DOI: 10.1111/nyas.15122

CONCISE REPORT

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES

Barriers to implementing good nutrition in pregnancy and early childhood: Creating equitable national solutions

Monique Rainford[1] | Linda A. Barbour[2] | Darlena Birch[3] | Patrick Catalano[4] | Ella Daniels[5] | Caron Gremont[6] | Nicole E. Marshall[7] | Kurt Wharton[8] | Kent Thornburg[9]

[1]Department of Obstetrics, Gynecology and Reproductive Sciences, Yale School of Medicine, New Haven, Connecticut, USA

[2]Division of Endocrinology, Metabolism and Diabetes, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, Colorado, USA

[3]Public Health Nutrition, National WIC Association, Washington, District of Columbia, USA

[4]Department of Obstetrics and Gynecology, Tufts University, Boston, Massachusetts, USA

[5]Veggies Early & Often, Partnership for a Healthier America, Washington, District of Columbia, USA

[6]Share Our Strength, Washington, District of Columbia, USA

[7]Department of Obstetrics and Gynecology, Oregon Health & Science University, Portland, Oregon, USA

[8]Department of Obstetrics and Gynecology, Oakland University William Beaumont School of Medicine, Rochester, Michigan, USA

[9]Knight Cardiovascular Institute, Center for Developmental Health, and Moore Institute for Nutrition & Wellness, Oregon Health & Science University, Portland, Oregon, USA

Correspondence
Kent L. Thornburg, Bob and Charlee Moore Institute for Nutrition & Wellness, Oregon Health & Science University, 3030 S. Moody Ave, Portland, OR 97201, USA. Email: thornbur@ohsu.edu

Funding information
Bob's Red Mill; The Vitamix Foundation

Abstract

Exposure to deleterious stressors in early life, such as poor nutrition, underlies most adult-onset chronic diseases. As rates of chronic disease continue to climb in the United States, a focus on good nutrition before and during pregnancy, lactation, and early childhood provides a potential opportunity to reverse this trend. This report provides an overview of nutrition investigations in pregnancy and early childhood and addresses racial disparities and health outcomes, current national guidelines, and barriers to achieving adequate nutrition in pregnant individuals and children. Current national policies and community interventions to improve nutrition, as well as the current state of nutrition education among healthcare professionals and students, are discussed. Major gaps in knowledge and implementation of nutrition practices during pregnancy and early childhood were identified and action goals were constructed. The action goals are intended to guide the development and implementation of critical nutritional strategies that bridge these gaps. Such goals create a national blueprint for improving the health of mothers and children by promoting long-term developmental outcomes that improve the overall health of the US population.

KEYWORDS
infant and childhood nutrition, nutrition during pregnancy, nutrition policy, pregnancy health, racial disparities in nutrition

INTRODUCTION

People in the United States are poorly nourished before becoming pregnant, during pregnancy, and during lactation.[1] The current food culture in the United States promotes an unhealthy diet; as a result, chronic disease rates continue to climb. For example, 13% of US adults had type 2 diabetes in 2018,[2] and this rate is projected to increase to 33% by 2050.[3] Additionally, the American Heart Association (AHA)

predicts that the total costs of cardiovascular disease in the United States will reach $1.1 trillion by 2035.[4]

Early-life malnutrition underlies most chronic disease cases[5]; consequently, focusing on good nutrition before and during pregnancy and lactation and early childhood has the potential to reverse the current upward trajectory of chronic disease prevalence in the United States. It has been suggested that the number of type 2 diabetes and heart disease cases could be reduced by half in one generation if babies were born at a normal weight and were prevented from putting on excess fat before the age of eight.[5] Therefore, to make the most impact on chronic disease reduction and the reversal of current trends, contemporary strategies need to be paired with a focus on improving early-life nutrition and reducing social stress.

The conference "Nutrition in Pregnancy: Creating a National Blueprint for Healthy Mothers and Children" (June 2–3, 2022, in Washington DC) brought together leaders from academic, nonprofit, and government organizations who were experts in issues surrounding nutrition for people in their reproductive years. Attendees included other national experts who were interested in the topic. The purpose of the conference was to identify major gaps in current practices that prevent people who are likely to become pregnant, are pregnant, or are lactating from consuming a healthy diet. An additional purpose was to identify goals that if met, would close identified gaps. The meeting included a series of presentations that informed the audience of current programs designed to meet the nutritional needs of people during pregnancy and presentations that highlighted major deficits in current practice. The program highlighted disparities and inequities in nutritional care among populations based on race and socioeconomic circumstances.

Over the past two decades, it has been obvious to members of the scientific community, community-based health workers, and nonprofit organizations who care for pregnant people that there is a need to articulate the barriers to providing healthy diets and social environments for people before and during their pregnancy and lactation. Experts attending the nutrition in pregnancy conference were from academia, National Institutes of Health (NIH), US Department of Health and Human Services Office on Women's Health, Headstart, Share our Strength, 1000 Days, March of Dimes, National WIC Association, US Breastfeeding Committee, Center for American Indian Health, Partnership for a Healthier America (PHA), No Kid Hungry, GrowBaby Health, Vitamix Foundation, National Birth Equity Collaborative, MomsRising, Food and Friends, Catalysis, Academy for Nutrition and Dietetics, American College of Obstetrics and Gynecology (ACOG), American College of Nurse Midwives, American Academy of Family Physicians (AAFP), and the American Academy of Pediatrics (AAP). Speakers representing African American women, Native American women, and other underserved ethnic populations focused on the acute needs of these groups.

The action goals presented at the end of this review were created to address knowledge and application gaps in nutrition during pregnancy and early childhood and are based on the recommendations from assembled experts who attended the conference.

Racial disparities, adverse childhood experiences, and health outcomes

In the United States, many maternal health disparities are especially experienced by Black women and their infants.[6–15] Non-Hispanic Black women in the United States experience the highest rates of pre-pregnancy obesity, pregnancy-related mortality, maternal mortality, cesarean deliveries, and stillbirth compared to any other race (**Table 1**). The pregnancy-related mortality ratio is over three times higher than the ratio for non-Hispanic White and Hispanic women, and the maternal mortality rate is nearly three times higher. Infant mortality rates are approximately two times higher when the mother is non-Hispanic Black, American Indian, Alaskan Native, or a Native Hawaiian/Pacific Islander than when the mother is non-Hispanic White, Hispanic, or Asian. Low birth weight occurs about twice as frequently when the mother is non-Hispanic Black versus non-Hispanic White or Hispanic. Additionally, Black infants are 15% less likely to have ever been breastfed than White infants, representing yet another racial disparity, given the compelling benefits of breastfeeding for both infants and mothers.[16]

Considering the worse maternal–fetal health outcomes of Black women relative to all other racial/ethnic groups evaluated, one wonders the extent to which genetics play a role in this observation. However, several studies demonstrate that the fetuses of foreign-born (i.e., outside of the United States) Black women experience healthier intrauterine growth than those born in the United States.[17] Among Black women, birth outcomes are most favorable for infants born to African-born women, followed by infants of Caribbean-born women; they are least favorable for infants born to US-born Black women.[18] Furthermore, foreign-born Blacks, including those from minority White and racially mixed regions, also have superior health compared to US-born Blacks. In contrast, Black women from regions that are a majority White (i.e., Europe) have similarly poor health outcomes as those in the United States, suggesting that living in a majority White population has negative effects on the health of Black individuals.[19]

Causes of these racial disparities in maternal and infant health include implicit bias, epigenetics, allostatic load (weathering), adverse childhood experiences (ACEs), structural racism, and social inequities. Implicit bias affects understanding, actions, and decisions in an unconscious manner and may include both favorable and unfavorable assessments of those around us. These biases are involuntary; individuals are neither aware of them nor in control of them, as they reside deep in the subconscious.[20] Surprisingly, levels of implicit bias have been found to be similar between healthcare professionals and the wider population,[21] and such implicit biases are likely to affect the quality of care received by Black patients.[22]

Environmental factors, such as nutrition and social stress, can exert epigenetic effects that influence human health.[23–25] For example, epigenetic marking and unmarking of regions of DNA regulate gene expression by altering transcription and the spatial conformation of chromatin.[23] The critical time for environmental factors to affect epigenetics is during pregnancy and in the first 1000 days after

TABLE 1 Racial disparities.

	Non-Hispanic White	Non-Hispanic Black	American Indian or Alaska Native	Native Hawaiian or Other Pacific Islander	Asian	Hispanic or Latino
Pre-pregnancy obesity[6] (%)	26.6%	39.1%	–	–	–	32.4%
Pregnancy-related mortality ratio[a,7]	13.4	41.7	28.3	13.8		11.6
Maternal mortality rate[b,8]	19.1	55.3	–	–	–	18.2
Infant mortality rate[c,9]	4.6	10.8	8.2	9.4	3.6	4.9
Singleton preterm birth rate[10] (%)	7.36%	12.18%	10.30%	–	7.29%	8.54%
Low birthweight (origin of mother)[11] (%)	6.84%	14.19%	–	–	–	7.4%
Total cesarean deliveries[12] (% of live births)	30.9%	35.8%	28.9%	32.6%	–	–
Preeclampsia[13] per 100 hospitalizations with delivery	1.8	3.2	–	–	–	2.9
Fetal deaths per 1000 live births and stillbirths[14] (origin of mother)	4.89	10.32	7.22	4.29		5.01
COVID-19–related maternal deaths[b] (2020 and 2021)	4.5	13.2	–	–	–	8.9

[a]Estimate of the number of pregnancy-related deaths (death while pregnant or within 1 year of the end of pregnancy, from any cause related to or aggravated by pregnancy) per every 100,000 live births.
[b]Deaths per 100,000 live births.
[c]Number of infant deaths (death prior to first birthday) per 1000 live births.

conception,[24] with early life nutrition being particularly important in terms of epigenetic effects that may modify disease risk later in life.[23] Epigenetics contributes to "programming" in the womb, whereby early life adaptations to a poor environment lead to elevated disease risk in later life. Stressors, including under- and over-nutrition in the womb, have been shown to dramatically increase the risk of several adult-onset diseases. For instance, excessively rapid growth in the womb is linked to metabolic disease, obesity, and breast and lung cancers. The accumulation of transgenerational epigenetic changes from deleterious exposures may go further to explain racial disparities than other mechanisms.

Geronimus et al. proposed the *weathering hypothesis* to account for the early health deterioration observed among Blacks.[26] This hypothesis is based on the idea that the cumulative effect of experiencing frequent political marginalization and economic or social adversity, which consequently exposes individuals to repeated or chronic stress, results in early health deterioration due to allostatic load, or the accumulation of wear and tear on the body over time.[26,27] Research has shown that allostatic load is worse for Black women than for White women or Black men and that this is not explained by poverty, as non-poor Blacks are also more likely to have a higher allostatic load than poor Whites.[28] However, high adiposity in these groups and among American Indians/Alaska Natives underlies a propensity for type 2 diabetes and heart disease in later life.[29]

It is reported that, in the United States, the prevalence of ACEs is highest among non-Hispanic Black children.[30] ACEs may include abuse and neglect, witnessing domestic violence, or having family members with substance abuse disorders. Individuals with ≥4 ACEs are at an increased risk of multiple poor health outcomes compared with those who have no ACEs.[31] The strongest associations between ACEs and negative health outcomes are with problematic drug use and interpersonal and self-directed violence. ACEs also have a strong association with sexual risk-taking, poor mental health, and problematic alcohol use. A moderate association was reported between ACEs and heavy use of alcohol, smoking, heart disease, cancer, respiratory disease, and poor self-rated health. A weak to moderate association was reported with physical inactivity, being overweight or obese, and diabetes. ACEs can also influence epigenetic profiles in affected individuals.[32] As a result, it is likely that children born to mothers with severe nutritional stress and epigenetic propensities for chronic disease will have higher risks for adverse outcomes post puberty than less affected individuals.

Finally, African Americans face a number of social inequities, including lower attainment of college degrees, higher rates of unemployment, lower incomes, and lower rates of home ownership compared with Whites.[33] In 2004, the life expectancy at birth for Blacks was 73.1 years compared to 78.3 years for Whites.[34,35] By 2019, the Black population experienced greater gains in life expectancy compared with other races; life expectancy was 75.3 years for Blacks and 78.9 years for Whites.[36] However, provisional 2020 data showed that those gains have been erased, with life expectancy dropping for both Blacks and Whites, though the drop was more substantial for the Black

population (Black population, 71.8 years; White population, 77.6 years).[37] It should also be noted that food insecurity is far more common in Black households with children (1 in 3) than in White households with children (1 in 10)[38] and that early exposure to food insecurity is linked to long-term negative health outcomes.[39]

Solutions or interventions to help eliminate racial disparities in health care are needed, and studies have demonstrated strategies to improve implicit bias and pregnancy outcomes. One study reported the successful implementation of training to counteract implicit bias.[40] Another investigated the effects of increasing the support available to African American women during pregnancy and childbirth and after delivery by providing them with doulas.[41] That study found that women who had the assistance of a doula had improved outcomes; the chance of having a low-birth-weight baby was reduced by four times and the likelihood of birth complications was reduced by two times. These mothers were also significantly more likely to initiate breastfeeding versus mothers who were not doula-assisted.

Another successful strategy is group prenatal care, which has been shown to improve pregnancy outcomes for African American women and to improve their prenatal knowledge, readiness for labor and delivery, and satisfaction with care.[42] Women who received group prenatal care also initiated breastfeeding at a higher rate than those who did not. Lifestyle changes, such as exercise during pregnancy, healthy dietary patterns, and mindfulness-based interventions, have also proved beneficial in some studies.[43–45]

Breastfeeding provides enormous benefits to mother and child

Breastfeeding has many benefits, including providing nutrients, antigens and allergens, immune cells, antibodies, cytokines/chemokines, growth factors, enzymes, hormones, and commensal microbes, to the infant.[46] This mode of feeding has a bidirectional effect. The mother benefits from a positive stimulation of immune function with lactation and the development of immunity against the infant's oral cavity microbes.[46] Breastfeeding can also reduce the risk of ovarian cancer and high blood pressure and has been shown to decrease the risk of developing type 2 diabetes in mothers with a history of gestational diabetes.[44] For the infant, beneficial effects include immune system development, immune system priming, protection from pathogens, influence on the developing gut microbiota, and a reduction in the risk of necrotizing enterocolitis, otitis media, respiratory infections, diarrhea, sudden infant death syndrome, asthma, atopy, Crohn's disease, celiac disease and ulcerative colitis, obesity, and both type 1 and type 2 diabetes.[46–50] The risk of possible or probable asthma by the time a child turns 3 years old is increased when infants are fed via indirect (pumped) breastmilk, direct or indirect breastmilk plus formula, or formula alone compared with direct breastfeeding.[51] A review of 117 studies found that "more versus less breastfeeding" was associated with a 22% reduced risk of asthma (pooled odds ratio [OR] 0.78; 95% confidence interval, CI [0.74, 0.84]), with the strongest effects being observed before 2 years of age.[52]

Human milk contains proteins, glycoproteins, enzymes/proteases, human milk oligosaccharides, and endogenous peptides that support infant growth, innate and adaptive immunity, and gut development.[53] More recently, bioactive compounds, including microRNAs, lipokines/signaling lipids, small molecules/metabolites, and fructose, have been found in breast milk; however, it remains unclear how these components are impacted by maternal physiology and how they affect infant outcomes.[54] Breastfeeding in the modern world provides many challenges to mothers.[55] Some have difficulties with infant latching or have concerns about the adequacy of their milk supply. These women would benefit from more instruction on how to breastfeed. Some mothers struggle to be successful in lactation due to lack of support from their partners and family. Working women often cannot take long maternity leaves and may feel uncomfortable and isolated when breastfeeding and pumping, causing them to stop breastfeeding early.

In the United States, breastfeeding is initiated in 84.1% of births but with disparities among ethnic groups.[56,57] The lowest initiation rates are found among Black (73.6) and American Indian/Alaska Native (76.6) mothers, with the highest rates among Asians (90.3). Hispanic (87.4) and White (85.5) mothers are above the average. This disparity is even more pronounced at age 3 months where the breastfeeding rate for Black infants was 58% while the rate for White infants was 72.7%.[56,57]

These disparities should be investigated so that Black and American Indian/Native American mothers can receive more support in their efforts to provide human milk for their babies. There is also room for improvement for initiation and continuation in other races as well.

Current nutritional guidelines focusing on infants and young children and barriers to compliance

An extensive review of the literature supporting the most robust recommendations for optimal nutrition in pregnant women was not the focus of this conference. However, a recent review of this literature conducted by many of the experts who attended the conference has recently been published. Recommendations include the consumption of whole, unprocessed foods and beverages; a diet rich in fruits and vegetables, whole grains, and complex carbohydrates, including ancient grains; healthy fats (monounsaturated and polyunsaturated), including nuts and seeds; healthy fish; plant-based protein; lean meats and dairy products; and the increased ingestion of water.[1] The conference did highlight both the US Dietary Guidelines for Americans and the AAP, which recommend that infants are exclusively breastfed until they reach 6 months of age.[58,59] It is advised that infants continue to receive human milk through at least the first year of life, and longer if desired.[58] A recent update to the AAP guidelines supports breastfeeding through the first 2 years of life and beyond if mutually desired.[59] If human milk is unavailable, infants should be fed iron-fortified infant formula during the first year of life, and all infants should be provided with supplemental vitamin D soon after birth.[58] Nutrient-dense foods, complementary to breast or formula feeding, should be introduced at 6 months of

age; potentially allergenic foods such as peanut butter should also be introduced.[58] Infants and toddlers should be encouraged to consume a wide variety of foods from all food groups, with a focus on those rich in iron and zinc, especially for infants fed human milk. Foods and beverages high in added sugars or artificial sweeteners, including fruit juice, should be avoided, and those high in sodium should be limited.

Despite the recommendations for feeding infants exclusively human milk through 6 months, only 25.8% of infants are fed accordingly.[59] It is estimated that low rates of breastfeeding add over $3 billion annually to medical costs for mothers and children in the United States.[16] Therefore, it is important to find ways to address barriers to breastfeeding and provide meaningful support to those caring for infants. A recent study among low-income women who intended to breastfeed reported higher achievement of the breastfeeding goal (exclusive breastfeeding at 1 month) when breastfeeding support was provided during the birth hospitalization.[60] Hospital-provided support consisted of educating and assisting the mothers with six maternity care practices that support breastfeeding (feeding breast milk exclusively, breastfeeding within the first hour of birth, rooming-in, demonstrating breastfeeding to the mothers, no use of pacifiers, and practicing on-demand breastfeeding). Experiencing a higher number of these steps was associated with a higher probability of meeting the breastfeeding goal.

Most toddlers aged 12–23 months consume less human milk; infant formula is no longer recommended.[58] Toddlers should be encouraged to eat a variety of vegetables (dark green, red, and orange vegetables; bean, peas, and lentils; starchy vegetables), fruit, grains (primarily whole grains), dairy, protein (meats/poultry, eggs, seafood, nuts, seeds, and soy products), and oils. For those still consuming human milk, the pattern should be similar, though the caloric intake from these foods should be reduced according to the amount of human milk consumed.

On average, American toddlers exceed the recommended intakes of dairy and processed grains; however, over 95% of toddlers fall short of the recommended intake of whole grains.[58] Nearly 60% of American toddlers meet or exceed recommended intakes for fruits, and average protein intakes fall within the recommended range. However, nearly 90% of American toddlers fall short of the recommended 0.66–1 cup of total vegetables per day, with dark green vegetables having the lowest average daily intake. Several hurdles to sufficient childhood exposure to vegetable flavors have been identified. A study on the variety and content of commercial vegetable products for infants and children in the United States reported that less than 10% of vegetable products evaluated were single-vegetable products, and none featured dark green vegetables or beans/peas.[61] Fruits were added to many vegetable-containing infant and toddler foods, masking and thus reducing exposure to vegetable flavors, which appears to be important early in developing a proclivity for vegetables.[62] Another potential barrier to adequate exposure of infants and toddlers to vegetable flavors was the limited variety of commercial foods available with an optimal composition to facilitate increased acceptance of vegetables.[62] These findings represent a barrier for children developing a liking for vegetables early in life and indicate room for improvement in relation to supporting children's acceptance of vegetables in infant and toddler food product lines. Unfortunately, children are not predisposed to prefer diets high in vegetables and low in salt and sugar with the biological development of taste preference. However, the fact that taste preferences are flexible in early childhood and can be modified and shaped through dietary experiences is encouraging.[63]

There are many important programs supported by the US government that offer nutritional support to women, children and families.[64] These include the Supplemental Nutrition Assistance Program (SNAP), Back to School 2023, the School Breakfast Program, the National School Lunch Program, the Child and Adult Care Food Program (CACFP), Women, Infants, and Children (WIC), Afterschool Nutrition Programs and Summer Nutrition Programs and others.

Most states have programs that address food insecurity for children and school lunch quality. These national and statewide programs are highly beneficial. However, there are a number of issues that remain unresolved. These include the numbers of WIC-eligible people who do not enroll into the program. This fact was recently noted in a USDA (US Department of Agriculture) study.[65] The study makes several key points:

- The average monthly WIC-eligible population totaled 12.13 million in calendar year 2021.
- In the average month of 2021, WIC served an estimated 51.2% of those eligible for WIC, which is slightly lower than the revised coverage rate in 2020 (52.0%).
- Coverage rates were highest for Hispanic (58.1%) WIC-eligible individuals and lowest for non-Hispanic White (44.2%) WIC-eligible individuals.
- Nationally, more than 50% of WIC-eligible SNAP and Medicaid recipients do not participate in WIC.

Issues that need to be addressed: The WIC program depends on congressional support on an ongoing basis. Although a very valuable program, it is not yet able to meet all of the needs of women and children who are in desperate need of nutritional assistance. State governments should be encouraged to supplement the program for their own residents.

Perhaps the most exciting program of government intervention comes from the Netherlands, where large sums of money have been invested in improving the care of people during preconception, pregnancy, and lactation. These programs are aimed to improve health at the community level[66,67] and could be a model for national and state level governments.

Barriers for achievement of adequate maternal and childhood nutrition in communities

The well-established Developmental Origins of Health and Disease concept states that the risk of obesity and its related chronic conditions are set during pregnancy and early life.[5,68] However, reversal of the process is also possible, although there are too few studies providing

mechanistic insights to explain how early nutrition and related exposures drive future disease risk and healthy development. Filling this critical gap may identify opportunities for intervention, despite the significant barriers that exist in the engagement of pregnant women about their nutrition. Although geared toward identifying ways to improve recruitment for clinical trials during pregnancy, the barriers to clinical trial participation identified by Strömmer et al., such as lack of trust in the trial and/or research staff, being too busy to participate, and concerns about study requirements, may also apply to engagement in any public health initiative, including health improvement efforts during pregnancy.[69] Other barriers to improving maternal health, particularly among very young pregnant women (15–22 years), include a lack of knowledge on how to eat well during pregnancy and how to do so within the limits of personal food preferences and financial constraints.[70] Additionally, among very young pregnant women, individual differences in barriers result in variable responses to behavior and change interventions. For engagement to be effective, it must be genuinely enabling, meaning that it must support women by providing them with concrete opportunities to feed themselves and their families better. To facilitate these changes, not only education but monetary support and a supportive environment should be provided.

The community food environment strongly impacts pregnancy. For example, the Pregnancy, Infection & Nutrition cohort study found that living >4 miles from a supermarket was associated with lower diet quality during pregnancy (adjusted OR 2.16; 95% CI [1.2, 4.0]).[71] A medical records review revealed that individuals living in food deserts were more likely to have at least one morbidity during pregnancy versus those who did not (adjusted OR 1.64; 95% CI [1.18, 2.29]).[72] A study conducted in Brazil revealed excessive gestational weight gain was associated with the number of food-purchasing establishments near an individual's place of residence,[73] and another study found that gestational diabetes mellitus (GDM) was less likely for women living in areas with better access to healthier foods. Furthermore, these women were less likely to require medication to control GDM or to deliver an infant with macrosomia.[74] GDM risk was increased for women living in neighborhoods with more fast-food restaurant access.[75]

The PHA reports four main barriers to food equity.[76] These include access, affordability, time, and marketing. Around 23.5 million Americans live far away from a grocery store, limiting their access to healthy foods. Healthy food is more costly, with an increased price of approximately $1.50 per day per person (versus unhealthy food), making it unaffordable or difficult to afford for many. Additionally, parents are busy, with 31% reporting that they always feel rushed, potentially limiting their ability to cook healthy meals. Finally, over 80% of food advertising promotes junk food.

Community interventions and national policies

Both educational and environmental interventions can be made to improve the food environment during pregnancy. A combination of these two types of interventions may work better that either alone. Such interventions can be supported by policy, potentially strengthening their impact. Environmental interventions include creating new institutions, such as new supermarkets, developing farmer's markets, improving transportation, and introducing urban farms. Additionally, access can be changed within existing food stores. Examples of this include improving the availability of healthy foods in smaller stores that are based within communities, relocating foods within stores so that healthier foods are more visible, store renovations, reducing the availability of less healthy foods, and providing price support (i.e., charging less for healthy foods and more for unhealthy foods). Policies to improve the food environment include worksite wellness programs, staple food ordinances, sugar-sweetened beverage/junk food taxes, urban farm tax credits, re-zoning, and improving access to the Special Supplemental Nutrition Program for WIC.

Community-based interventions have been shown to help improve nutrition. For instance, interventions that help bring birth weight toward the mean can offer protection against type 2 diabetes in the offspring of Native American pregnancies.[77] The Family Spirit Nurture curriculum was designed in partnership with tribal communities; it is a six-lesson home-visiting intervention that aims to reduce obesity in early childhood within the Native American community.[78] The curriculum was designed to address specific parent-feeding practices associated with an increased risk of childhood obesity. This is particularly important for Native American communities, as obesity rates are highest among children in these communities, which increases their lifetime risk for obesity, as well as obesity-related morbidity and mortality.[79] A clinical trial among Navajo mothers with infants evaluated the effectiveness of the Family Spirit Nurture curriculum. The study found that, for the intervention group, there was a significant decrease in infant sugar-sweetened beverage consumption, responsive feeding practices were significantly better, and the age at which infants received their first food was significantly older versus the nonintervention group. Intervention group infants also had significantly lower body mass index z-scores than those in the nonintervention group. This study provides an example of how community interventions may benefit the health of children.

Another example is the Food & Friends community-based organization in Washington DC that is offered through AmeriHealth Caritas. They provide medically tailored meals and nutrition therapy to low-income and chronically ill patients. Pregnant women in the program receive medically tailored meals, groceries, and nutrition counseling from the time they are referred to 8 weeks postpartum. Among participants with sufficient data for a 3-year claims review (1 year prior to meal delivery through 1 full year after), there was a striking 61% reduction in total cost, a 32% reduction in low-acuity emergency department visits, a 75% reduction in emergency medical services visits, and a 100% reduction in the total number of visits in both potentially preventable admissions and 30-day all-cause admissions. Additionally, a participant survey revealed that 79% reported eating about 75% of the food they received. As a result of participation, 74% were better able to follow doctor's orders, 79% experienced less stress procuring food, and 63% were better able to manage their pregnancy and postpartum

transition. Seventeen states now provide postpartum Medicaid coverage for up to 12 months instead of being limited to 6–8 weeks. Continued postpartum nutrition counseling should be encouraged during this critical period for mothers and infants.

Through the education campaign Veggies Early & Often, the PHA is bringing together early childhood educators, health professionals, and industry leaders around innovative cross-sector approaches that initially present and encourage the continued intake of a wide array of vegetables that are well-received and liked by children. In 2021, Veggies Early & Often was initiated alongside the release of an analysis by the PHA entitled "Yes, Kids CAN Learn to Love Veggies", which demonstrated that the taste preferences of children are flexible and can be modified and shaped early in life through dietary experiences.[80] This paper helps food industry leaders, early childhood educators, and medical professionals align on evidence to support early childhood nutrition and feeding development. One critical component of the campaign is PHA's product icon to clarify to parents whether baby and toddler food products meet the PHA's strict 2020 Dietary Guidelines for Americans-based Veggies Early & Often icon requirements. Products or menu items approved to use PHA's icon must contain over 50% vegetables and no additives. PHA seeks to add new commitments from companies to reformulate their current commercial food products according to these standards or to develop new vegetable-forward product options at all price points for young eaters. Veggies Early & Often has developed four key messages to encourage children to develop a liking for vegetables.[80] These key messages include (1) the importance of early and frequent exposure to veggies to encourage children to love veggies; (2) the fact that early and frequent consumption of veggies is critical to a healthy and happy life; (3) the encouragement of adults to be role models for kids by cooking and eating a well-balanced, plant-forward diet; and (4) the exposure to a variety of veggies early on is crucial for kids to learn to be healthy, happy, and adventurous eaters. These messages are geared toward educating parents, makers of baby and toddler foods, caregivers, and healthcare professionals on how important it is to expose children to vegetables early in life and frequently.

NUTRITION EDUCATION FOR HEALTHCARE PROFESSIONALS AND STUDENTS

It is well-known that physicians and other healthcare providers can inspire their patients and encourage them to live a healthy lifestyle.[81] However, there are barriers that prevent healthcare providers from offering sound information to their patients. The early prenatal period can be very important in terms of messaging for pregnant people, especially regarding nutrient intake and establishing a healthy diet. A review of barriers to prenatal care written in the late 1980s shows that the needs of pregnant people in the early gestational period are similar to those of today.[82] In the chapter survey, data suggested that the barriers to receiving prenatal care by a professional provider were, in order of priority, inadequate finances, lack of transportation, lack of interest in prenatal care, unaware of being pregnant, lack of a local healthcare provider, dislike of a person's healthcare provider, fear of being pregnant and an assortment of family reasons. Several of these are related to the difficulties in finding a trusted healthcare provider who can follow the pregnancy throughout the whole gestational period.[82]

The medical workforce has, over the past 70 years, been populated with White male healthcare providers. That situation is gradually changing. Nevertheless in 2017, 50.4% of medical school matriculants identified as female, 7.3% as Black, 8.9% as Hispanic, 24.6% as Asian, and 58.9% as White. Although there is some progress, the current number of medical school matriculants does not mirror the population of Black and Hispanic persons in the United States which is 14.1% and 17%, respectively.[83]

It is of utmost importance that nutritional education become a permanent addition to healthcare education programs across the United States so that new healthcare providers are grounded in nutritional knowledge at the start of their careers. At present, most medical schools do not include a comprehensive course in nutrition, nor do they cover the concept of *food as medicine* beyond applied nutrition in the biochemistry sections of the curriculum. Thus, physicians are poorly prepared to understand the power of nutrition in promoting health during pregnancy, lactation, and childhood. Several professional societies recognize the need for improved nutritional education for pediatricians, obstetricians, family practice doctors, and midwives and are working toward developing nutritional education programs.

The AAP has worked toward providing better training and tools for early-care physicians and healthcare practitioners to facilitate the support patients and families need in addressing nutrition. As part of this effort, the AAP significantly revised and updated its Pediatric Nutrition policy manual.[84] The 8th edition includes a new chapter titled Pediatric Global Nutrition, and other chapters were completely revised and reorganized based on developments in nutritional science and new evidence-based guidelines recommending changes in practice. It also includes a new policy statement on sugary drinks and new clinical reports on food insecurity, fruit juice consumption, fish and shellfish consumption, and the use of donor human milk for preterm infants. The AAP is also leading the Bright Futures national health promotion and prevention initiative, which provides theory-based guidelines and evidence-driven guidance for preventative care screenings and well-child visits.[85] Materials have also been developed specifically for families. Additionally, the AAP has developed all-new clinical resources that provide point-of-care decision support tools based on its policy for the nutrition of newborns and infants. These include support tools for formula feeding, breastfeeding support, nutrition (enteral) in special circumstances, food-drug interactions, parenteral nutrition, complementary feeding, daily reference intakes and upper limits, and vitamin and mineral deficiency, among others.

The ACOG established the ACOG Nutrition Expert Work Group in 2021 and initiated work with a Nutrition Training program. Members of the work group recently met with nutritional experts from the USDA to discuss several topics of interest, including the developmental origins of health and disease, predictive adaptive responses, the impact of early and mid-pregnancy undernutrition, and the impact of diet on gestational diabetes, gestational hypertension, pre-eclampsia, and

preterm delivery. One important step forward is the inclusion of recommendations for pregnancy, breastfeeding, and infants and toddlers in the USDA 2020–2025 Dietary Guideline for Americans.[58] Another is the expected inclusion of recommendations for breastfeeding women and young children in the 2025–2030 guidelines.

The AAFP recently added curriculum related to nutrition and health determinants. In doing this, they taught students about easily sharable nutritional resources for patients, such as MyPlate.[86] They also worked to raise awareness among the students of the difficulties associated with eating healthy on a strict budget to help students better relate to the struggles their patients may be facing when providing nutritional counseling. The AAFP noted that the importance of effective communication, including the understanding of cultural practices, should be emphasized, as nutritional counseling can be a particularly difficult and sensitive topic. Additionally, they found that bringing together educators from different disciplines allowed for the leveraging of individual strengths to better educate students about nutrition.

Experts from the American College of Nurse-Midwives have noted that midwifery education is missing several major components related to nutrition education. These include the integration of social determinants of health and nutrition, the developmental origins of health and disease perspective, and the epigenetic effects of poor maternal nutrition on offspring.

Useful efforts to engage professional societies to have greater involvement in nutrition education include advocation for nutrition education for society members, the identification of champions of nutrition education within society leadership and membership, the establishment of working groups to promote nutrition education, and the incorporation of nutritional questions into continuing medical education practices and board re-certifications. Nutrition education should be on the agenda of every society meeting. It is of great importance that professional education programs include nutrition education so that healthcare professionals can more knowledgeably address nutrition with their patients. Additionally, interdisciplinary collaboration among professional societies is key; leaders from different groups are encouraged to overcome barriers to communication and come together to successfully work toward achieving the overall goal of improving nutrition during pregnancy and early childhood.

There are a number of very important research questions in the field of maternal nutrition that need urgent research. Examples include:

- Does ethnic background and genetic history alter the need for specific nutrients during pregnancy?
- To what extent does improved nutrition over the year before pregnancy alter the pregnancy outcome?
- What epigenetic modifications are made in the placenta and offspring by dietary insufficiency? Do these modifications underlie risk for chronic conditions such as metabolic disease, cardiovascular disease and pulmonary disease?
- Are the nutritional needs of pregnant teens different from older pregnant people?

These questions require allocations of funds from the NIH and other funding bodies. These and surrounding issues should be given the highest priority in order to improve the health of the entire US population. One powerful step forward by the NIH is the newly formed Office of Nutrition Research. This organization will help shape the research agenda in the area of nutrition for the next decade.

Setting the future policy agenda to improve maternal nutrition in pregnancy

Creating a National Blueprint for Healthy Mothers and Children conference, attendees identified major gaps, especially in the successful implementation of good nutrition practices during pregnancy and early childhood, and developed Action Goals to address these gaps. The full list of gaps is provided in Text S1 (Supporting Information). Collectively, the conference attendees recommended the following prioritized Action Goals, which have been classified according to goals: cross-cutting, policy and intervention, healthcare professional training, and research. The full set of action goals is provided in Text S1 (Supporting Information).

Recommended cross-cutting action goals:

- Make maternal and infant health a visible priority for government and nonprofit organizations. Educate leaders about how good nutrition during development and across the lifespan can positively impact maternal and infant health outcomes and long-term population health.
- Focus on broad and swift implementation of evidence-based strategies for developing effective programs for improving nutrition and reducing unhealthy stressors in women of reproductive age. Examples include providing resources for the expansion of WIC and the Supplemental Nutritional Assistance Program (SNAP). Food & Friends is an example of medically tailored food delivery.
- Reduce racial disparity in pregnancy and childbirth outcomes.
- Prioritize community-driven and community-centered messaging and solutions.

Recommended policy and intervention action goals:

- Ensure high-quality and culturally competent clinical care.
- Improve the coverage of nutrition, maternal, lactation, and neonatal services under Medicaid and other insurance.
- Increase access to affordable and nutritious food.
- Integrate nutrition interventions with social support services.
- Implement universal paid family leave to facilitate the institution of early good nutritional practices.
- Enhance support and education for breastfeeding and lactation.
- Provide greater financial security as a means to help people make healthy choices.
- Partner with community-based organizations to deliver care and resources.

Recommended healthcare professional training action goals:

- Expand nutrition education across healthcare professional training programs and mandate some degree of competency in Continuing Medical Education–related or board renewal activities.
- Require internships for registered dietitians to be paid.
- Build a medical consensus statement across the largest associations (AHA, American Medical Association (AMA), AAFP, AAP, ACOG) about the fundamental role of nutrition in maternal and child health.

Recommended research action goals:

- Advocate for the NIH to support longer grant cycles (beyond 3–5 years) to support transgenerational research, mechanistic studies in epigenetics, and nutritional interventions in order to more robustly study mother/infant dyads across the lifespan.
- Suggest the addition of a Community Advisory Board for community-based NIH grants. Encourage NIH grants that support community development, community investments, and peer-to-peer support.
- Prioritize cost analysis research of effective programs to demonstrate economic as well as health benefits.
- Diversify the scientific pipeline so that racial and ethnic influences and inequalities can be better understood and more effectively addressed.
- Encourage all 50 US states to provide 12 months of postpartum Medicaid coverage.

CONCLUSION

Given the importance of nutrition in maternal and childhood health in reducing long-term chronic disease risk and evidence of the striking shortfall in reaching nutritional goals, it is critical to identify gaps, devise strategies, and implement policies to bridge these gaps. It is the opinion of the authors that the action goals presented herein represent a path forward toward creating a national blueprint for improving the health of mothers and children through more successful implementation of constructive nutritional strategies. Short- and long-term health depends on improved nutrition both before and during pregnancy and during infancy and childhood that will play a critical role in ensuring a healthier US population both in the short- and long-term.

AUTHOR CONTRIBUTIONS

All authors were involved in the planning of the conference program and in editing the final document. Kent Thornburg gave final approval of the manuscript.

ACKNOWLEDGMENTS

The Vitamix Foundation and Bob's Red Mill provided funding for the 2022 conference "Nutrition in Pregnancy: Creating a Blueprint for Healthy Mothers and Children", which stimulated the idea of this report. The funders had no role in the planning of the conference or writing of the manuscript. Editorial support, specifically assistance with review writing (outline and manuscript first draft) and styling, was provided by BioCentric, Inc. (Sarah S. Bubeck, PhD, Collingswood, NJ) and was funded by Oregon Health & Science University. Lisa Rhuman, Bernadette Battilega, Kim Rogers, and Liana Haywood were important in planning and carrying out the logistics of the conference. Liana Haywood and Lisa Rhuman contributed to the editing of the final document. Christine Wallace Caldwell and Lauren Moreno of Catalysis LLC provided leadership for small group discussions and synthesizing the information generated by small group discussions.

COMPETING INTERESTS

The authors declare no conflicts of interest.

PEER REVIEW

The peer review history for this article is available at: https://publons.com/publon/10.1111/nyas.15122

REFERENCES

1. Marshall, N. E., Abrams, B., Barbour, L. A., Catalano, P., Christian, P., Friedman, J. E., Hay, W. W., Hernandez, T. L., Krebs, N. F., Oken, E., Purnell, J. Q., Roberts, J. M., Soltani, H., Wallace, J., & Thornburg, K. L. (2022). The importance of nutrition in pregnancy and lactation: Lifelong consequences. *American Journal of Obstetrics and Gynecology*, *226*(5), 607–632.
2. Centers for Disease Control and Prevention; U.S. Department of Health and Human Services. (2020). National Diabetes Statistics Report. https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf
3. Boyle, J. P., Thompson, T. J., Gregg, E. W., Barker, L. E., & Williamson, D. F. (2010). Projection of the year 2050 burden of diabetes in the US adult population: Dynamic modeling of incidence, mortality, and prediabetes prevalence. *Population Health Metrics*, *8*, 29.
4. American Heart Association and American Stroke Association. (2017). Cardiovascular disease: A costly burden for America; Projections through 2035. https://www.heart.org/-/media/files/get-involved/advocacy/burden-report-consumer-report.pdf
5. Barker, D. J. P. (2007). The origins of the developmental origins theory. *Journal of Internal Medicine*, *261*(5), 412–417.
6. Driscoll, A. K., & Gregory, E. C. W. (2020). Increases in prepregnancy obesity: United States, 2016–2019. *NCHS Data Brief*, (392), 1–8.
7. Centers for Disease Control and Prevention; Reproductive Health. (2022). Pregnancy mortality surveillance system. https://www.cdc.gov/reproductivehealth/maternal-mortality/pregnancy-mortality-surveillance-system.htm
8. Centers for Disease Control and Prevention; National Center for Health Statistics. (2020). Maternal mortality rates in the United States, 2020. https://www.cdc.gov/nchs/data/hestat/maternal-mortality/2020/maternal-mortality-rates-2020.htm
9. Centers for Disease Control and Prevention; Reproductive Health. (2022). Infant mortality. https://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm
10. Martin, J. A., & Osterman, M. (2022). Exploring the decline in the singleton preterm birth rate in the United States, 2019–2020. *NCHS Data Brief*, (430), 1–8.
11. Driscoll, A. K., & Gregory, E. C. W. (2021). Prepregnancy body mass index and infant outcomes by race and Hispanic origin: United States, 2020. *National Vital Statistics Reports*, *70*(16), 1–8.
12. March of Dimes; Peristats. (2022). Delivery methods. https://www.marchofdimes.org/peristats/data?lev=1&obj=1&reg=99&slev=1&stop=355&top=8

13. Tanaka, M., Jaamaa, G., Kaiser, M., Hills, E., Soim, A., Zhu, M., Shcherbatykh, I. Y., Samelson, R., Bell, E., Zdeb, M., & Mcnutt, L.-A. (2007). Racial disparity in hypertensive disorders of pregnancy in New York State: A 10-year longitudinal population-based study. *American Journal of Public Health*, *97*(1), 163–170.
14. U.S. Government Accountability Office. (2022). Maternal health: Outcomes worsened and disparities persisted during the pandemic. https://www.gao.gov/assets/gao-23-105871.pdf
15. Kaiser Family Foundation. (2020). Number of births by race. https://www.kff.org/other/state-indicator/births-by-raceethnicity/
16. Centers for Disease Control and Prevention; Breastfeeding. (2021). Breastfeeding: Why it matters. https://www.cdc.gov/breastfeeding/about-breastfeeding/why-it-matters.html
17. Cabral, H., Fried, L. E., Levenson, S., Amaro, H., & Zuckerman, B. (1990). Foreign-born and US-born black women: Differences in health behaviors and birth outcomes. *American Journal of Public Health*, *80*(1), 70–72.
18. Elo, I. T., & Culhane, J. F. (2010). Variations in health and health behaviors by nativity among pregnant Black women in Philadelphia. *American Journal of Public Health*, *100*(11), 2185–2192.
19. Read, J. G., & Emerson, M. O. (2005). Racial context, black immigration and the U.S. Black/White health disparity. *Social Forces*, *84*(1), 181–199.
20. Kirwan Institute; The Ohio State University. (2012). Module 1: Understanding implicit bias. https://kirwaninstitute.osu.edu/implicit-bias-module-series/module-1-understanding-implicit-bias
21. Fitzgerald, C., & Hurst, S. (2017). Implicit bias in healthcare professionals: A systematic review. *BMC Medical Ethics [Electronic Resource]*, *18*(1), 19.
22. Green, A. R., Carney, D. R., Pallin, D. J., Ngo, L. H., Raymond, K. L., Iezzoni, L. I., & Banaji, M. R. (2007). Implicit bias among physicians and its prediction of thrombolysis decisions for black and white patients. *Journal of General Internal Medicine*, *22*(9), 1231–1238.
23. Tiffon, C. (2018). The impact of nutrition and environmental epigenetics on human health and disease. *International Journal of Molecular Sciences*, *19*(11), 3425.
24. Acevedo, N., Alashkar Alhamwe, B., Caraballo, L., Ding, M., Ferrante, A., Garn, H., Garssen, J., Hii, C. S., Irvine, J., Llinás-Caballero, K., López, J. F., Miethe, S., Perveen, K., Pogge von Strandmann, E., Sokolowska, M., Potaczek, D. P., & van Esch, B. C. A. M. (2021). Perinatal and early-life nutrition, epigenetics, and allergy. *Nutrients*, *13*(3), 724.
25. Thornburg, K. L., Shannon, J., Thuillier, P., & Turker, M. S. (2010). In utero life and epigenetic predisposition for disease. *Advances in Genetics*, *71*, 57–78.
26. Geronimus, A. T. (1992). The weathering hypothesis and the health of African-American women and infants: Evidence and speculations. *Ethnicity & Disease*, *2*(3), 207–221.
27. Mcewen, B. S. (1993). Stress and the individual. Mechanisms leading to disease. *Archives of Internal Medicine*, *153*(18), 2093–2101.
28. Geronimus, A. T., Hicken, M., Keene, D., & Bound, J. (2006). "Weathering" and age patterns of allostatic load scores among blacks and whites in the United States. *American Journal of Public Health*, *96*(5), 826–833.
29. Dennis, J. A. (2019). Birth weight and maternal age among American Indian/Alaska Native mothers: A test of the weathering hypothesis. *SSM - Population Health*, *7*, 100304.
30. Child Trends. (2018). The prevalence of adverse childhood experiences, nationally, by state, and by race or ethnicity. https://www.childtrends.org/publications/prevalence-adverse-childhood-experiences-nationally-state-race-ethnicity
31. Hughes, K., Bellis, M. A., Hardcastle, K. A., Sethi, D., Butchart, A., Mikton, C., Jones, L., & Dunne, M. P. (2017). The effect of multiple adverse childhood experiences on health: A systematic review and meta-analysis. *Lancet Public Health*, *2*(8), e356–e366.
32. Lang, J., Mckie, J., Smith, H., Mclaughlin, A., Gillberg, C., Shiels, P. G., & Minnis, H. (2020). Adverse childhood experiences, epigenetics and telomere length variation in childhood and beyond: A systematic review of the literature. *European Child & Adolescent Psychiatry*, *29*(10), 1329–1338.
33. Economic Policy Institute. (2018). 50 years after the Kerner Commission: African Americans are better off in many ways but are still disadvantaged by racial inequality. https://www.epi.org/publication/50-years-after-the-kerner-commission/
34. Arias, E. (2007). United States life tables, 2004. *National Vital Statistics Reports*, *56*(9), 1–39.
35. Williams, D. R., Mohammed, S. A., Leavell, J., & Collins, C. (2010). Race, socioeconomic status, and health: Complexities, ongoing challenges, and research opportunities. *Annals of the New York Academy of Sciences*, *1186*, 69–101.
36. GBD US Health Disparities Collaborators. (2022). Life expectancy by county, race, and ethnicity in the USA, 2000–19: A systematic analysis of health disparities. *Lancet*, *400*(10345), 25–38.
37. Kaiser Family Foundation. (2022). Health status, outcomes, and behaviors. https://www.kff.org/report-section/key-facts-on-health-and-health-care-by-race-and-ethnicity-health-status-outcomes-and-behaviors/
38. The Hamilton Project. (2020). About 14 million children in the US are not getting enough to eat. https://www.hamiltonproject.org/publication/post/about-14-million-children-in-the-us-are-not-getting-enough-to-eat/
39. Kaiser Family Foundation. (2020). Food insecurity and health: Addressing food needs for medicaid enrollees as part of COVID-19 response efforts. https://www.kff.org/report-section/food-insecurity-and-health-addressing-food-needs-for-medicaid-enrollees-as-part-of-covid-19-response-efforts-issue-brief/
40. Devine, P. G., Forscher, P. S., Austin, A. J., & Cox, W. T. L. (2012). Long-term reduction in implicit race bias: A prejudice habit-breaking intervention. *Journal of Experimental Social Psychology*, *48*(6), 1267–1278.
41. Gruber, K. J., Cupito, S. H., & Dobson, C. F. (2013). Impact of doulas on healthy birth outcomes. *The Journal of Perinatal Education*, *22*(1), 49–58.
42. Ickovics, J. R., Kershaw, T. S., Westdahl, C., Magriples, U., Massey, Z., Reynolds, H., & Rising, S. S. (2007). Group prenatal care and perinatal outcomes: A randomized controlled trial. *Obstetrics and Gynecology*, *110*(2 Pt. 1), 330–339. (Erratum in: Obstet Gynecol, 2007, 110:937.).
43. Moyer, C., Reoyo, O. R., & May, L. (2016). The influence of prenatal exercise on offspring health: A review. *Clinical Medicine Insights: Women's Health*, *9*, 37–42.
44. Dhillon, A., Sparkes, E., & Duarte, R. V. (2017). Mindfulness-based interventions during pregnancy: A systematic review and meta-analysis. *Mindfulness (N Y)*, *8*(6), 1421–1437.
45. Chia, A.-R., Chen, L.-W., Lai, J. S., Wong, C. H., Neelakantan, N., van Dam, R. M., & Chong, M. F.-F. (2019). Maternal dietary patterns and birth outcomes: A systematic review and meta-analysis. *Advances in Nutrition*, *10*(4), 685–695.
46. Ogra, P. L., Walker, W. A., & Lonnerdal, B. (2020). Milk, mucosal immunity & the microbiome: Impact on the neonate. *Nestlé Nutrition Institute Workshop Series*, *94*, VII–IX.
47. Centers for Disease Control and Prevention; Division of Nutrition, Physical Activity, and Obesity. (2021). Breastfeeding benefits both baby and mom. https://www.cdc.gov/nccdphp/dnpao/features/breastfeeding-benefits/index.html
48. American Academy of Pediatrics. (2021). Benefits of breastfeeding. https://www.aap.org/en/patient-care/breastfeeding/breastfeeding-overview/
49. Yasuhi, I., Yamashita, H., Maeda, K., Nomiyama, M., Mizunoe, T., Tada, K., Yorozu, M., Ogawa, M., Kodama, T., Yamaguchi, K., Okura, N., Kawakami, K., Maekawa, Y., & Hayashi, K. (2019). High-intensity breastfeeding improves insulin sensitivity during early post-partum period in obese women with gestational diabetes. *Diabetes Metabolism Research and Reviews*, *35*(4), e3127.

50. Gunderson, E. P., Hedderson, M. M., Chiang, V., Crites, Y., Walton, D., Azevedo, R. A., Fox, G., Elmasian, C., Young, S., Salvador, N., Lum, M., Quesenberry, C. P., Lo, J. C., Sternfeld, B., Ferrara, A., & Selby, J. V. (2012). Lactation intensity and postpartum maternal glucose tolerance and insulin resistance in women with recent GDM: The SWIFT cohort. *Diabetes Care*, *35*(1), 50–56.
51. Klopp, A., Vehling, L., Becker, A. B., Subbarao, P., Mandhane, P. J., Turvey, S. E., Lefebvre, D. L., Sears, M. R., Azad, M. B., Daley, D., Silverman, F., Hayglass, K., Kobor, M., Turvey, S., Kollmann, T., Brook, J., Ramsey, C., Macri, J., Sandford, A., … Scott, J. (2017). Modes of infant feeding and the risk of childhood asthma: A prospective birth cohort study. *Journal of Pediatrics*, *190*, 192–199.e2.e192.
52. Dogaru, C. M., Nyffenegger, D., Pescatore, A M., Spycher, B. D., & Kuehni, C. E. (2014). Breastfeeding and childhood asthma: Systematic review and meta-analysis. *American Journal of Epidemiology*, *179*(10), 1153–1167.
53. Zhu, J., & Dingess, K. A. (2019). The functional power of the human milk proteome. *Nutrients*, *11*(8), 1834.
54. Gregg, B., Ellsworth, L., Pavela, G., Shah, K., Berger, P. K., Isganaitis, E., Vanomen, S., Demerath, E. W., & Fields, D. A. (2022). Bioactive compounds in mothers milk affecting offspring outcomes: A narrative review. *Pediatric Obesity*, *17*(7), e12892.
55. Ares Segura, S. (2022). The challenges of breastfeeding in a complex world. *Anales de Pediatria*, *96*(4), 283–285.
56. Beauregard, J. L., Hamner, H. C., Chen, J., Avila-Rodriguez, W., Elam-Evans, L. D., & Perrine, C. G. (2019). Racial disparities in breastfeeding initiation and duration among U.S. infants born in 2015. *MMWR Morbidity and Mortality Weekly Report*, *68*(34), 745–748.
57. Chiang, K. V., Li, R., Anstey, E. H., & Perrine, C. G. (2021). Racial and ethnic disparities in breastfeeding initiation horizontal line United States, 2019. *MMWR Morbidity and Mortality Weekly Report*, *70*(21), 769–774.
58. U.S. Department of Agriculture. (2020). Dietary guidelines for Americans 2020–2025. https://www.dietaryguidelines.gov/sites/default/files/2021-03/Dietary_Guidelines_for_Americans-2020-2025.pdf
59. Meek, J. Y., & Noble, L. (2022). Policy statement: Breastfeeding and the use of human milk. *Pediatrics*, *150*(1), e2022057988.
60. Beauregard, J. L., Nelson, J. M., Li, R., Perrine, C. G., & Hamner, H. C. (2022). Maternity care practices and breastfeeding intentions at one month among low-income women. *Pediatrics*, *149*(4), e2021052561.
61. Moding, K. J., Ferrante, M. J., Bellows, L. L., Bakke, A. J., Hayes, J. E., & Johnson, S. L. (2018). Variety and content of commercial infant and toddler vegetable products manufactured and sold in the United States. *American Journal of Clinical Nutrition*, *107*(4), 576–583. Erratum in: Am J Clin Nutr, 2018, 108, 426.
62. Bakke, A. J., Carney, E. M., Higgins, M. J., Moding, K., Johnson, S. L., & Hayes, J. E. (2020). Blending dark green vegetables with fruits in commercially available infant foods makes them taste like fruit. *Appetite*, *150*, 104652.
63. Mennella, J. A., Reiter, A. R., & Daniels, L. M. (2016). Vegetable and Fruit Acceptance during Infancy: Impact of ontogeny, genetics, and early experiences. *Advances in Nutrition*, *7*(1), 211S–219S.
64. Food Research & Action Center (FRAC). Federal Nutrition Programs. https://frac.org/programs
65. U.S. Department of Agriculture, Food and Nutrition Service. (2021). National and State Level Estimates of WIC Eligibility and Program Research in 2021. https://www.fns.usda.gov/research/wic/eligibility-and-program-reach-estimates-2021
66. Princeton Unviversity—Innovations for Successful Societies. (2022). A solid start for every child: The Netherlands integrates medical and social care, 2009–2022. https://bernardvanleer.org/publications-reports/a-solid-start-for-every-child-the-netherlands-integrates-medical-and-social-care-2009%E2%88%922022/
67. Ministry of Health Welfare and Sport. (2020). Solid start: The action programme. https://open.overheid.nl/documenten/ronl-adc5e99a-be83-4483-bd4a-e98d5d5be22e/pdf
68. Hales, C. N., Barker, D. J., Clark, P. M., Cox, L. J., Fall, C., Osmond, C., & Winter, P. D. (1991). Fetal and infant growth and impaired glucose tolerance at age 64. *BMJ*, *303*(6809), 1019–1022.
69. Strömmer, S., Lawrence, W., Rose, T., Vogel, C., Watson, D., Bottell, J. N., Parmenter, J., Harvey, N. C., Cooper, C., Inskip, H., Baird, J., & Barker, M. (2018). Improving recruitment to clinical trials during pregnancy: A mixed methods investigation. *Social Science & Medicine*, *200*, 73–82.
70. Strömmer, S., Weller, S., Morrison, L., Soltani, H., Stephenson, J., Whitworth, M., Rundle, R., Brewin, J., Poston, L., Lawrence, W., & Barker, M. (2021). Young women's and midwives' perspectives on improving nutritional support in pregnancy: The babies, eating, and LifestyLe in adolescence (BELLA) study. *Social Science & Medicine*, *274*, 113781.
71. Laraia, B. (2004). Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Preventive Medicine*, *39*(5), 869–875.
72. Tipton, M. J., Wagner, S. A., Dixon, A., Westbay, L., Darji, H., & Graziano, S. (2020). Association of living in a food desert with pregnancy morbidity. *Obstetrics and Gynecology*, *136*(1), 140–145.
73. Silva, T. P. R. D., Viana, T. G. F., Pessoa, M. C., Felisbino-Mendes, M. S., Inácio, M. L. C., Mendes, L. L., Velasquez-Melendez, G., Martins, E. F., & Matozinhos, F. P. (2022). Environmental and individual factors associated with gestational weight gain. *BMC Public Health [Electronic Resource]*, *22*(1), 540.
74. Fonge, Y. N., Jain, V. D., Harrison, C., Brooks, M., & Sciscione, A. C. (2020). Examining the relationship between food environment and gestational diabetes. *American Journal of Obstetrics & Gynecology MFM*, *2*(4), 100204.
75. Kahr, M. K., Suter, M. A., Ballas, J., Ramin, S. M., Monga, M., Lee, W., Hu, M., Shope, C. D., Chesnokova, A., Krannich, L., Griffin, E. N., Mastrobattista, J., Dildy, G. A., Strehlow, S. L., Ramphul, R., Hamilton, W. J., & Aagaard, K. M. (2016). Geospatial analysis of food environment demonstrates associations with gestational diabetes. *American Journal of Obstetrics and Gynecology*, *214*(1), 110.e1–110.e9.
76. Partnership for a Healthier America. (2022). Food equity; ensuring every family, in every zip code, has affordable access to good food. https://www.ahealthieramerica.org/articles/food-equity-868
77. Olaiya, M. T., Wedekind, L. E., Hanson, R. L., Sinha, M., Kobes, S., Nelson, R. G., Baier, L. J., & Knowler, W. C. (2019). Birthweight and early-onset type 2 diabetes in American Indians: Differential effects in adolescents and young adults and additive effects of genotype, BMI and maternal diabetes. *Diabetologia*, *62*(9), 1628–1637.
78. Rosenstock, S., Ingalls, A., Foy Cuddy, R., Neault, N., Littlepage, S., Cohoe, L., Nelson, L., Shephard-Yazzie, K., Yazzie, S., Alikhani, A., Reid, R., Kenney, A., & Barlow, A. (2021). Effect of a home-visiting intervention to reduce early childhood obesity among native American children: A randomized clinical trial. *JAMA Pediatrics*, *175*(2), 133–142.
79. Bullock, A., Sheff, K., Moore, K., & Manson, S. (2017). Obesity and overweight in American Indian and Alaska Native children, 2006–2015. *American Journal of Public Health*, *107*(9), 1502–1507.
80. Partnership for a Healthier America. Yes, kids can learn to love veggies. https://pha-cms.s3.amazonaws.com/documents/131/9bb3e90c-4e9b-4e4b-ab83-8f6b2bd11536.pdf?1611695061
81. Chen, J. N., Dennis, J. A., St John, J. A., & Shen, C.-L. (2022). Self-reported patient compliance with physician advised lifestyle behavior changes among adults with musculoskeletal conditions. *Frontiers in Public Health*, *10*, 821150.
82. Institute of Medicine. (1988). *Prenatal care: Reaching mothers, reaching infants*. The National Academies Press.
83. Stanford, F. C. (2020). The importance of diversity and inclusion in the healthcare workforce. *Journal of the National Medical Association*, *112*(3), 247–249.
84. Kleinman, R. E., & Greer, F. R. (2020). *Pediatric nutrition: Policy of the American Academy of Pediatrics* (8th ed.). American Academy of Pediatrics.

85. Georgetown University. (2023). Bright futures at Georgetown University. https://www.brightfutures.org
86. U.S. Department of Agriculture. (2020). MyPlate; Learn how to eat health with MyPlate. https://www.myplate.gov/

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Rainford, M., Barbour, L. A., Birch, D., Catalano, P., Daniels, E., Gremont, C., Marshall, N. E., Wharton, K., & Thornburg, K. (2024). Barriers to implementing good nutrition in pregnancy and early childhood: creating equitable national solutions. *Ann NY Acad Sci.*, 1–12. https://doi.org/10.1111/nyas.15122

Supporting information

Nutrition in Pregnancy: Creating a National Blueprint for Healthy Mothers and Children

Rainford M, et al.

Text S1. Gaps and detailed Action Goals identified during the Nutrition in Pregnancy: Creating a National Blueprint for Healthy Mothers and Children conference

Question 1: What are the significant (most urgent) gaps that must be filled to improve maternal nutrition across the nation?

The gaps identified covered the following categories:

1. Presence of food insecurity and inadequate access to healthy foods.
2. Inadequate awareness and coordination of social services (including Medicaid, Special Supplemental Nutrition Program for Women, Infants, and Children [WIC], and Supplemental Nutritional Assistance Program [SNAP]).
3. Lack of public policies that benefit the health of women before pregnancy, during pregnancy, and during lactation.
4. Inadequate funding for nutrition research applied to developmental health.
5. Lack of emphasis and resources devoted to medical nutrition education for all medical professionals.
6. Requirement of community involvement to change the nutritional landscape at the local level; women and communities are currently not engaged in developing solutions.
7. Presence of implicit bias and racial disparities in women's health and birth outcomes. There is also a lack of diversity among nutrition professionals.
8. Nutrition is not embraced as a form of disease prevention on a societal level and among health professionals.
9. Inadequate knowledge of and support for breastfeeding.

10. Lack of comprehensive family leave which is associated with reduced rates of breastfeeding and family nutritional care and increased family stress.

Question 2: What Action Goals will fill these gaps?

CROSS-CUTTING GOALS

1) Make maternal and infant health a visible priority for government and nonprofit organizations. Educate leaders about how good nutrition during development and across the lifespan can positively impact maternal and infant health outcomes and long-term population health.
2) Focus on broad and swift implementation of evidence-based strategies for developing effective programs for improving nutrition and stress environments in women of reproductive age. Examples include providing resources for the expansion of WIC and the Supplemental Nutritional Assistance Program (SNAP). Food & Friends is example of medically tailored food delivery.
    a. Expand the impact of WIC and SNAP programs.
    b. Increase the amount and duration of WIC and SNAP benefits.
    c. Standardize better options in the WIC food package, extend the Cash-Value Benefit benefit and make it permanent.
    d. Dramatically increase eligibility for WIC and SNAP (consider universal eligibility).
    e. Provide stable and consistent funding for WIC.
    f. De-stigmatize receiving social services such as WIC and SNAP.
    g. Streamline qualification and application processes for various benefit programs.
3) Reduce racial disparity in pregnancy and childbirth outcomes.
    a. Identify and expand programs that improve health disparities.
    b. Address structural racism (eg, breastfeeding, implicit bias in healthcare, health promotion, food deserts).
4) Prioritize community-driven and community-centered messaging and solutions.
    a. Engage with communities to identify needs and develop solutions.
    b. Value expertise from people with lived experience.
    c. Use community-based participatory research methods.
    d. Personalize messaging to meet the needs of specific communities.

e. Develop and use simple, community-centered nutrition messages and education strategies.
f. Take an affirming, strength-based approach that connects to cultural foods.
g. Create simple tools and resources (eg, endorsement system for nutrition messaging, simplified nutrition labels, education toolkits).
h. Use social media campaigns to reach communities where they are.
i. Leverage the power of personal stories (not facts) to communicate key messages.
j. Provide nutrition and cooking education “early and often”.

POLICY AND INTERVENTION GOALS

1) Ensure high-quality and culturally competent clinical care.
    a. Provide culturally sensitive interventions.
    b. Require cultural competence, implicit bias, and anti-racism training for providers.
    c. Implement patient surveys to evaluate provider’s cultural competence.
    d. Increase presence of registered dieticians/registered dietitian nutritionists in clinics.
    e. Promote a team approach for patients (eg, leverage a patient navigator role).
2) Improve the coverage of nutrition, maternal, lactation, and neonatal services under Medicaid and other insurance.
    a. Add additional billable Current Procedural Terminology® codes for specific nutrition services.
    b. Extend Affordable Care Act credits for 12-month post-partum medical care.
    c. Present to the National Association for Medicaid Providers on the importance of nutrition, the developmental origins of health and disease, and racial health disparities.
    d. Promote coverage of successful interventions with positive patient outcomes and economic benefits.
3) Increase access to affordable and nutritious food.
    a. Set a minimum number of grocery stores required per population density and provide grants to support start up for new stores in food deserts.
    b. Increase community demand for fruits and vegetables.
    c. Coordinate grocery delivery to underserved communities.
    d. Work with National Grocers Association to eliminate food deserts.
    e. Support improvements to school lunch programs.

    f. Ensure prenatal vitamins with adequate iodine supplementation are available.
4) Integrate nutrition interventions with social support services.
    a. Integrate nutrition education and/or food delivery with home-health care visits and/or doula-based care.
    b. Include support at preconception, during pregnancy, and postpartum.
    c. Provide grants for pilot projects on integrated services.
5) Implement universal paid family leave to facilitate the institution of early good nutritional practices.
6) Enhance support and education for breastfeeding and lactation.
    a. Grow the lactation consultant workforce by incentivizing training and/or training community health workers.
    b. Destigmatize public breastfeeding.
    c. Support parents who return to work with easy access to lactation suites, breast pumps, and other support.
7) Provide greater financial security as a means to help people make healthy choices.
    a. Increase support for childcare.
8) Partner with community-based organizations to deliver care and resources.

HEALTHCARE PROFESSIONAL TRAINING GOALS

1) Expand nutrition education across healthcare professional training programs and mandate some degree of competency in Continuing Medical Education-related or board renewal activities.
    a. Set meaningful requirements for nutritional knowledge in professional colleges.
    b. Inspire health care professionals to elevate the role of nutrition to their patients.
2) Require internships for registered dietitians to be paid.
3) Build a medical consensus statement across the largest associations (AHA, American Medical Association [AMA], AAFP, AAP, ACOG) about the powerful role of nutrition in maternal and child health.

RESEARCH GOALS

1) Advocate for National Institutes of Health (NIH) to support longer grant cycles (beyond 3–5 years) to support transgenerational research, mechanistic studies in epigenetics, and

nutritional interventions in order to more robustly study mother/infant dyads across the lifespan.

2) Suggest the addition of a Community Advisory Board for community-based NIH grants. Encourage NIH grants that support community development, community investments, and peer-to-peer support.
3) Prioritize cost analysis research of effective programs to demonstrate economic as well as health benefits.
4) Diversify the scientific pipeline so that racial and ethnic influences and inequalities can be better understood and more effectively addressed.
5) Encourage all 50 states to provide 12 months of postpartum Medicaid coverage.