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ORIGINAL ARTICLE

Changes in bone mineral density and body composition during pregnancy and postpartum. A controlled cohort study

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Abstract

Summary In a controlled cohort study, bone mineral density (BMD) was measured in 153 women pre-pregnancy; during pregnancy; and 0.5, 4, 9, and 19 months postpartum. Seventy-five age-matched controls, without pregnancy plans, were followed in parallel. Pregnancy and breastfeeding cause a reversible bone loss, which, initially, is most pronounced at trabecular sites but also involves cortical sites during prolonged breastfeeding.

Introduction Conflicting results have been reported on effects of pregnancy and breastfeeding on BMD and body composition (BC). In a controlled cohort study, we elucidate changes in BMD and BC during and following a pregnancy.

Methods We measured BMD and BC in 153 women planning pregnancy (n=92 conceived), once in each trimester during pregnancy and 15, 129, and 280 days postpartum. Moreover, BMD was measured 19 months postpartum (n=31). Seventy-five age-matched controls, without pregnancy plans, were followed in parallel.

Results Compared with controls, BMD decreased significantly during pregnancy by 1.8±0.5% at the lumbar spine, 3.2±0.5% at the total hip, 2.4±0.3% at the whole body, and 4.2±0.7% at the ultra distal forearm. Postpartum, BMD decreased further with an effect of breastfeeding. At 9 months postpartum, women who had breastfed for <9 months had a BMD similar to that of the controls, whereas BMD at the lumbar spine and hip was decreased in women who were still breastfeeding. During prolonged breastfeeding, BMD at sites which consist of mostly trabecular bone started to be regained, whereas BMD at sites rich in cortical bone decreased further. At 19 months postpartum, BMD did not differ from baseline at any site. During pregnancy, fat- and lean-tissue mass increased by 19±22% and 5±6% (p<0.001), respectively. Postpartum, changes in fat mass differed according to breastfeeding status with a slower decline in women who continued breastfeeding. Calcium and vitamin D intake was not associated with BMD changes.

Conclusion Pregnancy and breastfeeding cause a reversible bone loss. At 19 months postpartum, BMD has returned to pre-pregnancy level independently of breastfeeding length. Reversal of changes in fat mass depends on breastfeeding status.

Keywords Body composition · Bone mineral density · Breastfeeding · Pregnancy

Introduction

During pregnancy and breastfeeding, major changes occur in the maternal calcium homeostasis and bone metabolism in order to fulfil the demand of calcium to the foetus and the newborn child. In previous studies, discrepant data have been published on changes in bone mineral density (BMD) during pregnancy [1–6]. Some studies have found that BMD decreases in response to the transfer of calcium to the foetus in combination with decreased renal calcium reabsorption [1, 4–6]. Others have reported unchanged or even increased BMD and interpreted this as an effect of high levels of estradiol and increased intestinal calcium absorption [2, 3]. After delivery, most studies have reported a decrease in BMD, but the relative effect of breastfeeding

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on BMD changes at different skeletal sites is still a matter of dispute [7–10]. Moreover, pregnancy and breastfeeding cause large changes in body weight and body composition, but longitudinal studies on changes in body composition during pregnancy and postpartum are few [11–15]. In general, previous studies have been limited by the inclusion of relatively few study subjects, by the lack of pre-conceptional measurements, as well as by the lack of a control group of non-pregnant women. So far, only five controlled studies with pre-pregnancy measurements on less than 42 women have been published [8, 12, 16–18]. Only one of these studies continued to follow the included women postpartum [8]. The studies showed an approx. 4% decrease in BMD at the lumbar spine [8, 16, 18], whereas BMD at the femoral neck and total hip either decreased or remained unchanged during pregnancy [8, 16, 17]. In a study by Olausson et al. [12], BMD was measured prior to pregnancy as well as 2 weeks postpartum in a group of 34 British women and compared with the concomitant changes in a group of 84 non-pregnant women. The study showed that compared with the control group, pregnancy was associated with an approx. 2–3% decrease in BMD at the lumbar spine, hip, and whole body.

In addition, eight uncontrolled studies with pre-pregnancy measurement [1, 3, 19–24] have been published. One study followed 60 women [20], another followed 38 [24], whereas 16 or less study subjects were included in the remaining studies [1, 3, 19, 21–23]. Either no changes in whole body BMD [3, 22], or a 13% decrease was found [23]. In accordance with the controlled studies with pre-pregnancy measurements, BMD decreased at the lumbar spine [21] and decreased or remained unchanged at the femoral neck and total hip [1, 20, 21]. Several studies with the first measurement early in pregnancy have included forearm measurements. However, these studies have shown discrepant results with increased [16, 22], decreased [3, 8, 24], or unchanged [1, 16, 19, 21, 25] BMD levels.

In order to improve our understanding of the physiological changes in bone mass and body composition during pregnancy and postpartum, we performed a controlled cohort study in which we followed a group of women from prior to conception until 9 months postpartum, and compared the observed changes with the findings in a group of matched non-pregnant controls followed for a similar time period.

Subjects and methods

In a population-based controlled cohort study, we included 153 healthy Caucasian women, aged 25–35 years with immediate pregnancy plans, and 75 age-matched women who did not plan pregnancy within the next 21 months. The women were recruited by direct mailing to 11,175 randomly selected women within the population of 21,317 women aged 25–35 years living in the community of Aarhus, Denmark. We obtained names and addresses from the Danish Civil Registration System. Our letter of invitation included a short questionnaire on pregnancy plans, as we aimed to recruit women who had immediate plans for pregnancy, as well as women with no pregnancy plans. A total of 561 responded positively, among whom 333 were excluded for various predefined reasons as detailed in Fig. 1. Women were included between October 2006 and January 2008. Women planning pregnancy were excluded if pregnancy was not achieved within 6 months after inclusion (n=53). The women who conceived (n=92) were followed up at six occasions attending our outpatient clinic three times during their pregnancy (once at each trimester, i.e. at pregnancy weeks 11±2, 22±1, and 35±2) and three times following delivery, i.e. 15±7, 129±12, and 280±15 days postpartum. The control group followed a schedule with clinical visits at time points similar to those of the pregnancy group, i.e. investigations were performed at inclusion and 3, 6, 9, 11, 15, and 21 (±1 to 2) months after inclusion. As BMD data at the last visit (9 months postpartum) showed that women in the pregnancy group had a decreased BMD compared with baseline values, we added an amendment to the protocol allowing us to ask women in the pregnancy group for an additional DXA scan approx. 19 months postpartum.

Pregnancy was confirmed by a pregnancy test carried out by the participants themselves, followed by an appointment at their general practitioner, who confirmed the pregnancy. Also, a routine ultrasound scan was performed at pregnancy week 12.

The women who gave birth intended to breastfeed on demand and exclusively for the first 4 to 6 months. In order to study effects of breastfeeding on changes in BMD, we categorised women post hoc into three breastfeeding groups according to whether they were breastfeeding or not. Those classified in the non-breastfeeding group had completely stopped breastfeeding. The three groups were “category 1”, breastfeeding ≤4 months (duration of breastfeeding (mean ± standard deviation, SD), 94±68 days, n=13); “category 2”, breastfeeding 4 to 9 months (199±51 days, n=31); and “category 3”, breastfeeding ≥9 months (≥282±17 days, n=29). Unfortunately, we do not have a precise date of the end of breastfeeding for the women who stopped breastfeeding in-between visits 7 and 8. Due to the relative small sample size in each category, we did not aim to stratify whether infants' formula was provided concomitantly with breastfeeding.

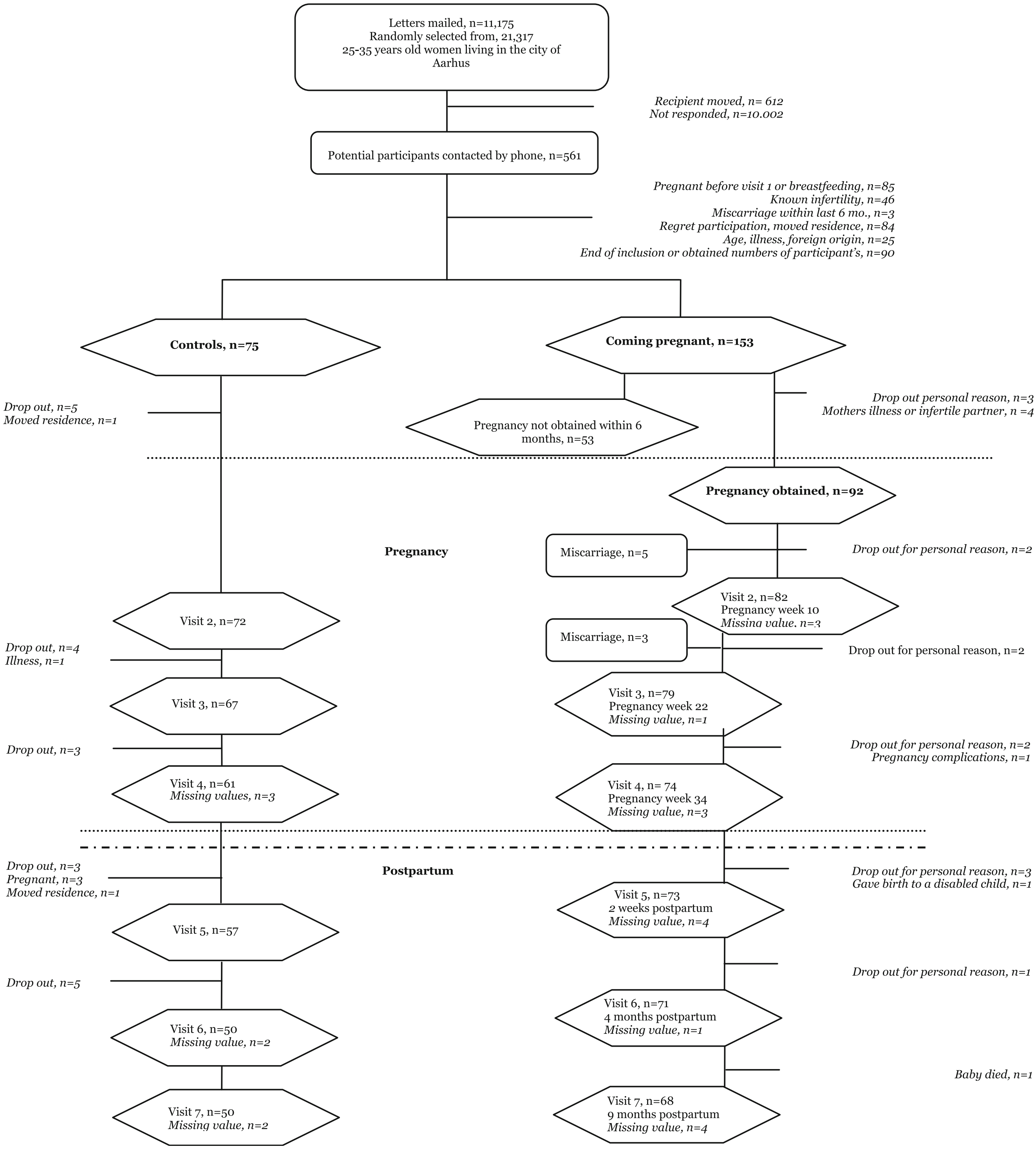

Fig. 1 Study profile

The study was performed according to The Helsinki Declaration II. The study was notified to the Danish Data Protection Agency (#2004-41-4737) and approved by the Regional Scientific Ethical Committee of Aarhus County (# 20040186).

Measurements

At visit 1 (before pregnancy) and at visits 5 to 7 (postpartum), we measured BMD at the whole body, the lumbar spine, and the hip, and we assessed body composition. In addition, BMD at the forearm (ultra distal (UD) forearm, total forearm, and the proximal 1/3 of the distal forearm) was assessed at all seven visits. All DXA scans were performed using a Hologic Discovery scanner (Hologic, Waltham, MA, USA). We assessed long-term stability through daily scans of an anthropometrical phantom. Precision error for BMD was 1% at the lumbar spine and 2% at the total hip. At each visit, scale body weight was measured at the same scale (Seca, Sa-med, Kvistgaard, Denmark) with the women in light indoor clothing.

A case report was drawn up for every participant, in which incident diseases and use of drugs were recorded. Participants were asked to fill in a non-validated internet-based questionnaire, prior to each visit, on diseases, use of drugs, smoking habits, and use of calcium and vitamin D supplements, including multivitamin pills. Importantly, food in Denmark is not fortified with vitamin D. Total daily calcium intake was assessed according to the reported dietary intake (dietary calcium (mg/day) = 200 + 200 × (number of glasses of milk) + 200 × (number of portions with rolled oats or cornflakes with milk) + 150 × (number of bread slices with cheese)) [26] plus the use of calcium supplements.

Analytical approach and statistics

Assuming a mean BMD of 1.1 g/cm^2 (SD, 0.1 g/cm^2) and a 5% BMD difference between groups at the sixth visit, sample size calculations revealed that 52 women had to be included in each study group (2α=0.05 and β=0.20). In order to allow for dropouts, including those not achieving pregnancy and miscarriages, we aimed to include 75 controls and 200 women planning pregnancy. However, due to a higher-than-expected pregnancy rate among women planning pregnancy, we decided to stop inclusion after 153 women planning pregnancy had been included.

All data collected prior to the drop out were used in the analyses. At each time point of measurement, percentage changes from baseline values were calculated for each participant, and between-group differences over time were assessed by repeated measures of analyses of variance followed by a two-sampled test if significant.

As calcium intake from diet and supplements and vitamin D intake from supplements were assessed several times during the study, i.e. at each visit, we calculated average intakes during the 9 months of pregnancy and during the 9 months postpartum using an areas under the curves approach, which was calculated by trapezoidal integration and transformed to mean daily intake by division with the length of the actual study period. We used Spearman's rho for correlation analyses. Using a general linear regression model, we adjusted for changes in body weight or overall changes in fat- and lean-tissue mass, as well as for changes in fat- and lean-tissue mass at specific sites (fat- and lean-tissue mass at the trunk was used to adjust lumbar spine, right leg and arm to adjust total hip and forearm, respectively). Similarly, we adjusted for mean calcium and vitamin D intakes. We report results by their mean ± SD or by their median with 25 and 75 percentiles (p25, p75) or range (minimum–maximum) depending on their distribution. All calculations were performed by SPSS (version 17.0).

Results

The 228 women included had a median (min–max) age of 29 (25–35) years. Anthropometric, diet, and lifestyle characteristics did not differ at baseline between women planning (n=153) or not planning (n=75) pregnancy, except that vitamin supplements were used more frequently by women who planned pregnancy (Table 1). Eight women dropped out due to personal reasons, illness, or an infertile partner prior to visit 2. In the pregnancy group, 92 (63%) succeeded to become pregnant within a median 1.3 (−1.2 to 8.7) months after baseline. The free routine ultrasound scan at approx. pregnancy week 12, showed that the date of conception was prior of visit 1 or just around visit 1 for 15 women (min to max: 0 days to 1.2 months). Most pregnancies had a normal physiological course without pregnancy-related pathologies, but an early miscarriage was encountered in eight (4%) women. Ten pregnant women dropped out of the study during pregnancy due to personal reasons. One gave birth to a disabled child, and one child died unexpectedly at 4 months old due to a cerebral haemorrhage. Sixty eight in the pregnancy group and 50 of the controls completed the study, as illustrated in the study profile (Fig. 1). At baseline, BMD did not differ between groups (Table 1). All women in the pregnancy group were offered a follow-up measurement performed at 19 (±3) months postpartum among whom 31 accepted a follow-up scan.

BMD changes during pregnancy

BMD decreased significantly during pregnancy (Figs. 2 and 3). Compared with the concomitant changes in the control group, BMD in the group of pregnant women decreased from visit 1 to 5 by 1.8±0.5% at the lumbar spine, by 3.2±0.5% at the hip, and by 2.4±0.3% at the whole body (p<0.01). At the UD forearm, measurements performed during pregnancy showed a progressive decrease in BMD compared with the concomitant changes in the control group (p<0.001) (Fig. 2). Compared with the concomitant changes in the control group, BMD in the pregnancy group was significantly decreased by approx. 2% to 3% at all four measured sites at visit 5, 15 days after delivery (Figs. 2 and 3).

Table 1 Baseline characteristics of 228 Caucasian women who either planned or did not plan pregnancy

	Pregnancy group, n=153	Control group, n=75	p value
Age, years	29 (25–35)	29 (25–34)	0.64
Nulliparas, n (%)	104 (69)	50 (67)	0.77
Height, cm	167 (153–186)	168 (156–180)	0.56
Bodyweight, kg	64 (48–114)	67 (48–122)	0.06
BMI, kg/m^2	23 (17–44)	24 (18–43)	0.15
Body composition			
Lean mass	46 (33–61)	48 (37–68)	0.17
Fat mass	19 (10–53)	21 (10–57)	0.07
Smokers, n (%)	28 (19)	10 (13)	0.45
Total calcium intake, mg/day	800 (350–2200)	800 (350–2050)	0.70
Use of vitamin D supplements, n (%)	87 (58)	24 (32)	<0.001
Total vitamin D supplement, µg/day	5 (1–30)	5 (3–20)	<0.001
Use of hormonal contraceptives, n (%)	0	52 (69)	–
BMD, g/cm^2			
Whole body	1.179±0.086	1.180±0.096	0.88
Lumbar spine	1.047±0.112	1.062±0.119	0.37
Total hip	0.958±0.106	0.961±0.108	0.87
Ultra distal forearm	0.382±0.043	0.382±0.043	0.96
Distal proximal 1/3 of the forearm	0.678±0.048	0.684±0.048	0.40
Total forearm	0.529±0.041	0.533±0.043	0.50

Median (min–max), number (%), or mean ± SD

BMD changes postpartum

BMD decreased further after delivery, with a marked effect of breastfeeding status (Figs. 2 and 3). Between visits 5 and 6, BMD decreased significantly in breastfeeding categories 2 and 3, i.e. by approx. 1% at the whole body, by approx. 5% at the lumbar spine, and by approx. 2% at the total hip (Fig. 3). BMD at the UD forearm changed only in women who breastfed ≤4 months (category 1) among whom BMD increased by 2±3% (p=0.02) (Fig. 2).

Between visits 6 and 7, BMD at the lumbar spine increased significantly in all three breastfeeding categories, i.e. by 2±2% (p<0.001) in category 3, by 4±2% (p<0.001) in category 2, and by 4±3% (p=0.01) in category 1. Also, within the group of women who stopped breastfeeding between 4 and 9 months postpartum (category 2), BMD increased by 1±2% (p=0.02) at the whole body. BMD at the hip and UD forearm did not change significantly in any of the three breastfeeding categories between visits 6 and 7 (Fig. 3).

At the visit 9 months postpartum, categories 1 and 2 had a BMD similar to that of the control group (Fig. 3). However, the women still breastfeeding had a decreased BMD at the lumbar spine (p=0.01) and hip (p=0.06) compared with the controls. Compared to pre-pregnancy, breastfeeding for more than 4 months (categories 2 and 3) leads to a lower BMD at 9 months postpartum at the whole body, lumbar spine, and hip (p<0.001). Breastfeeding for less than 4 months leads to a lower BMD than pre-pregnancy (p=0.04). At the measurement performed at 19 (±3) months postpartum in the pregnancy group (n=31), 74% had regained their pre-pregnancy BMD level, and BMD no longer differed from baseline values at any measurement site (Table 2). At the visit 19 months postpartum, none of the women were breastfeeding.

In the pregnancy group, oral contraceptives were used by two women at visit 6 and by 19 women at visit 7. BMD changes in the pregnancy group between visits 6 and 7 did not differ between users and non-users of oral contraceptives at each visit, respectively (data not shown).

Body weight and body composition during pregnancy and breastfeeding

As shown in Fig. 4, women in the pregnancy group gained weight during pregnancy followed by a weight loss postpartum (p<0.001). Assessment of body composition, as performed at visit 5 (15 days postpartum), showed that the women in the pregnancy group, during pregnancy, had gained 19±22% fat and 5±6% lean-tissue mass compared to pre-pregnancy measurements (p<0.001). These changes differed significantly from the concomitant changes in the control group (p<0.001). Lean-tissue mass returned quickly to the level of the control group, whereas changes in fat mass differed according to breastfeeding status. Fat mass declined more quickly in category 1 (breastfed, <4 months)

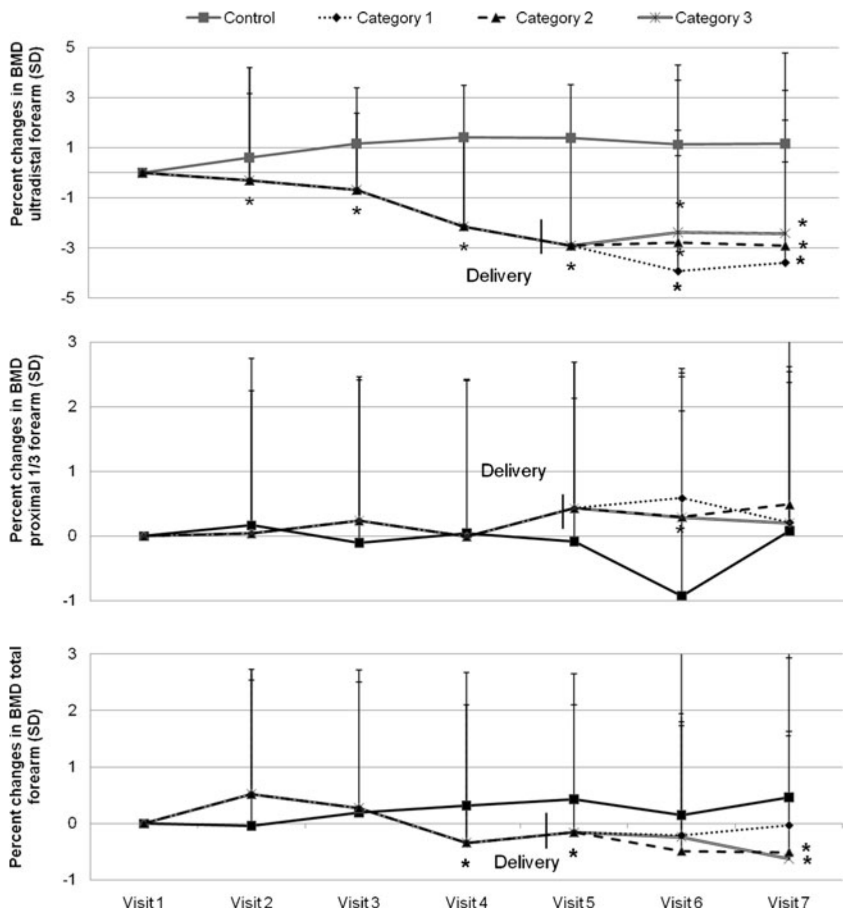

Fig. 2 Percentage change (mean (SD)) from pre-pregnancy levels in BMD at the ultra distal forearm, proximal 1/3 of the distal forearm, and total forearm, stratified according to postpartum breastfeeding status. All changes differed over time between groups in repeated measurement analysis of variance ($p<0.01$). *Category 1* breastfed <4 months postpartum, *category 2* breastfed 4 to 9 months postpartum, *category 3* breastfed >9 months postpartum. *$p<0.05$: Changes in BMD from baseline to each visit respectively differ from the control group

compared with categories 2 and 3 (breastfed, >4 months). However, 9 months postpartum, the breastfeeding groups no longer differed.

Additional analysis

Adjustments for changes in body weight and overall changes in body composition (fat- and lean-tissue mass), as well as adjustments for regional changes in these indices, did not change the BMD results to any major degree (data not shown).

At visit 6, 23 (15%) of the new mothers had resumed menstruation (8 in category 1, 8 in category 2, and 7 in category 3). At visit 7, 54 (48%) had resumed menstruation (12 in category 1, 22 in category 2, and 20 in category 3). The chance of resuming menstruation was higher, when the women ceased breastfeeding ($p=0.001$), and a positive correlation was seen between the numbers of days breastfeeding and days with amenorrhea ($R=0.60$, $p=0.001$). Stratification by amenorrhea status showed results similar to stratification by breastfeeding status, i.e. BMD decreased less postpartum in women who resumed their periods early compared with women who had amenorrhea for a prolonged time (data not shown).

Compared with the controls, women within the pregnancy group had a higher daily total intake of calcium (921 mg vs. 1,019 mg, $p=0.001$) and a higher daily intake of vitamin D from supplements (2 μg vs.7 μg, $p\leq0.001$) during their 9 months of pregnancy. Postpartum, daily intake of vitamin D from supplements was higher in the pregnancy group (5 μg) compared with that of the control group (2 μg, $p=0.001$), whereas averages of total daily calcium intake did not differ between groups (931 mg vs. 921 mg, $p=0.18$). Adjustments for calcium and vitamin D intake did not change the BMD findings to any major degree (data not shown). Neither did stratification by parity (nulliparous vs. multipara) reveal differences on changes in BMD during pregnancy or postpartum.

Discussion

In a population-based controlled cohort study, we compared BMD changes in a group of women during pregnancy and breastfeeding with the simultaneously measured variations in an age-matched group of non-pregnant women. During pregnancy, BMD decreased gradually. After delivery, BMD continued to decline in women who were breastfeeding. As

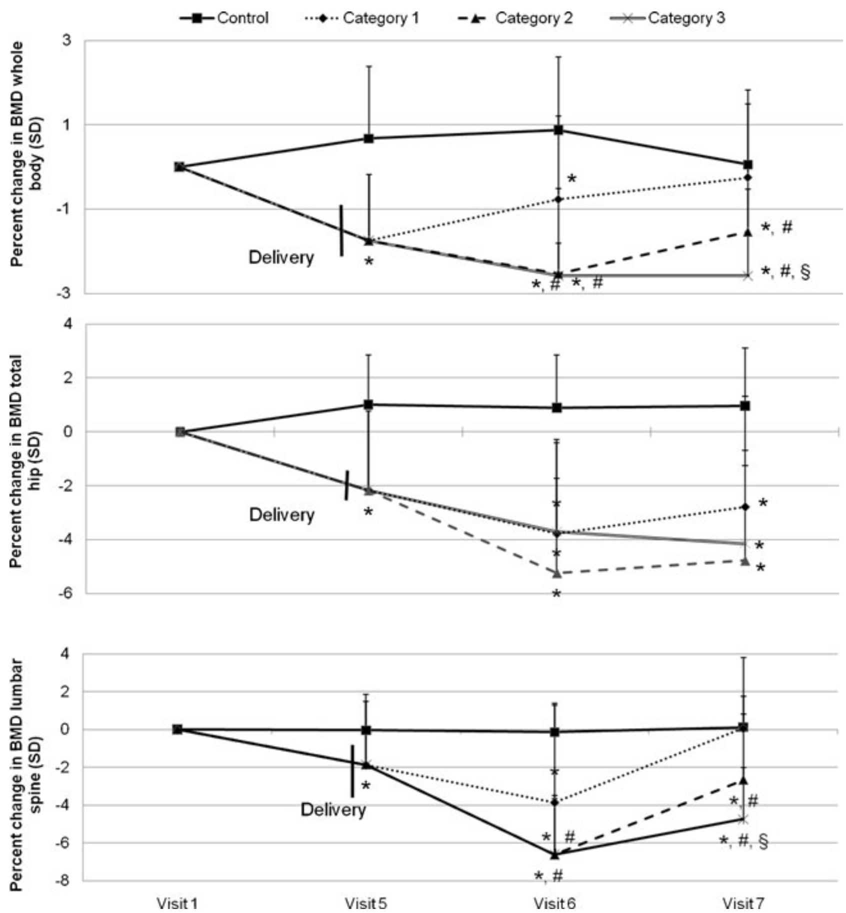

Fig. 3 Percentage change (mean ± SD) from pre-pregnancy levels in BMD at the whole body, lumbar spine, and total hip, stratified according to postpartum breastfeeding status. All changes differed over time between groups in repeated measurement analysis of variance ($p<0.001$). *Category 1* breastfed less than 4 months postpartum, *category 2* breastfed 4 to 9 months postpartum, *category 3* breastfed more than 9 months postpartum. *$p<0.05$: Changes in BMD from baseline to each visit, respectively, differ from the control group; #$p<0.05$: Changes in BMD from baseline to each visit, respectively, differ from category 1; §$p<0.05$: Changes in BMD from baseline to each visit respectively differ from category 2

expected, pregnancy caused large changes in body composition which were reversed after delivery. Women who were breastfeeding for a prolonged period had a slower decline in their fat mass than women who stopped breastfeeding early. Apparently, daily intakes of calcium and vitamin D did not affect the findings.

BMD changes in pregnancy

Only a few previous studies have reported BMD data prior to conception showing discrepant results on effects of pregnancy on BMD. A decreased BMD during pregnancy has been reported by some investigators at the lumbar spine [1, 8, 16, 20, 22–24] and UD forearm [22], whereas no changes at the lumbar spine [3, 21] and total forearm [1, 2] have been reported by other investigators. Similarly, BMD at the hip has been reported to either decrease [1, 8, 20, 23] or remain unchanged [16, 17, 21] during pregnancy. The discrepant results may be due in part to the relatively small size of previous published studies [1, 3, 8, 16, 17, 20–24] and the fact that only a few had included a matched control group [8, 12, 16–18]. Our findings are in accordance with

Table 2 Bone mineral density at the lumbar spine and whole body in the pregnancy group at 9 and 19 months postpartum (mean ± SD)

	BMD, lumbar spine	BMD, whole body
9 months postpartum, $n=68$		
BMD (g/cm^2)	1.022±0.099 ($p<0.001$)	1.166±0.083 ($p<0.001$)
Regained BMD[a] (%)	41	24
19 months postpartum, $n=31$		
BMD (g/cm^2)	1.047±0.094 ($p=0.38$)	1.174±0.094 ($p=0.48$)
Regained BMD[a] (%)	74	74

p values are based on comparison with baseline (paired sample test)

[a] Percentages who have regained their pre-pregnancy BMD level. Regained is defined as BMD which is no more than 1% below pre-pregnancy level

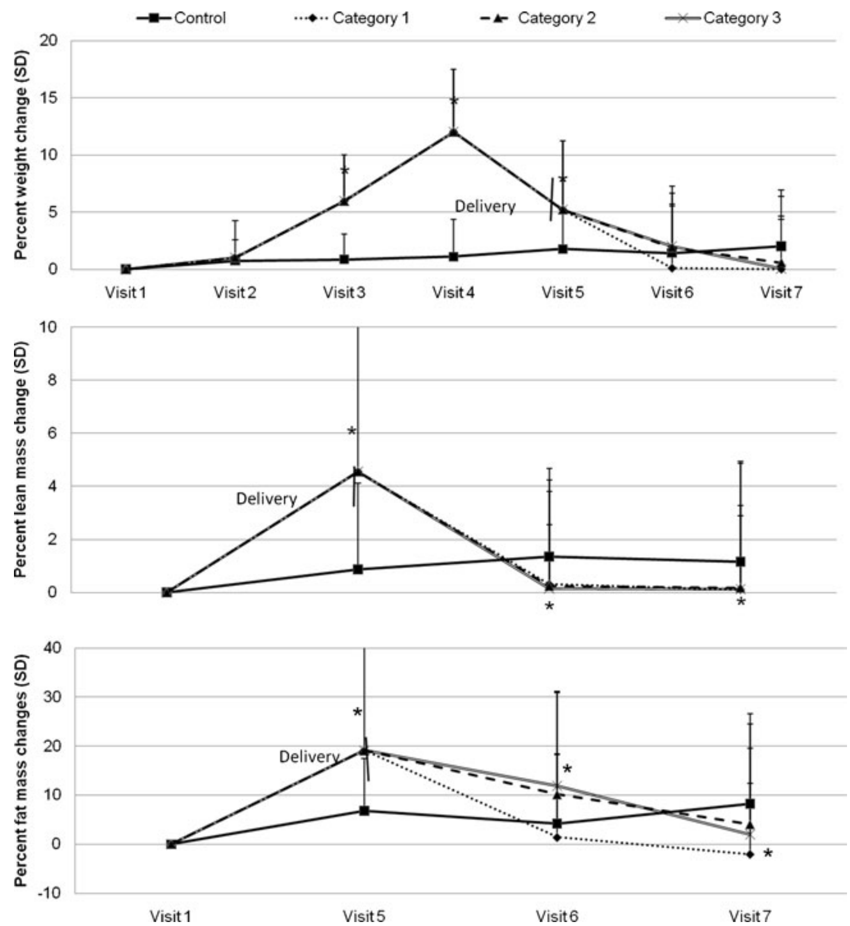

Fig. 4 Percentage change (mean ± SD) in body weight, fat, and lean mass from pre-pregnancy values throughout the study, stratified by breastfeeding status. All changes over time differed significantly between groups in repeated measurement analysis of variance ($p<0.001$). *Category 1* breastfed less than 4 months postpartum; *category 2* breastfed 4 to 9 months postpartum; *category 3* breastfed more than 9 months postpartum. *$p<0.05$: Changes from baseline to each visit respectively differ from the control group

the results from the study by Olausson et al. [12] also showing a decrease in BMD during pregnancy. Calcium homeostasis is markedly altered in pregnant women. Calcium is transferred to the foetus; as a compensation, the intestinal calcium absorption is increased caused by high 1,25-dihydroxyvitamin D levels [27]. It has been suggested that the increased calcium amount absorbed together with high oestrogen levels during pregnancy may protect against bone loss [2, 3]. However, our findings do not support that these compensatory mechanisms fully balance the increase in calcium losses, as we found a decrease in BMD during pregnancy at most sites of measurements, although changes may differ between different skeletal sites. BMD decreased at the UD forearm (mainly trabecular bone) and total forearm (both trabecular and cortical bone) during pregnancy, whereas an increase occurred at the distal proximal 1/3 of the forearm (mainly cortical bone). However, BMD decreased at other sites composite of largely cortical bone such as the whole body and the hip. It is well known that the forearm may respond differently from other skeletal sites in various disease states such as primary hyperparathyroidism [28]. According to our findings, it appears that pregnancy is another example of differential responses at the forearm compared with other skeletal sites.

A pregnancy-related reversible overall bone loss is further supported by studies showing an increased bone turnover, as measured by biochemical markers. Markers of bone resorption increase early in pregnancy [29–31] followed by increased levels of markers of bone formation later in pregnancy [29–31]. Histological changes during pregnancy have only been reported by one group of investigators [32, 33], performing quantitative histomorphometric analyses on transilial bone biopsies obtained from pregnant women in either the first trimester ($n=15$) or at term ($n=13$). Compared with biopsy and autopsy samples from a group of normal premenopausal non-pregnant women ($n=25$), bone resorption was increased, and trabecular thickness was reduced early in pregnancy. In contrast, at late pregnancy, bone formation was increased, and bone volume was entirely restored caused by an increased number of trabeculae. However, our findings do not support a complete restoration of cancellous bone at the axial skeleton in late pregnancy, as we found a decreased lumbar spine BMD at measurements performed 15 days after delivery. Additional histological studies from pregnant women are warranted, including assessment of histomorphometric indices of cortical bone. Osteoporosis in pregnancy is a rare clinical condition with an unknown aetiology, but the increased bone turnover with a decreased BMD most likely contributes to a risk of fractures during pregnancy [34].

BMD changes postpartum

Postpartum, BMD decreased further with a marked effect of breastfeeding on BMD changes which agrees with most previous studies comparing postpartum changes with concomitant measurements in groups of non-pregnant women [7–10]. Similarly to breastfeeding status, the length of amenorrhea was a determinant of BMD changes. The length of the breastfeeding period and thereby the amenorrhoea period are to some extent culture based. In Denmark, most women breastfeed on demand and exclusively for the first 4 to 6 months, followed by partial breastfeeding for an additional 4 to 6 months. In line with this, we scheduled BMD measurements to 4 and 9 months postpartum. At these time points, 13 and 44 women had stopped breastfeeding, respectively. Previously, it has been suggested that bone loss during the first months of breastfeeding mainly originates from loss of cancellous bone, whereas breastfeeding for a prolonged time period causes loss of cortical bone [5, 24, 35–37]. This notion is supported by our study, which revealed that lumbar spine BMD (consisting of mainly trabecular bone) started to increase despite prolonged breastfeeding for more than 4 months, whereas whole body BMD (consisting of mainly cortical bone) did not increase significantly in women who continued to breastfeed.

Breastfeeding for >4 months leads to decreased BMD related to the length of the breastfeeding period, with lower BMD at visit 7 at all measured sites compared to pre-pregnancy. However, at the follow-up approx. 19 months after delivery, BMD no longer differed from baseline values, indicating that bone mass at that time probably had recovered fully. The large changes in BMD seen in pregnancy and postpartum may predispose to pregnancy-related osteoporosis and thereby increase the risk of fracture.

Body composition

Longitudinal studies on changes in body composition during pregnancy and postpartum are very limited. In a group of Swedish women [11], measured by magnetic resonance imaging (MRI) through pregnancy and breastfeeding, the majority of the fat deposited during pregnancy was localized subcutaneously. Postpartum, the reduction in fat mass was due to a decrease in subcutaneous adipose tissue, whereas the non-subcutaneous volume of adipose tissue actually increased [11]. Due to the relatively small sample size and the fact that 13 of the 15 Swedish women continued to breastfeed for at least 10 months, the study did not allow for conclusions on effects of breastfeeding on postpartum changes in body composition. However, using total body potassium counting and a four-component model, Hopkinson et al. [13] found a greater decline in fat mass in breastfeeding women (n=40) compared with non-breastfeeding (n=36) women, within a cohort of women followed for 1 year postpartum. Similarly, Dewey et al. [14] reported a larger body weight loss and decreased triceps skinfold thickness in women who breastfed for >12 months (n=46) compared with women who stopped breastfeeding within 3 months after delivery (n=39). Nevertheless, the study by Dewey et al. [14] showed an inverse association between breastfeeding intensity and weight loss, as higher breastfeeding frequency was associated with less weight loss at 3±6 months postpartum. Similarly, our study showed a postponed weight loss due to a lower decline in fat mass in women who breastfed for >4 months compared with women who breastfed for <4 months. As breastfeeding length as well as physical activity and several other indices related to body weight and composition is highly culture based [15], more studies in different populations are warranted on changes in body composition postpartum.

Strengths and limitations to the study

To the best of our knowledge, the present study is the largest longitudinal study assessing BMD and body composition in a group of healthy women throughout a complete reproductive cycle from pre-pregnancy to 9 months postpartum, in which changes are compared with the concomitant changes in a group of healthy age-matched controls. In accordance with our a priori sample size calculations, we managed to include the intended number of participants, and as fewer than expected dropped out, we ended up with 71 women who completed visit 6 instead of the pre-planned 52 women, thereby improving our statistical power to determine significant changes. Our participants were randomly selected from the local background population of women aged 25–35 years living in our community. We cannot exclude that women participating in a study with a long duration like this may be more aware of a healthy lifestyle than non-participating women. Moreover, a healthy lifestyle may be more common among women who plan pregnancy. Actually, our studied subjects had a relatively high frequency of use of vitamin supplementation as well as a relative high daily calcium intake, whereas only few were smoking. However, as lifestyle characteristics were similar in the control group, our results are apparently not confounded by between-group differences in lifestyle. All but two pregnant women achieved pregnancy within 6 months after inclusion, and therefore, it is reasonable to assume that the baseline data reflect the skeletal status before conception. The two women with the prolonged time to pregnancy (7 and 8 months) did not differ from the rest. A more detailed assessment of breastfeeding patens may have increased our ability to differentiate changes due to breastfeeding.

In conclusion, our study supports that a net decrease in BMD occurs during pregnancy. Postpartum, BMD decreases further and is related to the length of the breastfeeding period. During prolonged breastfeeding, BMD at sites with mostly trabecular bone begins to be regained, whereas BMD at sites rich in cortical bone decreases further. However, 19 months following delivery, BMD is apparently fully regained independently of length if breastfeeding. Reversal of pregnancy-induced changes in body composition is also related to breastfeeding status, as the decrease in fat mass postpartum is postponed in women who continue to breastfeed.

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Conflicts of interest None.

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