Bone mass is recovered from lactation to postweaning in adolescent mothers with low calcium intakes1–3

Flávia F Bezerra, Laura MC Mendonça, Erika C Lobato, Kimberly O O’Brien, and Carmen M Donangelo

ABSTRACT

Background: Adolescent mothers may be at increased risk of irreversible bone loss during pregnancy and lactation, particularly when calcium intake is low.

Objective: Longitudinal changes in bone mass from lactation to postweaning were evaluated in 10 adolescent mothers aged 15–18 y who habitually consumed <500 mg Ca/d.

Design: Total-body bone mineral content (TBBMC), total-body bone mineral density (TBBMD), and lumbar spine bone mineral density (LSBMD) were measured at lactation (6–24 wk postpartum) and after weaning (12–30 mo postpartum). Serum hormones (intact parathyroid hormone, estradiol, and prolactin), serum calcium, and markers of bone turnover [urinary N-telopeptide cross-linking region of type I collagen (NTx) and plasma activity of bone alkaline phosphatase] were measured at lactation.

Results: TBBMC, total calcium content, TBBMD, and LSBMD increased from lactation to postweaning (P < 0.01). TBBMD and LSBMD were, respectively, 3.6% and 9.7% lower than predicted at lactation and 0.3% and 4.8% lower than predicted in the postweaning period. The increase in age-matched TBBMD adequacy was correlated with the time after resumption of menses (r = 0.86, P < 0.01). Calcium accretion from lactation to postweaning correlated negatively with estradiol (r = −0.86) and prolactin (r = −0.69) and positively with intact parathyroid hormone (r = 0.72) and NTx (r = 0.84) measured at lactation (P < 0.05).


KEY WORDS Adolescent mothers, lactation, weaning, bone mineral density, calcium, Rio de Janeiro

INTRODUCTION

Lactation promotes a temporary loss of bone to provide adequate amounts of calcium for milk production (1, 2). Several studies have shown that, during this period, adult mothers lose 3–9% of their bone mineral density (BMD), especially at trabecular bone–rich sites (3). Despite the important decrease in bone mass during lactation, longitudinal studies have shown an almost complete recovery of bone density in the postweaning period (4–7). Bone changes during lactation have been extensively studied in adult mothers and appear to occur irrespective of habitual calcium intake (6–9). Less is known about changes in bone density during lactation in adolescent mothers.

Adolescence is a critical time for bone mass acquisition. It is well recognized that the rate of bone accretion peaks during pubertal growth because of hormonal changes, including changes in concentrations of sex steroids (10, 11). Environmental factors that may contribute to optimization of bone accretion during adolescence, within the limits of genetics, include physical activity and calcium intake (11, 12). Optimizing bone acquisition during adolescent growth may contribute to the adequacy of bone mineral content (BMC) throughout life and is considered an efficient strategy to protect against osteoporosis (11). On the other hand, common physiologic conditions in adolescence that may adversely affect bone acquisition, such as pregnancy and lactation, need to be investigated.

Few studies have evaluated bone changes during pregnancy and lactation in adolescent mothers. Studies using ultrasound measures observed that adolescent mothers lose more bone than do adults during pregnancy (13) and during lactation (14). Adolescents with higher calcium intakes during pregnancy appear to be protected against loss of trabecular bone in the early postpartum period (15). BMC decreased 10% after 16 wk of lactation in adolescent mothers consuming 900 mg Ca/d but no loss was observed in those consuming >1600 mg Ca/d (16). These studies support the hypothesis of an increased susceptibility of bone loss during pregnancy and lactation in adolescents, especially when calcium intake is low. It is not known, however, whether adolescents are able to recover bone mass in the postweaning period at the same level as when they were not pregnant and not lactating. The aim of the present study was to evaluate longitudinal...

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changes in bone mass from lactation to postweaning in adolescent mothers who habitually consume low-calcium diets (<500 mg Ca/d).

SUBJECTS AND METHODS

Subjects

Ten lactating adolescents aged 15–18 y were recruited from a public health center in Rio de Janeiro with the intention of following them for ≥12 mo postpartum. Written informed consent was obtained from each subject and a responsible adult. All women were healthy, primiparous nonsmokers and gave birth to healthy full-term infants. At the time of entry into the study, the participants were 6–24 wk postpartum, exclusively or predominantly breastfeeding, and none of them had resumed menses. The study protocol was approved by the Ethical Committee of the State Health Secretary of Rio de Janeiro.

Study design

BMD was evaluated at 2 time points for each woman: lactation (6–24 wk postpartum) and postweaning (12–30 mo postpartum). Weaning was defined as no more than one period of breastfeeding per day.

Morning fasting blood (10 mL) and urine (50 mL) samples were obtained during lactation. The blood samples were obtained within 30 min after a suckling episode. Aliquots of plasma, serum, and urine—acidified with hydrochloric acid and nonacidified—were stored at −20 °C until analyzed.

Habitual calcium intake was assessed with the use of four 24-h dietary recall questionnaires applied at lactation and during the postweaning period. Dietary nutrient analysis was conducted with the THE FOOD PROCESSOR program (ESHA Research, Salem, OR) by using the database adapted to Brazilian foods based on published information (17).

Laboratory analysis

Calcium in serum was measured with methyl thymol blue (BioMérieux, Marcy-Etoile, France). Serum prolactin was measured with an immunoradiometric assay (Diagnostic Products Corporation, Los Angeles). Serum estradiol was measured by radioimmunoassy (Diagnostic Products Corporation, Los Angeles). Serum intact parathyroid hormone (iPTH) was determined with a chemiluminescent enzyme-labeled immunometric assay (Diagnostic Products Corporation). Plasma activity of bone-specific alkaline phosphatase was measured according to Farley et al (18). The N-telopeptide cross-linking region of type I collagen (NTx) was measured in urine samples with an enzyme-linked immunosorbent assay (Ostex International Inc, Seattle) and expressed as a creatinine ratio. Urinary creatinine was determined by the Jaffe reaction, according to Husdan and Rapoport (19). All materials used for sample collection, storage, and analysis were either disposable or previously soaked overnight in dilute nitric acid (1:4, by vol) and rinsed with deionized water.

Bone measurements

Total-body BMC (TBBMC), total-body BMD (TBBMD), and lumbar spine (L2–L4) BMD (LSBMD) were assessed at lactation and postweaning by dual-energy X-ray absorptiometry with the Lunar DPX densitometer with software version 4.6A (Lunar Radiation Corporation, Madison, WI). The percentage adequacy of bone measurements and z scores were obtained by comparison with an age-matched reference with the use of the Lunar DPX normative values based on North American and European populations. There is evidence that these populations are appropriate as a reference for the Brazilian population (20). Total-body calcium content was calculated as 38% of TBBMC (21).

RESULTS

Mean age at entry in the study (6–24 wk postpartum) was 16.2 y (Table 1). In all but one adolescent, <6 y had elapsed since the onset of menses. The median years elapsed since the onset of menarche was 3 y. Body mass index (in kg/m²) values (mean: 23.4) were within the normal range or slightly increased, as expected during the first weeks postpartum. Mean dietary intake of calcium at entry in the study (444 ± 288 mg Ca/d) was close to that expected during lactation. Calcium intake in the postweaning period (402 ± 238 mg Ca/d) was similar to that observed during lactation.

Concentrations of serum calcium, hormones (iPTH, estradiol, and prolactin), and markers of bone turnover (NTx and bone-specific alkaline phosphatase) at lactation are shown in Table 2.

| Table 1 | General characteristics of the adolescent mothers  
| --- | ---  
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>16.2 ± 0.9 (15–18)</td>
</tr>
<tr>
<td>Time elapsed since menarche (y)</td>
<td>4.2 ± 2.3 (2–9)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.4 ± 4.5 (18.5–30.0)</td>
</tr>
<tr>
<td>Time postpartum (wk)</td>
<td>12.2 ± 5.2 (6–24)</td>
</tr>
<tr>
<td>Dietary calcium intake (mg/d)</td>
<td>444 ± 288 (110–973)</td>
</tr>
<tr>
<td>Duration of lactation (mo)</td>
<td>10.8 ± 6.0 (4–24)</td>
</tr>
<tr>
<td>Duration of postpartum amenorrhea (mo)</td>
<td>5.8 ± 3.3 (2–10)</td>
</tr>
</tbody>
</table>

1 Values are ± SD; range in parentheses. n = 10.

2 At entry in the study (lactation).

Index | Value |
--- | --- |
Serum calcium (mmol/L)  | 2.54 ± 0.29 |
Serum iPTH (pmol/L)  | 2.14 ± 0.90 |
Serum estradiol (nmol/L)  | 0.17 ± 0.07 |
Serum prolactin (ng/mL)  | 40.1 ± 29.1 |
Plasma bone-specific alkaline phosphatase (U/L)  | 20.8 ± 5.2 |
Urinary NTx (nmol/mmol creatinine)  | 198.2 ± 60.4 |

1 All values are ± SD; n = 10. Lactation, 6–24 wk postpartum; iPTH, intact parathyroid hormone; NTx, N-telopeptide cross-linking region of type I collagen.
Biochemical indexes were not influenced by the length of time elapsed postpartum or by the years since menarche.

Bone status evaluation

TBBMC, total calcium content, TBBMD, and LSBMD increased from lactation to postweaning in all adolescents (Table 3). Mean increases in TBBMC, total calcium content, TBBMD, and LSBMD were 4.5%, 4.8%, 3.9%, and 6.3%, respectively. Estimated daily calcium accretion from lactation to postweaning was 0.082 ± 0.067 g (median: 0.081 g). Bone measurements at lactation were significantly associated with postmenarcheal period (r ≥ 0.66, P < 0.05). Increases in bone measurements from lactation to postweaning were not influenced by years elapsed since menarche, except for LSBMD, which tended to be higher when the time since menarche was <3 y (n = 5) than when it was ≥3 y (n = 5): 0.095 ± 0.06 and 0.137 ± 0.10, respectively (P < 0.10).

At lactation, bone density adequacy for age was on average lower than that predicted for TBBMD (3.6%) and for LSBMD (9.7%) (Table 4). The deficit in LSBMD was 13–28% in 5 (50%) of the adolescents. In the postweaning period, deficits in bone density were 0.3% and 4.8% for TBBMD and LSBMD, respectively. Bone density adequacy for age increased from lactation to postweaning in all of the adolescents, although 3 continued to have deficits in LSBMD ranging from 13% to 14%.

The increase in age-matched TBBMD adequacy from lactation to postweaning was positively correlated with the period of time (months) after the resumption of menses (r = 0.86, P < 0.002). Similar, but nonsignificant trends (P < 0.10), were also found for increases in TBBMC (r = 0.63) and LSBMD (r = 0.60). Changes in TBBMC, TBBMD, and LSBMD were not correlated with either the period of time after weaning or with the interval between lactation and postweaning measurements. The increase in LSBMD z score correlated positively, although not significantly, with the habitual calcium intake (r = 0.58, P = 0.09).

Associations between bone mass and biochemical indexes

At lactation, TBBMD and LSBMD correlated positively with serum estradiol concentrations and negatively with serum iPTH (Table 5). Similar correlations were observed when z scores were used instead of TBBMD and LSBMD.

In the postweaning period, bone measurements were associated with the hormones measured at lactation (Table 5). TBBMD and LSBMD were negatively correlated with serum iPTH. LSBMD also correlated positively with serum estradiol. Similar results were obtained when z scores were used. Increases in TBBMC and in LSBMD from lactation to postweaning correlated positively with serum iPTH and negatively with serum estradiol. Total and daily calcium accretion from lactation to postweaning correlated negatively with serum prolactin and serum estradiol. Total calcium accretion correlated positively with serum iPTH and urinary NTx concentrations at lactation.

DISCUSSION

The reversible bone loss that occurs during lactation in adult women is well documented (3). The present study provides evidence that a similar pattern of bone loss during lactation and bone recovery after weaning occurs in adolescent mothers. Our study is the first one to report longitudinal changes in bone density from lactation to postweaning in adolescents with a habitually low calcium intake (mean: <500 mg Ca/d). Low calcium intake appears to be common in Brazilian adolescents (24, 25).
than the predicted value, with one-third of the adolescents having was on average adequate for age, but LSBMD was 4.8% lower in adult women (5–7, 9). In the postweaning period, TBBMD during lactation in adolescent mothers, as also observed in studies of adult women (5–7, 9). In the postweaning period, TBBMD was on average adequate for age, but LSBMD was 4.8% lower than the predicted value, with one-third of the adolescents having deficits of ≥13%. This finding indicates a recovery of bone mass after weaning that may be less complete than that seen in adult women (4–9). Although lactation and postweaning bone measurements were not made at similar intervals in all subjects, the elapsed time did not significantly affect the observed changes in bone. However, adolescents that delivered an infant within 3 y elapsed time did not significantly affect the observed changes in bone. However, adolescents that delivered an infant within 3 y after the onset of menses tended to have a more pronounced lumbar spine bone recovery after weaning, which may be indicative of an increased efficiency of bone accretion postweaning in those who are skeletally less mature. Further studies are needed to confirm this possibility. As previously observed in adults (7), the resumption of menses was also a significant determinant of bone recovery in these lactating adolescents.

The estimated daily bone calcium accretion observed from lactation to postweaning (81 mg/d) was comparable with the calcium accretion rate (61 mg/d) observed in adolescents of similar age and postmenarcheal stage (26). This comparable rate of calcium accretion was achieved, however, with a habitual calcium intake of <50% of that reported in the study by Mølgaard et al (26). This suggests a more efficient utilization of dietary calcium (high calcium absorption) in Brazilian lactating adolescents, as was observed in Brazilian lactating adults with similarly low calcium intakes (27). However, this calcium accretion rate may not be sufficient for the recovery of bone loss during pregnancy and lactation in adolescent mothers. Significantly greater bone losses have been reported in pregnant (13) and lactating (14) adolescents than in women. The findings of the current study suggest that this higher loss may be followed by an insufficient recovery of bone mass postweaning. Therefore, pregnancy and lactation may limit bone mineral acquisition in adolescent mothers.

Markers of bone turnover were high at lactation, as previously observed in lactating adolescents (24). Higher bone turnover during lactation appeared to favor later bone recovery, because calcium accretion from lactation to postweaning was more pronounced in those adolescents who had higher bone resorption (urinary NTx) during lactation. This suggests a compensatory mechanism that contributes to catch-up bone growth in those with increased bone turnover during lactation.

Although there is no indication that the classic calcitropic hormones regulate changes in BMD during lactation in adult women (3, 5, 8), PTH may be involved in calcium and bone metabolic changes during lactation in adolescent mothers when calcium intake is low. The association between the observed bone recovery in the postweaning period and iPTH concentrations in our study is consistent with this hypothesis.

Estradiol has a recognized effect on bone, stimulating osteoblastic activity (28), and it may influence bone changes in lactating adolescents, as suggested by the findings of our study. Although lactation is a classic hypoestrogenemic state, higher circulating estrogen concentrations in lactating adolescents appear to protect bones from excessive loss, thus favoring bone recovery after weaning. Similar results were observed during lactation in women (5).

Prolactin has been suggested to stimulate bone mobilization during lactation (3), although studies relating bone density changes with prolactin concentrations during lactation in women are controversial (5, 29). In our study, prolactin concentrations did not affect bone density measurements, but bone calcium accretion from lactation to postweaning was negatively associated with prolactin concentrations at lactation, which suggests a limiting effect of prolactin on bone recovery in adolescent mothers.

Our study evaluated adolescent mothers who habitually consumed about one-third of the recommended calcium intake; it is possible that different results could have been obtained at higher calcium intakes. A beneficial effect of increasing calcium intake on bone mass in adolescents was reported during pregnancy (15) and lactation (16), even when the habitual calcium intake was adequate. A higher calcium intake during the last trimester of pregnancy—when the efficiency of calcium absorption is significantly elevated—was found to positively influence lumbar spine z scores postpartum (15). In our study, the relation between increases in lumbar spine z scores from lactation to postweaning
and calcium intake during lactation was nearly significant. Our ability to fully pursue the effect of calcium intake on the regain of bone in the postpartum period may have been somewhat limited by the fact that most of the adolescents studied (70%) had intakes <400 mg/d, and only 30% of teens had intakes >700 mg/d. Taken together, these results suggest that higher calcium intakes are protective against bone loss during pregnancy and lactation and favor lumbar spine bone recovery in the postweaning period in adolescent mothers.

In conclusion, it appears that adolescent mothers with habitually low calcium intakes recover the lactation-associated bone loss in the postweaning period, after the resumption of menses. However, the rate of bone accretion may not be sufficient to ensure full bone recovery at levels similar to those in adolescents who were never pregnant. Hormones regulating bone turnover during lactation—such as PTH, estradiol, and prolactin—may influence bone recovery after weaning in these women.

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REFERENCES