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Current evidence around key underrepresented women's health topics in pregnancy and postpartum nutrition: a narrative review

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Abstract

Adequate nutrition during pregnancy and postpartum is critical to maternal and child health, but there is often a missing focus around health outcomes specifically for women. Women's health includes sex-specific biological attributes and socially constructed gender roles framing behaviours and practices. This narrative review aims to highlight key areas where women's health has been underrepresented in pregnancy and postpartum nutrition research. Current evidence and research gaps are discussed for nutritional requirements during pregnancy and lactation, maternal mortality and morbidity nutritional risk factors, preconception and postpartum nutrition, and gendered cultural norms and inequities in access to nutritious foods during pregnancy and postpartum. Important areas for future research include strengthening empirical evidence for nutritional requirements in pregnant and lactating populations, the relationship between maternal iron status, anaemia and maternal morbidities, linkages between nutrient status among women and adolescent girls to maternal health outcomes, postpartum nutrition for recovery, lactation, and long-term women's health outcomes, and strength-based cultural practices that can support adequate maternal nutrition. There is an ongoing need to include women in nutritional requirements research, and measure health outcomes for women to ensure creation of an evidence base on both sex and gender-based datasets.

Key words: review, nutrition during pregnancy, postpartum and lactation, nutritional requirements, pregnancy complications, gender roles

Introduction

Adequate nutrition during pregnancy and postpartum plays a vital role in ensuring maternal health and wellbeing (Ho et al. 2016; Mate et al. 2021; Marshall et al. 2022). Globally, pregnancy nutrition gained widespread attention within the influential First Thousand Days framework, which emphasizes the importance of early life nutrition from conception to a child's second birthday for optimal growth and development throughout the lifespan (Black et al. 2013; Cusick and Georgieff 2013; Mason et al. 2015; Wrottesley et al. 2016). The First Thousand Days is frequently discussed in low- and middle-income countries (LMICs) where the primary objective is the reduction of childhood stunting, with far-reaching implications on cognitive development and human capital, and support breaking cycles of intergenerational poverty (Adair et al. 2013). It is also a focus in high-income countries (HICs), often with the objective of reducing childhood overweight and obesity, with implications for the reduction of non-communicable diseases in later life (Perreault et al. 2016; Woo Baidal et al. 2016; Hamner et al. 2022; Aubert et al. 2023). However, particularly during pregnancy and exclusive breastfeeding, the focus remains on maternal nutrition for offspring growth and development outcomes. While the beneficial effects on child health are invaluable, there is a missing focus around health outcomes for women (Kinshella et al. 2020). This review aims to shift the focus of maternal nutrition to health issues and outcomes especially in women.

Women are burdened by both increased nutritional demands during pregnancy and lactation as well as gender inequities in poverty (Delisle 2008). Following the Government of Canada and Canadian Institutes for Health (CIHR) Gender-Based Analysis Plus approach (Canadian Institutes of Health Research 2018; Government of Canada 2021), women's health includes consideration of the sex-specific biological attributes among females as well as socially constructed gender roles, which intersects with other identity factors such as race and ethnicity. Biologically, females experience increased nutrient requirements during pregnancy to support the multitude of physiological changes that occur, including increased blood volume, hormonal shifts, and growth of the placenta and fetal tissues (Mousa et al. 2019; Tsakiridis et al. 2020). Pregnancy complications are sex-specific health conditions that require targeted nutrition research. Additionally, gendered societal expectations, cultural norms, and socio-economic factors impact women's dietary choices and access to nutritious food (Rao 2020; Das and Mishra 2021; Feskens et al. 2022). A 2021 review by Devries and Jakobi of publications in *Applied Physiology, Nutrition and Metabolism* found that only 11% of articles identified females as the primary experimental group, only 10% included sex as a bivariate measure, and almost two-thirds of review papers did not identify sex or gender (Devries and Jakobi 2021). Shortfalls in the consideration of sex and gender in study designs, analysis, and data reporting raise concerns about the applicability of current scientific evidence to diverse populations, and can also lead to neglect of health topics unique to women (Holdcroft 2007; Mazure and Jones 2015; Devries and Jakobi 2021; Feskens et al. 2022). The missing explicit focus on the importance of maternal nutrition for mothers contributes to shortfalls in evidence-based data and subsequently to weaker recommendations, lower prioritization, and less future research in the area (Kinshella et al. 2020).

The purpose of this comprehensive narrative review is to summarize current evidence and key areas where women's health outcomes have been underrepresented in pregnancy and postpartum nutrition research. The review will first describe nutritional requirements during pregnancy and lactation outlined by the dietary reference intakes (DRIs), then the known associations and knowledge gaps between dietary risk factors for maternal mortality and morbidity, followed by summarizing current evidence on preconception and postpartum nutrition, and lastly on gendered cultural norms and inequities in access to nutritious foods during pregnancy and postpartum.

Methodology

Systematic searches were conducted on Medline Ovid and the Cochrane Library. Each database was searched from its inception to August 2024. Targeted searches were then conducted to further explore issues raised in initial studies compiled. Additionally, consultations with experts in the field were also conducted, as well as searches on reference lists and relevant grey literature, such as the World Health Organization (WHO) and the Institute of Medicine/National Academies Press, as well as Google Scholar. See Table S1 for search terms.

With the aim of understanding the broad, global landscape of research, we utilized a hierarchical literature review approach that first prioritized reviews (umbrella reviews, reviews of reviews, systematic reviews and meta-analyses, scoping and narrative reviews). When reviews were unavailable, randomized controlled trials for interventions and large cohort studies for exposures were utilized, then subsequently cross-sectional studies, case-controlled studies, and qualitative studies when trials and cohort studies were unavailable (Hiatt et al. 2014; Kinshella et al. 2022*b*; Elawad et al. 2024). Some topic areas, especially around gender roles and social norms, are more amenable and better reported through qualitative studies. For DRIs in particular, publications from the Institute of Medicine, United Kingdom Department of Health and WHO were reviewed. Where available, reviews were first selected, then reference lists scanned, and key studies (i.e., seminal studies, subsequent studies) identified if relevant to provide more depth into topics. Whilst every attempt was made to provide a comprehensive summary of the literature, a formal systematic review on each topic was not undertaken due to the scope in focus.

Review topic areas were determined a priori by authors (DRIs, nutritional risk factors for maternal mortality and morbidity, preconception and postpartum nutrition, gendered cultural norms and inequities in access to nutritious foods during pregnancy and postpartum). Publications included in the review were required to report on topic areas within the context of the maternity continuum. Where there were multiple publications on a similar topic, the most recent were prioritized. Across the four topic areas, searches resulted in 6889 references screened, 183 full texts reviewed, and 122 publications included in the narrative review (Table S1).

Dietary reference intakes during pregnancy and lactation

DRIs in Canada and the United States include the estimated average requirement (EAR), which is the average daily nutrient intake estimated to meet the requirement in half of healthy individuals in a particular life stage and gender group. Based on the EAR, the recommended dietary allowance (RDA) is an estimate of the daily average dietary intake that meets the nutrient needs of 97%–98% healthy individuals within their population group (Institute of Medicine 2006). DRIs were developed with intended use in North America, but are widely adopted globally for policy setting, public health programming, and commercial references (Smith et al. 2021). For instance, in the development of the United Nations International Multiple Micronutrient Antenatal Preparation (UNIMMAP) formula, the American/Canadian RDAs were put forth as the nutritional reference standard, with additions from the UK—reference nutrient intakes and WHO/United Nations Food and Agriculture Organization reference values (Department of Health 1991; World Health Organization et al. 1999).

Relevance of nutrition

Higher nutritional requirements support the physiological changes observed in pregnant and lactating populations, including gestational weight gain associated with appropriate development of the fetus, placenta, uterus, and mammary gland, cardiac and hematological alterations, and hormonal changes (Mousa et al. 2019; Tsakiridis et al. 2020; Jouanne et al. 2021). Nutrients are essential for several metabolic and cellular activities critical to support these physiological changes and fetal development, including cell differentiation, proliferation, hemoglobin production, oxygen transport, and mineralization (Kominiarek and Rajan 2016; Jouanne et al. 2021).

During the postpartum period, nutrients support maternal recovery after childbirth and breastmilk quality. Exclusively breastfed infants receive all their hydration and nutrients from their mother for a recommended first 6 months of life.

State of current knowledge

Table 1 summarizes the North American EARs and RDAs for macro- and micronutrients across non-pregnant, pregnant, and lactating adult females and reports the method of determining DRIs among maternal populations. DRIs recommend increased vitamins A, B_1, B_2, B_3, B_6, B_9, B_{12}, and C, as well as copper, iodine, selenium, and zinc during pregnancy and lactation (Institute of Medicine 2006). Increased dietary energy for most populations, carbohydrates, and protein were also recommended during pregnancy and lactation (Institute of Medicine 2006; National Academies of Sciences, Engineering, and Medicine 2023). Increased iron and magnesium were recommended in pregnancy, and vitamin E during lactation (Institute of Medicine 2006).

Nutritional requirement studies using stable isotope tracer techniques in pregnant populations have been conducted for a limited number of nutrients: iron and protein/amino acids. These studies have overall highlighted significant changes in requirements during pregnancy and lactation (Elango and Ball 2016; Cai et al. 2020; Rasmussen et al. 2020), and variation between gestational periods (Stephens et al. 2015; Cai et al. 2020; Rasmussen et al. 2020). The mean physiologic requirement for iron was determined to be 3.05 mg/day in total, which is twice the value than non-pregnant females of reproductive age, and increased from 2.04 mg/day in the first trimester to 3.26 mg/day in the second trimester and 4.13 mg/day in the third trimester (Cai et al. 2020). For protein, requirements were on average 1.2 g/kg per day around 16 weeks gestation and increased to an average 1.52 g/kg per day around 36 weeks gestation in late pregnancy, compared to current EAR recommendations of 0.88 g/kg per day protein intake across all stages of pregnancy (Elango and Ball 2016). Protein requirements for exclusively breastfeeding women between 3 and 6 months postpartum was determined to be 1.7–1.9 g/kg per day, compared to the current EAR of 1.05 g/kg per day (Rasmussen et al. 2020). DRI recommendations are static throughout pregnancy or postpartum, with the exception being energy requirements for lactation differentiated between 0–6 months and 7–12 months postpartum, and by exclusive or partial breastfeeding status (National Academies of Sciences, Engineering, and Medicine 2023).

Current gaps

There are concerns that the evidence underlying DRI values underrepresents racial/ethnic minorities, people living in low- and middle-income countries, and pregnant populations (Smith et al. 2021). Current DRIs acknowledge the lack of direct data informing many of nutritional requirements during pregnancy and lactation (Institute of Medicine 2006; Gannon et al. 2020). DRIs are often based on data from a limited number of individuals, which is extrapolated for different ages, sexes, and life stages. Estimating reference values for pregnant and lactating females is challenged by maternal adaptations to increased nutrient demands and net loss of nutrients due to physiological mechanisms during the dynamic stages of gestation and postpartum (Institute of Medicine 2006). Estimations may be especially challenged if data sources were originally studies conducted with males.

A review evaluating the studies underlying the DRIs found that only 17.4% (n = 117 of 671) studies included lactating or pregnant females, and 16.5% (n = 111) studies included only males (Smith et al. 2021). Overall, pregnant and lactating females accounted for about 4.6% of all study participants (n = 42 147 of 914 137 total). In contrast, males accounted for 71.1% (n = 650 215) of all study participants, including 44.4% (n = 405 629) from male only studies. In the life stages section of DRIs where reference values for pregnant and lactating females are discussed, less than 25% of studies included pregnant or lactating populations for 13 micronutrients (vitamins B_1, B_3, B_6, B_7, B_{12}, C, E, K, choline, carotenoids, copper, iron, selenium) Additionally, 17 micronutrients (vitamins A, B_1, B_3, B_5, B_7, B_{12}, C, D, E, K, choline, calcium, carotenoids, copper, magnesium phosphorus, zinc) did not include **any** study with pregnant and lactating populations in selecting key indicators. This may have contributed to not selecting adverse pregnancy health outcomes as indicators for setting pregnancy reference values (Smith et al. 2021, see also Table 1). For example, while a review of vitamin A requirements in pregnancy and lactation found associations with a number of maternal health outcomes (pre-eclampsia, gestational diabetes, selected infectious diseases) (Gannon et al. 2020), DRIs in pregnancy considered the age-specific requirement plus estimated daily accumulation by fetus. Smith and colleagues also reported that studies with rigorous design elements (i.e., controlled feeding and stable isotope studies) were most likely to include males only, and a factorial (mathematical) approach was most commonly used in setting DRIs for pregnancy.

Factorial estimations of nutrient needs assume nutrient fetal transfer and accumulation rates based on growth in pregnancy, and amounts secreted in human milk during lactation. The factorial process may oversimplify the multitude of physiological processes. For example, vitamin B_1, B_2, and B_3 requirements are estimated based on the age-specific adult requirements plus energy utilization and growth needs during pregnancy. EARs for dietary carbohydrate intake during pregnancy are based on fetal brain glucose utilization but assumes no placental glucose consumption (Hernandez and Rozance 2023). Increased requirements during lactation, based on human milk concentrations, do not account for potential processes associated with maternal recovery after childbirth. Further, a dramatic rise in maternal calcitriol [1,25(OH)2D] levels, the hormonal form of vitamin D (Hollis and Wagner 2017), and heightened fetal needs for calcium especially in late gestation (Kovacs 2016) have been documented, although requirements for vitamin D and calcium do not change between pregnant and non-pregnant female populations (Institute of Medicine 2011). Maternal adaptions to meet demands for calcium and vitamin D have been suggested to occur to meet requirements; however, mechanisms still remain unclear (Prentice 1994) (Table 1).

Table 1. Dietary reference intakes (DRIs) in Canada and the United States for non-pregnant, pregnant, and lactating adult females.

	Non-pregnant adult female	Pregnant adult female	Lactating adult female	Determining DRIs for pregnancy and lactation
Micronutrients				
Vitamin A	EAR: 500 μg/day RDA: 700 μg/day	EAR: 550 μg/day RDA: 770 μg/day	EAR: 900 μg/day RDA: 1300 μg/day	Pregnancy: age-specific requirement + estimated daily accumulation by fetus Lactation: age-specific requirement + average amount of vitamin A secreted in human milk
Vitamin B_1 (thiamine)	EAR: 0.9 mg/day RDA: 1.1 mg/day	EAR: 1.2 mg/day RDA: 1.4 mg/day	EAR: 1.2 mg/day RDA: 1.4 mg/day	Pregnancy: age-specific requirement + increased energy utilization and growth needs during pregnancy Lactation: age-specific requirement + energy expenditure of human milk production
Vitamin B_2 (riboflavin)	EAR: 0.9 mg/day RDA: 1.1 mg/day	EAR: 1.2 mg/day RDA: 1.4 mg/day	EAR: 1.3 mg/day RDA: 1.6 mg/day	Pregnancy: age-specific requirement + increased energy utilization and growth needs during pregnancy Lactation: age-specific requirement + energy expenditure of human milk production
Vitamin B_3 (niacin)	EAR: 11 mg/day RDA: 14 mg/day	EAR: 14 mg/day RDA: 18 mg/day	EAR: 13 mg/day RDA: 17 mg/day	Pregnancy: age-specific requirement + increased energy utilization and growth needs during pregnancy Lactation: age-specific requirement + energy expenditure of human milk production
Vitamin B_6 (pyidoxine)	EAR: 1.1 mg/day RDA: 1.3 mg/day	EAR: 1.6 mg/day RDA: 1.9 mg/day	EAR: 1.7 mg/day RDA: 2.0 mg/day	Pregnancy: plasma pyridoxal 5′-phosphate level of at least 20 nmol/L Lactation: amount of vitamin B_6 secreted in milk
Vitamin B_9(folate)	EAR: 320 μg/day RDA: 400 μg/day	EAR: 520 μg/day RDA: 600 μg/day	EAR: 450 μg/day RDA: 500 μg/day	Pregnancy: maintenance of normal erythrocyte and serum folate levels Lactation: folate intake necessary to replace folate secreted in human milk + folate needed to maintain folate status
Vitamin B_{12} (cobalamin)	EAR: 2.0 mg/day RDA: 2.4 mg/day	EAR: 2.2 mg/day RDA: 2.6 mg/day	EAR: 2.4 mg/day RDA: 2.8 mg/day	Pregnancy: age-specific requirement + fetal deposition of the vitamin B_{12} Lactation: age-specific requirement + amount of vitamin B_{12} secreted in human milk
Vitamin C	EAR: 60 mg/day RDA: 75 mg/day	EAR: 70 mg/day RDA: 85 mg/day	EAR: 100 mg/day RDA: 120 mg/day	Pregnancy: age-specific requirement + transfer to the fetus Lactation: age-specific requirement + average amount of vitamin C secreted in human milk
Vitamin D	EAR: 400 IU (10 μg)/day RDA: 600 IU (15 μg)/day	EAR: 400 IU (10 μg)/day RDA: 600 IU (15 μg)/day	EAR: 400 IU (10 μg)/day RDA: 600 IU (15 μg)/day	Pregnancy and lactation: insufficient evidence on the association of maternal serum 25OHD level with maternal bone mass density during pregnancy, fetal calcium homeostasis or skeletal outcomes, or with infant 25OHD levels during lactation except with very high maternal vitamin D intake
Vitamin E	EAR: 12 μg/day RDA: 15 μg/day	EAR: 12 μg/day RDA: 15 μg/day	EAR: 16 μg/day RDA: 19 μg/day	Pregnancy: age-specific requirement + plasma concentration Lactation: age-specific requirement + vitamin E secreted in milk
Calcium	EAR: 800 mg/day RDA: 1000 mg/day	EAR: 800 mg/day RDA: 1000 mg/day	EAR: 800 mg/day RDA: 1000 mg/day	Pregnancy and lactation: calcium supplementation trials did not show benefits of additional calcium intake on bone mineral mass beyond non-pregnant requirement
Copper	EAR: 700 μg/day RDA: 900 μg/day	EAR: 800 μg/day RDA: 1000 μg/day	EAR: 1000 μg/day RDA: 1300 μg/day	Pregnancy: adult female EAR plus fetal accumulation of copper Lactation: adult female EAR plus average amount of copper secreted in human milk
Iodine	EAR: 95 μg/day RDA: 150 μg/day	EAR: 160 μg/day RDA: 220 μg/day	EAR: 209 μg/day RDA: 290 μg/day	Pregnancy: thyroid iodine accumulation and turnover balance data during pregnancy Lactation: adult female EAR plus average amount of iodine secreted in human milk
Iron	EAR: 8.1 mg/day RDA: 18 mg/day	EAR: 22 mg/day RDA: 27 mg/day	EAR: 6.5 mg/day RDA: 9 mg/day	Pregnancy: factorial modeling of basal iron losses; fetal requirements in pregnancy; increased requirements during growth for the expansion of blood volume; and increased tissue and storage iron Lactation: adolescent female EAR minus menstrual losses plus average amount of iron secreted in human milk
Magnesium	EAR: 265 mg/day RDA: 320 mg/day	EAR: 290 mg/day RDA: 350 mg/day	EAR: 265 mg/day RDA: 320 mg/day	Pregnancy: age-specific requirement + gain in lean mass Lactation: dietary balance studies of magnesium
Phosphorus	EAR: 580 mg/day RDA: 700 mg/day	EAR: 580 mg/day RDA: 700 mg/day	EAR: 580 mg/day RDA: 700 mg/day	Pregnancy and lactation: serum Pi (serum inorganic phosphate concentration)

Table 1. (*concluded*).

	Non-pregnant adult female	Pregnant adult female	Lactating adult female	Determining DRIs for pregnancy and lactation
Selenium	EAR: 45 μg/day RDA: 55 μg/day	EAR: 49 μg/day RDA: 60 μg/day	EAR: 59 μg/day RDA: 70 μg/day	Pregnancy: age-specific requirement + saturation of fetal selenoprotein Lactation: age-specific requirement + human milk content requirement
Zinc	EAR: 6.8 mg/day RDA: 8 mg/day	EAR: 9.5 mg/day RDA: 11 mg/day	EAR: 10.4 mg/day RDA: 12 mg/day	Pregnancy: adult female EAR plus fetal accumulation of zinc Lactation: adult female EAR plus average amount of zinc secreted in human milk
Macronutrients				
Energy	EER: Inactive PAL—1959 kcal/day Low active PAL—2122 kcal/day Active PAL—2260 kcal/day Very active PAL—2487 kcal/day	Second and third trimesters: +300 kcal/day for underweight; +200 kcal/day for normal weight; +150 kcal/day for overweight; –50 kcal/day for obese	Exclusively breastfeeding 0–6 months postpartum: +540 kcal/day minus 140 kcal/day Partial breastfeeding 7–12 months postpartum: +380 kcal/day	Pregnancy: non-pregnant EER plus pregnancy energy disposition (which is 0 in the first trimester because weight gain is minor, based on recommended gestational weight gain in second and third trimester) Lactation: non-pregnant EER plus milk energy output minus energy mobilization from stores (weight loss between 0 and 6 months postpartum)
Dietary carbohydrates (sugars and starches)	EAR: 100 g/kg/day RDA: 130 g/kg/day	EAR: 135 g/kg/day RDA: 175 g/kg/day	EAR: 160 g/kg/day RDA: 210 g/kg/day	Pregnancy: adult female EAR plus fetal brain glucose utilization Lactation: adult female EAR plus average human milk content of carbohydrate
Total protein	EAR: 0.66 g/kg/day RDA: 0.80 g/kg/day	EAR: 0.88 g/kg/day RDA: 1.1 g/kg/day	EAR: 1.05 g/kg/day RDA: 1.3 g/kg/day	Pregnancy: age-specific requirement plus protein deposition Lactation: age-specific requirement plus milk nitrogen

Note: DRIs—dietary reference intakes; EAR—estimated average requirement; EER—estimated energy requirements; g—gram; kcal—kilocalorie; kg—kilogram; μg—microgram; mg—milligram; nmol/L—nanomoles per litre; PAL—physical activity level; RDA—recommended dietary allowance.

Nutritional risk factors for maternal mortality and morbidity

Maternal mortality and morbidity

An estimated 287 000 deaths due to complications during pregnancy and childbirth occurred in 2020, equating to about 800 maternal deaths a day (World Health Organization 2023*a*). Global reductions in maternal mortality have stagnated; the global maternal mortality ratio was 223 deaths per 100 000 live births in 2020 compared to 227 in 2015 (World Health Organization 2023*a*). Hemorrhage, hypertensive disorders, and sepsis were the leading obstetric causes of maternal deaths, accounting for a majority (52%) of the burden (Say et al. 2014). While 95% of maternal deaths occur in LMICs and reflect inequities in access to quality health care services, risks for pregnancy complications are found worldwide (World Health Organization 2024).

Relevance of nutrition

Direct associations between nutritional supplementation and maternal mortality or severe morbidity are unclear though maternal nutritional interventions may support reducing risk for major causes of maternal mortality (Christian 2002; Bullough et al. 2005). Key interventions include calcium supplementation during pregnancy to reduce maternal mortality due to pre-eclampsia, and multiple micronutrient/iron/iron–folic acid supplementation during pregnancy to reduce maternal anaemia and subsequently maternal mortality due to hemorrhage (Kulier et al. 1998; Tomkins 2001; Villar et al. 2003; Christian et al. 2015; Clermont and Walker 2017; Christian 2018; Keats et al. 2021).

State of current knowledge

An umbrella review pooled randomized controlled trials from 91 individual meta-analyses, including all Cochrane systematic reviews on nutritional supplements during pregnancy and placental complications (Kinshella et al. 2021). Supplementation trials reporting effects on maternal mortality included vitamin A (5 trials, 161 474 participants), vitamin C and/or E (6 trials, 17 574 participants), calcium (5 trials, 10 057 participants), zinc (1 trial, 85 participants), multiple micronutrients (8 trials, 84 081 participants), and lipid-based nutrient supplements (3 trials, 5628 participants). No significant effects were found with any maternal nutritional supplements based on low to moderate certainty of evidence assessed using GRADE. A systematic review on LMIC-based studies found that evidence was largely limited to a protective effect of iron–folic acid supplementation on the reduction of maternal anaemia and calcium supplementation to prevent pre-eclampsia (Keats et al. 2021).

Current gaps

Overall, there are limited data on the micronutrient status and macronutrient imbalances among women and their linkages to maternal morbidities and mortality (Victora et al. 2021). Only anaemia among women of reproductive age is tracked as an indicator for Sustainable Development Goal Two to end hunger.

Many maternal nutrient supplementation trials did not report health outcomes in mothers beyond fetal and infant outcomes (Keats et al. 2021). Two earlier reviews of reviews (Kulier et al. 1998; Villar et al. 2003) and a narrative review (Tomkins 2001), published around the inception of the Millennium Development Goals, where the reduction of maternal mortality received previously unparalleled global efforts as one of the eight global goals, examined the association between nutrition and maternal mortality and morbidity. These three reviews all called for more research on health outcomes in mothers. Over two decades later, these reviews remain as the only three that explicitly focused on maternal mortality and morbidities. Subsequent reviews evaluating both maternal and infant outcomes have noted stronger reporting on perinatal outcomes, with poor reporting on maternal outcomes, especially maternal morbidities (Ramakrishnan et al. 2012*b*; Keats et al. 2021; Kinshella et al. 2021). The following uses the examples of the three leading direct causes of maternal death worldwide—maternal hemorrhage, pre-eclampsia, and sepsis—to explore nutritional risk factors and interventions to prevent maternal mortality and morbidities in greater depth.

Maternal hemorrhage

Maternal hemorrhage, or severe bleeding during pregnancy or after childbirth, is the leading obstetric cause of maternal death (World Health Organization 2024). Postpartum hemorrhage (PPH) is the most frequent form, commonly defined as blood loss of 500 mL or more within 24 h after birth (World Health Organization 2023*b*). PPH can cause a severe drop blood pressure, which can restrict blood flow to the brain, heart, liver, kidneys, and other organs, leading to shock and potentially death if not treated immediately (Wormer et al. 2024).

Relevance of nutrition

During pregnancy, there is an increased need for iron to support increases in maternal blood volume as well as to support the growing fetus and placenta (Institute of Medicine Committee on Nutritional Status During Pregnancy and Lactation 1990). Iron is essential for the production of hemoglobin in red blood cells, which functions in the delivery of oxygen. Consequently, anaemia (defined as low hemoglobin levels <11 g/dL) reduces the oxygen-carrying capacity of blood and exacerbates vulnerability to shock after blood loss. A review found that dietary factors associated with lower consumption of iron-rich foods, including two or less meals per day, consumption of meat once a week or less, eating vegetables three times a week or less, a dietary diversity of score of three or less, as well as factors that reduce bioavailability of iron such as tea/coffee after meals were risk factors for anaemia during pregnancy (Zhang et al. 2022). Vitamin D may also support contractility of uterine smooth muscle, which can help prevent severe PPH (Palacios et al. 2024). There is not much evidence for other nutrients.

State of current knowledge

A meta-analysis of 16 observational studies found that pregnant individuals with anaemia (defined as hemoglobin level <11 g/dL) had higher odds of PPH compared to those without anaemia (Glonnegger et al. 2023). In particular, severe anaemia (hemoglobin <7 g/dL) was found to be associated with increased odds of PPH in a meta-analysis of 13 observational studies (OR 3.54, 95% CI: 1.20–10.4, $I^2 = 83\%$, 12 135 participants), but not mild (hemoglobin <11 g/dL) or moderate (hemoglobin <10 g/dL) anaemia (Omotayo et al. 2021). Certainty of the evidence was challenged by high heterogeneity across study results. However, review findings were supported by a recent large cohort study from Pakistan, Nigeria, Tanzania, and Zambia that found increased odds of PPH with a 10 g/dL reduction in hemoglobin levels during pregnancy (adjusted OR 1.29, 95% CI 1.21–1.38, 10 561 participants) (Mansukhani et al. 2023). While PPH is more commonly reported in LMICs, a French cohort-nested case-control study found that anaemia during pregnancy was associated with higher odds of severe PPH (adjusted OR 1.7, 95% CI: 1.5–2.0, 1669 cases/3234 controls) (Guignard et al. 2021).

While a Cochrane review found that preventative daily oral iron supplementation compared to supplementation with no iron or placebo substantially reduced the risk of maternal anaemia at term (RR 0.30, 95% CI: 0.19–0.46, $I^2 = 80\%$, 14 trials, 2199 participants), there was no significant difference on either antepartum (RR 1.48, 95% CI: 0.51–4.31, $I^2 = 0\%$, 2 trials, 1157 participants) or PPH (RR 0.93, 95% CI: 0.59–1.49, $I^2 = 0\%$, 4 trials, 1488 participants) (Pena-Rosas et al. 2015). A Cochrane review found that vitamin D supplementation during pregnancy may reduce the risk of severe PPH based on low-certainty evidence due to only one trial reporting this outcome (RR 0.68, 95% CI: 0.51–0.91, 1134 participants (Palacios et al. 2024).

Current gaps

Severe anaemia can arise from multiple causes, such as malaria, hookworm, chronic infections like HIV, and vitamin deficiencies (Christian 2018) and the proportion of anaemia attributable to iron deficiency in the earlier studies are unknown (Omotayo et al. 2021). A 2015 Cochrane review found no significant effect of iron supplementation compared to supplementation with no iron or placebo on either antepartum or PPH (Pena-Rosas et al. 2015). The review included 61 randomized controlled trials of iron supplementation during pregnancy; of these, only five trials reported hemorrhage outcomes. This highlights the underreporting of maternal outcomes in supplementation trials, which impacts the ability to understand causal relationships (Pena-Rosas et al. 2015) and may contribute to the absent discussion around iron supplementation during pregnancy in the WHO's "Roadmap to combat postpartum haemorrhage between 2023 and 2030" (World Health Organization 2023*b*).

Pre-eclampsia

Pre-eclampsia, the most serious of the hypertensive diseases of pregnancy, is the second leading direct cause of maternal deaths globally (World Health Organization 2024). Pre-eclampsia is characterized by novel hypertension (≥140/90 mm Hg) after 20 weeks gestation with proteinuria, maternal end-organ involvement, and/or uteroplacental dysfunction.

Relevance of nutrition

Nutrition plays important roles in the development of the placenta and certain micronutrients have antioxidant, anti-inflammatory, or blood pressure regulating properties that have been explored in association with the development of pre-eclampsia (Achamrah and Ditisheim 2018; Kinshella et al. 2022*a*). Multiple umbrella and evidence reviews have identified elevated serum iron, low serum zinc, and vitamin D deficiencies as notable risk factors for pre-eclampsia, while vitamin D and/or calcium supplementation and healthy maternal diets may be protective (Giannakou et al. 2018; Townsend et al. 2019; Kinshella et al. 2021, 2022*b*). With important roles in managing oxidative stress in the development of pre-eclampsia, essential trace elements such as zinc, copper, and selenium are components of antioxidants (superoxide dismutase and glutathione peroxidase) while free iron in plasma are pro-oxidative transition metals (Kinshella et al. 2022*a*).Vitamin D supports adequate placentation through regulation of inflammation and angiogenesis, as well as supporting absorption of calcium in the intestine.

State of current knowledge

An umbrella review found evidence for vitamin D supplementation (RR 0.62, 95% CI: 0.43–0.91, I^2 0%, 12 trials, 1353 participants), calcium supplementation (RR 0.52, 95% CI: 0.41–0.65, I^2 67%, 24 trials, 27 442 participants), vitamin D/calcium supplemented together (RR 0.49, 95% CI: 0.31–0.77, I^2 0%, 3 trials, 1120 participants), and multiple micronutrient supplementation during pregnancy (RR 0.40, 95% CI: 0.27–0.59, I^2 0%, 2 trials, 510 participants); no significant effects on pre-eclampsia incidence were found for supplementation of vitamin B6, vitamin C and/or E, iron and/or folic acid, magnesium, zinc, garlic, balanced protein energy, or omega-3 polyunsaturated fatty acids (Kinshella et al. 2021). However, there was low certainty of evidence, due to high heterogeneity and potential small study bias with calcium supplementation trials and an updated Cochrane review on vitamin D supplementation recently removed a number of trials following assessments of trustworthiness (Palacios et al. 2024). A network meta-analysis and two recent trials in Tanzania and India have suggested the non-inferiority of lower dosages (500 mg) of calcium (Woo Kinshella et al. 2022; Dwarkanath et al. 2024), which can support feasibility and acceptability (Omotayo et al. 2016).

There is also increasing interest in dietary patterns (Schoenaker et al. 2014; Traore et al. 2021; Xu et al. 2024). Healthy diets characterized by high intake of fruits, vegetables, whole-grain foods, fish, and poultry were protective (OR 0.78, 95% CI: 0.70–0.86, $I^2 = 39\%$, 4 studies, participant numbers unclear) (Kibret et al. 2019), while diets characterized by ultra-processed foods were associated with increased odds of pre-eclampsia (OR 1.28, 95% CI: 1.15–1.42, $I^2 = 0\%$, 4 studies, 112 307 participants) (Paula et al. 2022). The Mediterranean diet (high intake of fruits, vegetables, whole grains, nuts, legumes, fish, and use of olive oil as a source of fat) is a well-known healthy dietary pattern. A systematic review recently found that high adherence of a Mediterranean diet was associated with reduced odds of developing pre-eclampsia compared to those with the lowest adherence (OR, 0.77, 95% CI: 0.64–0.93; $I^2 = 0\%$, 3 studies, 13 581 participants) (Xu et al. 2024). A narrative review recommended increased consumption of fruits and vegetables (≥400 g/day), a high-fibre diet (25–30 g/day), plant-based foods and vegetable oils, and a limited intake of foods high in fat, sugar, and salt as protective against developing pre-eclampsia (Perry et al. 2022).

Current gaps

Overall, calcium supplementation with or without vitamin D supplementation and healthy maternal diets are promising approaches to pre-eclampsia prevention, though understanding the underlying biological mechanisms require further research as physiological adaptations during pregnancy and postpartum and timing of interventions during gestation are still unclear. The impact of underlying nutritional status in supplementation trials is not well elucidated. While maternal micronutrient supplementation has potential for preventing pre-eclampsia, especially in resource-limited settings where access to healthy maternal diets may be constrained, no studies reporting pre-eclampsia outcomes have utilized a standardized formula. To date, none of the UNIMMAP studies have reported on pre-eclampsia outcomes.

Maternal sepsis

Maternal sepsis is defined as infection with organ dysfunction during pregnancy and postpartum, accounting for 5% of maternal deaths in HICs and 11% in LMICs (Stephens et al. 2023). Rates of sepsis are increasing globally, including in HICs such as the United States (Stephens et al. 2023).

Relevance of nutrition

The role of nutrition in maternal sepsis is not well understood. Deficiencies in vitamin A and zinc, as well as maternal anaemia, may be associated with reduced immune function, which compromises resistance to pathogen exposures (Green et al. 1931; Tomkins 2001; Melkie and Dagnew 2021). Obesity may increase the risk of wound infection, especially following caesarean section, which is more frequent among obese pregnancies (Acosta et al. 2012).

State of current knowledge

Associations between maternal nutritional supplements and risk of maternal sepsis were not reported in any Cochrane reviews. However, Cochrane reviews found reduced risk of maternal clinical infection with vitamin A supplementation (RR 0.45, 95% CI: 0.20–0.99, $I^2 = 88\%$, 5 trials, participant numbers not reported) (Carducci et al. 2021) but did not find a significant difference with zinc supplementation (RR 0.94, 95% CI: 0.72–1.23, $I^2 = 0\%$, 4 trials, 1891 participants) (McCauley et al. 2015).

Evidence suggests a possible association with maternal nutritional status, including both under- and overnourishment. In comparison to nourished mothers, maternal undernourishment defined by mid-upper arm circumference (MUAC) was associated with increased odds of sepsis in studies from Bangladesh (MUAC < 21.5 cm OR 1.16, 95% CI: not reported, $p < 0.05$, 41 660 participants) (Sikder et al. 2014), and Ethiopia (MUAC < 21 cm adjusted OR 4.43, 95% CI: 1.96–10.01, 495 participants/MUAC < 23 cm adjusted RR 3.55, 95% CI: 1.83–6.89, 721 participants) (Figa et al. 2024; Oyato et al. 2024). Maternal obesity may also be a risk factor, particularly in HIC settings. A Swedish national cohort study found that obese women (BMI $\geq$ 30 kg/m^2) at their first antenatal care visit had almost doubled the odds of maternal sepsis compared to those with normal weight (adjusted OR 1.85, 95% CI: 1.37–2.48, 1 558 752 deliveries) (Axelsson and Blomberg 2017). Similar findings were found in Scotland (BMI $\geq$ 30 kg/m^2 adjusted OR 2.12, 95% CI: 1.14–3.89, 89 uncomplicated sepsis cases/412 controls) (Acosta et al. 2012).

There was also evidence of anaemia during pregnancy as a risk factor for maternal sepsis from studies in both HICs and LMICs, including from Scotland (adjusted OR 3.44, 95% CI: 1.93–6.13, 89 cases/412 controls) (Acosta et al. 2012), Canada (OR 3.9, 95% CI: 3.5–4.3, 3 653 783 hospitalizations) (Balki et al. 2022), and Ethiopia (OR 5.68, 95% CI: 4.38–7.36, $I^2 = 0\%$, 2 studies, participant numbers unclear) (Melkie and Dagnew 2021).The finding from Ethiopia is supported by similar findings in a subsequent Ethiopian case-control study (adjusted OR 6.05, 95% CI: 2.57–14.26, 495 participants) (Oyato et al. 2024).

Current gaps

Of the three leading causes of maternal mortality, the association between maternal nutrition and sepsis has been the least researched. While there are potential associations between maternal nutritional status and anaemia with increased risk of maternal sepsis, biological mechanisms are not well established and the proportion of anaemia attributable to iron deficiency is overall unclear.

Preconception and postpartum nutrition

The International Federation of Gynecology and Obstetrics recommends a life course approach that situates maternal nutrition within the context of women's overall health, from the importance of strengthening nutrition during adolescence to preconception to during and post-pregnancy (Hanson et al. 2015). Preconception supplementation can support nutritional status since many individuals may not be aware of their pregnancy status, particularly early after conception (Ramakrishnan et al. 2012*a*; Stephenson et al. 2018). Appropriate nutrition during the postpartum period supports recovery after delivery, adequate lactation, and may support preparation for a future pregnancy.

Relevance of nutrition

Adolescent girls may be at risk of iron deficiency due to menstrual blood loss and growth spurts may have higher calcium requirements (Hanson et al. 2015). Preconception folic acid supplementation is most known for prevention of neural tube defects (De-Regil et al. 2015). However, other nutrients are also required in early pregnancy. Vitamin D supports adequate placentation, while iron, zinc, iodine, and long-chain n-3 polyunsaturated fatty acids play critical roles in development of the fetal brain and nervous system, whereas vitamins A, B_6, B_9, and B_{12} influence oxidative pathways and methylation (Ramakrishnan et al. 2012*a*; Hanson et al. 2015; Harding et al. 2017). Iodine is often lacking in diets where iodized salt is not used, calcium intake may be inadequate where diets are low in dairy products, while vitamin B_9, vitamin B_{12}, and iron intake may be inadequate in diets low in animal source foods (Hanson et al. 2015). Food sources of vitamin D are minimal unless fortified and inadequate intake is common, especially with minimal sun exposure due to environment or clothing customs and/or darkly pigmented skin (Hanson et al. 2015). The role of nutrition to support postpartum recovery is not well understood.

State of current knowledge

There are mixed results on the effects of periconception (preconception and early pregnancy) nutrient supplementation on maternal outcomes, potentially due to varying underlying nutritional status/dietary patterns and adherence to supplementation regimes. A Cochrane review on periconception folate supplementation compared to no folate did not find a significant effect on miscarriage (RR 1.10, 95%: 0.94–1.28, $I^2 = 5\%$, 5 trials, 7391 participants) (De-Regil et al. 2015). However, all but one included study were conducted in HICs and a recent scoping review of periconception dietary patterns found that pro-inflammatory features of western diets (high intake of processed foods; low intake of fruit) increased miscarriage rates regardless of folate supplementation (Montagnoli et al. 2022). A Chinese cohort published after the Cochrane review suggested reduced risk of miscarriage (OR 0.53, 95% CI: 0.52–0.54, 1 535 066 participants) with folic acid supplementation beginning three months before pregnancy (He et al. 2016). A review found that suboptimal preconception folate and vitamin B_6 status, especially when together, may be associated with early pregnancy loss but evidence was limited to two case-control studies from China (Ramakrishnan et al. 2012*a*). A review of LMIC-based studies found that preconception iron–folic acid supplementation reduced rates of anaemia, especially when supplemented weekly (RR 0.70, 95% CI: 0.55–0.88, $I^2 = 82\%$, 6 trials, 3430 participants) and in a school setting where adherence was more consistent (RR 0.66, 95% CI: 0.51–0.86, $I^2 = 87\%$, 4 trials, 3005 participants) (Lassi et al. 2020). A Cochrane review on periconception calcium supplementation only found one trial (Hofmeyr et al. 2019*b*). The Calcium in Pregnancy trial in South Africa, Zimbabwe, and Argentina evaluated periconception calcium supplementation (500 mg daily) among women with a history of pre-eclampsia, which found reduced rates of pre-eclampsia when supplementation adherence was more than 80% (RR 0.66, 95% CI: 0.44–0.98, $p = 0.037$) (Hofmeyr et al. 2019*a*).

Pre-pregnancy weight has been associated with adverse maternal outcomes; obesity is associated with adverse pregnancy outcomes, including difficulties with conception, gestational diabetes, and pre-eclampsia (Dean et al. 2014; Poston et al. 2016; Howell 2018; Stephenson et al. 2018; Schoenaker et al. 2020). Compared to women with a normal weight (BMI 18.5–24.9 kg/m^2), maternal obesity (BMI $\geq$ 30 kg/m^2) during preconception was associated with four to nine times higher risk of gestational diabetes and three to ten times higher risk of pre-eclampsia (Poston et al. 2016). A review of 34 studies of pre-pregnancy underweight did not find a significant association with pre-eclampsia or gestational diabetes (Dean et al. 2014).

Preconception nutritional supplementation may have long-term effects on maternal health. Compared to preconception supplementation of folic acid, iron–folic acid, or multiple micronutrients, including iron–folic acid, follow-up of 1599 participants in the PRECONCEPT trial in rural Vietnam found significantly lower prevalence of underweight (BMI < 18.5 kg/m^2) among the multiple micronutrient group at 6–7 years postpartum (multiple micronutrients: 5.8%; iron–folic acid: 10.3%; folic acid: 14.3%, $p < 0.05$%) (Ramakrishnan et al. 2024).

Evidence on postpartum nutritional supplementation or healthy postpartum diets in association with maternal outcomes is largely uncertain. Postpartum vitamin A supplementation may reduce maternal morbidities, but evidence is limited to a single small study from Bangladesh (Roy et al. 1997) and a Cochrane review concluded lack of certainty in the association (Oliveira et al. 2016). The WHO recommends oral iron supplementation with or without folic acid to postpartum women for 6–12 weeks post-delivery to reduce anaemia in populations with high anaemia during pregnancy (World Health Organization 2016*a*). The recommendation was based on three small trials in Hong Kong (Tam et al. 2005), Mexico (Khambalia et al. 2006), and Turkey (Baykan et al. 2006), but the accompanying review was withdrawn from the Cochrane Database (Neufeld et al. 2017). A systematic review of six studies found that healthy postpartum diets (as defined by individual studies) were associated with fewer postpartum depression symptoms (Opie et al. 2020).

Current gaps

Evidence for preconception and postpartum nutrition is currently limited, especially for maternal outcomes. For example, a Cochrane review found insufficient data on preconception iodine supplementation and combined preconception, pregnancy, and postpartum supplementation in meta-analyses (Harding et al. 2017). Three large preconception nutrition interventions, the "Women's First" multi-country trial in the Democratic Republic of Congo, Guatemala, India, and Pakistan (Dhaded et al. 2020; Krebs et al. 2021), a randomized controlled trial in Vietnam (Ramakrishnan et al. 2016; Nguyen et al. 2017), and the Mumbai Maternal Nutrition Project in India (Potdar et al. 2014), all primarily measured birth weight and infant growth indicators.

Nutrient recommendations for breastfeeding women are sparse and recommendations inconsistently implemented in health promotion initiatives. A qualitative study from Ontario, Canada, highlighted frustration among early postpartum participants with the lack of information about appropriate nutrition and exercise for recovery after childbirth (Murray-Davis et al. 2019). When it existed, information was largely associated with postpartum mental health (Murray-Davis et al. 2019). Postpartum supplementation trials often focused on breastmilk content outcomes (i.e., iodine supplementation (Mulrine et al. 2010; Bouhouch et al. 2014); vitamin A supplementation (Rice et al. 2000; Ayah et al. 2007); vitamin D supplementation (Roth 2016; Dawodu et al. 2019); zinc supplementation (Krebs et al. 1995)). While it is important to ensure breastmilk content/composition is measured to better understand infant growth and outcomes, emphasis on maternal nutrition status of these micro-nutrients simultaneously would add perspectives to the mother–infant dyad, and close the knowledge gap on postpartum nutrition in women.

Gender roles, cultural norms, and inequities in access to nutritious foods during pregnancy and postpartum

This section transitions to the roles that gender can play around food during pregnancy and postpartum, including the societal and cultural norms impact women's dietary choices and behaviours, as well as the gendered inequities around food security. The State of Food Security and Nutrition in the World (2022) reported increasing food insecurity among women with a growing global gender gap (FAO et al. 2022). This confirms an earlier meta-analysis that found 40% higher odds of household food insecurity among women respondents compared to men (OR 1.40, 95% CI: 1.27–1.54, 42 studies, 233 153 adults) (Jung et al. 2017).

Relevance of nutrition

Food taboos during pregnancy reflect meanings of food in different cultural systems (Meyer-Rochow 2009). Transition periods within a person's life, such as pregnancy and childbirth, are liminal spaces between social states of being, where dangers may be managed through certain foods to eat and avoid. While some restricted foods may be highly nutritious, some taboos could potentially protect women against unhealthy eating habits (Köhler et al. 2019; Iradukunda 2020; Gebregziabher et al. 2023).

Food insecurity during pregnancy is associated with higher risk of maternal depression and adverse maternal–fetal outcomes (Laraia et al. 2010; Iqbal and Ali 2021) Food insecurity may manifest in cycles of deepening vulnerability, as maternal complications can lead to increased long-term chronic health risks and low birthweight, and the associated needs of these vulnerable infants and additional children can exacerbate household food insecurity challenges (McKerracher et al. 2020).

State of current knowledge

A qualitative review of cultural beliefs and practices influencing perinatal nutrition in LMICs found widespread conceptualization of food as medicine from enriching blood and helping to preserve the pregnancy, to stimulate labour or prepare the birth canal, to protect the unborn baby from evil spirits, to help with recovery, regaining energy postpartum, and stimulating lactation (Raman et al. 2016). Two reviews both found common belief, especially in Asia, that pregnancy was considered a "hot state"; consequently, "cooling" foods such as most fruits and vegetables were recommended (Raman et al. 2016; Withers et al. 2018). However, as childbirth was associated with a loss of body heat, "cold" foods were avoided during the postpartum period for fears of causing allergies, skin rashes, and illnesses such as diarrhea and/or decreasing breastmilk supply (Raman et al. 2016; Withers et al. 2018). While foods considered to be harmful during pregnancy and lactation varied around the world, three reviews of food taboos found animal-based foods such as meat and eggs were the most commonly restricted food during pregnancy, though specific types of meat and seafood varied between cultures (Köhler et al. 2019; Iradukunda 2020; Gebregziabher et al. 2023). Milk and milk products, fruits, and vegetables were generally widely recommended during pregnancy, with exceptions among a minority of cultural groups (Iradukunda 2020). Food taboos are not limited to LMICs. Studies from Poland, Australia, and Canada also reported common avoidance of caffeine, spicy foods, cruciferous vegetables like broccoli and cabbage, garlic and onions, beans, and dairy products during breastfeeding, which was seen to cause infant gas, unsettled infant crying–fussing behaviour and fears of developing allergies among infants (Kidd et al. 2019; Karcz et al. 2020; Iacovou et al. 2021).

The qualitative review also highlighted strong local perceptions of the influence of poverty on maternal nutrition, emphasizing a common theme that women and their households often ate the cheapest available food (Raman et al. 2016). A scoping review including four studies found that food insecurity was negatively associated with vegetable intake during pregnancy (Simmons et al. 2022). A systematic review of food insecurity during pregnancies in HICs found significant associations with increased obesity compared to food secure women (OR 1.53, 95% CI: 1.39–1.66, $I^2 = 0\%$, 7 studies, 17 554 participants), though not significantly associated with underweight (OR 1.12, 95% CI 0.89–1.34, $I^2 = 0\%$, 4 studies, 16 937 participants) (Nguyen et al. 2024). However, the review is limited by inadequate reporting of obesity and underweight definitions, though some variations were presented (i.e., two studies used BMI < 30 kg/m^2 as the reference group). Compared to food secure women, food insecurity was associated with higher odds of inadequate gestational weight gain (OR 1.16, 95% CI: 1.05–1.28, $I^2 = 0\%$, 7 studies, 6563 participants) (Nguyen et al. 2024).

A systematic review of LMICs- and HICs-based studies found household food insecurity was lower with exclusive breastfeeding in particular (OR 0.61, 95% CI: 0.49–0.76, $I^2 = 57\%$, 10 studies, participant numbers unclear) (Buccini et al. 2024); results are more mixed in association with overall breastfeeding practices (Guerrero et al. 2024; Pasha et al. 2024). A Canadian study with 10 450 women highlighted that food insecure women initiated breastfeeding at similar rates compared to food secure women after adjusting for socio-demographic characteristics, but had lower rates of sustaining exclusive breastfeeding to 4 or 6 months (Orr et al. 2018). Another Canadian study with 459 mothers found no difference in intention to exclusive breastfeed, but lower odds of breastfeeding practice among food insecure household (OR 0.54, 95% CI 0.29–0.98) (Francis et al. 2024). A Kenyan study found that women from food insecure households felt that access to adequate food was necessary for successful exclusive breastfeeding, citing concerns about infant hunger and perceived breastmilk insufficiency (Webb-Girard et al. 2012).

Current gaps

Cultural norms have often been researched as harmful traditional practices and there is a gap in strength-based approaches. Cultural norms and traditional beliefs around food during pregnancy tend to be framed as barriers to best practices and there is limited discussion around protective practices to strengthen current health promotion programs (Raman et al. 2016; Withers et al. 2018; Ryan et al. 2022).

There are some studies that have shown gendered expectations that mothers will restrict their own intake (eat less or skip meals) in favour for their children, which is less expected in men (McIntyre et al. 2003; Martin and Lippert 2012; Macaulay et al. 2023), but none of these studies were during pregnancy or postpartum.

Gender intersects with race/ethnicity (Santos et al. 2023) and rural residency (Sinclair et al. 2019), and other social determinants such as educational attainment, household income, and social networks (Broussard 2019) to compound women's vulnerabilities to food insecurity. These factors are relevant to pregnant and postpartum women, though factors contributing to food insecurity within maternal populations in various contexts is under-researched. No research was available on sexual minority and gender diverse people in association to food security during pregnancy and postpartum.

Conclusion and areas for future research

The WHO recommends dietary counselling during antenatal care (World Health Organization 2016*b*), but there are a number of areas where evidence on women's health outcomes are unclear in pregnancy and postpartum nutrition. This narrative review has aimed to shift the conversation within maternal nutrition to highlight health issues and outcomes especially in women. Based on review findings, future research in the following areas may provide an increased understanding:

1. Evidence underlying DRIs can be supported by more experimental research including maternal populations.

   a. Direct research with maternal populations can better incorporate the dynamic and continuum life changes that can impact nutritional needs (i) during pregnancy, postpartum, and lactation, (ii) between gestational periods, and (iii) support linking nutritional intake to clinical outcomes.
   b. More research especially with rigorous design elements such as stable isotope and controlled feeding studies.
   c. Further research into ideal biomarkers for identifying essential nutrient needs and linking with adverse pregnancy outcomes where possible, and linking nutritional intake to surrogate outcomes strongly correlated to clinical outcomes and/or immediate markers that have physiological relevance to clinical outcomes.
   d. Accompanying research on barriers for pregnant and lactating females on participating in research, alongside development of methods to overcome barriers such as providing reimbursement for childcare, home visits by researchers, flexible hours, etc.
2. Dietary interventions and nutritional supplementation trials conducted with maternal populations should report maternal outcomes, such as maternal mortality, maternal hemorrhage, pre-eclampsia and other hypertensive disorders, sepsis, and other maternal morbidities. The current underreporting of maternal outcomes impacts the ability to understand causal relationships.
   a. While undernutrition and nutritional deficiencies is often assumed to be an underlying factor, more consistent reporting on baseline nutritional status can strengthen the evidence base. Macronutrient imbalances and overnutrition (overweight and obesity) can also be further explored as contributing factors.
   b. Healthy maternal dietary patterns appears to be a promising approach to pre-eclampsia prevention that can be extended to research on maternal hemorrhage, sepsis, and other maternal outcomes.
   c. Further research on the linkages between iron-deficiency, maternal anaemia, and maternal hemorrhage can support better understanding. The associations between maternal iron levels, anaemia, and pre-eclampsia/maternal sepsis can also be further explored.
   d. Studies utilizing the standardized UNIMMAP formula reporting pre-eclampsia and other maternal outcomes to support better understanding on the protective effect of maternal multiple micronutrient supplementation
   e. More research is recommended on maternal nutritional risk factors for maternal sepsis.
3. Preconception nutrition trials should report maternal outcomes, not just fetal and child health outcomes.
   a. Much of the preconception nutrition research is focused on folate and more research on other micronutrients, including iron, zinc, iodine, calcium, long-chain n-3 polyunsaturated fatty acids, vitamins A, B_6, B_{12}, and D, as well as macronutrients and dietary patterns, can strengthen the evidence base.
   b. There is a need to better understand postpartum nutritional requirements that support recovery after childbirth as limited qualitative research with mothers has identified this as an area of interest.
   c. More qualitative research can improve understanding women's experiences with nutrition over the reproductive life course from adolescence, preconception, to during and post-pregnancy.
4. Associations between social experiences of gender to sex-specific health and nutrition outcomes during pregnancy and lactation can be strengthened in future research.
   a. Strength-based approaches to research could better elucidate cultural norms and practices around food during pregnancy, childbirth, postpartum, and lactation.
   b. More research is needed on the influence of intersecting identity factors on the association between gender and food insecurity within pregnant/postpartum/lactating populations, including race/ethnicity, rural residency, sexual minority status, and gender diverse identities.
   c. Overall, research on nutritional requirements, pregnancy complications, and nutrition across the maternity continuum could benefit from more integration of cultural norms and socio-economic factors related maternal dietary intake.

Each topic area, nutritional relevance, state of current knowledge and gaps, and areas for future research are summarized in Table S2. Additionally, further integration between nutritional requirements, pregnancy complications, pregnancy and postpartum nutrition, and gendered experiences of maternal nutrition can synergistically strengthen the field as a whole. A strength of this review was the hierarchical literature review approach, which allowed us to rapidly review a large body of literature. The process of prioritizing publications with stronger evidence (i.e., reviews) while pragmatically cascading to individual studies allowed us to better understand the broad landscape of maternal nutrition research and spotlight current areas where further research could strengthen. However, a limitation is that this was not a systematic review and does not provide definitive evidence for specific recommendations in each topic. Rather, this review highlights areas where women's health topics have been underrepresented in maternal nutrition research and supports a call to action to focus more on women's health experiences, priorities, and outcomes within the field. While this narrative review has demonstrated a wide breadth and depth of maternal nutrition research, there is an ongoing need to include women in research for nutritional requirements during pregnancy and lactation, and measure health outcomes for women to ensure creation of an evidence base on both sex and gender-based datasets.

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Data availability

Data generated or analyzed during this study are provided in full within the published article and its supplementary materials.

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The authors report no conflicts of interest.

Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/apnm-2024-0127.

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