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Perspective

Perspective: Organic food consumption during pregnancy and the potential effects on maternal and offspring health

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A B S T R A C T

Pregnancy represents a critical window for both maternal and child health. Previous studies have shown that the consumption of an organic diet during pregnancy can reduce pesticide exposure compared with the consumption of a conventional diet. It is possible that this could, in turn, improve pregnancy outcomes, because maternal pesticide exposure during pregnancy has been associated with increased risk of pregnancy complications. Organic foods are produced by methods that comply with organic standards, generally restricting the use of agrochemicals, such as synthetic pesticides. In the past few decades, the global demand for organic foods has increased drastically, driven in large part by consumer beliefs that organic foods provide benefits to human health. However, the effects of organic food consumption during pregnancy on maternal and child health have not been established. This narrative review aims to summarize current evidence regarding the consumption of organic foods during pregnancy and the potential effects on short- and long-term health outcomes in mothers and offspring. We performed a comprehensive literature search and identified studies investigating the association between organic food consumption during pregnancy and health outcomes in mothers and their offspring. The outcomes identified from the literature search included pre-eclampsia, gestational diabetes mellitus, hypospadias, cryptorchidism, and otitis media. Although existing studies suggest that consumption of organic foods (overall or a specific kind) during pregnancy may have health benefits, further investigation to replicate the findings in other populations is needed. Moreover, because these previous studies have all been observational and thus may be limited by the potential for residual confounding and reverse causation, causal inference cannot be established. We argue that the next necessary step in this research is a randomized trial to test the efficacy of organic diet intervention in pregnancy on maternal and offspring health.

Keywords: organic food, pregnancy, diet, pesticides, maternal and child health, pre-eclampsia, gestational diabetes mellitus

Statement of significance

The effects of organic food consumption during pregnancy on maternal and child health have not been established. This narrative review summarized current evidence regarding the consumption of organic foods during pregnancy and the potential effects on short- and long-term health outcomes in mothers and their offspring.

Introduction

In the past few decades, the global demand for organic foods has increased dramatically; between 1999 and 2017, worldwide sales of organic foods increased from $15.2 to $97 billion [1]. In the United States, organic products comprise the single fastest-growing sector of the American food industry [2]. Although organic food standards have often originated from a desire to benefit the environment and animal welfare [3], studies

Abbreviations: GDM, gestational diabetes mellitus; GMO, genetically modified organism.

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have consistently shown that the demand for these products is driven primarily by the belief of consumers that organic diets provide a personal (and family) health benefit [4]. Various regions and countries throughout the world have developed their regulatory bodies to define and standardize the requirements for organic food certification (Table 1). These standards are not uniform; for example, the Eastern African Organic Standard emphasizes the preservation of indigenous species, whereas the United States National Organic Program significantly focuses on increasing biodiversity [3,5]. However, consistent across countries and regions is a requirement that certified organic foods be produced without the use of most synthetic agrochemicals, including pesticides and fertilizers [5–12].

These requirements result in measurable differences in pesticide residues on food products. Compared with conventional foods, studies have shown organic foods contained fewer pesticide residues, including insecticides and herbicides. The maximum exceedance rate of residue levels in organic products is much lower than that in conventionally produced foods [13]. In the United States, organic foods contain approximately 1-third as many pesticide residues as conventionally grown foods [14]. Across multiple populations, dietary intervention studies have consistently shown that consumption of organic foods quickly and significantly reduces exposure to agricultural pesticides in adults and children [15–22]. These dietary intervention studies have occurred in countries ranging from the United States, Switzerland, and Australia to Cyprus and in cohorts that have included children, adolescents, adults, pregnant women, and families. These studies have investigated different classes of pesticides, including organophosphate insecticides, pyrethroid insecticides, neonicotinoids, and herbicides including glyphosate.

Organic foods, in general, are nutritiously comparable to conventional foods [1]. However, organic foods contain higher concentrations of some beneficial nutrients. For example, polyphenol content and antioxidant capacity are higher in organic vegetables and fruits than in conventional products [23,24]. Higher antioxidant and lower cadmium concentrations have also been reported in organically grown crops than in conventional crops [25]. Total PUFA and *n*-3 PUFA content are higher in organic meat than in conventional meat [26] and in organic milk than in conventional milk [27].

Pregnancy represents a critical window for both maternal and children's health. Previous studies have shown that an organic diet intervention during pregnancy can reduce pesticide exposures [28]. It is possible that this could, in turn, improve pregnancy outcomes, as maternal pesticide exposure during pregnancy has been associated with increased pregnancy complications and adverse birth outcomes [29,30]. However, whether and how organic food consumption during pregnancy has health benefits on mothers and their offspring is not fully established. In this study, we reviewed current evidence about the consumption of organic foods during pregnancy and the potential effects of organic food consumption during pregnancy on maternal and child health outcomes.

Prevalence and correlates of organic food consumption during pregnancy

Sparse data are available on the rates of organic food consumption during pregnancy worldwide. According to available evidence in several countries, the rate of ever-used organic food during pregnancy varied from 38% to 88% [31–33]. The rate of frequent use of organic foods during pregnancy ranged from 3% to 9.1% [31–33].

In general, pregnant organic food consumers were found to have higher socioeconomic status and healthier dietary and lifestyle habits than pregnant women who did not choose organic diets. For example, a Danish National Birth Cohort reported that organic food consumption during pregnancy was associated with older age, high-level occupational status, living in high urbanization areas, doing light or moderate physical activities, and being vegetarian [32]. Similarly, a study in the Netherlands found that pregnant women who consumed organic foods were older, had a higher level of education, and a slightly lower BMI, and were more likely to adhere to certain healthy lifestyles compared with nonorganic consumers [31]. In addition, a study conducted among pregnant women in the United States showed that women who were older, white, married, highly educated, and with a higher household income were more likely to pursue environmentally healthy behaviors, including consuming organic foods [34].

However, a large cohort study in Norway found that organic food consumption during pregnancy was not always associated with healthy population characteristics [33]. In this study, besides traditional high sociodemographic characteristics and healthy lifestyle factors (i.e., older than 40 y, lower BMI, a vegetarian diet, regular exercise, high levels of education, and urban living area), other factors, such as younger than 25 y, smoking and alcohol use during pregnancy, low levels of education, and low household income were associated with frequent organic food consumption during pregnancy [33]. This suggests that a simple label such as "healthy lifestyle" or "high socioeconomic level" cannot be applied to describe women who use organic food during pregnancy [33]. The complexity of health motivation, economic ability, and social and community environment might contribute to organic food consumption.

Effects of organic diet intervention during pregnancy on pesticide exposure

Only 1 intervention study concerning the effects of organic diet intervention during pregnancy on pesticide exposure was identified. Curl et al. [28] conducted a 24-wk randomized trial to assess the impact of an organic produce intervention on pesticide exposure among pregnant women. Twenty women were recruited from the Idaho Women, Infants, and Children program during their first trimester of pregnancy. Eligible women were 18- to 35-y-old nonsmokers who reported eating exclusively conventionally grown food. The participants were then randomly assigned to receive either organic or conventional fruits and vegetables throughout the remainder of their pregnancies. Pesticide biomarkers were measured longitudinally in weekly spot urine samples. Integrating across an average intervention period of 24 wk, urinary concentrations of 3-phenoxybenzoic acid, a biomarker of pyrethroid pesticide exposure, were significantly lower in samples collected from women in the organic produce intervention group than in the Conventional produce control group (0.27 vs. 0.95 μg/L, $P = 0.03$). Moreover, *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid, another pyrethroid biomarker, was detected less

TABLE 1
Definitions and standards for organic food certifications in different regions around the world [10]

Region and certifying organization	Prohibited materials and practices and conversion time requirements	Encouraged practices for soil fertility	Pest management alternatives	Animal requirements
USA (USDA's National Organic Program) [6,7]	*Prohibited** Synthetic fertilizers* Most synthetic pesticides* Genetically modified organisms (GMOs)* Sewage sludge* Ionizing radiation *Conversion time requirements* 36 mo since last use of prohibited materials	*Cover crops* Conservation tillage* Crop rotation* Contour cultivation* Strip cropping* Nutrient management via legumes	*Encouraged practices** Providing habitat for beneficial insects* Increasing biodiversity *Allowed pesticides** Biologicals/botanicals Oils* Insecticidal soaps* Minerals Pheromones	*Access to outdoors, direct sunlight, fresh air, and room to exercise* Access to pasture during the grazing season (at least 120 d) for ruminants* No hormones or antibiotics for any reason* Vaccinations encouraged when appropriate
Eastern Africa [Eastern Africa Organic Production Standard (EAOPS)] [5]	*Prohibited** Synthetic fertilizers* Most synthetic pesticides* GMOs Sewage sludge* Ionizing radiation *Conversion time requirements:** 12 mo since last use of prohibited materials (can be extended depending on past land use)	*Focus on preserving indigenous species* Cover crops* Conservation tillage* Intercropping* Agroforestry Crop rotation	*Encouraged practices** Choice of appropriate species and varieties *Allowed pesticides** Biologicals/Botanicals Oils* Insecticidal soaps* Minerals* Pheromones	*Protection from direct sunlight, excessive noise, heat, rain, mud, and wind* Access to pasture during the grazing season (at least 120 d) for ruminants* Hormonal treatment may be used only for therapeutic reasons and under veterinary supervision* Vaccinations allowed but discouraged
Canada (Canada Organic Regime, a CFIA accredited certification body) [9]	*Prohibited** Synthetic crop production aids and materials* Synthetic pesticides, preservatives, and fumigants* GMOs Sewage sludge* Ionizing radiation (here termed "irradiation") *Conversion time requirements** 36 mo since last use of prohibited materials, with at least 12 mo since the use of pesticides not of animal, plant, or mineral origin	*Crop rotation, including • planting legumes for nitrogen fixation • plow down • catch crops • deep-rooting plants	*Encouraged practices** Managing organic systems with a variety of methods such that a balanced ecosystem is created to minimize loss from pests *Allowed pesticides** Must be of plant, animal, microbial, or mineral origin* Should be produced through physical, enzymatic, or microbial methods	*Access to outdoors, sunlight, shade, shelter, areas to exercise, and graze* Ruminant animals should have access to pasture throughout the entire grazing season* Hormones, antibiotics, and all other synthetic veterinary drugs are prohibited in the absence of illness; if an animal receives such treatments more than 2 times in 1 y, the animal loses organic status* Vaccines should be used in conjunction with other preventive measures if diseases in question can be transmitted to livestock and no other method
Asia [Asian Regional Organic Standard (AROS)] [8]	*Prohibited** Synthetic fertilizers* Synthetic pesticides* GMOs* Human excrement* Ionizing radiation *Conversion time requirements** 12 mo for annuals and 18 mo for perennials since last use of prohibited materials	*Diverse planting practices should be central to an organic system* Crop rotation is recommended for annual crops, whereas ground covers of plant origin are recommended for perennial crops	*Encouraged practices** Those that increase biodiversity and minimize pest outbreaks (e.g., integrate plants that attract useful insects). *Allowed pesticides** Plant and animal origin, mineral origin, organisms, others, and traps/barriers/repellents	It is anticipated that in the future, the scope of AROS may be broadened to include livestock, aquaculture, and other types of production
Australia (Department of Agriculture and Water Resources) [11]	*Prohibited** Synthetic fertilizers* Pesticides produced from synthetic chemicals* GMOs* Human and industrial wastewater (allowed for timber lots and irrigation *only* after treatment per state guidelines)*	*Intentional management of landscape to promote biodiversity through sheet composting and rotation of deep-rooting plants* Allowed fertilizers include but not limited to Minerals and trace elements* Biological preparations* Wood byproducts	*Encouraged practices** Varied microenvironments, appropriate choice of species and varieties, and habitats that offer protection of the natural enemies of pests *Allowed pesticides** Mechanical controls* Flame/steam weeding* Biological control	*Access to daylight, shade, shelter. Living conditions must also provide for the natural behaviors of animals* Use of any veterinary drugs in the absence of illness is prohibited* Vaccines are only allowed if management practices are insufficient to contain the

(*continued on next page*)

TABLE 1 (*continued*)

Region and certifying organization	Prohibited materials and practices and conversion time requirements	Encouraged practices for soil fertility	Pest management alternatives	Animal requirements
	Ionizing radiation *Conversion time requirements* 36 mo since the last use of prohibited materials			disease, of which farmers must provide evidence
European Union (European Commission) [12]	*Prohibited** All chemically synthetic inputs (includes synthetic fertilizers and plant protection products)* GMOs* Ionizing radiation *Conversion time requirements** Time requirements since the last use of prohibited materials vary for different species	*Cultivation and tillage methods that increase biodiversity, maintain soil stability and decrease soil erosion* Multi-annual crop production that incorporates legumes and green manure	*Encouraged practices** Reliance on natural enemies of pests, diseases, and weeds, choice of appropriate species/varieties, crop rotation *Allowed pesticides** Must have a plant, animal, biological, or mineral base	*Constant access to open-air spaces, ideally pasture* Hormones, synthetic veterinary drugs, hormones, antibiotics, and synthetic amino acids are prohibited unless acute illness warrants such treatment* No mention of vaccines* Recommend adequate housing and choice of species suited to the local climate

frequently in women in the organic produce intervention group than in the Conventional produce control group (4% vs. 16%, $P = 0.05$).

Potential health effects of organic food consumption during pregnancy

We conducted a comprehensive literature search in PubMed and EMBASE databases with a combination of search terms “organic food,” “organic diet,” “pregnancy,” and “gestational” or their synonyms without time restriction (Supplementary text) and identified relevant studies for maternal and child outcomes in this review (Fig. 1). There was no limit regarding the time and language of the publications.

Studies regarding the associations between organic food consumption during pregnancy and health outcomes in mothers and their offspring are scarce. In our comprehensive literature search, we have identified 6 relevant studies, all conducted in European countries, namely, Norway, Denmark, Netherland, and France, from 2013 to 2021. All were observational studies, and none was a randomized controlled trial. Three assessed maternal pregnancy outcomes, 2 evaluated birth outcomes, and 1 investigated the effect of an organic diet on child health (Table 2). The quality of these studies was assessed using the Newcastle–Ottawa Quality Assessment Scale (Table 3). In general, these studies were limited by potential exposure misclassification, as organic food consumption habits were assessed via self-reports and insufficient adjustment for potential confounders.

Maternal pregnancy outcomes

Using data from the Norwegian Mother and Child Cohort Study (MoBa), Torjusen et al. [35] examined the association between the consumption of 6 groups of organic foods, namely, vegetables, fruit, cereals, eggs, meat, and milk, during pregnancy and the risk of pre-eclampsia. Participants were asked during the first 4–5 months of pregnancy “Have you consumed organic food products since you became pregnant?” the potential options were “Seldom/never,” “Sometimes,” “Often,” or “Mostly.” This study included 28,192 nulliparous pregnant women, among whom 39.8% reported consuming at least one organic food group “sometimes.” Compared with women who reported to have eaten organic vegetables “never/rarely” or “sometimes,” women who ate organic vegetables frequently ($n = 2493$, 8.8%) had a lower risk of pre-eclampsia [crude OR: 0.76; 95% CI: 0.61, 0.96]. The association was significant even after adjustment for hypertension before pregnancy, prepregnancy BMI, maternal height, maternal age, maternal education levels, household income status, maternal smoking in pregnancy, total energy intake, and gestational weight gain (adjusted OR: 0.79; 95% CI: 0.62, 0.99). The association was also independent of a healthy food pattern, including a generally higher vegetable intake. However, no associations with pre-eclampsia were found for high intake of organic fruit, cereals, eggs, meat, or milk, or a combined index reflecting organic consumption.

To our knowledge, 2 studies using the same dataset, that is, the KOALA birth cohort, have reported the relationship between organic food consumption and gestational diabetes mellitus (GDM). In the first study published in 2017 ($n = 1339$), organic food consumption was defined according to questions on the origin (organic, conventional, or other food-specific possibilities) of 7 food groups, namely, meat, eggs, vegetables, fruit, milk and milk products, bread, and dried food products, and the percentage of organic origin of purchases of each food group: not at all, less than 50%, between 50% and 90%, or more than 90% [36]. Fewer participants in the organic group were found to have diabetes in pregnancy than in the conventional (reference) group, with the percentage of GDM of 2.0%, 0.5%, 0%, and 0% for those with 0%, <50%, 50%–90%, and >90% of organic-origin purchase [36]. However, the sample size of GDM ($n = 17$) in that study [36] was limited, and no controlling for potential confounders was performed. In the second study conducted in 2021 [44], more participants were enrolled ($n = 2803$), and organic food consumption was categorized into 2 groups: “<50% organic” (if some food groups were of organic origin but not all were reported as being more than 50% organic) and “>50% organic” (if in all consumed food groups at least 50% was of organic origin). After adjustment for maternal age and gravidity, no significant association between organic food consumption and gestational diabetes was observed. It is worth

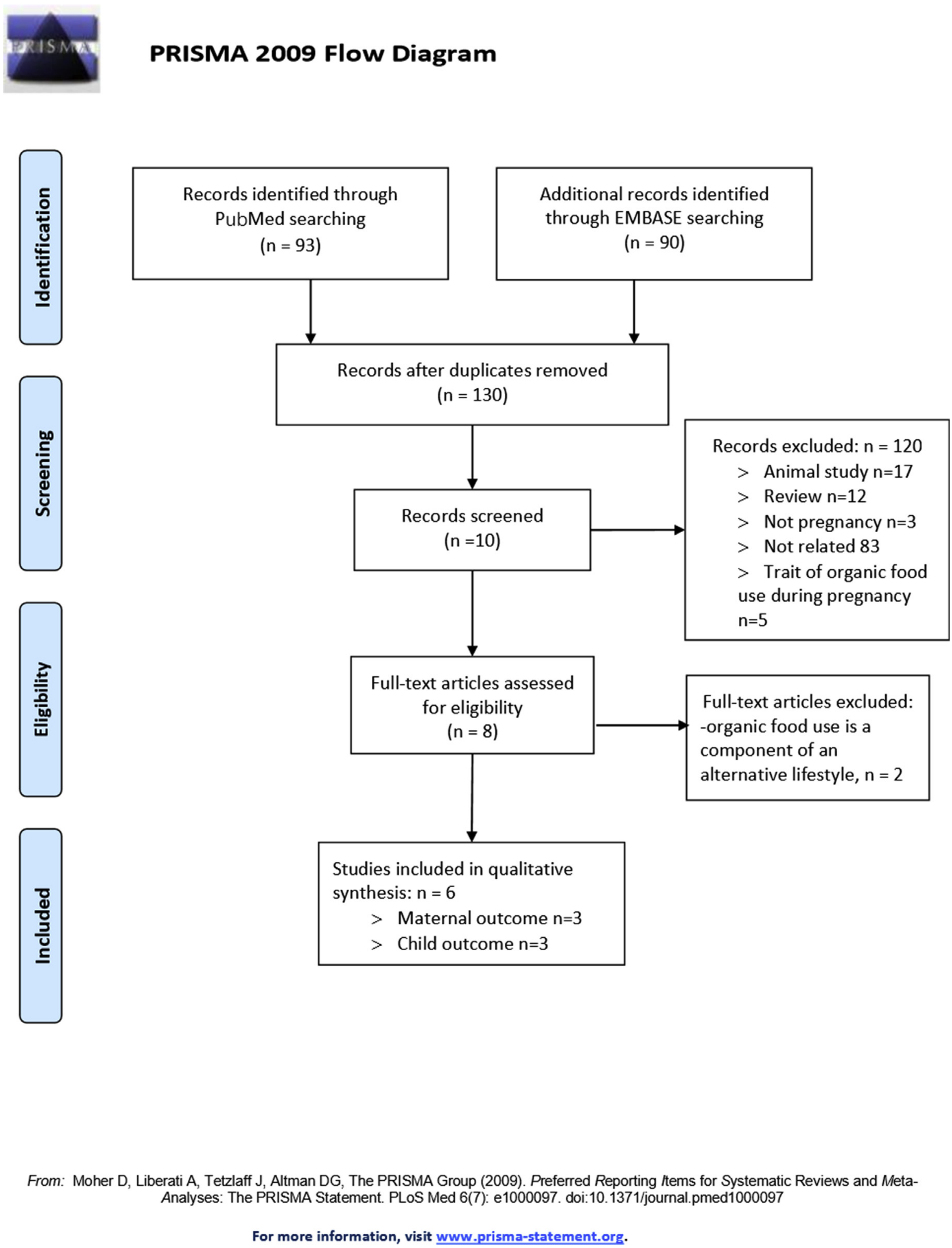

FIGURE 1. PRISMA flow diagram.

noting that although the sample size of women with GDM increased in the latter study, it is still small ($n = 37$). Of note, organic food consumption was queried at 34 weeks of pregnancy in the KOALA study, which is after the timing of gestational diabetes diagnosis at 24–28 weeks of pregnancy.

Besides gestational diabetes, Simoes-Wust et al. [36] also reported the association between organic food consumption and hypertension in pregnancy and several biomarkers in blood samples collected at 34–36 weeks of pregnancy. They found that individuals who purchased 50%–90% organic origin of total food had a lower prevalence of hypertension in pregnancy than the other groups. The authors concluded that consumption of organic food was associated with higher levels of trans-fatty acids from natural origin and lower levels of trans-fatty acids

TABLE 2
Observational studies regarding the association of organic food consumption in pregnancy with maternal and child health outcomes

Author, year, and country	Study design	Sample size	Exposure	Outcome	Covariates	Main results
Maternal pregnancy outcomes						
Torjusen et al., 2014, Norway [35]	Prospective cohort study (MoBa)	28,192	Organic food consumption (vegetables, fruit, cereals, milk/dairy, eggs, and meat) (collected during the first 4–5 months of pregnancy)	Pre-eclampsia	Hypertension prior to pregnancy, prepregnant BMI, maternal height, maternal age, maternal education, household income, maternal smoking in pregnancy, total energy intake, and gestational weight gain	Women who eat organic vegetables “often” or “mostly” had a lower risk of pre-eclampsia than those who reported “never/rarely” or “sometimes” (crude OR: 0.76; 95% CI: 0.61, 0.96; adjusted OR: 0.79; 95% CI: 0.62, 0.99). No significant association was found for organic fruit, cereals, eggs or milk, or a combined index reflecting organic consumption
Simoes-Wust et al., 2017, Netherlands [36]	Prospective cohort study (KOALA)	1339	Organic food consumption (collected at 34 weeks of pregnancy)	Gestational diabetes; hypertension in pregnancy (collected at 30 weeks of pregnancy); Biomarkers (Fe, homocysteine, 25(OH)D, plasma lipids) (collected at 34–36 weeks of pregnancy	Maternal age, parity, alcohol consumption, and smoking For some biomarker analyses, alcohol and smoking status were not adjusted	In the organic groups, fewer participants had diabetes in pregnancy than in the conventional group The 50%–90% organic group showed a lower prevalence than the other groups The consumption of organic food is associated with lower plasma level of a *trans*-fatty acid marker of industrially hydrogenated fats and higher plasma levels of markers of *trans*-fatty acids from natural origin, as well as lower plasma levels of homocysteine, which may be indicative of higher folate intake
Simoes-Wust et al., 2021, Netherlands [44]	Prospective cohort study (KOALA)	2803	Organic food consumption (collected at 34 weeks of pregnancy)	Gestational diabetes	Mother’s age at delivery and gravidity	Organic food consumption during pregnancy was not significantly associated with gestational diabetes
Offspring outcome at birth						
Christensen et al., 2013, Denmark [37]	Case–control study	306 cases and 306 controls	Organic food consumption (milk, other dairy products, eggs, meat, fruit, and vegetables) (collected during the first trimester)	Hypospadias	Maternal age, alcohol consumption during the first trimester, and BMI	Organic choice of food items during pregnancy was not associated with hypospadias in the offspring. Frequent current consumption of high-fat dairy products while rarely/never choosing the organic alternative to these products during pregnancy was associated with increased odds of hypospadias (adjusted OR: 2.18; 95% CI: 1.09, 4.36)
Brantsæter et al., 2016, Norway [38]	Prospective cohort study (MoBa)	35,107	Organic food consumption (vegetables, fruit, bread/cereal, milk/dairy products, eggs, and meat) (collected during	Hypospadias and cryptorchidism	Maternal education, household income, maternal prepregnancy BMI, small for gestational age baby, preterm delivery Each organic food group was adjusted	Women who consumed any organic food during pregnancy were less likely to have a boy with hypospadias (OR: 0.42; 95% CI: 0.25, 0.70) than women who reported they never or seldom consumed organic food. Associations

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TABLE 2 (*continued*)

Author, year, and country	Study design	Sample size	Exposure	Outcome	Covariates	Main results
			the first 4 months of pregnancy)		for total daily intake of food group items (organic and nonorganic) and adjusted for being an organic food user	with specific organic foods were strongest for vegetable (OR: 0.36; 95% CI: 0.15, 0.85) and milk/dairy (OR: 0.43; 95% CI: 0.17, 1.07) consumption. No substantial association was found between organic food consumption and cryptorchidism
Offspring outcomes in childhood						
Buscail et al., 2015, France [39]	Prospective cohort study (PELAGIE)	1461	Organic dietary consumption (not reported)	Otitis media	Sex, older siblings, daycare attendance, atopic disorder, breastfeeding, maternal age, maternal history of allergy, maternal education, parental smoking, maternal smoking during pregnancy, and maternal consumption of shellfish during pregnancy	An organic diet during pregnancy was associated with a decreased risk of parent-reported otitis media (at least 1 episode) in children before the age of 2 y (OR: 0.69; 95% CI: 0.47, 1.00)

from industrially hydrogenated fats, as well as lower levels of homocysteine [36].

Offspring outcomes at birth

Our search criteria identified 2 studies that had examined the association between maternal organic food consumption in pregnancy and birth outcomes in the offspring. Christensen et al. [37] conducted a case–control study among 306 boys with hypospadias and 306 healthy boys. Maternal consumption of organic foods (i.e., milk, other dairy products, eggs, meat, fruit, and vegetables) during the first trimester was assessed through telephonic interviews. An increase in odds of hypospadias was found among those who rarely/never use organic dairy products, compared with those who consumed organic dairy products often/sometimes (unadjusted OR: 1.46; 95% CI: 1.04, 2.06). However, the association became nonsignificant after adjustment for maternal age, alcohol consumption during the first trimester, and BMI. No significant associations were observed between hypospadias and other kinds of organic foods, respectively. No association was found for the overall use of organic food, a cumulative measure of organic choice, as well. However, it is worth noting that when combining choice and frequency of consumption, the researcher found a significantly increased OR of hypospadias among mothers who rarely/never used organic alternatives during pregnancy and currently consumed butter and cheese more than once daily (OR: 2.18; 95% CI: 1.09, 4.36).

Brantsæter et al. [38] employed data from 35,107 women–male infant pairs from the MoBa study to investigate the relationship between organic food consumption and hypospadias. This cohort included 74 (0.2%) male newborns with hypospadias. The OR of having a boy with hypospadias was 0.42 (95% CI: 0.25, 0.70) for women who consumed any organic food during pregnancy, compared with those who never/seldom consumed organic foods. Of all food categories, consumption of organic vegetables (OR: 0.36; 95% CI: 0.15, 0.85) and milk/dairy (OR: 0.43; 95% CI: 0.17, 1.07) showed the strongest association with decreased odds of hypospadias. The researchers adjusted for maternal education, household income, maternal prepregnancy BMI, small for gestational age baby, and preterm delivery in the analyses. For each organic food group, the researchers also adjusted for the total daily intake of specific food group items (organic and nonorganic) and consumption of any organic food. In addition to hypospadias, this analysis also examined the association between organic food consumption and cryptorchidism [38]. The MoBa cohort included 151 (0.4%) male newborns diagnosed with cryptorchidism. After adjustment for maternal education, household income, and paternal age, the authors did not observe any association between cryptorchidism and any organic food consumption (adjusted OR: 0.91; 95% CI: 0.66, 1.26), or specific types of organic food [organic vegetables: adjusted OR: 0.92 (95%

Table 3
The score of the Newcastle–Ottawa Quality Assessment scale

Author, year, and country	Selection	Comparability	Outcome
Torjusen et al., 2014, Norway [35]	3	2	3
Simoes-Wust et al., 2017, Netherlands [36]	2	0	2
Simoes-Wust et al., 2021, Netherlands [44]	2	0	2
Christensen et al., 2013, Denmark [37] [1]	3	0	1
Brantsæter et al., 2016, Norway [38]	3	2	3
Buscail et al., 2015, France [39]	3	1	3

[1] Case control study.

CI: 0.66, 1.30); organic fruit 1.04 (95% CI: 0.73, 1.44); organic cereals: 0.86 (95% CI: 0.57, 1.30); organic milk/dairy products: 0.70 (95% CI: 0.47, 1.05); organic eggs: 0.97 (95% CI: 0.69, 1.36); and organic meat: 0.78 (95% CI: 0.45, 1.33)].

Outcomes in childhood

We identified only 1 study that examined the association between maternal organic food consumption and subsequent outcomes in childhood [39]. Using data from the PELAGIE mother–child cohort, Buscail et al. [39] assessed the risk of otitis media during early childhood among 1461 mother–child pairs. In this study, 910 children (63.1%) were reported to have at least 1 episode of otitis media during the first 2 years of life, and 408 (28.3%) children had at least 3 episodes during that period. Mothers were asked how frequently they consumed foods from various food groups and the percentage of organic food [39]. Children whose mothers reported consuming an organic diet during pregnancy were found to have a reduced risk of otitis media (at least 1 episode, *P*-trend = 0.01). Compared with those who "never" consumed organic food, the OR of at least 1 otitis media episode was 0.76 (95% CI: 0.60, 0.97) for those who "sometimes" consumed organic foods and 0.69 (95% CI: 0.47, 1.00) for those who "frequently" consumed organic foods during pregnancy. The association of maternal organic food consumption during pregnancy with the risk of at least 3 otitis media episodes was not statistically significant; the corresponding OR was 0.94 (95% CI: 0.73, 1.21) and 0.88 (95% CI: 0.58, 1.33), respectively.

Limitations of available studies regarding health effects of organic food consumption during pregnancy

There is a lack of evidence from randomized controlled trials on the health benefits of organic food consumption during pregnancy on maternal and offspring health. Although there was a randomized controlled trial of organic diet intervention during pregnancy [28], it focused on the reduction in pesticide exposure and did not assess health outcomes.

Several challenges limit the ability of any observational study to indicate a causal linkage between organic food consumption and maternal and child health outcomes. First, there is significant potential for uncontrolled confounding by socioeconomic status, other dietary and lifestyle factors, or even unknown factors. Previous studies have shown that people who purchase organic food are more likely to have dietary and lifestyle habits generally associated with better health [40]. Moreover, people who buy organic food usually have a higher socioeconomic status, for example, higher education level and family income [41]. In Norway, the diets of pregnant women with frequent organic consumption were more in line with dietary recommendations for health and ecological sustainability [42]. Therefore, randomized controlled trials are needed in the future to address these concerns and establish the efficacy of organic diet intervention on maternal and offspring health outcomes. Second, reverse causation could occur among pregnant women with subclinical conditions. In this scenario, the magnitude of the observed association between organic food consumption and the disease outcome would have been underestimated. In other words, the real association would be even stronger than reported in previous observational studies. Third, the heterogeneity in regulations and practices in organic food production may complicate the comparisons of results in different countries. For example, there has been considerable variation in the use of copper as plant protection in organic agriculture across European countries, a substance now being phased out in revised European legislation [43]. Last but not least, in all the available studies, organic food consumption was based on self-reported dietary intake or purchase records, which is notoriously subject to recall bias or reporting bias. Strategies to reduce recall bias, for example, well-defined questions and appropriate data collection methods, should be applied carefully.

Furthermore, although reduced pesticide exposure is hypothesized to be a potential mechanism by which organic food consumption may improve health [35,37,38,44], no observational cohort study to date has measured pesticide concentrations to confirm questionnaire-based exposure assignments or assessed the pesticide exposure to serve as an effect modifier concerning organic food consumption and health outcomes.

Conclusions and future perspectives

In summary, findings from available studies on health outcomes of organic food consumption during pregnancy, all in observational nature, indicated that maternal organic food consumption during pregnancy was associated with reduced risk of pre-eclampsia, gestational diabetes, and some adverse outcomes in offspring. However, given the inherent concern about uncontrolled confounding and reverse causation in observational studies, there is a critical and urgent need to conduct randomized controlled trials to establish the relationship between the consumption of an organic diet during pregnancy and maternal and child health outcomes. Future studies should also consider how country-specific regulations on organic food labeling and tolerance levels for individual pesticides may influence results. In addition, future studies should include measurements of pesticide biomarkers to confirm whether pesticide exposure was the potential mechanism underlying the health effects of organic food consumption.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.advnut.2022.11.001.

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