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Report of a Meeting

Food Insecurity, Neighborhood Food Environment, and Health Disparities: State of the Science, Research Gaps and Opportunities

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A B S T R A C T

Food insecurity and the lack of access to affordable, nutritious food are associated with poor dietary quality and an increased risk of diet-related diseases, including cardiovascular disease, diabetes, and certain types of cancer. Those of lower socioeconomic status and racial and ethnic minority groups experience higher rates of food insecurity, are more likely to live in under-resourced food environments, and continue to bear the greatest burden of diet-related chronic diseases in the United States. Despite the growing body of literature in this area, there are still significant gaps in our understanding of the various pathways that link food insecurity and neighborhood food environments to racial/ethnic and socioeconomic disparities in health and the most effective intervention strategies to address these disparities. To better understand the science in this area, the National Institutes of Health, in collaboration with the Centers for Disease Control (CDC) and Prevention and the United States Department of Agriculture (USDA), convened a virtual 3-d workshop 21–23 September 2021: Food Insecurity, Neighborhood Food Environment, and Nutrition Health Disparities: State of the Science. The workshop brought together a diverse group of researchers, practitioners, policymakers, and federal partners with expertise in nutrition, the food environment, health and social policy, and behavioral and social sciences. The workshop had the following 3 research objectives: *1*) summarize the state of the science and knowledge gaps related to food insecurity, neighborhood food environments, and nutrition health disparities, *2*) identify research opportunities and strategies to address research gaps, and *3*) examine evidence-based interventions and implementation approaches to address food insecurity and neighborhood food environments to promote health equity. This article summarizes workshop proceedings and describes research gaps and future opportunities that emerged from discussions.

Keywords: food insecurity, food deserts, food environment, neighborhoods, nutrition security, health disparities, health equity

Introduction

Food insecurity and the lack of access to affordable, nutritious food are associated with poor dietary quality and an increased risk of diet-related diseases, including cardiovascular disease, diabetes, and certain types of cancer [1–4]. Those of lower socioeconomic status (SES) and racial and ethnic minority groups experience higher rates of food insecurity, are more likely to live in under-resourced food environments, and continue to bear the greatest burden of diet-related chronic diseases in the United States [5–7]. In the United States, ~13.5 million people have limited access to supermarkets or large grocery stores, so they have poor access to fresh and healthy foods [8]. One recent longitudinal analysis found that higher diet quality was associated with proximity to and density of food stores, neighborhood SES, and with perceptions of healthy food environments and that the associations were stronger in minority racial and ethnic populations [9]. Some studies have found that people who live in neighborhoods that lack access to grocery stores and have many fast-food restaurant (FFR) experience a higher risk of hypertension, cardiovascular and diabetes, and lower cancer survival [10–12].

Despite the growing body of literature in these areas over the last several decades, there are still significant gaps in our understanding of the various underlying mechanisms, and pathways that link food insecurity and neighborhood food environments to racial/ethnic and

Abbreviations: CDC, Centers for Disease Control and Prevention; FFR, fast-food restaurant; GIS, geographic information system; GPS, Global Positioning System; GusNIP, Gus Schumacher Nutrition Incentive Program; HFFI, Healthy Food Financing Initiative; NEMS, Nutrition Environment Measures Survey; NOSI, Notice of Special Interest; NSLP, the National School Lunch; SES, socioeconomic status; SNAP, Supplemental Nutrition Assistance Program; UBI, universal basic income; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

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socioeconomic disparities in health and the most effective intervention strategies to address these disparities. Diet is strongly influenced by the social determinants of health—specifically "the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life" [13]. Social determinants of health, such as food insecurity and access to healthy and affordable foods, are shaped by factors, such as structural racism and inequitable policies, and distribution of resources, known as structural determinants of health, are root causes of the inequities that perpetuate disparities by race and SES [14,15]. Social determinants of health and structural factors interact with cultural norms, traditions, beliefs, and values to shape what people eat [16]. Elucidating the role of these social and environmental conditions on diet and nutritional status could help improve population health and promote health equity.

To better understand the body of science in this area, the NIH, in collaboration with the Centers for Disease Control and Prevention (CDC) and the USDA, convened a virtual 3-d workshop on September 2021, titled "Food Insecurity, Neighborhood Food Environment, and Nutrition Health Disparities: State of the Science." The workshop was a key activity by the NIH Office of Nutrition Research's Nutrition and Health Disparities Implementation Working Group following the release of the 2020–2030 Strategic Plan for NIH Nutrition Research. It brought together a diverse group of researchers, policymakers, and practitioners with expertise in nutrition, the food environment and food security, public health and social policy, and behavioral and social sciences to examine the current literature and share their perspectives and recommendations regarding emerging research priorities, gaps, and opportunities in this area. The workshop objectives were as follows:

- Summarize the state of the science and knowledge gaps related to food insecurity, neighborhood food environments, and nutrition health disparities.
- Identify research opportunities and strategies to address those research gaps.
- Examine evidence-based interventions and implementation approaches to address food insecurity and neighborhood food environments to promote health equity.

This article reports on the workshop proceedings and highlights critical discussions, gaps, and opportunities for future research on food insecurity, neighborhood food environments, and health disparities. See Appendix A for workshop sessions and presenters.

Overview of Workshop Sessions

The workshop was organized into 3 themed sessions, 1 for each day. Day 1 began with an overview of the state of the science on food insecurity and its impact on health, followed by presentations focused on innovative interventions to address food insecurity. Day 2 of the workshop focused on neighborhood food environments and their impact on diet and health, with the next section describing interventions to improve neighborhood food environments and the findings of research on changing food environments. Day 3 of the workshop was cross-cutting and addressed the issues affecting both food insecurity and neighborhood food environments, including the potential of using implementation science and community-engaged research approaches to understand and address these issues. Major federal funding initiatives to improve nutrition and health and prominent local and regional organizations described their efforts to work both with and in communities to improve nutrition and health. Each day concluded with highlights of existing research gaps and opportunities. This workshop was convened to focus specifically on food security and neighborhood food environments in the United States. Although global food security and food systems were beyond the scope of the workshop, we acknowledge that research to understand the social and structural drivers of the high prevalence of food insecurity and current threats to global food systems is critically important to advance the science in this area [17]. In addition, given that the United States imports 15% of its food supply from global food systems, understanding the levels of food insecurity in low- and middle-income countries has implications for domestic food security and food access [18].

State of the Science in Food Insecurity: At-Risk Populations, Measurement, and Health Impacts

Presenters highlighted the following 4 overarching topic areas related to food insecurity and nutrition disparities: *1*) subgroups disproportionately at risk of food insecurity/food security disparities, *2*) food insecurity measurement, *3*) multilevel determinants of food insecurity, and *4*) the complex relationship between food insecurity, diet, and health. These topics underscored research gaps and opportunities that limit our current understanding of the causes, contributors, and health and social consequences of food insecurity. Lastly, the workshop explored policy and programmatic approaches and interventions being implemented in community-based and healthcare settings to address food insecurity, improve health outcomes, and reduce disparities. The workshop primarily focused on food insecurity in adults and/or at the household level. Less coverage was given to intervention studies in pediatric populations and/or specifically food insecurity in children aged <18 y. However, several recent reviews have emphasized the need for more research targeting interventions in pediatric populations [19–22].

Food Insecurity Overview

According to the USDA, food security ("access by all people at all times to enough food for an active, healthy life") is one of the several conditions necessary for a population to be healthy and well nourished. In contrast, food insecurity "means that households were, at times, unable to acquire adequate food for one or more household members because they had insufficient money and other resources for food" [23]. Food insecurity is a significant public health concern in the United States, affecting 10.2% (13.5 million) of all households in 2021 [13]. Rates of food insecurity were higher than the national average for households with children (12.5%), households with children headed by a single female (24.3%) or a single male (16.2%), households with incomes <185% of the poverty threshold (26.5%), and households headed by Black (19.8%) and Hispanic (16.2%) individuals. Many of these disparities, including by race/ethnicity and SES, have persisted for decades [6,7,24]. Although initial reports predicted a significant increase in food insecurity after the start of the COVID-19 pandemic in March 2020, overall rates of food insecurity remained unchanged from 2019 to 2021. However, food insecurity rates for those most at risk, including Black and Hispanic households, increased. In addition, the prevalence of food insecurity in 2022, 12.8% (17.0 million), was statistically significantly higher than the 10.2% (13.5 million) in 2021.

Although food security primarily centers on the access to adequate quantities of food, given the linkages between food insecurity and diet-related disease, the concept of nutrition security emerged to better include considerations of dietary quality and nutritional adequacy. Specifically, as indicated by USDA, nutrition security is defined by the

USDA as "all Americans [having] consistent and equitable access to healthy, safe, affordable foods essential to optimal health and well-being" [25,26]. This includes not only getting enough food but also the equitable availability and affordability of healthy foods to aid in disease prevention and management.

Food Insecurity Measurement

USDA's food security statistics are based on results from the United States Household Food Security Survey Module (18-item), which is included as an annual supplement to the monthly Current Population Survey conducted by the Bureau of the Census for the Bureau of Labor Statistics. A version of the food security measure is also administered as part of the NHANES and National Survey of Children's Health. In addition to being used in national surveys, the United States Household Food Security Survey Module is designed to be adaptable to various research and local contexts and captures the frequency of the kinds of household conditions, events, behaviors, and subjective reactions to uncertain and inconsistent access to food [27,28].

Contributors to Inequities in Food Insecurity

Consistent evidence indicates that individuals and households that are socially vulnerable, specifically those experiencing poverty, material hardship, unemployment, and racial discrimination, are at greater risk of food insecurity [29–33]. Although workshop speakers acknowledged the important role of individual and household drivers, a key theme was the importance of moving beyond the individual- and household-level factors to include understanding multilevel determinants such as neighborhood conditions and city/state, national, and federal policies. For example, people experiencing food insecurity frequently reside in neighborhoods with a higher prevalence of low food access, poverty, racial segregation, substandard housing, smoking, and inadequate access to healthcare. Consequently, solutions should take person-centered and community-centered intervention approaches that are impactful in changing individual behaviors, the environment, and policies that reduce health disparities.

Food Insecurity and Health Outcomes

Multiple pathways (e.g., psychological, behavioral, and immune) link food insecurity and health outcomes, including obesity and cardiometabolic diseases [1]. For example, workshop presenters highlighted studies showing that food insecurity has the potential to alter metabolic processes through a stress pathway with food scarcity triggering stress, which then activates the hypothalamic pituitary adrenal axis, stimulating glucocorticoid release and contributing to an increase in both visceral fat storage and accumulation. Food insecurity is also associated with immune activation and inflammation, with poor diet quality impacting the composition and response of the microbiome, which impairs immune functioning, all contributing to worse cardiometabolic health [34,35]. A systematic review and meta-analysis published by Pourmotabbed et al. [36] evaluated >300,000 individuals across 10 countries and 19 studies. Results of this review indicated that food insecurity was associated with increased odds of depression by 40% and stress by 34% universally, and by 29% for anxiety in North American settings [36].

Interventions to Address Food Insecurity

The NIH workshop also explored the current evidence on clinical, policy, and community-based interventions and implementation approaches to address food insecurity and promote health equity. The workshop focused both on interventions, programs, and policies designed to reduce the prevalence and/or prevent vulnerable households from becoming food insecure, such as population-based strategies [e.g., the Supplemental Nutrition Assistance Program (SNAP)] and those that center on mitigating the adverse health or nutritional consequences of food insecurity.

Administered by the USDA Food and Nutrition Service, the 16 federal nutrition assistance programs, including the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), SNAP, and the National School Lunch Program (NSLP) and the School Breakfast Program, provide the most robust response for preventing and alleviating the burden of food insecurity in the United States Although strong evidence has demonstrated the impact of these programs on population rates of food insecurity, challenges with program implementation have included the inadequacy of current benefit levels, the stigma associated with program participation, and the limited access/eligibility among some economically and socially vulnerable groups [37–40]. During the COVID-19 pandemic, several policy approaches were leveraged to ease program administration and provide greater flexibilities to address the needs of individuals and families experiencing food insecurity and improve access, including Pandemic Electronic Benefit Transfer (EBT), which offered temporary emergency nutrition benefits to school children eligible for free school meals via an EBT card, temporary increases in SNAP allocations, a lower minimum identified student percentage participation threshold for the Community Eligibility Provision in the NSLP, and remote certification appointments in the WIC program [41–44].

Workshop participants also explored how broader economic mobility policy could be leveraged to address food insecurity. For example, the WAGE$ Study, a natural experiment, followed a community-based sample of workers recruited in Minneapolis, Minnesota, and Raleigh, North Carolina, to examine relationships between minimum wage, food insecurity, and weight outcomes. Preliminary data from 2018 to 2020 from the study indicates that as the average hourly wage of participants rose in both cities, the prevalence of food insecurity declined. SNAP participation decreased in 2019 and increased in 2020 in both cities as minimum wages increased. Other studies have reported similar findings regarding increases in minimum wage, as well as Earned Income Tax Credit on decreases in food insecurity by successfully lifting families above the poverty threshold, increase in household income, and labor force participation [45–47]. However, the presenters indicated that additional research needs to be conducted to understand the relationships between minimum wage policies, food assistance participation, and food insecurity.

Over the last decade, innovative interventions to alleviate the nutritional consequences of food insecurity at the local, state, and national levels have emerged across multiple settings (e.g., health care, community-based organizations, and government) [48–52]. Some examples of interventions include nutrition incentive programs to increase healthy food purchases, produce prescriptions, medically tailored meals, grocery, food packages, and grocery delivery services, screen and referral programs, on-site pantries, and creating stronger linkages between health care, food assistance programs, and the charitable food system. One of the largest national nutrition investments is the Gus Schumacher Nutrition Incentive Program

(GusNIP), a USDA-funded program with the goal to support health and reduce food insecurity by promoting the purchase and consumption of fruits and vegetables among low-income consumers. In 2019–2020, USDA NIFA funded 52 GusNIP projects with awards covering all 4 United States regions. In the healthcare setting, focusing on chronic diseases such as cardiometabolic disease and cancer, 1 presentation shared preliminary results from a randomized controlled trial examining the impact of 3 different interventions on food insecurity and treatment outcomes in patients with cancer [53]. The research team found that a voucher plus pantry access was the most effective intervention for improving treatment completion compared with grocery delivery plus pantry access and pantry access only.

Research Themes, Gaps, and Opportunities

Workshop presenters provided perspectives on research opportunities and gaps related to the link between food insecurity and nutrition disparities, as well as what strategies are needed to address those gaps (see Table 1). Some of these research opportunities are highlighted below.

Research Design and Measurement

- Examine determinants and drivers of food insecurity in subgroups that are understudied. Although studies report that the general prevalence of food insecurity in the general population is high, 5 groups remain overlooked: American Indians, Black persons in the Upper Midwest, young adults not in college, 50- to 59-y olds, and people with disabilities. More research needs to be conducted to understand the determinants and drivers of food insecurity in these and other understudied populations.
- Pathways and mechanisms that link race/ethnicity and SES to food insecurity risk. Although the higher prevalence of food insecurity experienced by racial/ethnic minorities and low-income populations is well documented, these disparities could be driven by various risk factors such as disability and structural oppression, explaining the source of the unequal burden. More work is needed to understand the pathways and mechanisms that contribute to elevated risk.
- Food insecurity and its intergenerational impacts. Because food insecurity and its effects can be intergenerational, speakers expressed a need to develop or identify measures and to design studies to understand the intergenerational effects of food insecurity and longitudinal studies on the long-term impacts of food insecurity across the life course.
- Prioritize research that promotes action and informs policy change. There is a need to understand the interaction of broader economic policies and income supports, such as the minimum wage policy on food insecurity. For example, minimum wage, a key social determinant of health, can influence nutrition and nutrition outcomes through multiple channels and is a potential policy lever for addressing health equity.
- Develop measures to assess nutrition security. Given the increased focus on improving nutrition security in the nation, novel measures are needed to assess nutrition security. During the workshop, several presenters stressed the importance of measuring nutrition security once these measures have been developed.

Intervention Studies

- Consider the impact of neighborhood context on food insecurity. Session speakers noted that poor neighborhood conditions coexist in neighborhoods with higher proportions of racial/ethnic minority groups and those experiencing food insecurity. Strategies and solutions that emerged include evaluating the efficacy of structural and upstream approaches, such as universal basic income (UBI) interventions and childcare subsidies in social, economic, and political environments that contribute to food insecurity outcomes [54]. Intervention approaches should explore strategies that apply decolonizing methodologies, use indigenous and critical theories, examine intersectionality, and build on the experiences of underserved populations within the context of their environment and address the stigma attached to food insecurity [55–58].
- Integrate the food sovereignty model in interventions. In contrast to traditional approaches, speakers advocated for using a food sovereignty model, which encompasses food systems in which the community stakeholders and residents produce, distribute, and consume food, as well as control the mechanisms and policies for food production and distribution [59–61]. It was proposed that food sovereignty model-guided interventions are likely to facilitate long-term systems change, particularly in American Indian and other historically marginalized communities.
- Consider innovative approaches to expand access to food assistance programs. Speakers indicated that programs and policies need to consider a more comprehensive way to support people throughout their lives to access necessary nutritional services, such as SNAP, WIC, and other government programs. This includes creating innovative partnerships and community linkages to increase enrollment and participation in federal nutrition programs.
- Address food insecurity as a poverty issue. Although SNAP has been shown to be effective in reducing food insecurity, food insecurity prevalence is greatly impacted by unemployment and industry closures. One recommended potential is the restructuring of SNAP as a UBI program through which each household receives maximum nutrition assistance without having to demonstrate need on the basis of the income relative to the federal poverty line [62]. If implemented, some experts suggest that UBI could potentially lead to a 98% decrease in food insecurity in the United States [62]. Nontraditional intervention studies that focus on wealth building (e.g., Building Wealth and Health Network) have also shown promise in reducing food insecurity [63]. A key focus could be to develop targeted interventions to disrupt the poverty cycle at every stage of life and apply an equity lens.
- Increase support for nutrition education and incentive programs. Recent studies suggest that providing funding for nutrition incentives and nutrition education supports healthy eating. For example, expanding efforts such as the GusNIP can help broaden the reach to other communities.
- Evaluate the effectiveness of food security interventions targeting multiple health conditions. For example, interventions that target cardiometabolic risk have the potential to reduce food insecurity and can simultaneously help address health challenges. Research shows that food insecurity impairs these pathways, interacts in a vicious cycle, is linked to obesity, and disproportionately affects minority populations [34,35]. Many interventions in health care settings are small-scale and may not be representative of those that are disproportionately impacted by food insecurity disparities. More research is needed to understand who enrolls/participates in these programs, the effective dose, and the mechanism by which they work.

State of the Science in Neighborhood Food Environments: Measurement Issues, Health Impacts, and Research Gaps

Two overarching topic areas related to the current research on neighborhood food environments were discussed—including the retail, restaurant, and food service environment. Speakers *1*) explored the association between food environments and poor dietary behaviors, chronic disease, and health disparities; and *2*) highlighted available measures of the community and consumer neighborhood food environments, including geographic information system (GIS) technologies and technology-aided measurements. Speakers also discussed gaps in knowledge and research opportunities.

Neighborhood Food Environments Overview

An overview of the "food environment hypothesis" first described the overall conceptualization of neighborhood food environments and how they can influence food intake, risk factors, and disease profiles.

TABLE 1
Food insecurity and neighborhood food environments research gaps and opportunities

	Research gaps and opportunities
Food insecurity	Measurement and research design • Examine determinants and drivers of food insecurity. More research needs to be conducted to understand the determinants and drivers of food insecurity in these and other understudied populations, including American Indians, Black persons in the Upper Midwest, young adults not in college, 50- to 59-y-olds, and people with disabilities. • Examine the pathways and mechanisms linking race/ethnicity and socioeconomic status to food insecurity risk. Although the higher prevalence of food insecurity experienced by racial/ethnic minorities and low-income populations is well documented, these disparities could be driven by various risk factors such as disability and structural oppression, explaining the source of the unequal burden. • Understand the intergenerational implications of food insecurity and longitudinal studies on the long-term impacts of food insecurity across the life course. • Prioritize research that understands and promotes action and policy change. There is a need to understand the interaction of broader economic policies and income supports such as increases in minimum wage and expansion of Earned Income Tax Credit on food insecurity rates. • Develop measures to assess nutrition security. Nutrition security includes not only getting enough food but also the equitable availability and affordability of healthy foods to aid in disease prevention and management. Given the increased focus on improving nutrition security in the nation, novel measures are needed to assess nutrition security. Intervention studies • Consider the impact of the broader neighborhood context such as lack of affordable housing on food insecurity and build on the lived experiences of underserved populations within the context of their environment. • Address the stigma attached to food insecurity and participation in food assistance programs. Consider innovative approaches to expand access to Food and Nutrition Assistance Programs. • Integrate models of food sovereignty and social justice in interventions, particularly in American Indian and other historically marginalized communities. • Address food insecurity as a poverty issue and support nontraditional intervention studies (e.g., Building Wealth and Health Network) • Increase support for nutrition education programs. Recent studies suggest that providing supplemental funding for food and nutrition education increases the odds of making healthy food choices. • Explore interventions targeting key cardiometabolic health that have the potential to improve food insecurity and simultaneously address multiple health challenges.
Neighborhood food environments	Measurement and research design • Develop research to better characterize the current food retail environment and consumer behavior through additional measures and using new technologies. Direct observation studies using Global Positioning System (GPS) and GIS data can predict food environment interactions and inform intervention development. Eye tracking data can also help to identify mechanisms of behavioral choice within food store environments. • Investigate online food shopping environments and consumer shopping patterns to better understand their role in influencing diet and diet quality. Online food environments are often characterized by personalized messaging and frequent change using digital algorithms, which introduces challenges for measurement and interpretation. Because many shoppers who use online shopping combine that method with in-store shopping, research to understand "hybrid" food environments will be critical. • Integrate rigorous food choice and diet outcome measures in research study designs. Additional neighborhood characteristics may influence the effects of interventions, and these relationships and pathways are part of understanding the link between neighborhood food environments and health. Furthermore, using store sales data at both the aggregate (store) and individual (shopper) levels to estimate food choices may be useful. Intervention studies • Develop multilevel, multicomponent interventions to improve the healthy food environments and choices. A better understanding of the supply chain for small stores can inform effective strategies in these challenging retail food environments. Multilevel interventions that address unhealthy food marketing, individual- and family-level nutrition knowledge, point-of-purchase consumer guidance, and economic incentives to reduce costs of healthy foods are needed to effectively impact dietary behaviors. • Investigate the impact of interventions and policies to achieve healthier retail food environments and whether/how they impact dietary intake. For example, an important research focus would be to examine the national impact of the Healthy Food Financing Initiative (HFFI) and the GusNIP Incentive Program on food purchases and dietary intake health indicators and to explore the association of the effects across diverse communities. From a broad perspective, understanding the health, economic, and quality of life effects of opening new supermarkets in underserved communities or "food deserts" would significantly contribute to understanding retail food environments. • Community-engaged research methods in health disparities populations including rural, socioeconomically disadvantaged, and racial/ethnic minority communities. This includes expanding the use of equity-oriented strategies, measures, and outcomes in intervention research and exploring solutions to the root causes of inequities in healthy food access, including historical disinvestment in communities, structural racism, and racial/ethnic neighborhood segregation. • Develop interventions targeting the food environment that explicitly consider health equity and integrate other social determinants of health.

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TABLE 1 (*continued*)

	Research gaps and opportunities
Cross-cutting themes	• Use study designs that are methodically strongest for addressing biases and unmeasured confounders including novel trial designs. Earlier studies have yielded different or limited results on whether diet changes after a neighborhood intervention such as a new full-service grocery store. Data and technology • Collect new data to better understand the intergenerational impacts of food insecurity. Furthermore, studies are needed to collect data investigating the effects of food insecurity in relation to other life events and leverage existing efforts. • Consider the use of GPS and GIS data in research focused on the assessment of the neighborhood food environment. Innovated data sources can provide real-time changes in food environments and better capture consumer purchasing patterns in the neighborhood context. • Disaggregate data, although protecting individual and community privacy, to better identify populations most impacted by food insecurity, hunger, and nutrition insecurity. Subpopulations within communities may experience unique risks, and disaggregated data can assist with developing more tailored approaches to prevent and alleviate the burden of food and nutrition security among these demographics. • Implement culturally and community-responsive technologies and methodologies for promoting nutrition and health. For example, data scientists have designed participatory technologies, mobile mapping, and SMS platform to link equitable food systems and community-powered health interventions. Partnerships • Promote efforts to increase community data capacity beyond federal grants, and increase training in data science, including using participatory technology and community-driven data to transform the food environment and increase access to healthier foods using an equitable, community-centered approach. Existing datasets are often limited, given disparities in research participation and this approach brings equity and accuracy to community-level data. • Foster new partnerships, which are key to achieving health equity. Partnerships with various sectors, such as food retailers, foundations, community-based organizations, and advocacy groups, are critical to addressing food insecurity and increasing healthy food access. • Leverage existing local, regional, and federal efforts, such as Project Bread, CDC's Racial and Ethnic Approaches to Community Health (REACH) program, federal assistance programs (e.g., SNAP, GusNIP Incentive Program, Centers for Medicaid, and Medicare Services), to reduce food insecurity and address neighborhood food environments. Community-engaged research and perspectives of those with lived experience • Promote community-engaged research methods in health disparities populations to broaden knowledge about solutions to address food access and food insecurity in these high-risk populations. For example, rural areas provide an optimal context for examining how geography, income, and race contribute to food security and neighborhood food environments. Community-engaged approaches, including qualitative and mixed-methods research, are also critical for the empowerment of historically disadvantaged groups to take agency over the developing • Increase support for underrepresented researchers with lived experience, which can contribute to innovative questions and effective solutions. Prioritizing support for researchers from and funding for minority and underrepresented groups could bring an expanded lens to food insecurity and neighborhood food environment research, which can contribute to innovative questions and effective solutions. Researchers with lived experience and those immersed in community-engaged research have the potential to identify intervention strategies that lead to innovative solutions to reduce health disparities.

An important distinction exists between the "community nutrition environment" (location and types of stores) and the "consumer food environment" (what consumers encounter in stores, including available food choices, nutritional quality, and prices) [64]. Although large supermarkets remain the largest source of food purchases, non-supermarket sources have an increasing role in communities historically underserved by traditional retail, and online grocery ordering increased during the COVID-19 pandemic beginning in early 2020 [65].

Contributors to Inequities in Neighborhood Food Environments

There is significant literature about differences between neighborhood food environments by income and race/ethnicity, with socioeconomically disadvantaged and minority neighborhoods having less access to healthful, affordable food choices and an excess of FFR that offer inexpensive, low-nutrient prepared foods in comparison to higher income neighborhoods. There has also been an increasing body of research examining the associations between neighborhood store and restaurant environments and diet and chronic disease, with some large systematic reviews finding that many associations were null and studies were generally of low quality [66]. For example, a longitudinal study based on the Coronary Artery Risk Development in Young Adults study found that fast-food consumption was related to fast-food availability, but only among low-income male respondents [67]. Meanwhile, greater supermarket availability was found to be unrelated to diet quality and fruit and vegetable intake; the relationship between grocery store availability and diet outcomes was also inconclusive [67].

Neighborhood Food Environments and Health Outcomes

The workshop explored associations between retail food store environments and their diet and chronic disease. Despite the assumption that building new large food stores in underserved neighborhoods would contribute to healthier diets and lower obesity rates, research assessing the impact of retail interventions has yielded inconsistent results [68,69]. Furthermore, there is limited evidence showing a consistent association between local food environments and obesity;

however, reviews suggest that these findings should be interpreted with caution because of the low quality of available studies [66]. Workshop presenters highlighted that considering urban–rural distinction, neighborhood ownership of food stores, price/cost, and cultural relevance may be important factors in study design and when interpreting results. A review of restaurant and food service environments underscored that ~20% of calories are currently consumed from restaurant food, which tends to be high in calories and low in nutrient density. The example of the Silver Diner study, where a full-service regional chain restaurant offered more prominent healthy kids' menu options by default, illustrated how menu changes and labeling interventions can increase sales of healthier items for children [70] and adults [71].

Neighborhood Food Environment Measurement

Measurement of the community food environment, consumer food environment, and technology-aided measurement was also a theme that emerged in the workshop. The USDA's Food Environment Atlas, Food Access Research Atlas, and associated GIS mapping software provide quality tools for researchers and for public health nutrition practitioners [72]. A wide range of tools are available to assess the consumer food environment, with the most commonly used measures being the Nutrition Environment Measures Survey (NEMS) and the USDA Thrifty Food Plan [73,74]. Specifically, the NEMS was developed to assess both the consumer food environment in stores (NEMS-S) and restaurants (NEMS-5), and since its creation in 2007, other adaptations have been developed for different food environment settings (e.g., NEMS corner stores and NEMS vending environments) [74]. However, reviews of neighborhood food environment assessments strongly recommend using reliability testing, at minimum, in a new study or location [75].

Interventions to Improve Neighborhood Food Environments

For this part of the workshop, presentations covered interventions that might improve the retail food environment and health outcomes. Exemplars included placing new grocery stores in existing food deserts, banning new FFRs in areas with a high density of FFRs, providing healthy-choice pantries, and improving access to healthier food choices in small retail food sources (e.g., corner stores, bodegas, convenience stores). Several speakers reported on store-scale interventions in neighborhood food environments: building new supermarkets in "food deserts," healthy corner store interventions, and interventions within community food pantries. Federal and state initiatives and funding have been used to place new supermarkets in low-access, often socioeconomically disadvantaged neighborhoods. One such initiative is the Healthy Food Financing Initiative (HFFI), part of the federal Farm Bill, which intends to increase the availability and affordability of healthy food in low-resourced United States neighborhoods. Since its inception in 2011, it is estimated that the federal government has invested >$500 million in opening full-service supermarkets in food deserts. Natural experiments examining these and other similar efforts have found little evidence that shopping at the new supermarkets led to significant changes in diets, but residents viewed their nearby healthy food options as being improved. The Pittsburgh Hill/Homewood Research on Eating, Shopping, and Health study, for example, used a quasi-experimental longitudinal design to examine the effect of opening a supermarket in an intervention neighborhood compared with a comparison neighborhood that was sociodemographically and geographically matched with the intervention neighborhood [69]. The study found positive effects of the supermarket intervention on dietary quality, average daily intakes of kilocalories and added sugars, and percentage of kilocalories from solid fats, added sugars, and alcohol; however, there were no changes in average BMI, consumption of fruit and vegetables, or consumption of whole grains [69]. Another evaluation of the HFFI in the Englewood community in Chicago, IL, found that a new supermarket did not improve the healthfulness of foods sold in nearby stores and minimal changes in the availability of healthy food and beverage and marketing 1–2 y after the new store opened [76]. However, there was evidence that the wide range of staple food items offered by the supermarket expanded healthy food retail in the neighborhood [76]. Overall, the complexity of trying to build new food stores is an important observation from these studies and demonstrates the key consideration of other factors that influence dietary behaviors beyond supermarket access.

Interventions in small stores, including corner stores, have found some success at increasing healthy food availability but limited impact on food intake and health [77]. Innovative approaches, such as tackling the healthy food "sourcing" challenge from store managers' perspectives and staple food ordinances, show some promise in this space. Food pantries are another venue with the potential to improve the food choices of low-income users, and several studies have tested educational and placement strategies with some success [78]. An ongoing study called the Mitzvah Market Study uses behavioral economics principles through a redesign of the online ordering system, a simplified traffic light labeling system, the use of "healthy swaps," and 2 languages on the ordering system to test the impact on the quality of food selected and consumed (NCT04011384).

Another presentation reported on the evaluation of a fast-food restaurant ban, in which local zoning regulation restricted the opening and remodeling of standalone FFRs in South Los Angeles beginning in 2008 [79,80]. Findings from data from the California Health Interview Survey from 2007 to 2011 showed that fast-food consumption and overweight/obesity rates actually increased during this time period [80]. Declines in soft drink consumption were observed since 2007, but these decreases were similar in magnitude in all areas, not just South Los Angeles [80]. Overall, these findings suggest that this policy strategy may be based on unrealistic expectations and highlights the complexities of dietary behavior choices and that complementary or alternative strategies are needed to promote dietary behavior change [79,80]. Another presentation reported on the evaluation of an FFR ban, in which local zoning regulation restricted the opening and remodeling of standalone FFRs in South Los Angeles beginning in 2008 [79,80]. Findings from data from the California Health Interview Survey from 2007 to 2011 showed that fast-food consumption and overweight/obesity rates actually increased during this time period [80]. Declines in soft drink consumption were observed since 2007, but these decreases were similar in magnitude in all areas, not just South Los Angeles [80]. Overall, these findings suggest that this policy strategy may be based on unrealistic expectations and highlights the complexities of dietary behavior choices and that complementary or alternative strategies are needed to promote dietary behavior change [79,80].

Research Gaps and Opportunities

Speakers provided perspectives on research opportunities to close knowledge gaps related to neighborhood food environment measurement and intervention strategies. Some of these potential research opportunities considered most likely to be impactful are summarized below (also included in Table 1).

Neighborhood Food Environment Measurement

Develop research to better characterize the current food retail environment and consumer behavior through additional measures and new technologies. For example, crowdsourced data can complement direct observation data, add variables of interest, fill content gaps, and classify food stores by category and price of products for sale. Direct observation studies using Global Positioning System (GPS) and GIS data can predict food environment interactions and inform intervention development. Eye tracking data can also help to identify mechanisms of behavioral choice within food store environments.

Investigate online food shopping environments and consumer shopping patterns to better understand their role in influencing diet and diet quality, given the growing use of the online food retail space. Online food environments are often characterized by personalized messaging and frequent change using digital algorithms, which introduces challenges for measurement and interpretation. Because many shoppers who use online shopping combine that method with in-store shopping, research to understand "hybrid" food environments will be critical.

Integrate rigorous food choice and diet outcome measures in research study designs. Additional neighborhood characteristics may influence the effects of interventions, and these relationships and pathways are part of understanding the link between neighborhood food environments and health. Furthermore, using store sales data at both the aggregate (store) and individual (shopper) levels to estimate food choices may be useful.

Neighborhood Food Environment Interventions

Develop multilevel, multicomponent interventions to improve healthy food environments and choices, including for small retail food stores. A better understanding of the supply chain for small stores can inform effective strategies in these challenging retail food environments. Multilevel interventions that address unhealthy food marketing, individual- and family-level nutrition knowledge, point-of-purchase consumer guidance, and economic incentives to reduce costs of healthy foods are needed to effectively impact dietary behaviors.

Investigate the impact of interventions and policies to achieve healthier retail food environments and whether/how they impact dietary intake. For example, an important research focus would be to examine the national impact of the HFFI and the GusNIP Incentive Program on food purchases and dietary intake health indicators and to explore the association of the effects across diverse communities [81, 82]. From a broad perspective, understanding the health, economic, and quality of life effects of opening new supermarkets in underserved communities or "food deserts" would significantly contribute to understanding retail food environments.

Develop interventions targeting the food environment that explicitly consider health equity and integrate other social determinants of health. This includes expanding the use of equity-oriented strategies, measures, and outcomes in intervention research and exploring solutions to the root causes of inequities in healthy food access, including historical disinvestment in communities, structural racism, and racial/ethnic neighborhood segregation.

Use study designs that are methodologically strongest for addressing biases and unmeasured confounders, including novel trial designs, including cluster-randomized control trials, quasi-experimental studies, and time series-based natural experiments. Earlier studies have yielded different or limited results on whether diet changes after a neighborhood intervention such as a new full-service grocery store.

Cross-Cutting Themes

Several cross-cutting themes that impact food insecurity and neighborhood food environments were highlighted during the workshop.

Cross-cutting themes discussed included using data and technology to better understand the impact of food insecurity on the neighborhood food environment and the role of community partnerships to provide the opportunity to leverage and study innovative community-based models. Community partnerships are critical, particularly when working with communities that experience health disparities and historical inequities. Related, community-engaged research and integrating perspectives of those with lived experience are also critical for identifying community-derived approaches.

Data and Technology

Speakers provided their perspectives on research opportunities to utilize data and technology to advance the science of food insecurity and neighborhood food environments. Potential research opportunities are summarized below (see Table 1).

Collect new data to better understand the intergenerational impacts of food insecurity and its effect on individuals in the same household. Furthermore, studies are needed to collect data investigating the effects of food insecurity in relation to other life events and leverage existing efforts.

Consider the use of GPS and GIS data in research focused on the assessment of the neighborhood food environment. Innovated data sources can provide real-time changes in food environments and better capture consumer purchasing patterns in the neighborhood context.

Disaggregate data, although protecting individual and community privacy to better identify populations most impacted by food insecurity, hunger, and nutrition insecurity. Subpopulations within communities may experience unique risks, and disaggregated data can assist with developing more tailored approaches to prevent and alleviate the burden of food and nutrition security among these demographics.

Implement culturally and community-responsive technologies and methodologies for promoting nutrition and health. An example is the pilot study of a mobile application (Baltimore Urban Food Distribution) that connects corner stores with local producers and wholesalers to improve access to healthier foods. Data scientists have also designed a participatory technology, mobile mapping, and SMS platform (Streetwyze) to link equitable food systems and community-powered health interventions.

Partnerships

Speakers discussed the importance of leveraging community strengths and assets for innovative community-based models for research. Some of the research opportunities discussed are highlighted below (Table 1).

Promote efforts to increase community data capacity beyond federal grants and improve training in data science. The joint research effort between the University of California San Francisco and San Francisco State University, Social Innovation and Universal Opportunity Lab, is one model of such an effort. This model uses participatory technology and community-driven data to transform the food environment and increase access to healthier foods using an equitable, community-centered approach. Existing datasets are often limited, given

disparities in research participation and this approach brings equity and accuracy to community-level data.

Foster new partnerships, which are vital for achieving health equity related to food security and neighborhood food environments in the United States. Partnerships with various sectors, such as food retailers, foundations, community-based organizations, and advocacy groups, are critical to addressing food insecurity and increasing healthy food access.

Leverage existing local, regional, and federal efforts, such as Project Bread, CDC's Racial and Ethnic Approaches to Community Health program, and federal assistance programs (e.g., SNAP, GusNIP Incentive Program, Centers for Medicaid, and Medicare Services), to reduce food insecurity and address neighborhood food environments.

Community-Engaged Research and Perspectives of those with Lived Experience

Community-engaged research methods in health disparities populations, including rural, socioeconomically disadvantaged, and racial/ethnic minority communities, would broaden knowledge about solutions to address food access and food insecurity in these high-risk populations. For example, rural areas provide an optimal context to examine the intersections between geography, income, and race contribute to food security and neighborhood food environments, as well as intervene in and evaluate ways to integrate healthcare services and implement multilevel interventions. Community-engaged approaches, including qualitative and mixed-methods research, are also critical for empowering historically disadvantaged groups to have agency over identifying impactful solutions in their communities.

Increased support for underrepresented researchers with lived experience. Prioritizing support for researchers from and funding for minority and underrepresented groups could bring an expanded lens to food insecurity and neighborhood food environment research, which can contribute to innovative questions and effective solutions. Researchers with lived experience and those immersed in community-engaged research have the potential to identify intervention strategies that lead to innovative solutions to reduce health disparities.

Summary and Conclusions

Given the high prevalence of diet-related conditions in the United States, research understanding the structural and social factors that impact dietary behaviors can help inform programmatic and policy interventions to reduce disparities and improve population health. The consensus established at the NIH workshop was that food insecurity and unhealthy neighborhood food environments contribute to diet-related chronic diseases that worsen health disparities. Addressing these challenges would help tackle nutrition security, a growing priority for the USDA and other federal agencies [83]. Several factors, including social determinants of health such as employment, housing, and education, severely limit access to affordable, nutritious food among various racial/ethnic minority and rural populations. Workshop participants identified significant knowledge gaps, including the lack of food insecurity prevalence rates for United States population subgroups (e.g., American Indians, older individuals, and persons with disabilities). The paucity of research aimed at developing, testing, and evaluating novel interventions to address the root causes of food insecurity, poor neighborhood food environments, and health outcomes was also highlighted. Although not highlighted in the workshop, evidence is emerging regarding the need to apply a broader lens to identify populations at higher risk for food insecurity, drivers/determinants of food insecurity, and effective approaches to prevent and alleviate the burden of food insecurity. For example, several studies indicate that sexual and gender minorities, including individuals who identify as lesbian, gay, bisexual, transgender, Two-Spirit, and queer, are at greater risk for food insecurity as compared with the general population [84–87]. However, research regarding the prevalence, drivers, and consequences of food insecurity in this population is limited. In addition, as previously indicated, although the workshop primarily focused on food insecurity in adults and/or at the household level, more intervention research is needed to improve food security outcomes in pediatric populations and/or specifically food insecurity in children under 18 are needed.

Workshop participants also emphasized the need for additional methodological research, such as the development and validation of tools to accurately measure and standardize data collection related to nutrition insecurity and the food environment. Such tools are essential for conducting population surveillance of diet quality and establishing correlations with diet-related health disparities. In addition, there is nascent research examining the various mechanisms or pathways that may underlie the associations between food insecurity and chronic disease risk. Intervention strategies included implementing and evaluating multilevel approaches, including produce prescriptions, medically tailored meals and groceries, and medically tailored food pantries.

There was also a call for systems epidemiology approaches to assess interconnections and feedback loops between risk factors and computation simulations. System and data science can help to characterize the complex interconnected systems that create and sustain diet-related health disparities [88]. In addition, workshop participants emphasized the importance of assessing how nutrition programs and policies at multiple levels (e.g., local, state, and federal) improve food insecurity and neighborhood food environments throughout the life course. Recommendations included the role of restrictions and incentives, and economic policies to reduce food insecurity.

The research gaps and cross-cutting themes identified during the workshop highlight a critical need for multidisciplinary partnerships and collaboration across federal agencies, academia, healthcare systems, policymakers, and local communities. These partnerships are essential for creating a comprehensive research agenda to reduce hunger, improve diet quality and healthy food access, and eliminate health disparities. One federal partnership is the 2022 NIH Notice of Special Interest (NOSI)—"Stimulating Research to Understand and Address Hunger, Food and Nutrition Insecurity," an NIH-wide collaboration across 16 NIH Institutes and Centers. The NOSI encourages *1*) research on the efficacy of interventions that address nutrition security and the mechanisms of food insecurity on various health outcomes and *2*) the development of new measures for nutrition security and assessing food insecurity [89]. However, overall workshop discussions emphasized the need for greater conceptual clarity regarding the distinction between interventions designed to mitigate the adverse health or nutritional consequences of food insecurity for individuals compared with those that reduce its prevalence and/or prevent vulnerable households from becoming food insecure.

The 2022 White House Conference on Hunger, Nutrition, and Health and related follow-up activities are tackling such partnerships across numerous groups including the federal government, community and private partners, nonprofit organizations, and antihunger and nutrition advocates to enhance nutrition and food security research, and programs to end hunger, improve nutrition and physical activity, reduce diet-related disease, and close the disparities around them [90,91].

Relevant to Pillar 2 of the White House Conference focusing on integrating nutrition and health, the NIH issued a Request for Information to identify research opportunities and best practices for Food is Medicine research programs [92]. The overall goal is to launch the Food is Medicine Networks of Excellence initiative to promote research, provide diet-related chronic disease care, expand nutrition training and education, and implement community engagement and outreach strategies to reduce the burden of diet-related diseases and nutrition disparities [93]. Spurred by the historic White House Conference and heightened awareness of these societal issues, now more than ever is a time to stimulate research to eliminate diet-related health disparities and achieve health equity for all.

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Conflict of interest

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Appendix A. Supplementary data

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