*Actual. Osteol 2025; 21(3): 201-212.*
*https://ojs.osteologia.org.ar/ojs33010/index.php/osteologia/index*

**ACTUALIZACIONES / *Review***

# IMPLICATION OF CALCIUM SUPPLEMENTATION DURING PREGNANCY ON MATERNAL AND OFFSPRING BONE HEALTH

**Mercedes Lombarte[1], Agustina Velázquez[1], Laureana Villarreal[2], Patricia M. Lupión[2], Verónica E. Di Loreto[2], José Belizán[1], Lucas R. Brun[1]**

*1. Laboratorio de Biología Ósea y Metabolismo Mineral, Facultad de Ciencias Médicas, Universidad Nacional de Rosario - Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Santa Fe, Argentina.*
*2- Laboratorio de Biología Ósea y Metabolismo Mineral. Universidad Nacional de Rosario. Santa Fe, Argentina.*

Abstract

Pregnancy and lactation impose substantial demands on maternal calcium (Ca) metabolism to support foetal skeletal development and milk production. These physiological states trigger coordinated hormonal adaptations that increase intestinal Ca absorption during pregnancy and enhance bone resorption during lactation. In countries with low dietary Ca intake, such as Argentina, these demands may compromise maternal bone mass, raising concerns about long-term skeletal health. Although Ca supplementation is recommended by World Health Organization (WHO) to reduce the risk of hypertensive disorders during pregnancy, its effects on maternal bone mineral density and offspring skeletal development remain controversial. This review synthesizes current evidence on Ca metabolism during pregnancy and lactation, the role of regulatory hormones, and the impact of Ca supplementation on maternal and infant bone health, highlighting gaps in knowledge and implications for public health strategies. Evidence suggests that supplementation may be more effective when combined with vitamin D and extended into lactation. However, in populations with very low intake, supplementation could disrupt physiological adaptation and may result in adverse skeletal outcomes. The heterogeneity in study designs, populations, and supplementation protocols underscores the need for rigorous, long-term research to inform context-specific recommendations.

**Keywords:** bone and bones, bone density, calcium, pregnancy, offspring.

**E-mail: mercedeslombarte@gmail.com*

## *SUPLEMENTACIÓN CON CALCIO DURANTE EL EMBARAZO: IMPACTO EN LA SALUD ÓSEA MATERNA Y DE LA DESCENDENCIA*

***Resumen***

*El embarazo y la lactancia suponen un desafío para el esqueleto materno con el fin de cubrir las necesidades del feto y la producción láctea. Esos estados fisiológicos desencadenan adaptaciones hormonales coordinadas que conducen a un aumento de la absorción intestinal de calcio (Ca) durante el embarazo y potencian la resorción ósea durante la lactancia.*

*En poblaciones con baja ingesta de Ca, como ocurre en la Argentina, estas demandas pueden comprometer la masa ósea materna, generando preocupación con respecto a la salud ósea a largo plazo. Si bien la Organización Mundial de la Salud recomienda la suplementación con Ca para reducir el riesgo de trastornos hipertensivos durante el embarazo, sus efectos sobre la densidad mineral ósea materna y el desarrollo esquelético infantil son motivo de controversia. Esta revisión sintetiza la evidencia disponible sobre el metabolismo del Ca durante el embarazo y la lactancia, el papel de las hormonas reguladoras y el impacto de la suplementación en la salud ósea materna e infantil, destacando vacíos de conocimiento y sus implicanciones para las políticas de salud pública. La evidencia sugiere que la suplementación puede resultar más beneficiosa cuando se combina con vitamina D y se prolonga durante la lactancia. No obstante, en poblaciones con ingestas extremadamente bajas, la suplementación podría alterar el equilibrio fisiológico y generar efectos adversos sobre el esqueleto. La heterogeneidad en los diseños de estudio, las características poblacionales y los protocolos de suplementación subraya la necesidad de investigaciones rigurosas y de largo plazo que permitan establecer recomendaciones sólidas y contextualizadas.*

***Palabras claves:*** *tejido óseo, densidad mineral ósea, calcio, embarazo, descendencia*

### Introduction

Ca is an essential mineral for skeletal development and multiple metabolic processes. Pregnancy and lactation represent physiological states in which maternal Ca homeostasis is challenged to meet the mineral demands of both the mother and the foetus and the breastfeeding infant. Therefore, significant physiological adaptations in maternal mineral metabolism are required. These processes are regulated by hormonal changes and often lead to a decrease in maternal bone mass.[1]

During pregnancy, approximately 30 g of Ca are transferred from the mother to the foetus during gestation, most of it in the second half of pregnancy when foetal skeletal mineralization accelerates. The rate of foetal bone mineral accumulation increases from 50 mg/day at 20 weeks of gestation to 330 mg/day at 35 week' of gestation.[2,3] During lactation, the infant mineral requirement for the first six months postpartum is approximately 200 mg/day and 260 mg/day between six and 12 months of age.[4,5] To meet this demand, intestinal absorption increases during pregnancy, while during lactation, skeletal resorption increases to provide Ca to milk. These processes are regulated by several hormones, especially parathyroid hormone (PTH), parathyroid hormone-related peptide (PTHrP) and calcitriol among others (calcitonin, prolactin, and placental lactogen).[6,7]

In Argentina, Ca intake is below recommended levels (1000 mg/day in adults and 1200 mg/day in adolescents). National data indicate that pregnant women consume a median of 446 mg/day, and women of reproductive age approximately 367 mg/day—

less than half of the recommended intake. Furthermore only 1 % of women of childbearing age reported taking Ca supplements.[8]

Ca supplementation during pregnancy is recommended by the World Health Organization (WHO) to reduce the risk of hypertensive disorders, which in themselves involve serious risks to the mother and foetus.[9–12] However, its effects on maternal and infant bone health remain inconsistent across studies. Evidence from human trials shows heterogeneous results, while findings from animal models provide mechanistic insights but are not always directly translatable.[13–20]

Given these uncertainties, the objective of this narrative review is to synthesize current knowledge on Ca metabolism during pregnancy and lactation, describe the hormonal mechanisms involved, and evaluate the effects of Ca supplementation on maternal and offspring bone health. Additionally, we aim to identify gaps in literature and highlight considerations relevant for public health strategies in populations with low Ca intake.

## Methodology

This work corresponds to a narrative review of the literature. A literature search was conducted in PubMed/MEDLINE, SciELO, Scopus, and Google Scholar. Combinations of the following MeSH terms and keywords were used: *"Calcium supplementation," "Pregnancy," "Bone," "Bone Density,"* and *"Offspring."* The following were included: randomized clinical trials, longitudinal studies in humans, observational studies, systematic reviews and meta-analyses, and studies in animal models when they provided physiological information not available in humans. The following were excluded: studies without bone health data, case reports, articles without full-text access, and duplicate publications. Articles were selected by the authors through title, abstract, and full-text screening.

## Physiological adaptation during pregnancy, lactation and postweaning

Pregnancy and lactation are characterized by dynamic changes in Ca metabolism to meet the mineral demands of the developing foetus and breastfeeding infant. During pregnancy, maternal Ca absorption increases significantly, particularly in the second and third trimesters, when foetal skeletal mineralization accelerates.[2,3] Intestinal Ca absorption doubles from the first trimester, likely mediated by calcitriol-induced upregulation of Ca-transporting proteins.[6]

In contrast, lactation relies primarily on maternal skeletal resorption to supply Ca for milk production. This process involves osteoclast-mediated bone resorption and osteocytic osteolysis.[21] Renal Ca reabsorption is also enhanced, while intestinal absorption returns to baseline levels.[22–24]

Post-weaning, the maternal skeleton undergoes a rapid phase of remineralization.[3,25] Bone remodelling shifts toward net bone gain. Intestinal absorption of Ca and phosphorus is normal during post-weaning recovery.[22,26]

## Hormonal regulation

Ca homeostasis during pregnancy is regulated by a complex interplay of hormones. PTH secretion normally drops to low levels in early pregnancy and normal values in late pregnancy. This reduction of PTH secretion cannot occur in women with low Ca or vitamin D intake, or a high intake of phytate that hinder the absorption of Ca. In rodents, the level of PTH is influenced by the intake of Ca, rats typically have an increase in PTH during pregnancy that increases even more when diet is low in Ca.[2]

PTHrP appears to play a crucial role in the adaptations that occur during pregnancy and lactation. It begins to appear in maternal plasma and increases progressively from the first trimester of pregnancy until delivery, after which the levels decrease, unless lactation is initiated. PTHrP is produced by the placenta,

the breasts, and possibly the uterus and foetal tissues. Its effects (mimic PTH) include maintenance of ionic Ca, stimulation of $\alpha$-1-hydroxylase to produce elevated levels of calcitriol, and suppression and replacement of PTH.[7]

In addition to PTH (in rodents) and PTHrP (in humans), metabolites of vitamin D, prolactin, and placental lactogen are key regulators of Ca metabolism in mammals. Together they are responsible for increasing plasma Ca levels, by increasing bone resorption, stimulating intestinal Ca absorption through calcitriol synthesis and reducing urinary Ca excretion.[6]

The level of calcitriol increases during pregnancy in both humans and animals.[27–29] This increase may contribute to the positive regulation of intestinal Ca absorption during pregnancy by increases in Ca-transporting proteins [22] and, indirectly, to the suppression of PTH. Many, but not all, studies in rodents have shown that during pregnancy there is an increase in intestinal absorption of Ca and phosphorus without the need for calcitriol. Prolactin, placental lactogen, growth hormone, and other factors can contribute to increased absorption by directly increasing the expression of proteins responsible of Ca transport.[6]

On the other hand, calcitonin increases during pregnancy in women and animals, coming from the placenta and the breasts in addition to the C cells of the thyroid.[2,30] Calcitonin stimulates intestinal Ca absorption, although the mechanism seems to be through increased calcitriol production, instead of being independent of it.[31]

In most studies of lactating rats, PTH increased in a wide range of diets containing 0.4% to 1.4% Ca.[32] The low dietary Ca intake and the greater number of offspring cause a greater increase in PTH.[33,34] In women who tend to have diets with low Ca intake and a higher intake of phytate PTH is elevate. When adequate Ca is consumed, PTH is usually suppressed during lactation.[2]

The increased intestinal absorption of Ca that occurs during pregnancy continues during lactation in rodents. This is likely to be mediated in part by high levels of calcitriol, but also by calcitriol-independent mechanisms.[23,26,28,35] In contrast, intestinal Ca absorption decreases during lactation in women, accompanied by a drop in calcitriol. High or low Ca intake and high vitamin D intake do not appear to alter this rate in lactating women. In addition, urinary Ca excretion decreases, allowing it to be conserved to milk production.[2]

Calcitonin may be normal or increased in rodents and lactating women. Although it is largely considered a vestigial hormone, there is compelling evidence from animal models that calcitonin protects against excess skeletal resorption during lactation.[2,36–39]

Following lactation, the restoration of oestradiol to normal levels after weaning is thought to aid skeletal recovery, although it does not fully explain the process.[2] Levels of PTHrP decline, [34,40] while calcitriol concentration rise.[41] These hormonal shifts are associated with a reduction in bone resorption markers and an elevation in bone formation markers.[42]

**Bone Mass Changes in mothers during pregnancy, lactation and postweaning**

Animal models suggest that maternal bone mass may increase early in pregnancy, while late pregnancy bone mass is approximately equal to or slightly lower than pre-pregnancy values.[43] Bone remodelling increases during late pregnancy, when PTH secretion also increases, these changes are accentuated when a diet low in Ca is administered. Available data from pregnant women indicate that there is also a positive Ca balance towards the mid-pregnancy, but it has not been determined whether bone mineral density (BMD) objectively increases at this time.[21,44]

The primary adaptation during lactation is a temporary demineralization of the skeleton through two processes: osteoclast-mediated

bone resorption and osteocytic osteolysis. Notably, dietary Ca restriction during lactation does not alter the magnitude of bone loss.[45] Average losses of 25 to 35% occur in the lumbar spine during the 3 weeks of lactation in rodents; while losses of 5 to 10% in the lumbar spine are induced by 6 months of lactation in humans, with minor losses in other skeletal sites.[2,21]

After weaning, the maternal skeleton goes through a rapid phase of remineralization.[3,25] Bone remodelling continues to increase from pre-pregnancy values but is now decoupled in the opposite direction to lactation, favouring net bone gain. In rodents, mineralization and strength fully recover in 2-8 weeks, whereas women probably achieve it closer to 1 year after interrupting lactation.[21] However, adequate Ca is required,[3] as a low Ca diet prevented skeletal recovery in rats, while normalization of the diet 3 weeks later allowed normal recovery to occur.[46] Additionally, in women, adequate Ca intake during pregnancy appears to be associated with better BMD five years after childbirth.[47]

**Bone Effects of Ca Supplementation on Maternal Bone Health**

Ca supplementation during pregnancy has been widely studied for its role in preventing hypertensive disorders, but its impact on maternal bone health remains controversial.[12] The Table 1 summarizes the different studies included in this review.

In a double-blind, placebo-controlled trial conducted in Gambia, West Africa, pregnant women with extremely low Ca intake (350 mg Ca per day) were supplemented with 1,500 mg Ca daily. The results revealed a reduction in bone mineral content (BMC) and BMD in both the lumbar spine and hip at 13 and 52 weeks postpartum, with the group receiving Ca supplementation experiencing a greater decline compared to the placebo group. The observed biochemical profile indicated a greater mineral turnover between the maternal skeleton and the extracellular compartment in the Ca-supplemented group, resulting in a net loss of bone minerals. This was evidenced by increased urinary excretion of Ca and phosphorus, reduced plasma levels of PTH and 1,25(OH)2D, elevated plasma concentrations of calcitonin and 25-hydroxyvitamin D, and lower plasma bone alkaline phosphatase. Additionally, there were trends towards decreased plasma osteocalcin and increased urinary deoxypyridinoline excretion.[17]

In contrast, other studies found an increase in BMD and bone formation in women who intake Ca supplements than in those who did not.[13–15,18,20] These trials were conducted in women with intakes of Ca higher (600-1100 mgCa/day) than those of the groups analysed by Jarjou et al. Moreover, Ca supplements were administered during pregnancy and lactation,[13,15,18,20] in some cases accompanied by vitamin D.[14] One study was carried out in adolescent mother by Diogenes et al. In this trial supplementation with Ca plus vitamin D administered during pregnancy led to increased BMD at five weeks postpartum, although this effect was not sustained at one year. This study analysis in hip geometry too and found time effects in cross-sectional area, cross-sectional moment of inertia and section modulus parameters with decreases from the 5$^{th}$ to the 20$^{th}$ week postpartum followed by recovery from the 20$^{th}$ to the 56$^{th}$ week.[14,48,49] Given that peak bone mass is typically reached around age 25, differences in mineral metabolism between adolescents and adults may explain these transient effects.

A meta-analysis that contemplates several of mentioned trials highlighted the heterogeneity of studies in terms of baseline Ca intake, supplementation duration, dosage, and participant characteristics, making it difficult to draw firm conclusions.[50] Overall, the effect of Ca supplementation on maternal bone metabolism remains uncertain and warrants further investigation.

**Table 1.** Study Included.

| Study | Population | Baseline Ca Intake | Supplementation Protocol | Duration | Maternal Outcomes | Offspring Outcomes |
|---|---|---|---|---|---|---|
| **Jarjou et al., 2006, 2010, 2013 and Ward et al. 2017 (Gambia)** | Adult pregnant women | ~350 mg/day | 1500 mg/day Ca vs placebo | ~20 weeks of gestation until delivery. | Greater postpartum decline in BMD; increased mineral turnover Persistent lower BMD at 1 year of follow-up | No significant effects on infant growth or BMC during first year. Sex-specific effects at 8–12 years (girls: smaller bones; boys: greater body mass) |
| **Liu et al., 2011 (China)** | Adult pregnant women | ~500 mg/day | Milk + 600 mg/day Ca vs placebo | ~20 weeks of gestation until 6 weeks postpartum | Increased BMD and bone formation at 45 days postpartum | Not evaluated |
| **Ettinger et al., 2014 (Mexico)** | Adult pregnant women | ~1000 mg/day | 1200 mg/day Ca vs placebo | ~14 weeks of gestation until 1 month postpartum | Reduced bone resorption markers | Not evaluated |
| **Cullers et al., 2019 (USA)** | Adult pregnant women | 800–1100 mg/day | 1000 mg/day Ca vs placebo | ~16 weeks of pregnancy to 12 moth postpartum | Increased tibial BMD at 1 year postpartum | Not evaluated |
| **Diogenes et al., 2013, 2015, 2021 and Rached et al., 2024 (Brazil)** | Adolescent pregnant women | ~500 mg/day | 600 mg/day Ca + 200UI/day vitamin D vs placebo | ~26 weeks of gestation until delivery | Increased BMD at 5 weeks postpartum; effect not sustained at 1 year, without effect in geometry | No differences in infant bone mass at 5 weeks |

**Bone Effects of Ca Supplementation in Offspring**

The impact of maternal Ca supplementation on offspring bone health and development is equally complex. In the Gambian trial, Ca supplementation during pregnancy did not have a significant effect on Ca concentrations in breast milk in the subsequent lactation

period, and there was no evidence of beneficial outcomes for the child in terms of weight, length and BMC in the first year of life.[51] However, in a long-term follow-up, sex-specific effects of maternal Ca supplementation were observed in offspring aged 8 to 12 years. Girls whose mothers received Ca were shorter, lighter, and had smaller and less mineralized bones than girls in the placebo group. In contrast, boys whose mothers were in the Ca group tended to have a greater mid-upper arm circumference, more fat mass, and, in general, greater bone mass and size than boys in the placebo group, although these latter differences were not significant after adjusting for body size.[52]

These results are again contradicted by other studies that found positive effects of Ca supplementation during pregnancy on the offspring BMD; [53,54] or found no effect, positive or negative.[50]

In Brazilian adolescents with low Ca intake, it has been observed that maternal Ca plus vitamin D supplementation did not affect foetal femoral and humeral lengths at 36 weeks of gestation. In addition, increases in weight and length from birth to 5 weeks were similar in both groups, and there were no significant differences in bone mass, density, and area at 5 weeks of age.[55]

In summary, the effects of maternal Ca supplementation on offspring vary depending on the parameter measured, timing of evaluation, and population studied. While early-life bone outcomes appear unaffected, long-term growth and body composition may be influenced in a sex-specific manner, suggesting a complex influence of maternal Ca supplementation on offspring development. Despite these findings, the evidence regarding offspring bone health is considered inconclusive due to the high variability among studied populations and significant differences in supplementation protocols across groups.[50]

## Discussion and conclusion

The physiological adaptations of Ca metabolism during pregnancy and lactation are generally effective in meeting foetal and neonatal mineral demands while preserving maternal skeletal integrity. These adaptations—characterized by increased intestinal Ca absorption during pregnancy and enhanced skeletal resorption during lactation—are orchestrated by coordinated hormonal changes involving PTH, PTHrP, calcitriol, prolactin, and placental lactogen. Evidence from both human and animal studies indicates that these mechanisms are robust but become vulnerable when dietary Ca intake is insufficient.

When comparing findings across species, it becomes clear that the skeletal response to Ca supplementation during pregnancy and lactation is shaped by different physiological and endocrine adaptations in humans and animals, particularly rodents. Rodents maintain elevated intestinal absorption throughout lactation, supported by sustained calcitriol activity, whereas in humans, absorption returns to non-pregnant levels. These species-specific patterns could influence how supplementation interacts with mineral homeostasis. The accelerated bone formation and post-weaning recovery observed in rodents provide valuable mechanistic insight but do not mirror the slower, more tightly regulated human skeletal response. Together, these differences highlight that while animal models elucidate underlying biological pathways, physiological differences make extrapolation to humans difficult.

Across clinical trials, the effect of Ca supplementation during pregnancy on maternal bone health presents a paradox.[16,17] Trials conducted in populations with moderate Ca intake (600–1100 mg/day) generally report neutral or beneficial effects, including reduced bone resorption markers, increased tibial BMD, or improved postpartum recovery, particularly when supplementation extends into lactation or is combined with vitamin D. These findings are supported by studies in Chinese, Mexican, and U.S. cohorts, as well

as by trials in Brazilian adolescents, although the latter show only transient benefits, likely reflecting the unique mineral demands of the growing adolescent skeleton.[14,15,18,48,49] In contrast, the Gambian studies—conducted in women with extremely low Ca intake (~350 mg/day)—demonstrate an increase in postpartum bone loss among those receiving Ca supplements. The biochemical profile observed (lower PTH and calcitriol, higher calcitonin, increased urinary Ca and P excretion) suggests that supplementation may have disrupted the physiological adaptations that normally conserve Ca under conditions of chronic dietary scarcity. This "paradoxical effect" highlights the possibility that, in severely deficient populations, supplementation may shift mineral fluxes unfavourably by attenuating compensatory hormonal responses essential for skeletal protection. The long-term follow-up showing persistent lower BMD further underscores the need to contextualize supplementation strategies according to baseline intake and physiological adaptation.[16,17]

In adolescents, the transient benefits of supplementation suggest that age and skeletal maturity are critical factors. The lack of sustained improvement in BMD at one year postpartum[48] underscores the need for long-term follow-up and age-specific recommendations.

Regarding offspring outcomes, the evidence is similarly mixed. Most studies report no significant effects of maternal Ca supplementation on neonatal bone mass or early postnatal growth. However, long-term Gambian follow-up revealed sex-specific differences in growth and bone parameters, with girls showing reduced growth and bone size and boys showing increased fat and bone mass.[52] These findings suggest that maternal Ca intake may influence the programming of bone development, though mechanisms remain unclear and findings have not been replicated in other populations. Overall, the evidence for offspring bone health remains inconclusive, largely due to variability in study design, timing of assessments, and population characteristics.

Taken together, the available literature indicates that the skeletal effects of Ca supplementation during pregnancy are highly context-dependent. Factors such as baseline Ca intake, vitamin D status, age, skeletal maturity, and whether supplementation continues into lactation appear to influence outcomes. While Ca supplementation is unequivocally recommended by the WHO for the prevention of hypertensive disorders of pregnancy, its impact on maternal and offspring bone health cannot be generalized across populations.[9,1012] Future research should prioritize rigorous, long-term, and methodologically comparable studies that stratify participants by baseline Ca intake and nutritional status. Understanding the physiological thresholds at which supplementation becomes beneficial—or potentially disruptive—will be essential for developing context-specific public health recommendations. Meanwhile, improving Ca intake through dietary education, supplementation programs, and food fortification remains a critical strategy, especially in countries like Argentina where habitual Ca intake is less than 50% of the recommended amount.

## Conclusion

Ca supplementation during pregnancy is a recommended strategy for reducing the risk of hypertensive disorders; however, its effects on maternal and offspring bone health appear to be contingent on the nutritional context and the specific characteristics of the intervention.

- In populations with moderate Ca intake, supplementation—particularly when continued throughout lactation and combined with vitamin D—may contribute to improved postpartum bone recovery.
- In populations with extremely low Ca

intake, supplementation may interfere with adaptive physiological mechanisms and may be associated with greater maternal bone loss.

- In offspring, the reported effects are heterogeneous and remain inconclusive.

Received: december 2025
Accepted: june 2026
Published: july 2026

**Author Contributions:** Conceptualization: ML, VED, JB, LRB. Data curation: AV, LV, PML. Writing – original draft: ML, AV, LV. Writing – review & editing: ML, AV, LV, PML, VED, JB, LRB.

**Conflict of interest:** The authors declare no conflict of interest.

**Funding:** The authors declare that no funding or financial support was received for the conduct of this study or the preparation of this article.

**References**

1. Olausson H, Laskey A, Goldberg GR, Prentice A. Changes in bone mineral status and bone size during pregnancy and the influences of body weight and calcium intake. *Am J Clin Nutr* 2008;88:1032-41.
2. Kovacs CS. Maternal mineral and bone metabolism during pregnancy, lactation, and post-weaning recovery. *Physiol Rev* 2016;96(2):449-547.
3. Prentice A. Micronutrients and the bone mineral content of the mother, fetus and newborn. *J Nutr* 2003;133(5):1693S-99S.
4. Allen JC, Keller RP, Archer P, Neville MC. Studies in human lactation: milk composition and daily secretion rates of macronutrients in the first year of lactation. *Am J Clin Nutr* 1991;54(1):69-80.
5. Weaver CM. The quest for evidence for calcium requirements for bone during pregnancy and lactation. *Am J Clin Nutr*. 2019;109(1):3-4.
6. Fudge NJ, Kovacs CS. Pregnancy up-regulates intestinal calcium absorption and skeletal mineralization independently of the vitamin D receptor. *Endocrinology* 2010;151(3):886–95.
7. Ardawi M, Nasrat H, B'Aqueel H. Calcium-regulating hormones and parathyroid hormone-related peptide in normal human pregnancy and postpartum: a longitudinal study. *Eur J Endocrinol* 1997;137(4):402-9.
8. Ministerio de Salud, Argentina. Documento de resultados. Encuesta Nacional de Nutrición y Salud. Presidencia de la Nación Argentina; 2007.
9. Belizán JM, Villar J, Repke J. The relationship between calcium intake and pregnancy-induced hypertension: Up-to-date evidence. *Am J Obstet Gynecol* 1988;158(4):898-902.
10. Hofmeyr GJ, Lawrie TA, Atallah ÁN, Duley L, Torloni MR. Calcium supplementation during pregnancy for preventing hypertensive disorders and related problems. *Cochrane Database of Systematic Reviews* 2014;24(6):CD001059.
11. Gerede A, Papasozomenou P, Stavros S, et al. Calcium Supplementation in Pregnancy: A Systematic Review of Clinical Studies. *Medicina (B Aires)* 2025;61(7):1195.
12. World Health Organization. Guideline: Calcium supplementation in pregnant women. *World Health Organization* 2013;24.
13. Hacker A, King J, Loan M Van, et al. Calcium supplementation during pregnancy improves

tibial bone density at one year post-partum in racially diverse women. *The FASEB Journal* 2014;28(S1):250-3.
14. Diogenes MEL, Bezerra FF, Rezende EP, Taveira MF, Pinhal I, Donangelo CM. Effect of calcium plus vitamin D supplementation during pregnancy in Brazilian adolescent mothers: a randomized, placebo-controlled trial. *Am J Clin Nutr* 2013;98(1):82-91.
15. Ettinger AS, Lamadrid-Figueroa H, Mercado-García A, et al. Effect of calcium supplementation on bone resorption in pregnancy and the early postpartum: a randomized controlled trial in Mexican Women. *Nutr J* 2014;13(1):116.
16. Jarjou LM, Sawo Y, Goldberg GR, Laskey MA, Cole TJ, Prentice A. Unexpected long-term effects of calcium supplementation in pregnancy on maternal bone outcomes in women with a low calcium intake: a follow-up study. *Am J Clin Nutr* 2013;98(1):723-30.
17. Jarjou LM, Laskey MA, Sawo Y, Goldberg GR, Cole TJ, Prentice A. Effect of calcium supplementation in pregnancy on maternal bone outcomes in women with a low calcium intake. *Am J Clin Nutr* 2010;92(2):450-7.
18. Cullers A, King JC, Van Loan M, Gildengorin G, Fung EB. Effect of prenatal calcium supplementation on bone during pregnancy and 1 y postpartum. *Am J Clin Nutr.* 2019;109(1):197-206.
19. Goldberg GR, Jarjou LMA, Cole TJ, Prentice A. Pregnant Gambian women accustomed to a low calcium intake: effects on maternal blood pressure and infant growth. *Am J Clin Nutr.* 2013;98:972-82.
20. Liu Z, Qiu L, Chen YM, Su YX. Effect of milk and calcium supplementation on bone density and bone turnover in pregnant Chinese women: a randomized controlled trail. *Arch Gynecol Obstet* 2011;283(2):205-11.
21. Winter EM, Ireland A, Butterfield NC, et al. Pregnancy and lactation, a challenge for the skeleton. *Endocr Connect* 2020;9(6):R143-57.
22. Boass A, Toverud SU, Wesley PJ, Haussler MR. Calcium metabolism during lactation: enhanced intestinal calcium absorption in vitamin D-deprived, hypocalcemic rats. *Endocrinology* 1981;109(3):900-7.
23. Greer FR, Tsang RC, Searcy JE, Levin RS, Steichen JJ. Mineral homeostasis during lactation—relationship to serum 1,25-dihydroxyvitamin D, 25-hydroxyvitamin D, parathyroid hormone, and calcitonin. *Am J Clin Nutr* 1982;36(3):431-7.
24. Kalkwarf HJ, Specker BL. Bone mineral changes during pregnancy and lactation. *Endocrine* 2002;17(1):49-53.
25. Laskey M. Bone mineral changes during and after lactation. *ObstetGynecol* 1999;94(4):608-15.
26. Grizzo FMFF, Alarcão ACJJ, Dell' Agnolo CM, et al. How does women's bone health recover after lactation? A systematic review and meta-analysis. *Osteoporos Int* 2020;31(3):413-27.
27. Wilson SG, Retallack RW, Kent JC, Worth GK, Gutteridge DH. Serum free 1,25-dihydroxyvitamin D and the free 1,25-dihydroxyvitamin D index during a longitudinal study of human pregnancy and lactation. *Clin Endocrinol (Oxf)* 1990;32(5):613-22.
28. Pike J, Parker J, Haussler M, Boass A, Toverud S. Dynamic changes in circulating 1,25-dihydroxyvitamin D during reproduction in rats. *Science (1979)* 1979;204(4400):1427-9.
29. Wagner CL, Hollis BW. Early-life effects of vitamin D: a focus on pregnancy and lactation. *Ann Nutr Metab* 2020;76(2):16-28.
30. Garel JM, Jullienne A. Plasma calcitonin levels in pregnant and newborn rats. *J Endocrinol*. 1977;75(3):373-82.
31. Jaeger P, Jones W, Clemens TL, Hayslett JP. Evidence that calcitonin stimulates 1,25-dihydroxyvitamin D production and intestinal absorption of calcium in vivo. *J Clin Invest*. 1986;78(2):456-61.
32. Gonen E, Sahin I, Ozbek M, Kovalak E, Yologlu S, Ates Y. Effects of pregnancy and lactation on bone mineral density, and their

relation to the serum calcium, phosphorus, calcitonin and parathyroid hormone levels in rats. *J Endocrinol Invest* 2005;28(6):322-6.

33. Garner SC, Peng TC, Hirsch PF, Boass A, Toverud SU. Increase in serum parathyroid hormone concentration in the lactating rat: Effects of dietary calcium and lactational intensity. *J Bone Miner Res.* 2009;2(4):347-52.
34. Garner SC, Peng TC, Toverud SU. Modulation of serum parathyroid hormone and ionized calcium concentrations during reproduction in rats fed a low calcium diet *J Bone Miner Res.* 1988;3(3):319-23.
35. Boass A, Garner SC, Schultz VL, Toverud SU. Regulation of serum calcitriol by serum ionized calcium in rats during pregnancy and lactation. *J Bone Miner Res.* 1997;12(6):909-14.
36. Greer FR, Lane J, Ho M. Elevated serum parathyroid hormone, calcitonin, and 1,25-dihydroxyvitamin D in lactating women nursing twins. *Am J Clin Nutr* 1984;40(3):562-8.
37. Dahlman T, Sjöberg HE, Bucht E. Calcium homeostasis in normal pregnancy and puerperium: A longitudinal study. *Acta Obstet Gynecol Scand* 1994;73(5):393-8.
38. Hillman L, Sateesha S, Haussler M, Wiest W, Slatopolsky E, Haddad J. Control of mineral homeostasis during lactation: Interrelationships of 25-hydroxyvitamin D, 24,25-dihydroxyvitamin D, 1,25-dihydroxyvitamin D, parathyroid hormone, calcitonin, prolactin, and estradiol. *Am J Obstet Gynecol* 1981;139(4):471-6.
39. Woodrow JP, Sharpe CJ, Fudge NJ, Hoff AO, Gagel RF, Kovacs CS. Calcitonin plays a critical role in regulating skeletal mineral metabolism during lactation. *Endocrinology* 2006;147(9):4010-21.
40. Wysolmerski JJ. Interactions between breast, bone and brain regulate mineral and skeletal metabolism during lactation. *Ann N Y Acad Sci* 2010;1192:161.
41. Kalkwarf HJ, Specker BL, Ho M. Effects of calcium supplementation on calcium homeostasis and bone turnover in lactating women. *J Clin Endocrinol Metab.* 1999;84(2):464-70.
42. VanHouten JN, Wysolmerski JJ. Low estrogen and high parathyroid hormone-related peptide levels contribute to accelerated bone resorption and bone loss in lactating mice. *Endocrinology* 2003;144(12):5521-9.
43. Tojo Y, Kurabayashi T, Honda A, et al. Bone structural and metabolic changes at the end of pregnancy and lactation in rats. *Am J Obstet Gynecol* 1998;178(1 I):180-5.
44. Ó Breasail M, Ward KA, Schoenbuchner SM, et al. Pregnancy-Related Change in pQCT and Bone Biochemistry in a Population With a Habitually Low Calcium Intake. *J Bone Miner Res.* 2021;36(7):1269-80.
45. Ross RD, Meagher MJ, Sumner DR. Calcium restriction during lactation has minimal effects on post-weaning mineral metabolism and bone recovery. *J Bone Miner Metab* 2019;37(4):648-57.
46. Hagaman JR, Ambrose WW, Hirsch PF. A scanning electron microscopic and photon absorptiometric study of the development, prolongation, and pattern of recovery from lactation-induced osteopenia in Rats. *J Bone Miner Res* 1990;5(2):123-32.
47. O'Brien EC, Geraghty AA, Kilbane MT, McKenna MJ, McAuliffe FM. Bone resorption and dietary calcium in pregnancy-a window to future maternal bone health. *Osteoporos Int.* 2021;32(9):1803-14.
48. Diogenes MEL, Bezerra FF, Donangelo CM. Reduction in bone loss from 5 to 20 weeks postpartum in adolescents supplemented with calcium plus vitamin D during pregnancy is not sustained at 1 year postpartum: follow-up study of a randomized controlled trial. *J Nutr* 2021;151(3):548-55.
49. Rached V, Diogenes MEL, Crivelli M, Donangelo CM, Bezerra FF. Calcium plus vitamin D supplementation during pregnancy has no impact on postpartum transient longitudinal changes in hip geometry in adolescent mothers: a secondary analysis

of a randomised controlled trial. *Br J Nutr* 2024;132(10):1325–33.

50. Tihtonen K, Korhonen P, Isojärvi J, et al. Calcium supplementation during pregnancy and maternal and offspring bone health: a systematic review and meta-analysis. *Ann N Y Acad Sci* 2022;1509(1):23-36.
51. Jarjou LM, Prentice A, Sawo Y, et al. Randomized, placebo-controlled, calcium supplementation study in pregnant Gambian women: effects on breast-milk calcium concentrations and infant birth weight, growth, and bone mineral accretion in the first year of life. *Am J Clin Nutr* 2006;83:657-66.
52. Ward KA, Jarjou L, Prentice A. Long-term effects of maternal calcium supplementation on childhood growth differ between males and females in a population accustomed to a low calcium intake. *Bone* 2017;103:31-8.
53. Liu X, Wang X, Tian Y, et al. Reduced maternal calcium intake through nutrition and supplementation is associated with adverse conditions for both the women and their infants in a Chinese population. *Medicine* 2017;96(18):e6609.
54. Koo WWK, Walters JC, Esterlitz J, Levine RJ, Bush AJ, Baha Sibai. Maternal calcium supplementation and fetal bone mineralization. *ObstetGynecol* 1999;94(4):577-82.
55. Diogenes MEL, Bezerra FF, Rezende EP, Donangelo CM. Calcium plus vitamin D supplementation during the third trimester of pregnancy in adolescents accustomed to low calcium diets does not affect infant bone mass at early lactation in a randomized controlled trial. *J Nutr* 2015;145(7):1515-23.