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Changes in bone mineral density of adolescent mothers during the 12-month postpartum period

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Abstract

Objective: Bone mineral density (BMD) loss has been described in adult women in the 12-month postpartum period. However, little is known about the precise BMD pattern in adolescent mothers. The present study aimed to evaluate BMD in Argentinean adolescent mothers followed up during the 12-month postpartum period.
Design: Analytical, prospective clinical trial. BMD and body composition were determined by dual-energy X-ray absorptiometry; bone mineral content (BMC) and BMD were measured in the lumbar spine (L2–L4), femoral neck (FN), femur trochanter (TR), total hip (TH) and total body. Changes in BMD and BMC were analysed using ANOVA for pairwise comparisons. Other comparisons were performed with the paired-sample *t* test and Wilcoxon test; Pearson's correlation coefficient was used to analyse the relationship among continuous variables.
Setting: La Plata, Argentina.
Subjects: Adolescent mothers (*n* 35; 17 years old or less) were recruited within 15 d after delivery. Studies and follow-up were performed at 15 d and 3, 6 and 12 months postpartum.
Results: BMD and BMC losses at 3 and 6 months and recovery at 12 months fitted a quadratic curve (ANOVA) at the three sites studied (FN, TH, TR), in total-body BMD ($P = 0{\cdot}000$) and BMC ($P = 0{\cdot}038$). At hip sites, BMD loss occurred at 3 months (FN, $P = 0{\cdot}000$; TR, $P = 0{\cdot}000$; TH, $P = 0{\cdot}000$) and 6 months (FN, $P = 0{\cdot}000$; TR, $P = 0{\cdot}000$; TH, $P = 0{\cdot}000$) compared with basal values. Percentage BMD loss immediately after delivery up to 6 months was about 5 %.
Conclusions: Adolescents showed significant BMD and BMC losses at 6 months postpartum, with an almost total recovery at 12 months in all sites studied.

Keywords
Bone mineral density
Body composition
Lactation
Adolescence

Bone mineral density (BMD) loss has been described in adult women during the 12-month postpartum period[1,2]. However, little is known about the precise pattern of recovery in adolescent mothers.

Different factors influence bone mass, including hereditary factors, intake of Ca and vitamin D, body weight, age, reproductive history (age at menarche, consumption of oral contraceptives, age at first pregnancy, interval between births, parity) and lifestyle habits (alcohol consumption, physical activity, smoking, sun exposure)[3].

During puberty, bone accretion is associated with increments in skeletal length and mass that increase Ca demands; approximately 40 % of bone mass is accumulated in this period[4,5]. In pregnant adolescents, Ca is required for fetal bone formation[6] and for the continuous demand of the maternal skeleton, which is still growing[7]. During lactation, Ca is needed for maternal milk[8]. Although intestinal Ca absorption increases during pregnancy, it remains the same as before pregnancy during lactation. However, urinary Ca elimination increases during pregnancy, returns to prepregnancy levels during lactation, and is lower than baseline at the post-weaning period. This is probably due to hormonal changes, although the mechanisms are poorly understood[9].

Adult lactating women lose BMD, particularly at trabecular bone sites. Such loss occurs during months 3–6 of lactation, affecting lumbar spine and femoral neck by 3 to 5 %. These percentages are higher than those observed in early menopause during the same period[10].

The aim of the present study was to evaluate BMD in adolescents from Argentina followed up for 12 months postpartum.

Methods

The study employed an analytical, prospective clinical design to assess thirty-five adolescent mothers recruited

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within 15 d after delivery from the Maternity Department at the Hospital General de Agudos 'José de San Martín', La Plata, Argentina. Follow-ups were performed at the Outpatient Ward of the Instituto de Desarrollo e Investigaciones Pediátricas 'Prof. Fernando E. Viteri' (IDIP), Children's Hospital 'Sor Maria Ludovica', La Plata, Argentina.

Women included in the study were healthy, ≤17 years of age, with BMI of 18·5–24·9 kg/m^2, primiparous, with a term singleton pregnancy (newborn birth weight ≥2500 g), exclusively breast-feeding for at least 3 months, and using natural contraceptive methods or an intra-uterine device. Exclusion criteria were the presence of chronic and/or acute diseases, history of rickets and osteomalacia, infectious disease the time of the study, use of any medication, use of Ca and/or vitamin D supplements, drug consumption, and not willing to participate in the study.

The study protocol was approved by the Ethical Committee of the Hospital General de Agudos 'José de San Martin', La Plata, Argentina.

A social worker surveyed the adolescent mothers within 15 d after delivery, and invited those who complied with the inclusion criteria to participate in the study. Written informed consent was obtained from each adolescent and a responsible adult. Studies and follow-ups were performed at 15 d and at 3, 6 and 12 months postpartum. A general clinical examination was done before starting the trial, and a questionnaire about breast-feeding, resumption of menses and contraceptive methods was also performed by the nutritionist and the clinician.

Body weight was measured electronically with a Tanita 1582 digital balance (100 g accuracy) and height was measured with a SECA 222 stadiometer (mm graduation, 1 cm accuracy) at each visit.

The food-frequency method[11] was used to survey dietary intake; according to the food ingested, the amount of nutrient consumption per day was calculated, estimating daily intake of energy (kJ/d, kcal/d), proteins (g/d), Ca (mg/d), P (mg/d) and vitamin D (IU/d) with the US Department of Agriculture food composition database[12].

Overall physical activity was classified according to intensity of effort and time engaged in activity such as resting and very light, light, moderate and heavy work[13].

Bone mineral densitometry was performed by dual-energy X-ray absorptiometry (DEXA) with a LUNAR DPX-L instrument with paediatric software version 4·6f (GE Lunar Corporation, Madison, WI, USA). BMD CV% *in vivo* (reproducibility): lumbar spine (L2–L4), 1·3 %; femoral neck (FN) 1·5 %; femur trochanter (TR), 1·4 %; total hip (TH), 0·9 %; total body, 0·8 %. Studies were performed by a single expert observer. Bone mineral content (BMC) and total-body BMD were determined; BMD was also measured in L2–L4, FN, TR and TH. Body composition was also estimated by DEXA[14,15].

Adolescent mothers were further divided into two groups, younger (14–15 years) and older (16–17 years) mothers, to analyse changes in BMC during the study period.

Statistical analysis

Repeated-measures ANOVA with pairwise comparisons with Bonferroni adjustment to the significance was used to study changes in BMD and BMC. Repeated-measures ANOVA was also used to compare BMC between older and younger mothers. Basal (15 d) *v.* 3-, 6- and 12-month values were compared with the paired-samples *t* test for anthropometric variables and the Wilcoxon test for nutrient intake. The relationship among continuous variables was analysed with Pearson's correlation coefficient. Student's *t* test was used to compare BMD and BMC in mothers who had or had not resumed menses at 3 months postpartum.

Results

Mean age at entry in the study was 15·43 (SD 0·81) years; mean age at onset of menarche was 12 (SD 0·92) years. All adolescents belonged to low-income families receiving care at a public maternity unit of the Province of Buenos Aires, and practised light physical activity. During pregnancy, mean weight gain had been 14·7 (SD 5·8) kg.

Follow-up of infants from participating mothers was performed every month, and that of mothers was at 16 (SD 2), 88 (SD 5), 172 (SD 9) and 368 (SD 15) d.

Table 1 presents the results of the dietary surveys. A significant decrease in energy and intake of other nutrients can be observed from month 3 postpartum onwards. Of the total number of mothers, 82 % continued breast-feeding their infants 12 months after delivery.

Table 2 shows the anthropometric characteristics of the adolescent mothers 15 d and 3, 6 and 12 months postpartum. Mean height at baseline was 155·5 (SD 6·4) cm. Weight and BMI decreased significantly from 3 to 6 months postpartum, whereas the percentage of fat mass decreased significantly and progressively from 15 d to 12 months postpartum. Lean mass increased by 1·13 kg from 15 d to 12 months postpartum ($P < 0·001$), and fat mass loss was 4·5 kg ($P < 0·001$).

At 12 months, there was a positive correlation between body weight and total-body BMD ($r = 0·468$; $P = 0·007$) and between body weight and BMC ($r = 0·490$; $P = 0·004$). Likewise, there was a positive and statistically significant correlation between BMI and total-body BMD ($r = 0·527$; $P = 0·002$) and between BMI and BMC ($r = 0·427$; $P = 0·015$).

Figure 1 shows changes in BMD and BMC in the 12-month postpartum period. Losses at 3 and 6 months and recovery at 12 months fitted a quadratic curve according to repeated-measures ANOVA at the three hip sites studied (FN, TH, TR), in total-body BMD ($P = 0·000$) and BMC ($P = 0·038$).

At hip sites, BMD loss occurred at 3 months (FN, $P = 0·000$; TR, $P = 0·000$; TH, $P = 0·000$) and at 6 months (FN, $P = 0·000$; TR, $P = 0·000$; TH, $P = 0·000$) compared with basal values. Percentage BMD loss immediately after delivery

Table 1 Dietary survey results at baseline and different times postpartum: adolescent mothers (*n* 35; 17 years old or less), La Plata, Argentina

	Energy (kJ/d)		Energy (kcal/d)		Proteins (g/d)		Ca (mg/d)		P (mg/d)		Vitamin D (UI/d)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Basal (*n* 35)	9844	5093	2816	1281	91	38	895	734	1238	527	57	54
P (basal *v.* 3 months)	0·033		0·033		0·037		0·002		0·010		0·094	
3 months (*n* 35)	7687	2903	2331	731	75	20	543	236	960	281	36	16
P (3 months *v.* 6 months)	0·790		0·790		0·734		0·585		0·855		0·733	
6 months (*n* 34)	7515	2456	2349	805	72	34	572	318	994	339	41	27
P (6 months *v.* 12 months)	0·838		0·838		0·172		0·866		0·946		0·649	
12 months (*n* 31)	7926	3759	2319	1049	79	49	547	311	1015	537	38	25

Statistical comparisons are between measures at different postpartum months.

Table 2 Anthropometric parameters during the 12-month postpartum period: adolescent mothers (*n* 35; 17 years old or less), La Plata, Argentina

	Weight (kg)		BMI (kg/m^2)		Fat mass, DEXA (%)	
	Mean	SD	Mean	SD	Mean	SD
Basal (*n* 35)	55·6	6·8	23·0	2·18	35·6	4·8
P (basal *v.* 3 months)	0·001		0·001		0·004	
3 months (*n* 35)	54·1	7·3	22·3	2·24	33·5	5·4
P (3 months *v.* 6 months)	0·002		0·001		0·001	
6 months (*n* 34)	52·7	7·6	21·6	2·55	30·7	7·1
P (6 months *v.* 12 months)	0·399		0·593		0·011	
12 months (*n* 31)	52·2	7·6	21·3	2·54	28·6	6·6

DEXA, dual-energy X-ray absorptiometry.
Statistical comparisons are between measures at different postpartum months.

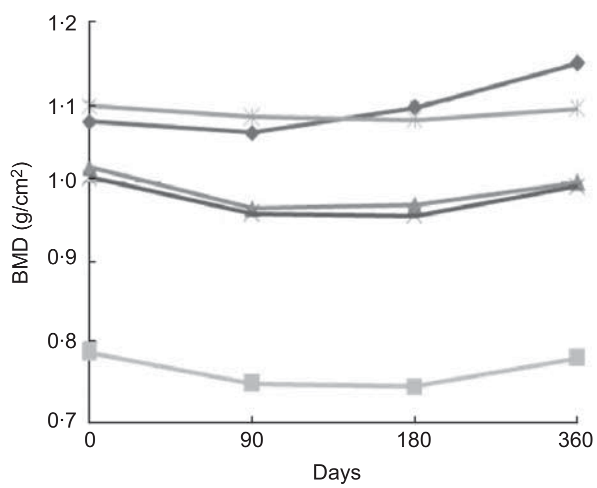

Fig. 1 Bone mineral density (BMD) at the different sites studied (—◆—, lumbar spine; —■—, femur trochanter; —▲—, femoral neck; —×—, total hip; —✳—, total body) at baseline (within 15 d after delivery) and 90, 180 and 360 d postpartum: adolescent mothers (*n* 35; 17 years old or less), La Plata, Argentina

up to 6 months was about 5 %. Similarly, losses in total-body BMD were significant at 3 ($P=0·019$) and 6 ($P=0·004$) months compared with values recorded 15 d postpartum.

Bonferroni test could not show statistically significant changes in BMC at any study point. Losses in total-body BMD and BMC were about 2 %.

Figure 1 shows that recovery in BMC, hip and total-body BMD was almost complete 12 months postpartum. Although there were no significant BMD losses in L2–L4 during the first 6 months postpartum, there was a significant increase from 6 to 12 months ($P=0·000$). Changes also fitted a quadratic model according to repeated-measures ANOVA ($P=0·000$). At 12 months, adolescents gained 6 % more than their basal value.

The impact of menses resumption on BMD was assessed by comparing BMD recovery at 12 months postpartum between adolescent mothers who had resumed menses at 3 months (Group 1) and those who were still amenorrhoeic during the same period (Group 2). Differences in total-body, hip and lumbar spine BMD between groups are shown in Table 3. Despite a slightly higher recovery in adolescents who had resumed menses, differences were not significant at the different hip sites and in BMC.

Regarding BMC in the two age groups of adolescent mothers at 15 d, it was slightly higher in older adolescents: 2·244 (SD 0·263) g *v.* 2·099 (SD 0·197) g ($P=0·080$). At 12 months postpartum, BMC was 2·255 (SD 0·280) *v.* 2·081 (SD 0·189) g ($P=0·053$) in older and younger adolescents, respectively. Older adolescents had higher values than younger ones during the study period ($P=0·019$; Fig. 2).

Discussion

Adolescents who become mothers are a particularly vulnerable nutritional group due to the enhanced nutrient

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Table 3 BMD and BMC recovery at 12 months postpartum at the different sites studied, according to resumption of menses: adolescent mothers (*n* 35; 17 years old or less), La Plata, Argentina

	Group 1	Group 2	*P*
Total-body BMD	100·8	99·0	0·044
BMC	101·0	98·3	0·321
Lumbar spine BMD	110·1	105·4	0·011
Femoral neck BMD	100·4	97·4	0·137
Trochanter BMD	101·9	98·5	0·217
Total hip BMD	101·2	98·3	0·153

BMD, bone mineral density; BMC, bone mineral content; Group 1, adolescent mothers who had resumed menses at 3 months; Group 2, those who had not.

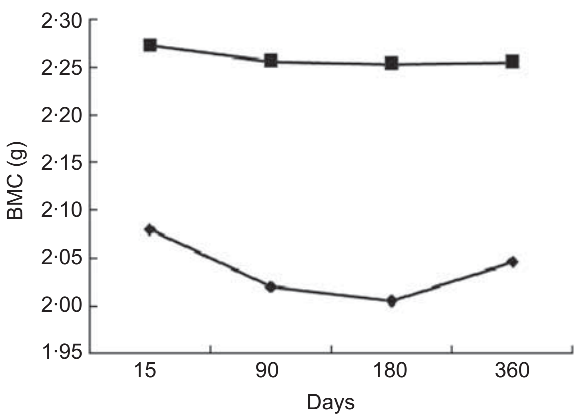

Fig. 2 Bone mineral content (BMC) at baseline (within 15 d after delivery) and 90, 180 and 360 d postpartum according to age (—◆—, 14–15 years; —■—, 16–17 years): adolescent mothers (*n* 35), La Plata, Argentina

demands of pregnancy and lactation and their demands for growth[16]. To our knowledge, the present study is the first detailed longitudinal study in adolescent mothers where dietary intakes, changes in body composition, BMD and BMC have been repeatedly measured from 15 d up to 12 months postpartum. Other authors have performed partial studies of BMD during the first year after delivery[17], beginning their study at different postpartum days[18]. The only longitudinal studies reported in the literature have been performed in adult women[1,2,19–24]. In our study, the lack of longitudinal data from non-pregnant, non-lactating young women followed up for 12 months and from a comparative group of adult lactating women limit the interpretation of our data.

Our dietary studies showed that despite Ca intake being below recommendations[25], it was higher than the mean value observed in the National Nutrition and Health Survey[26] in non-pregnant Argentine women under 19 years old. Such low Ca intake has also been reported in other studies performed in developing and developed countries[18,19,27]. Other investigators have shown that nulliparous adolescents present a higher net daily Ca retention compared with adult women because they absorb more Ca from their diet, in spite of excreting more Ca in urine and faeces, and of having a higher bone turnover[28–30]. In our study, energy balance was negative, as evidenced by weight and fat mass loss. The marked decrease in food intake also affected Ca intake.

We observed that losses in weight, fat mass and BMI were statistically significant at 3 months postpartum, as previously published by our research group[31]. Weight and lean body mass changes were similar to those reported by others in adult women[32,33]. Weight loss has been described in Mexican lactating adolescents, but body composition was not studied[34]. The relationship between BMD and weight has already been reported in adult pregnant[35,36] and lactating[37] women and in young adults[38,39]. Our results show the association of body weight and BMI with BMD and BMC.

Adolescent mothers showed decreased BMD in the total body and at different hip sites, similar to that reported in the above-mentioned studies. Chan *et al.* found a higher BMD loss in the radius compared with nulliparous adolescents and adult mothers[27].

BMD did not decrease in the lumbar spine and in fact a slight increase in this site was observed at 6 months postpartum, reaching 6 % above basal values at 12 months postpartum. This differs from reports by other authors, who observed BMD loss in this region in adolescents and adults[19,20–25,40].

In our population, 82 % of adolescents were still breast-feeding 12 months postpartum. In Argentina, mean annual breast feeding in low-income homes is 61·7 % (95 % CI 53·6, 69·1 %)[26]. Probably our inclusion criteria (adolescent mothers exclusively breast-feeding for at least 3 months) and our careful encouragement toward breast-feeding resulted in a higher prevalence of maternal lactation 12 months postpartum. Even when most adolescents continued breast-feeding their infants, BMD recovery occurred 1 year after delivery in all sites studied except FN.

Bezerra *et al.* reported a statistically significant increase in total BMD after weaning[18]. They also found a positive correlation between BMD and time elapsed after resumption of menses ($r = 0.86$; $P < 0.01$) in adolescent mothers. Resumption of menses, connected with restoration of oestrogen levels, is associated with lower loss of bone mass during lactation. A positive correlation has been described between duration of amenorrhoea and BMD loss in adult women[2,22,41,42]. In our study, we also found that mothers who resumed menses by 3 months postpartum had higher BMD and BMC at the end of the study period.

However, a significant bone mass recovery was observed, probably due to higher efficacy for Ca retention[7]. It has been postulated that the lower oestrogen concentration during the first months postpartum is a key factor associated with lower action of 1,25-dihydroxyvitamin D (1,25-$(OH)_2D$)[43]. There is a slow but progressive increase in the concentration of 1,25-$(OH)_2D$ as lactation is prolonged[44]. However, intestinal Ca absorption was greater in lactating mothers than in those who had resumed menses, and between 2 and 6 months post-weaning the concentration of 1,25-$(OH)_2D$ had the same increase as oestrogens in blood[45,46].

Since our study was focused on recovery one year postpartum, the impact of pregnancy on bone mass was not determined. In adolescent mothers followed up for a year postpartum, BMC and BMD loss and recovery follow a pattern similar to that observed in adult women[1,2,20–25]. To our knowledge, there are no papers reporting that BMC in lactating adolescents <16 years of age is lower than that of 16–17-year-old adolescents due to the fact that the former may not be completely physiologically mature, as described in teenage pregnancies with respect to linear growth[47].

Conclusions

A significant BMD and BMC loss was observed at 6 months postpartum, with an almost total recovery at 12 months in all sites studied. Reports in similar populations with non-pregnant lactating adolescents as well as adult lactating women and control groups are needed to further support our findings.

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References

1. Laskey MA & Prentice A (1999) Bone mineral changes during and after lactation. *Obstet Gynecol* **94**, 608–615.
2. Kalkwarf HJ & Specker BL (1995) Bone mineral loss during lactation and recovery after weaning. *Obstet Gynecol* **86**, 26–32.
3. Mazzes RB & Barden HS (1991) Bone density in premenopausal women: effects of age, dietary intakes, physical activity, smoking and birth-control pills. *Am J Clin Nutr* **53**, 132–142.
4. Gong E & Heald F (1994) Diet, nutrition and adolescence. In *Modern Nutrition in Health and Disease*, 8th ed., vol. 1, pp. 759–767 [M Shils, J Olson and M Shike, editors]. Philadelphia, PA: Lea & Febiger.
5. Weaver CM, Peacock M, Martin BR *et al.* (1997) Quantification of biochemical markers of bone turnover by kinetic measures of bone formation and resorption in young healthy females. *J Bone Miner Res* **12**, 1714–1720.
6. Forbes GB (1976) Calcium accumulation by the human fetus. *Pediatrics* **57**, 976–977.
7. Bailey DA, Martin AD, McKay HA *et al.* (2000) Calcium accretion in girls and boys during puberty: a longitudinal analysis. *J Bone Miner Res* **15**, 2245–2250.
8. Laskey MA, Prentice A, Hanratty LA *et al.* (1998) Bone changes after 3 mo of lactation: influence of calcium intake, breast-milk output, and vitamin D-receptor genotype. *Am J Clin Nutr* **67**, 685–692.
9. Cross NA, Hillman LS, Allen SH *et al.* (1995) Calcium homeostasis and bone metabolism during pregnancy, lactation and postweaning: a longitudinal study. *Am J Clin Nutr* **61**, 514–523.
10. Kovacs CS (2001) Calcium and bone metabolism in pregnancy and lactation. *J Clin Endocrinol Metab* **86**, 2344–2348.
11. Hankin JH (1992) Dietary intake methodology. In *Research: Successful Approaches*, pp. 173–194 [ER Mosen, editor]. Chicago, IL: American Dietetic Association.
12. US Department of Agriculture (2004) *USDA Food and Nutrient Database for Dietary Studies, 1.0.* Beltsville, MD: USDA Agricultural Research Service, Food Surveys Research Group.
13. Food and Nutrition Board, National Research Council, National Academy of Sciences (1989) *Recommended Dietary Allowances*, 10th ed., p. 27. Washington, DC: National Academy Press.
14. Brunton JA, Bayley HS & Atkinson SA (1993) Validation and application of dual-energy X-ray absorptiometry to measure bone mass and body composition in small infants. *Am J Clin Nutr* **58**, 839–845.
15. Mazzes RB, Barden HS, Bisek JP *et al.* (1990) Dual-energy X-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. *Am J Clin Nutr* **51**, 1106–1112.
16. Ward KA, Adams JE & Mughal MZ (2005) Bone status during adolescence, pregnancy and lactation. *Curr Opin Obstet Gynecol* **17**, 435–439.
17. Chan GM, Slater P, Ronald N *et al.* (1982) Bone mineral status of lactating mothers of different ages. *Am J Obstet Gynecol* **144**, 438–441.
18. Bezerra FF, Mendonça LMC, Lobato EC *et al.* (2004) Bone mass is recovered from lactation to postweaning in adolescent mothers with low calcium intakes. *Am J Clin Nutr* **80**, 1322–1326.
19. Affinito P, Tommaselli GA, Di Carlo C *et al.* (1996) Changes in bone mineral density and calcium metabolism in breastfeeding women: a one-year follow-up study. *J Clin Endocrinol Metab* **81**, 2314–2318.
20. Sowers M, Corton G, Shapiro B *et al.* (1993) Changes in bone density with lactation. *JAMA* **269**, 3130–3135.
21. Polatti F, Capuzzo E, Viazzo F *et al.* (1999) Bone mineral changes during and after lactation. *Obstet Gynecol* **94**, 52–56.
22. Ritchie LD, Fung EB, Halloran BP *et al.* (1998) A longitudinal study of calcium homeostasis during human pregnancy and lactation and after resumption of menses. *Am J Clin Nutr* **67**, 693–701.
23. Sowers M, Randolph J, Shapiro B *et al.* (1995) A prospective study of bone density and pregnancy after an extended period of lactation with bone loss. *Obstet Gynecol* **85**, 258–259.
24. Pearson D, Kaur M, San P *et al.* (2002) Recovery of pregnancy mediated bone loss during lactation. *Bone* **34**, 570–578.

25. Food and Nutrition Board, Institute of Medicine (2002) *Dietary Reference Intakes 1997–2001*. Washington, DC: National Academy Press.
26. Ministerio de Salud, Presidencia de la Nación (2007) ENNyS. Encuesta Nacional de Nutricion y Salud. Documento de Resultados 2007. http://www.msal.gov.ar/htm/site/ennys/pdf/documento_resultados_2007.pdf (accessed March 2009).
27. Chan G, Ronald N, Slater P *et al.* (1982) Decreased bone mineral status in lactating adolescent mothers. *J Pediatr* **101**, 767–770.
28. Weaver CM, Peacock M, Martin BR *et al.* (1996) Calcium retention estimated from indicators of skeletal status in adolescent girls and young women. *Am J Clin Nutr* **64**, 67–70.
29. Weaver CM, Martin BR, Plawecki KL *et al.* (1995) Differences in calcium metabolism between adolescent and adult females. *Am J Clin Nutr* **61**, 577–581.
30. Bezerra F, Laboissière FP, King JC *et al.* (2002) Pregnancy and lactation affect markers of calcium and bone metabolism differently in adolescent and adult women. *J Nutr* **132**, 2183–2187.
31. Gonzalez HF, Malpeli A, Mansur JL *et al.* (2005) Changes in body composition in lactating adolescent mothers. *Arch Latinoam Nutr* **55**, 252–256.
32. Butte NF, Garza C, Stuff JE *et al.* (1984) Effect of maternal diet and body composition on lactational performance. *Am J Clin Nutr* **39**, 296–306.
33. Fornes NS & Dorea JG (1995) Subcutaneous fat changes in low-income lactating mothers and growth of breast-fed infants. *J Am Coll Nutr* **14**, 61–65.
34. Casanueva E, Marín A, Gelis P *et al.* (1997) Changes in weight during pregnancy and lactation in adolescents. Evaluation of a nutritional intervention. *Ann N Y Acad Sci* **817**, 353–355.
35. Olausson H, Laskey MA, Goldberg GR *et al.* (2008) Changes in bone mineral status and bone size during pregnancy and the influences of body weight and calcium intakes. *Am J Clin Nutr* **88**, 1032–1039.
36. Promislow JH, Hertz-Picciotto I, Schramm M *et al.* (2004) Bed rest and other determinants of bone loss during pregnancy. *Am J Obstet Gynecol* **191**, 1077–1083.
37. Kulkarni B, Shatrugna V, Nagalla B *et al.* (2009) Maternal weight and lean body mass may influence the lactation-related bone changes in young undernourished Indian women. *Br J Nutr* **101**, 1527–1533.
38. Fehily AM, Coles RJ, Evans WD *et al.* (1992) Factors affecting bone density in young adults. *Am J Clin Nutr* **56**, 579–586.
39. Ho AY & Kung AW (2005) Determinants of peak bone mineral density and bone area in young women. *J Bone Miner Metab* **23**, 470–475.
40. O'Brien K, Schulman Nathanson M, Mancini J *et al.* (2003) Calcium absorption is significantly higher in adolescents during pregnancy than in the early post partum period. *Am J Clin Nutr* **78**, 1188–1193.
41. Sowers MF, Hollis BW & Shapiro B (1996) Elevated parathyroid hormone-related peptide associated with lactation and bone density loss. *JAMA* **276**, 549–554.
42. Kolthoff N, Eiken P, Kristensen B *et al.* (1998) Bone mineral changes during pregnancy and lactation: a longitudinal cohort study. *Clin Sci* **94**, 405–412.
43. De Santiago S, Alonso L, Halhali A *et al.* (2002) Negative calcium balance during lactation in rural Mexican women. *Am J Clin Nutr* **76**, 845–851.
44. King J, Hallorand B, Huq N *et al.* (1992) Calcium metabolism during pregnancy and lactation. In *Mechanisms Regulating Lactation and Infant Nutrient Utilization*, p. 135 [MF Picciano, editor]. Philadelphia, PA: Wiley-Liss.
45. Hillman L, Sateesha S, Haussler M *et al.* (1981) Control of mineral homeostasis during lactation: interrelationships of 25-hydroxyvitamin D, 24,25-dihydroxyvitamin D, parathyroid hormone, calcitonin, prolactin, and estradiol. *Am J Obstet Gynecol* **139**, 471–476.
46. Wilson S, Retallack R, Kent J *et al.* (1990) Serum free 1,25-dihidroxyvitamin D and the free 1,25-dihidroxyvitamin D index during a longitudinal study of human pregnancy and lactation. *Clin Endocrinol (Oxf)* **32**, 613–622.
47. Scholl TO, Hediger ML, Ances IG *et al.* (1988) Growth during early teenage pregnancies. *Lancet* **i**, 701–702.