum results cannot be ascribed to lactation per se, but two of the former studies demonstrate that these post-partum changes in bone are associated specifically with lactation and do not occur in women who do not lactate [26, 29].

On the other hand, the compact bone of ‘1/3 radius’ showed no changes at all. Also we observed no significant change of the UD radius BMD after delivery, the most pronounced loss for the UD radius BMD being seen in the period from W37 until M0. This is contrary to the findings of Kent et al. [21], who detected a 3% BMD loss in the UD radius between the 36th week of gestation and the 24th week of lactation but no change in bottle-feeding women, Cross et al. [27], who observed BMD losses in the UD and ‘1/3’ radius during the post-weaning period, and Affinito et al. [31], who detected a 5% BMD loss in the distal ‘1/10’ radius 6 months after delivery among breast-feeding women. The rapid bone mineral loss related to late pregnancy could in part account for the BMD loss of the UD radius detected by Kent et al. [21].

The patterns of changes in the lumbar spine and femoral neck BMD during lactation are similar to those detected during suppression with a gonadotropin-releasing hormone agonist, which in eumenorrhoic women was reported to result in a bone loss of 4% during 6 months of treatment and a regain towards baseline after treatment [33]. In our investigation, BMD losses larger than average were observed in women who lactated for a long period and resumed menses more than 8 months after delivery. Only women who resumed menstruation within 8 months regained their lumbar spine bone losses completely after 1 year. Differences in mean BMD between women with early and late resumption of menstruation were diminished and no longer significant in the lumbar spine and the femoral neck 18 months after delivery, suggesting that the bone deficit may not be permanent, and that recovery occurs after an extended period of time, when the impact on the hormonal balance of the lactation has been diminished (number of suckling episodes per day and length of weaning periods were not considered as single determinants of BMD in our study).

The number of months until resumption of menstruation after delivery was found to be the best determinant of the magnitude and duration of the bone loss, and the subsequent regain of bone mineral in the lumbar spine and femoral neck. However, the number of months until resumption of menstruation discriminated only slightly better than the duration of lactation when the individual changes in BMD over time were considered, both factors being closely interrelated. By changing lactation habits the time until regain of menstruation may be altered [14, 15], and so duration and magnitude of the temporary bone mineral changes.

Results of longitudinal measurements of the lateral lumbar spine post partum have never before been published. We expected to find larger losses of the mainly trabecular vertebral bodies and did so, but greater individual variations and greater precision errors gave statistically less significant changes compared with lumbar spine PA measurements.

We observed no association between bone mass changes and calcium intake, nor between bone mass changes and changes in body weight. This is in accordance with the findings of other investigations [27, 32, 34], suggesting that hormonal changes are the major determinants of bone mineral changes post partum.

Only six women had an estimated daily calcium intake below 1000 mg in our investigation. The bone mineral alterations of these six subjects were no different from those of the other participants. Neither did Cross et al. [27] and Kalkwarf et al. [32] find any effect of 1000 mg of calcium supplementation per day. In the latter investigation of women with low- to-moderate baseline intake of calcium, a small increment of BMD in the spine was observed in response to calcium supplementation among lactating women as well as among non-lactating ones, but bone loss during lactation was not prevented. Bone density increased after weaning both in women who received calcium and in those who did not. No effects were seen on breast milk calcium concentrations [32].

The dietary reference intake of calcium during pregnancy and lactation differs markedly between countries (Table 3). According to a recent editorial in the New England Journal of Medicine ‘accumulating scientific data suggest that breast-feeding women need not consume extra calcium’, assuming good nutrition, including adequate calcium intake [37]. Our data might suggest that the actual calcium intakes are suboptimal in the population studied. However, our study was not designed to detect the optimal calcium intake.

In conclusion, our findings suggest that the calcium needed for infant skeletal growth during pregnancy and lactation is drawn mainly from the maternal trabecular skeleton. Time until resumption
of menstruation and duration of lactation (both closely associated) were the best indicators of the magnitude and the duration of temporary changes in lumbar spine and femoral BMD. Calcium intake, body weight or initial BMD were not associated with these bone mineral changes.

ACKNOWLEDGMENTS

We are grateful for the technical assistance of Mrs Elisabeth Stark and Mrs Hanne Kobbernage1. We also thank Dr Kristian Jacobsen, Department of Obstetrics and Gynaecology, for helping with initial contact to participants. Statistical analysis was initially supported by the Danish Medical Research Council. We gratefully acknowledge financial support from the Foundation for Medical Research at Hospitals in the counties of Bornholm, Frederiksborg, Storstrom, and Vest-Jealand (Region 3), Olga Bryde Nielsen Foundation, King Christian IX and Queen Louise Foundation, and 10th June Foundation.

REFERENCES