Reduced maternal calcium intake through nutrition and supplementation is associated with adverse conditions for both the women and their infants in a Chinese population

Xiaohong Liu, MD, Xinjia Wang, MD, Yue Tian, MD, Zhixin Yang, MD, Li Lin, MD, Qing Lin, MD, Zhonghao Zhang, MD*, Li Li, MD*

Abstract
Effective nutritional guidelines for pregnant women in China are lacking. The aim of this study was to investigate the effect of dietary nutrition on the health condition of pregnant women and infants in China.

In total, 331 pregnant women who had prenatal examinations were included in this study. Data, including dietary nutrition questionnaires, the weight, height, age, and health condition of the pregnant women as well as the health condition of the infants, were recorded.

The average intake of milk, poultry and meat, fish and prawns, eggs, and bean products were 297.28 ± 129.67 mL/day, 123.34 ± 52.04 g/day, 157.31 ± 70.04 g/day, 67.34 ± 45.28 g/day, and 1.21 ± 0.62 per day, respectively. Among the 331 pregnant women, the intake rates of supplemental calcium and VD were 86.1% and 69.8%, respectively. The intake of milk, bean products, and meats was obviously lower (all P < .05) in the pregnant women with systemema compared to those without it. In addition, the body weight before and after delivery was higher (all P < .05) in the pregnant women with systemema. The calcium intake of the pregnant women and the infants’ BMD were remarkably lower in the infants with pillow baldness or a wider anterior fontanelle (P < .01) compared to those without the features.

The intake of milk, poultry and meat, fish and prawns, eggs, and bean products by pregnant women should be monitored, and in particular, the proper intake of milk, bean products, and meats, as well as calcium supplements, might decrease the occurrence of systemema in pregnant women and reduce the rate pillow baldness and a wider anterior fontanelle in infants.

Abbreviations: BMD = bone mineral density, SD = standard deviation, VC = vitamin C, VD = vitamin D.

Keywords: calcium supplements, infant health, maternal dietary nutrition, pregnancy, vitamin D

1. Introduction
Pregnant women undergo great physiological and metabolic changes that require specific maternal nutritional requirements, which play an important role in maternal and fetal development as well as in postpartum lactation.1,2 The maternal nutritional status is closely associated with the child’s health.3 The relationship between maternal nutrition and fetal health is complex and can be affected by various factors, including biological, demographic and socioeconomic factors, and maternal health and adequate nutrition during prepregnancy, pregnancy, and lactation are beneficial to improving fetal outcome and health.3 Therefore, a better understanding of maternal nutrition during pregnancy is necessary for infant health.

Experimental human and animal studies demonstrate the importance of the maternal nutritional status on fetal development and birth outcomes.4,5 In addition, a previous study reviewed the association of birth outcomes with maternal nutritional requirements during pregnancy, such as fatty acids, protein, folate, vitamin C (VC), VD, iron, calcium, magnesium, and zinc, and revealed that an adequate maternal nutrition reduces the risk of adverse birth outcomes.5 Usually the maternal nutritional requirements are provided through the consumption of milk, poultry and meat, fish and prawns, eggs, and bean products, suggesting the importance of the maternal dietary nutrition on infant health.6,7 Several studies report that certain aspects of the maternal diet, such as the intake of milk, meat, and seafood, improve both the maternal and infant health.8–11 Most of these studies were conducted in the United States and Europe, only a few studies have investigated the effect of maternal dietary nutrition on both maternal and infant health in China.
A recent study reported that pregnant women in developing countries had an inadequate micronutrient intake, had a predominantly plant-based diet and had imbalanced macronutrients. In particular, a large study investigating the nutrition and health status of pregnant women in China, covering 8 provinces, revealed a high rate of sural spasm during pregnancy, and a calcium deficiency seemed to be the leading cause of this occurrence. In addition, VD deficiency during pregnancy and early childhood is linked to a number of health problems in both the mother and the child and a recent study demonstrated a VD deficiency or insufficiency in newborns in Shanghai, China. There is a clear need for more studies relating maternal nutrition to infant health in China in order to provide better guidelines for pregnant Chinese women.

In the present study, dietary nutrition questionnaires from 331 pregnant women as well as the physical condition and bone mineral density (BMD) of the pregnant women and the infants were collected in order to investigate the effect of dietary nutrition on the health condition of the pregnant women and infants. These findings might contribute to the development of pregnancy-specific dietary guidelines in China.

2. Materials and Methods

2.1. Subjects

This study was approved by the Ethics Committee of Beijing Friendship Hospital, Capital Medical University. Pregnant women who had prenatal examinations in our hospital between January 2008 and December 2011 were enrolled in this study. The inclusion criteria were as follows: the pregnant women were asked to complete dietary nutrition questionnaires at 8 to 9 months of gestational age, which included their milk, poultry and meat, fish and prawns, eggs, bean products, calcium, and VD intakes and the intake rates of calcium and VD were 86.7% and 69.8%, respectively. Those without systremma (290.61 ± 28.79 g/day, 118.1 ± 47.2 g (181) 138.62, 118.1 ± 47.2 vs 129.8 ± 56.9, and 423.18 ± 171.64 vs 408.65 ± 92.67, respectively, all P < .05). Thus, on average, the women gained approximately 16 kg during pregnancy. The average intake of milk, milk and meat, fish and prawns, eggs, and bean products was 297.28 ± 129.67 mL/day, 123.34 ± 52.04 g/day, 157.31 ± 70.04 g/day, 67.34 ± 45.28 g/day, and 1.21 ± 0.62 per day, respectively. Among the 331 pregnant women, the intake rates of calcium and VD were 86.7% and 69.8%, respectively.

3. Results

3.1. Physical and dietary nutrition characteristics of the pregnant women

The average age and height of all of the pregnant women were 28.79 ± 3.48 years and 162.02 ± 5.04 cm, respectively. The average body weight of the pregnant women before pregnancy was 57.38 ± 7.44 kg, and before delivery, it was 73.31 ± 10.19 kg, P < .05. Thus, on average, the women gained approximately 16 kg during pregnancy. The average intake of milk, milk and meat, fish and prawns, eggs, and bean products was 297.28 ± 129.67 mL/day, 123.34 ± 52.04 g/day, 157.31 ± 70.04 g/day, 67.34 ± 45.28 g/day, and 1.21 ± 0.62 per day, respectively. Among the 331 pregnant women, the intake rates of calcium and VD were 86.7% and 69.8%, respectively.

3.2. The relationship between the incidence of systremma and the dietary nutrition of the pregnant women

During the third trimester, 54.7% of the pregnant women experienced systremma. The intake of milk, bean products, and meats was lower in the women with systremma compared to those who did not experience systremma (290.61 ± 121.74 vs 305.33 ± 138.62, 118.1 ± 47.2 vs 129.8 ± 56.9, and 423.18 ± 171.64 vs 408.65 ± 92.67, respectively, all P < .05). In addition, the weight of the pregnant women both before and after delivery was higher in the pregnant women with systremma compared to those without (74.5 ± 10.9 vs 71.9 ± 9.0 kg before and 65.12 ± 11.36 vs 63.53 ± 9.51 kg after, respectively, all P < .05) (Table 1). There was no significant difference in the BMD values of the mothers and infants between the pregnant women with and without systremma (Table 1).

3.3. The relationship between pillow baldness and the anterior fontanelle size of the infants and the dietary nutrition of the pregnant women

The infants were born at an average gestational age of 39.3 ± 1.23 weeks. The average height and body weight of the infants were 49.89 ± 1.44 cm and 3.39 ± 0.46 kg, respectively. The intake of

| Table 1 |
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| The dietary and bone mineral density in pregnant women with and without systremma (mean ± SD). |

|                         | Pregnant women with systremma (n) | Pregnant women without systremma (n) | P  |
|-------------------------|----------------------------------|-------------------------------------|----|
| Milk uptake, mL         | 290.61 ± 121.74 (181)            | 305.33 ± 138.62 (150)               | <.05|
| Bean products uptake, g | 118.1 ± 47.2 (181)               | 129.8 ± 56.9 (150)                  | <.01|
| Meats uptake, g         | 423.18 ± 171.64 (181)            | 408.65 ± 92.67 (150)                | <.05|
| Weight before delivery, kg | 74.5 ± 10.9 (181)             | 65.12 ± 11.56 (150)                 | <.05|
| Weight after delivery, kg | 71.9 ± 9.0 (181)                | 63.53 ± 9.51 (150)                  | <.05|
| Mother’s BMD            | 3117.86 ± 751.97 (111)           | 3106.06 ± 767.82 (69)               | NS  |
| Infant’s BMD            | 2669.86 ± 298.23 (111)           | 2701.67 ± 307.19 (69)               | NS  |

BMD = bone mineral density, NS = not significant, SD = standard deviation.
calcium in the pregnant women during pregnancy as well as the infants’ BMD values were remarkably lower in the infants with pillow baldness compared with the infants without pillow baldness (4.16 ± 2.45 vs 4.63 ± 2.34 and 2589.35 ± 315.77 vs 2857.52 ± 169.19, respectively, P < .01, Table 2). While the weight of the mothers and infants at 2 months postpartum were significantly higher for the infants with pillow baldness (66.38 ± 11.55 vs 60.77 ± 8.56 kg in the mothers and 6.25 ± 0.83 vs 5.36 ± 0.64 kg in the infants, all P < .01, Table 2). Moreover, the size of the anterior fontanelle of the infants was smaller when the calcium intake of the pregnant women and the infants were higher (P < .01, Table 3).

| Anterior fontanelle with 1 cm (n = 89) | Anterior fontanelle with 2 cm (n = 84) | Anterior fontanelle with 3 cm (n = 84) | P  |
|--------------------------------------|--------------------------------------|--------------------------------------|----|
| Calcium uptake, g                    | Calcium uptake, g                    | Calcium uptake, g                    |    |
| Infants’ BMD                         |                        |                        |    |
| Mothers’ body weight, kg             | 2792.09 ± 233.22         | 2656.69 ± 208.67         | 2606.14 ± 341.09         | <.01|
| Infants’ body weight, kg             | 6.25 ± 0.83 (105)        | 5.36 ± 0.64 (105)        |                |    |

4. Discussion

Maternal nutrition is related to the normal growth of a fetus. Poor or excess maternal nutrition might influence the brain development of an infant, leading to embryonic malformation and an increased incidence of birth defects.[19] According to the Dietary Guidelines for Chinese Residents (2016),[16] the average intake of milk, poultry and meat, fish and prawns, eggs, and bean products of pregnant women during the second and third trimester are up to par. However, detailed studies on whether these guidelines are good enough to ward off adverse effects in both the pregnant woman and her child remain unclear.

When considering the nutritional requirements during pregnancy, calcium intake is especially important because if the maternal calcium stores are depleted, maternal bone health can be adversely affected, resulting in a lower BMD and an increased rate of bone resorption. The third trimester is when it has the greatest consequence.[17] The body does not make calcium, and thus, calcium must be consumed through the dietary intake, after which it is sent to the skeletal system 98% of it is stored.[18] During pregnancy, fetal nutritional needs place great demand on the maternal nutritional needs in order to not deplete the maternal skeletal calcium storage.[17] In our study, we found that calcium intake, either through diet or a supplement was adequate based on the guidelines mentioned above, but when we examined our cohort of patients in more detail we found that the calcium intake actually could be divided into high and low groups and these were associated with certain conditions in both the women and the infants.

Systemema is known as a leg cramp induced by abnormal neuromuscular excitability and, it is related to fatigue, cold, hypocalcemia, and blocked blood flow.[19] Leg cramps commonly occur during pregnancy.[20] The incidence of systemema in this study was 54.7% during the third trimester, and the occurrence of systemema was associated with a reduced intake of milk, bean products, and meats as well as a higher weight before and after delivery. The maternal nutritional requirement for calcium increases during the second and third trimester,[18] and a lack of calcium might lead to the occurrence of systemema due to the increased neuromuscular excitability in pregnant women.[21] Notably, the intake of milk, bean products, and meats increases the amount of calcium the women receive,[22] which thereby reduces the occurrence of systemema. In addition, heavier pregnant women have a greater requirement for calcium and have an increased level of burden to their legs and muscular tension, which might also be a cause of systemema. However, systemema was not related to the BMD of the mothers and infants in this study, which might be due to the small sample size.

The bone mineral content plays a vital role in maternal health and fetal skeletal development, and BMD is an important symbol of bone quality.[23] Calcium supplementation increases the bone mineral content and prevents osteoporosis during pregnancy,[24] and VD is also reported to be associated with calcium metabolism and bone health.[25] A number of studies demonstrate significant decreases in bone mineral indicators in pregnancy, and the greatest changes occur during the third trimester when the maternal-fetal calcium transfer is the highest.[16–26] The BMD value is used as indicator of bone health and measures the density of the bone in grams per cubic centimeter. During pregnancy, the total BMD values have been shown to be decrease by up to 3.6%. [27] In fact the rate of bone loss during pregnancy is greater than the annual rate of loss in women after menopause.[30] Thus, it is very important that pregnant women intake adequate calcium levels.

Pregnant women need extra calcium to protect against the loss that occurs during the maternal–fetal transfer and to also ensure that the infant is gaining enough calcium as it develops in utero. It was well-known that the occurrence of pillow baldness and an increased size of the anterior fontanelle are both associated with inadequate calcium supplements.[31,32] In the present study, we revealed that when there were increased levels of the intake of...
calcium supplements during pregnancy and an elevated BMD in the infants, these were associated with a remarkable decrease in the occurrence of pillow baldness and a wider anterior fontanelle in the infants. These results suggested that the proper intake of calcium is indeed necessary for infant health.

5. Conclusions
According to the current Dietary Guidelines for Chinese Residents (2016), the intake of milk, poultry and meat, eggs, and bean products by the pregnant women in this study was reasonable. However, when we further studied this group of pregnant women, we found that they could be divided by the occurrence of systremma, and this was associated with a reduced intake of milk, bean products, and meats as well as a higher weight of the pregnant women. These products all contribute to the overall intake of calcium. Furthermore, for the women with an increased intake of calcium supplements and the infants with an elevated BMD, there was a decreased occurrence of pillow baldness and a wider anterior fontanelle in the infants. Together these findings suggest that adequate calcium intake by pregnant women is important for their health and for the health of their infants. In addition, this also suggests that the current guidelines should be refined to better assess calcium intake for pregnant Chinese women.

References
[1] Wu G, Bazer FW, Cudd TA, et al. Maternal nutrition and fetal development. J Nutr 2004;134:2169–72.
[2] Fall C. Maternal nutrition: effects on health in the next generation. Indian J Med Res 2009;130:593–9.
[3] Abu-Saad K, Fraser D. Maternal nutrition and birth outcomes. J Pediatr Child Health 2014;50:184–90.
[4] Moore VM, Davies MJ. Diet during pregnancy, neonatal outcomes and later health. Reprod Fertil Dev 2005;17:341–8.
[5] Zeisel SH. Is maternal diet supplementation beneficial? Optimal development of infants depends on mother’s diet. Am J Clin Nutr 2009;89:685–78.
[6] Koletzko B, Cetin I, Brenna JT. Dietary fat intakes for pregnant and lactating women. Br J Nutr 2007;98:873–7.
[7] Lagoiu P, Tamimi R, Mucci L, et al. Diet during pregnancy in relation to maternal weight gain and birth size. Eur J Clin Nutr 2004;58:231–7.
[8] Saito K, Yokoyama T, Miyake Y, et al. Maternal meat and fat consumption during pregnancy and suspected atopic eczema in Japanese infants aged 3–4 months: the Osaka Maternal and Child Health Study. Pediatr Allergy Immunol 2010;21:38–46.
[9] McGowan CA, McAuliffe FM. Maternal dietary patterns and associated nutrient intakes during each trimester of pregnancy. Public Health Nutr 2011;16:97–107.
[10] Innis SM. Human milk: maternal dietary lipids and infant development. Proc Nutr Soc 2007;66:397–404.
[11] Hibbeln JR, Davis JM, Steer C, et al. Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): an observational cohort study. Lancet 2007;369:578–85.
[12] Lee SE, Talegawkar SA, Mertzlik M, et al. Dietary intakes of women during pregnancy in low-and-middle-income countries. Public Health Nutr 2013;16:1340–53.
[13] Wang J, Zhao L, Piao J, et al. Nutrition and health status of pregnant women in 8 provinces in China. Wei Sheng Yan Jiu 2011;40:201–3.
[14] Weinert LS, Silveiro SP. Maternal-fetal impact of vitamin D deficiency: a critical review. Matern Child Health J 2015;19:94–101.
[15] Yu X, Wang W, Wei Z, et al. Vitamin D status and related factors in newborns in Shanghai, China. Nutrients 2014;6:3600–10.
[16] Wang SS, Lay S, Yu HN, et al. Dietary Guidelines for Chinese Residents (2016): comments and comparisons. J Zhejiang Univ Sci B 2016;17:649–56.
[17] Thomas M, Weisman SM. Calcium supplementation during pregnancy and lactation: effects on the mother and the fetus. Am J Obstet Gynecol 2006;194:937–45.
[18] Prentice A. Calcium in pregnancy and lactation. Annu Rev Nutr 2000;20:249–72.
[19] Mann R, Dipalma F. Leg cramps. Podiatr Manag 2009;10:204–6.
[20] Zhou K, West HM, Zhang J, et al. Interventions for leg cramps in pregnancy. Cochrane Database Syst Rev 2015;8:CD010655.
[21] Boppasiri P, Lumbiganon P, Thanikamonop J, et al. Calcium supplementation (other than for preventing or treating hypertension) for improving pregnancy and infant outcomes. Cochrane Database Syst Rev 2011;108:CD001626.
[22] Bhattachy A. Dietary calcium intake—a critical reappraisal. Indian J Med Res 2008;127:669–73.
[23] Prentice A. Micronutrients and the bone mineral content of the mother, fetus and newborn. Br J Nutr 2003;93:633–8.
[24] Johnston C Jr, Miller JZ, Slemenda CW, et al. Calcium supplementation and increases in bone mineral density in children. New Engl J Med 1992;327:822–7.
[25] Hollis BW, Wagner GL. Assessment of dietary vitamin D requirements during pregnancy and lactation. Am J Clin Nutr 2004;79:717–26.
[26] Drinkwater BL, Chesnut CH III. Bone density changes during pregnancy and lactation in active women: a longitudinal study. Bone Miner 1995;14:153–60.
[27] Affinito F, Tommaselli GA, di Carlo C, et al. Changes in bone mineral density and calcium metabolism in breastfeeding women: a one year follow-up study. J Clin Endocrinol Metab 1996;81:2314–8.
[28] Kent GN, Price RI, Gutteridge DH, et al. Effect of pregnancy and lactation on maternal bone mass and calcium metabolism. Osteoporos Int 1993;3:444–7.
[29] Sowers MF, Scholl T, Harris L, et al. Bone loss in adolescent and adult pregnant women. Obstet Gynecol 2000;96:189–93.
[30] Kalkwarf HJ, Specker BL. Bone mineral changes during pregnancy and lactation. Endocrine 2002;17:49–53.
[31] Champagne C, Farrant P. Hair loss in infancy and childhood. J Paediatr Child Health 2014;50:931–6.