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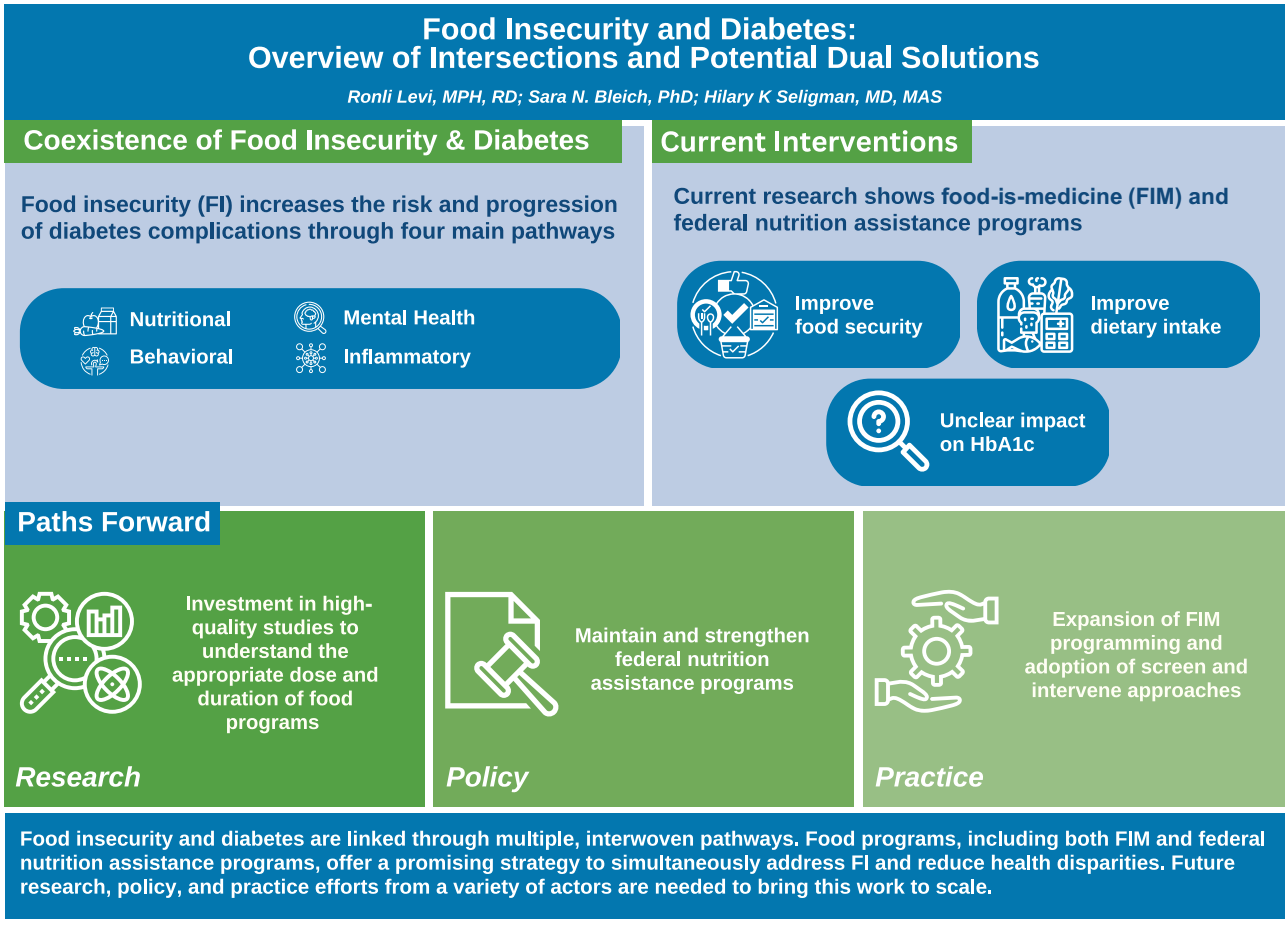

ARTICLE HIGHLIGHTS

- Our goal was to review the complex relationship that exists between food insecurity and diabetes.
- We sought to understand what strategies exist to simultaneously address food insecurity and diabetes.
- Several promising food security interventions have demonstrated positive impacts on diabetes outcomes.
- More rigorous research is needed to understand how to design and implement these programs for populations with diabetes. Policy and practice efforts are needed to scale and strengthen these programs.

Food Insecurity and Diabetes: Overview of Intersections and Potential Dual Solutions

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Food insecurity increases the risk of developing diabetes and its complications. In this article, we describe the complex relationship that exists between food insecurity and diabetes and describe potential mechanisms that may underlie this association. We then describe how two different types of interventions, food-is-medicine and federal nutrition assistance programs, may help address both food insecurity and health. Finally, we outline the research, policy, and practice opportunities that exist to address food insecurity and reduce diabetes-related health disparities.

Type 2 diabetes (T2D) is a leading cause of and contributor to death in the U.S., and it disproportionately impacts historically underserved populations (1). Overall, 11.3% of the U.S. population has been diagnosed with diabetes. Diagnoses are higher among Black (12.1%), Latinx (11.8%), and American Indian/Alaska Native (14.5%) populations than among White (7.4%) and Asian (9.5%) populations (1). Lower socioeconomic status is associated with increased diabetes mortality, diagnosis, and complications. For example, as household income and education level decline, the likelihood of being diagnosed with diabetes increases, and Black and Latinx adults experience disproportionately high rates of microvascular and macrovascular complications compared with non-Hispanic White adults (2).

T2D is caused by a complex web of individual, clinical, social/behavioral, and environmental factors. Each of these factors can influence dietary intake and nutrition, which play a critical role in the prevention and management of diabetes through their effects on weight, insulin resistance, blood pressure, and lipid levels (3). Poor diet is estimated to account for 18.2% of cardiovascular- and T2D-related costs (4). In general, dietary intake recommended for the prevention and control of diabetes includes high consumption of fruits and vegetables (particularly nonstarchy vegetables), shifts in carbohydrate intake toward more complex carbohydrates, and reduced consumption of added sugars, refined grains, processed foods, and *trans* fats (5). Solutions focused on modifiable risk factors, such as diet, are an important approach to slowing or reversing rising rates of T2D and its complications in the U.S. and globally.

Food insecurity, defined as a lack of consistent access to enough food for an active, healthy life, is a potent risk factor for the development and progression of diabetes (6). Data indicate that 13.5 million households in the U.S. experience food insecurity, with disproportionately higher rates among Black, Latinx, and American Indian/Alaska Native households (7,8). Food insecurity contributes to disparities in diabetes outcomes by impacting diabetes prevention and management (Table 1). Individuals who experience food insecurity are at greater risk of developing T2D and hyperglycemia (6). Food insecurity is also more common among those who are already diagnosed with T2D: approximately

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See accompanying articles, pp. 1587, 1590, and 1609.

Table 1—Influence of food insecurity on diabetes prevention, management, and outcomes (13,16,23)

Diabetes risk	Food insecurity is associated with a greater risk of T2D. It is also more common among those who are already diagnosed with diabetes.
Diet quality	Food insecurity is associated with lower overall diet quality and intake of fruits and vegetables. Individuals experiencing food insecurity are also more likely to choose low-cost, nutritionally poor foods.
Weight	Evidence for the association between food insecurity and weight is mixed and differs by age and sex.
Competing demands	Food insecurity is associated with increased spending trade-offs (choosing between paying for food and other necessities, including medical care, utilities, and transportation), purchasing cheaper food in order to afford diabetes supplies, skipping or delaying medical care, reducing the amount of food consumed to save it for household children, and utilization of charitable (e.g., food pantries) and federal (e.g., SNAP) nutrition assistance.
Diabetes self-management	Food insecurity is associated with reduced diabetes self-efficacy and lower medication adherence and blood glucose monitoring.
Mental health	Food insecurity is associated with increased stress, depression, diabetes distress, and anxiety.
Absenteeism	Food insecurity is associated with greater risk of overall and health-related missed workdays, which lowers household income and exacerbates food insecurity.
Glycemic control	Food insecurity is associated with more labile blood sugars, i.e., higher incidence of both hyperglycemia (as measured by HbA_{1c}) and hypoglycemia (as measured by diagnostic codes and self-report).
Health care utilization	Food insecurity is associated with greater health care expenditures and T2D-related health care utilization, including outpatient visits, emergency department visits, and hospitalizations. No clear relationship exists between food insecurity and utilization of diabetes-specific care (e.g., HbA_{1c} tests, eye and foot exams, and urine tests).

16% of adults with diabetes report food insecurity, compared with 9% of adults without diabetes (9). Prevalence rates are even higher among adults with more advanced forms of diabetes (e.g., those on insulin, 19%; those who had eye or kidney complications, 22%) (9). During pregnancy, food insecurity is associated with increased gestational weight gain and gestational diabetes, a risk factor for developing T2D (10,11).

The term "nutrition security" builds on long-standing efforts to advance food security by recognizing the critical role of diet quality in preventing and managing chronic disease. It also prioritizes equity and recognizes that structural inequities make it hard for people to eat healthy and be physically active. Nutrition security is defined by the U.S. Department of Agriculture (USDA) as the "consistent and equitable access to healthy, safe, and affordable food that is essential to health and well-being" (12). Because the term is relatively new and there is currently no standardized way to measure or monitor nutrition security (and thus very limited nutrition security research), in this article we primarily focus on the concept of food insecurity.

We begin with a review of the relationship between food insecurity and diabetes and a description of the underlying mechanisms that may drive this association. We then examine interventions that target food insecurity and diabetes prevention and management simultaneously. We conclude with a discussion of gaps and opportunities for research, policy, and practice.

COEXISTENCE OF FOOD INSECURITY AND DIABETES

A substantial body of research documents the bidirectional relationship between food insecurity and poor health (13). Broadly speaking, food insecurity can lead to poor health when patients are unable to afford enough nutritious food, resulting in the development or poor management of diet-related illness. Poor health can also lead to food insecurity through increased health care expenditures and increased trade-offs between food, medications, and other necessities. Further, worsening disease may lead to increased workplace absenteeism, resulting in decreased income and greater difficulty affording food. Food insecurity is also associated with a number of cardiometabolic risk factors and conditions, including overweight/obesity (although results differ by sex), hypertension, coronary heart disease, congestive heart failure, stroke, diabetes, and chronic kidney disease (6). Food insecurity is also associated with prediabetes, a strong predictor for later diabetes diagnosis, and this association differs by race/ethnicity and sex (14). A cross-sectional study using National Health Interview Survey (NHIS) data found an association between food insecurity and diabetes among non-Hispanic White women and non-Hispanic Black women, but no association was found between men and Hispanic women (15). Among those with T2D, food insecurity is associated with worse glycemic control, lower diabetes self-efficacy, poorer diabetes self-management behaviors, more depressive symptoms, greater diabetes distress (the emotional distress that results from the burden of living with and/or managing the disease), and lower adherence to medication and blood glucose monitoring (16).

Food insecurity is a powerful toxic stressor that can elicit behavioral, physiological, and psychological responses. Resulting hormonal and pathophysiological changes may increase an individual's risk of developing diabetes and its complications (17). There are several mechanisms by which food insecurity and diabetes have been hypothesized to co-occur (Fig. 1). According to a conceptual framework previously developed by Weiser et al. (18), food insecurity can lead to or worsen diabetes-related outcomes through three main paths: *1*) nutritional, *2*) behavioral, and *3*) mental health.

The link between food insecurity and poor diet quality defines the nutritional path. Faced with a limited household food budget, food insecurity may pressure

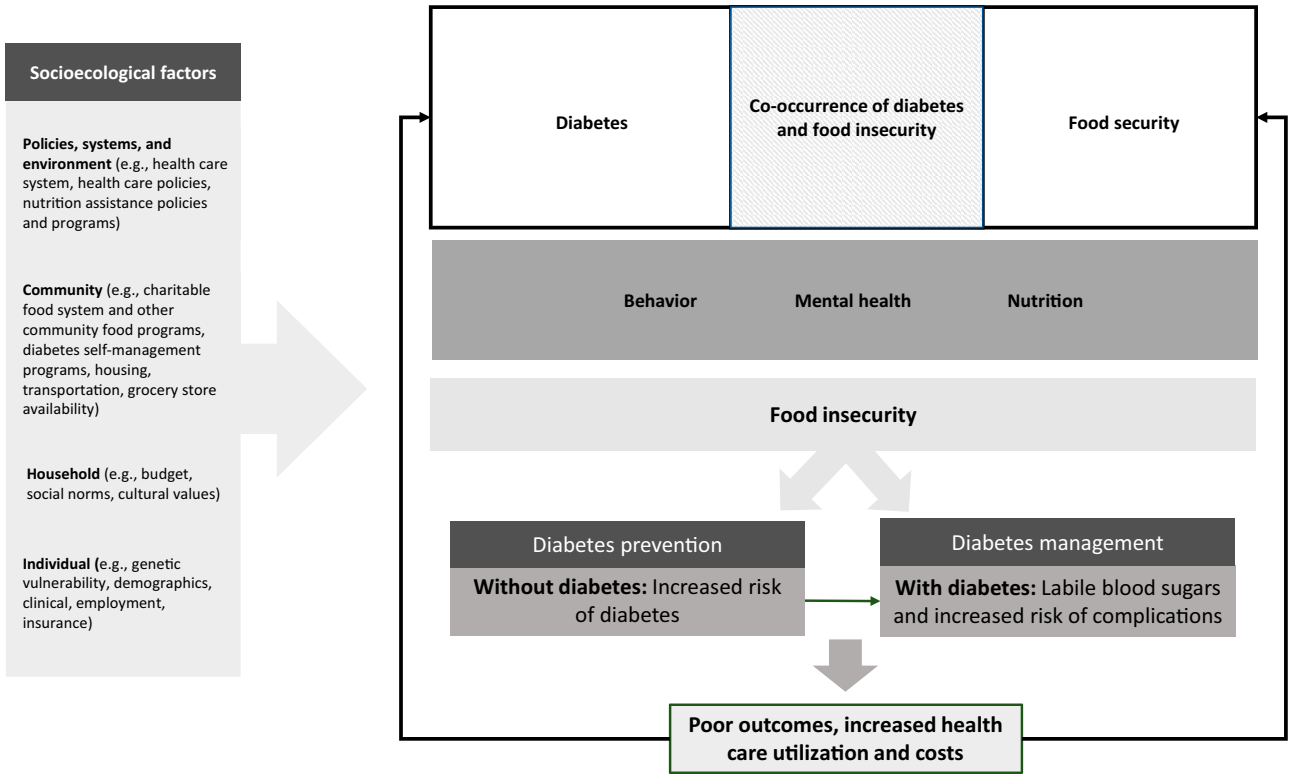

Figure 1—Co-occurrence of diabetes and food insecurity.

individuals to more frequently choose energy-dense, nutritionally poor, and more highly processed food items that tend to be lower in cost than more healthy alternatives. In fact, low income, high food prices, lack of time to shop and prepare food, lack of transportation, and limited access to grocery stores that stock healthy food are often cited as barriers to consuming a healthy diet (13). Thus, individuals living in food-insecure households consume fewer fruits and vegetables, have lower intake of important nutrients, and have worse overall diet quality than those living in food-secure households (6). This dietary pattern can lead to increased insulin resistance and higher blood glucose levels among individuals with diabetes. Conversely, low food availability at the end of the month can also result in hypoglycemia. Risk of an inpatient admission for hypoglycemia increases 27% during the last week of the month compared with the first week of the month in the lowest-income zip codes in California, a pattern not seen in higher-income zip codes (19). This pattern suggests the exhaustion of household food budgets at month's end can drive some health disparities (19). Similarly, using a national sample of commercial claims data, Basu et al. (20) observed that low-income individuals with diabetes had a greater chance of having an emergency room or inpatient hospital visit for hypoglycemia during the last week of the month compared with the earlier weeks. Households experiencing food insecurity are also more likely to report multiple episodes of hypoglycemia and are more likely to attribute those episodes to the inability to afford food (21). Individuals anticipating a lack of food in the future or with recent experiences of food inadequacy may also compensate by binging when food is available (13). For those with diabetes, this pattern may increase the risk for poor glycemic control and diabetes-related complications.

Competing demands force individuals experiencing food insecurity to make difficult decisions about whether to prioritize paying for food or other necessities (referred to in Fig. 1 as the behavioral pathway). For example, when faced with economic constraints, individuals may have to choose whether to pay for food, their diabetes medications, and/or medical care (22). Some may have to skip, delay, or reduce their medications (known as cost-related medication underuse) and/or health care visits to afford food or other basic needs, which may lead to worsening disease control. Among a sample of NHIS respondents, individuals who reported both cost-related medication underuse and food insecurity were more likely to be Hispanic or non-Hispanic Black, have no usual place of care, have no insurance, and have more chronic conditions (22). Competing demands and food insecurity may also reduce an individual's cognitive bandwidth to effectively manage their diabetes, as attention is focused on more pressing concerns.

Through the mental health pathway, food insecurity is linked to poor psychosocial outcomes, including a higher risk of depression, anxiety, and stress, as well diabetes-specific distress (23). Food insecurity may also contribute to self-doubt, worry, shame, and guilt (18). Although the causal nature of these relationships is still unclear, a dose-response relationship exists in which more severe forms of food insecurity are associated with an increased likelihood of suboptimal mental health (23). Some of these mental health outcomes, depression in particular, are risk factors for the development of diabetes (24).

Inflammation may be another important mechanism by which food insecurity leads to adverse health outcomes, potentially operating through the nutritional, behavioral, and mental health pathways (25). Food

insecurity is associated with elevated inflammatory markers associated with chronic disease risk (26,27). In a study of 121 individuals with T2D, food insecurity was associated with higher insulin resistance, partially explained by inflammation and stress hormones (28). Further, food-insecure individuals with T2D experienced more chronic, low-grade inflammation than their food-secure counterparts (28).

Food insecurity and T2D are both more common in historically underserved populations, which means these groups also are more likely to be affected by their synergistic effects.

WHAT INTERVENTIONS MIGHT TARGET BOTH FOOD INSECURITY AND DIABETES?

Policies and programs that support food security, healthy dietary intake, and optimal health are important for reducing the overall burden of diabetes and inequities in diabetes incidence and outcomes. We begin this section with a brief review of the impact of policies and programs that support food security and health (Table 2), followed by a more in-depth discussion of two interventions that hold promise for also addressing diabetes disparities: produce prescription programs and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Here, we divide these interventions into two broad categories: federal nutrition assistance and a suite of interventions commonly referred to now as "food is medicine."

Food Is Medicine

While there is no single agreed-upon definition for food is medicine, it is frequently defined as the integration of specific food and nutrition interventions in, or in close collaboration with, the health care system (29). These include a spectrum of

Table 2—Food programs and diabetes outcomes

Food-is-medicine programs	
Food pantry, food pharmacy and other healthy grocery distribution programs	Food pantry studies and food pharmacy studies that provide participants with appropriate food boxes or healthy groceries have demonstrated improvements in fruit and vegetable consumption, food security, food stability, depression, self-efficacy, trade-offs between food and health care, and self-reported health status (33–35). However, evidence for improvements in HbA_{1c} has been mixed (34,35).
Medically tailored meals	Medically tailored meals (MTM) are associated with improvements in diet quality, including increased consumption of produce and whole grains and decreased consumption of solid fat, alcohol, and added sugars among adults with diabetes (66). Further, studies have also observed reductions in food insecurity, BMI, hypoglycemia, depression, diabetes distress, self-reported stress, and trade-offs, along with improvements in quality of life and ability to manage diabetes (30). Studies have been less conclusive on their impact on HbA_{1c} as well as hospitalizations and emergency department visits among people with diabetes. However, among individuals with multiple health conditions, participation in MTM programs has been associated with lower health care utilization and lower health care costs (30).
Produce prescriptions programs	While most studies include a focus on individuals with diabetes or those at risk for chronic disease, few collect data on HbA_{1c}. Produce prescription program participation is associated with improved fruit and vegetable intake and food security (37,39). Among those with diabetes, there is some evidence to show improvements in glycemic control and BMI, but results are inconsistent (38,39).
Federal nutrition assistance programs	
SNAP	Among people experiencing food insecurity, SNAP participation is associated with improved glucose control and (among older adults) a moderate decrease in cost-related medication nonadherence (67,68). An increase in SNAP benefits is associated with reduced likelihood of hypoglycemia (69). State policies aimed at increasing SNAP participation were associated with slower growth in diabetes prevalence rates across a 10-year period in one study (70). In general, SNAP participation is associated with improved medication adherence, reduced health care costs, better self-reported health status, fewer trade-offs, reduced psychological distress, and (among older adults) decreased likelihood of nursing home or hospital admission (42). Receipt of SNAP during childhood is also associated with reductions in metabolic syndrome later in life (42).
WIC	WIC is associated with more appropriate gestational weight gain, longer gestational age, improved distribution of birth weight, and decreased preterm delivery and infant mortality (48). The new WIC food package is associated with increased consumption of healthy food items. Increases to the cash value benefit (CVB) allotment have also been associated with greater consumption of fruits and vegetables (49).
Other	
Diabetes self management education	In general, diabetes self management education (DSME) is associated with multiple positive clinical, psychosocial, and behavioral effects, and it has been demonstrated to be a cost-effective intervention (5). Although few studies have examined DSME interventions among food-insecure individuals, research has shown improvements in food security and fruit and vegetable intake but mixed results for HbA_{1c} (35,38).

programs designed to support chronic disease prevention, management, and treatment by providing access to nutritious foods, including medically tailored meals (MTMs), healthy groceries or food boxes, and produce prescription programs (30). As health systems and insurers increasingly recognize the link between acute social needs and chronic disease, more efforts are being made to integrate food-is-medicine programs into patient care. A growing body of research documents the efficacy of these interventions, particularly for individuals with diabetes (30) (Table 2). Pooled estimates from a recent systematic review and meta-analysis of healthy food interventions revealed a 22% (0.8 serving) increase in fruit and vegetable consumption and overall decreases in BMI (0.6 kg/m^2) and HbA_{1c} (0.8%) (31). Another systematic review and meta-analysis of 16 studies that examined the impact of food-is-medicine interventions on diabetes health outcomes found similar results, demonstrating improvements in fruit and vegetable intake and HbA_{1c} (32). However, both reviews included studies that were highly heterogenous and varied considerably in their methodologic quality.

Of all the food-is-medicine approaches, evidence is most robust for MTMs (e.g., medically appropriate meals often home delivered to individuals living with complex, severe, or chronic disease). MTM interventions for individuals with diabetes improve diet quality, decrease food insecurity and hypoglycemia, improve diabetes self-management, and support better psychosocial outcomes (29). Participation in MTM programs has also been associated with lower health care utilization and lower costs (29). However, MTMs are typically costly to implement (compared with other food-is-medicine interventions) and are likely most cost-effective for the most medically and socially complex patients, particularly those without capacity to shop for or prepare their own meals.

An increasing number of health systems are partnering with the charitable food sector, particularly food banks and pantries, to develop programs that connect patients to food resources if they are identified as food insecure while receiving care. Studies show that the provision of produce and/or diabetes-appropriate packages to adults with diabetes results in improved food security, dietary intake, diabetes self-efficacy, medication adherence, diabetes distress, and depression (33–35). However, effects on HbA_{1c} have been mixed (33–36). Although there are limited studies with a control group, one randomized controlled trial of a pantry intervention by Seligman et al. (35) found no effect on HbA_{1c}, except among those participants who were fully engaged in the intervention (a nonrandom sample). Closer integration with the health system may increase the efficacy of these programs.

Produce prescription programs have emerged as a popular, promising, and potentially cost-effective model for simultaneously reducing food insecurity, improving diet, and supporting improved diabetes outcomes. These programs typically provide individuals or households with benefits (in the form of physical vouchers or an electronic card) to purchase produce at participating farmers' markets and grocery stores. Like other food-is-medicine interventions, there is significant variation in program dose (e.g., the amount of the benefit), duration, and populations served. There is increasing momentum for produce prescription programs, and millions of dollars in dedicated federal funding are provided each year through the USDA's Gus Schumacher Nutrition Incentive Program (GusNIP) to support these interventions. Research shows that produce prescription programs are associated with improvements in dietary intake and food security (31,37). Several evaluations of produce prescription programs focus on patients with or at high risk for diabetes; some of these demonstrate evidence of improvements in BMI and HbA_{1c}, although findings are variable. For example, in a pre/post study of 97 adults with T2D enrolled in a produce prescription program coupled with diabetes self-management education (DSME), participants exhibited a 1.3% clinically and statistically significant decrease in HbA_{1c} (38). Reductions in HbA_{1c} were associated with higher redemption rates. In another pre/post study of 333 T2D adults receiving care at rural community health centers, patients demonstrated statistically significant reductions in HbA_{1c}, and the number of patients with uncontrolled T2D ($HbA_{1c} > 9\%$) decreased by 46% (2). However, this study also had a high attrition rate (48%), which could have biased study results. In a pilot trial of 128 adults with T2D ($HbA_{1c} > 8.0\%$) at a Federally Qualified Health Center (FQHC) randomized to receive either $80 in produce for up to 8 weeks or standard care, there were no significant differences between the intervention and control groups for any health metrics (HbA_{1c}, BMI, or blood pressure) after program completion (39).

Multiple simulation models have been conducted to estimate the downstream impacts of produce prescription programs. One of these analyses suggested that fruit and vegetable incentives have the potential to prevent 1.93 million cardiovascular disease events and save $39.7 billion in formal health care costs (40). A broader healthy food incentive, which covered the cost of fruits and vegetables, whole grains, nuts/seeds, seafood, and plant-based oils, was found to prevent 120,000 cases of diabetes (40). However, this same result was not found for the fruit and vegetable incentive only. A similar study found that a Supplemental Nutrition Assistance Program (SNAP) subsidy on produce would be expected to increase the alternative Healthy Eating Index (HEI) score (a measure of diet quality) and avert 39,000 cases of diabetes and 4,600 cardiovascular deaths over a 10-year period (41).

While more research is needed, produce prescription programs, compared with other food-is-medicine interventions, typically cost less to implement and may be more readily scaled. Thus, while interventions like MTMs may be reserved for the highest-risk patient populations, produce prescription programs may be better suited for a broader patient population, including those at risk for or living with diabetes but who do not have multiple, complex comorbidities or challenges with shopping for and preparing food.

Federal Nutrition Assistance

The USDA Food and Nutrition Service administers a suite of 15 nutrition assistance programs, which reach one in four Americans over the course of a year and provide income-eligible households with food or money to purchase food. Two of the largest are the Supplemental Nutrition Assistance Program (SNAP) (formerly known as food stamps) and WIC, both of which decrease food insecurity and improve nutrition and health.

SNAP, the nation's largest food assistance program, currently serves 41 million Americans each month, reduces food insecurity by 20–30%, and is one of the nation's largest antipoverty programs. Although it was designed primarily to support food security among participants, it is now clear that SNAP also improves health and

reduces health care costs (42). Multiple design changes have been proposed to nudge SNAP participants toward purchasing more healthy foods with their SNAP dollars, including financial incentives for fruit and vegetable purchases (such as those funded by the GusNIP program), or purchases of healthy foods more broadly, and restrictions on purchases of unhealthy foods. Although modeling studies consistently show a positive benefit of these design changes on health outcomes, including those related to diabetes, it is not clear what impact they would have on program enrollment, stigma, or the complexity of benefit redemption for participants (43).

WIC supports the health of more than 6 million income-eligible pregnant and postpartum individuals, infants, and children under the age of 5 years and at nutrition risk by providing nutritious foods, nutrition and breastfeeding education, and referrals to health care and other social services. Studies show that early nutrition, starting in utero, plays a key role in long-term behavior and health outcomes (44). Epidemiologic studies have identified suboptimal nutrition (both overnutrition and undernutrition) as a risk factor for the development of T2D later in life (44). Further, pregnant people experiencing food insecurity are more likely to develop gestational diabetes, a strong risk factor for the later development of T2D (45).

Although it is designed for a specific target population, WIC is the only federal nutrition assistance program established with the sole purpose of addressing health (rather than the dual purpose of supporting American agriculture and public health). While WIC is designed as a short-term intervention, its goal is to influence nutrition across the lifespan. WIC is also the nation's only federal produce prescription program. In addition to providing money for specific healthy food items, additional dollars (known as a cash value benefit [CVB]) are allotted for the purchase of fruits and vegetables. In 2009, the WIC food package was updated to better align with the latest nutrition science, and the USDA has recently announced proposed changes to supplement the foods and beverages participants already consume and fill in key nutritional gaps to support healthy growth and development (46).

Following the introduction of the 2009 WIC food package, participants were more likely to purchase and consume fruits and vegetables and whole grains, and they were less likely to purchase and consume fruit juice, refined grains, grain-based desserts, higher-fat milks, and sugar-sweetened beverage (47). WIC households also purchased fewer total calories (−11%), sodium (−12%), total fat (−10%), and sugar (−15%) than they did before 2009 (47). Improvements to the WIC food package have also contributed to a healthier food environment by increasing the availability and variety of healthy foods in grocery and corner stores. In a recent systematic review, WIC participation was associated with better maternal and child diet quality and nutrient intake (48). There is also a substantial body of literature demonstrating WIC's positive impact on birth outcomes, including a lower risk of inadequate gestational weight gain, infant mortality, and preterm delivery (48). However, studies have not yet been able to demonstrate any association between WIC and gestational diabetes outcomes.

During the coronavirus disease 2019 (COVID-19) pandemic, the USDA increased the CVB from $9–$11/month to $24–$47/month, and in summer 2021, the WIC CVB was temporarily increased to $35 for all WIC participants. This benefit increase was associated with increased purchasing and consumption of fruits and vegetables and greater dietary quality and variety among participants (49). The CVB increase has been temporarily extended through 30 September 2023, and the new amount is $25 for child participants, $44 for pregnant and postpartum participants, and $49 for fully and partially breastfeeding participants (50).

Given its effects on dietary intake, WIC may also be an important policy lever for improving obesity rates, thereby reducing chronic disease risk. A 2019 study by Daepp et al. (51) found that the 2009 changes to the WIC food package were associated with a 0.34 percentage point decrease in annual obesity prevalence among children aged 2–4 years old. Similar findings were found among children who received WIC from birth to age 4 years in Los Angeles County (52).

Participation in WIC likely reduces food insecurity, and aging out of WIC has a negative impact on child food security (53,54). Longer program participation is associated with lower odds of household food insecurity and better diet quality (as measured by HEI score) (53). Given the connection between childhood food insecurity and later disease risk (including diabetes risk), interventions such as WIC, designed to target both food insecurity and nutrition, may be an important primary prevention strategy.

Other Social Policies

Social policies designed to alleviate poverty, such as income supports, may also be an important solution for reducing food insecurity risk. For example, expansion of the child tax credit as part of the American Rescue Plan in 2021 resulted in reductions in food insecurity, including very low food security, and an Urban and Brookings Institute study found that the majority of recipients used their credit to purchase food (55–57). The earned income tax credit, a tax refund for low-income, working families, is associated with improvements in food insecurity, particularly in the short term. The effect of the earned income tax credit on health has been mixed in adults, but the majority of studies show improvements in long-term (but not short-term) health among children (58). Finally, studies that examined the effects of universal basic income (UBI) (otherwise known as unconditional cash transfers) both globally and domestically have demonstrated improvements in birth outcomes, educational attainment, and mental health and well-being (59). Although not specifically designed to target food insecurity, these programs may serve as an important policy lever for addressing food insecurity and supporting health by stabilizing household income.

The numerous mechanisms by which federal nutrition programs, food-is-medicine programs, or other social policies that reduce food insecurity work to improve health have yet to be fully explored. Theoretically, these programs may affect health by directly reducing food insecurity; by compensating for the effects of food insecurity, regardless of whether food insecurity is actually reduced; or by buffering the effects of food insecurity on health. For example, SNAP alleviates food insecurity, but it may also result in positive health outcomes by freeing up additional money in the household budget that may then be diverted to health care. Other programs, such as SNAP-Education (SNAP-Ed) or the Expanded Food and Nutrition Education Program (EFNEP), could positively influence health by supporting food security directly, but they may also buffer the detrimental effects of food insecurity on health

through education and peer group support. A better understanding of the different ways in which these programs support health can inform future program models and policies.

WHAT ARE THE PATHS FORWARD FOR RESEARCH, POLICY, AND PRACTICE?

Addressing the coexistence of food insecurity and T2D calls for a multilayered approach by policymakers, researchers, clinicians, and public health practitioners. Given the disproportionate impact on historically underserved populations, there is a need to prioritize solutions for these groups. Table 3 summarizes selected opportunities.

Research

Research is needed to fill important gaps. First, there is significant heterogeneity in the implementation of food-is-medicine programs, and there is currently no consensus on the optimal intensity, dose, and duration of these programs. More research is needed to understand the most effective delivery models for these programs, which is also likely to differ by target population. Further, the vast majority of food-is-medicine studies are pre/post, single-site, observational studies, which are also limited by relatively small sample sizes. Recommendations for food-is-medicine research call for more rigorous study designs that include both quantitative and qualitative approaches (30). Where randomized controlled trials are not feasible, alternative causal inference methodologies should be considered (30). A commentary by Hager and Mozaffarian (60) in response to a systematic scoping review of health care interventions to increase fruit and vegetable intake similarly outline current challenges and opportunities for food-is-medicine programs.

Limitations also exist in federal nutrition assistance program research. Because it is not possible to randomize federal nutrition assistance program recipients, evaluations of SNAP and WIC typically rely on observational or quasi-experimental approaches.

While there is currently no standardized measure of nutrition security, research is underway by the USDA and independent researchers to understand the conceptual underpinnings of nutrition security, its relationship to food security, and how it might be measured (61,62). Future research should continue to leverage existing measures of diet quality (like HEI) while metrics are under development.

While there is early evidence that supports the importance of food security interventions on diabetes outcomes, assessment of long-term impacts remains an important gap in the literature. More research is needed to elucidate the complex pathways that link food insecurity and diabetes outcomes in different populations in order to develop targeted prevention and treatment approaches (2). Finally, a significant gap remains in building equity into research design. More intentional action is needed to center racial equity across the research continuum to ensure interventions are both relevant and effective across different populations (30). Investment in these research actions represents an important step for advancing health equity in diabetes prevention and management.

Policy

Policy changes will be important to accelerate progress. At the federal level, major legislative vehicles can help to maintain or strengthen the federal nutrition assistance programs. For example, the Farm Bill sets policy and funding structure for many agriculture, food, and nutrition programs, including SNAP, and is reapproved about every 5 years (with the 2018 Farm Bill being the most recent). Child Nutrition Reauthorization (CNR) is used to fund and structure child nutrition programs, including WIC. Congress has not passed CNR legislation since the Healthy, Hunger Free Kids Act in 2010. Annual appropriations are a third key opportunity for change; the FY23 appropriations extended the WIC CVB as mentioned above. At the local and state levels, there is considerable opportunity to innovate and test promising approaches. For example, states can test Medicaid

Table 3—Opportunities for research, policy, and practice

Research	Understand the most effective food-is-medicine delivery models by target population, particularly for historically underrepresented populations where disparities in diabetes and food insecurity risk may be most prevalent
	Develop a measure of nutrition security
	Identify the optimal intensity/dose (e.g., how much food or money is provided) and minimum duration of intervention
	Invest in longitudinal and high-quality studies that include a control group and are adequately powered to detect outcomes of interest, especially HbA_{1c}
	Prioritize the collection of clinical data, such as HbA_{1c}, in addition to other outcome and process metrics, such as dietary intake, food insecurity, and program engagement, using standardized data collection tools where possible
	Assess the cost-effectiveness of food insecurity interventions across different populations and quantify their impact on health care utilization and costs
	Examine the complex pathways and mechanisms that underly the relationship between food insecurity and diabetes to develop targeted treatment and prevention approaches
	Apply an equity lens throughout the research design process
Policy	Leverage legislative vehicles to maintain and further strengthen the federal nutrition assistance programs
	Support coverage of the National Diabetes Prevention Program by state Medicaid agencies
	Encourage innovation by local and state governments
Practice	Support implementation of relevant recommendations in the National Strategy (63)
	Encourage all health systems to screen for food insecurity and provide individuals with food insecurity a warm hand off to the social safety net
	Build a coalition that includes health care and antipoverty advocates to support this work
	Provide more medical education about social determinants of health, including food insecurity and its clinical implications
	Foster better coordination of diabetes prevention and treatment across government agencies
	Encourage enrollment in the federal nutrition assistance programs to maximize participation

coverage of nutrition education and other nutrition supports using Medicaid Section 1115 demonstration projects.

The recent, historic White House Conference on Hunger, Nutrition, and Health and corresponding National Strategy included a number of policy recommendations that are particularly salient for diabetes prevention and management (63). These include strengthening federal nutrition assistance programs by providing a WIC CVB amount that supports adequate fruit and vegetable consumption (which is mentioned above and included in the fiscal year 2023 appropriation), updating WIC nutrition standards to align with national nutrition standards (which is mentioned above and is underway), and expanding incentives for fruits and vegetables in SNAP. These policy actions represent an important step for achieving nutrition security and promoting health equity.

Practice

The National Strategy also recommends administrative actions that can be taken by the federal government or the private sector. For example, it calls for the expansion of access to food-is-medicine programs by both public and private insurers and the implementation of nationally funded and state-funded produce prescription pilots. Specific to diabetes prevention and management are recommendations to expand access to the National Diabetes Prevention Program (DPP) and increase funding for the implementation of evidence-based strategies, especially those that focus on reducing health disparities. Recommendations also call for the adoption of universal food insecurity screening in federal health care settings and increased data infrastructure to support these screenings. The recommendation that food insecurity screening should happen in all health care settings elevates the importance of patients receiving a warm hand off to safety net programs (e.g., leverage case workers to help eligible individuals enroll in federal nutrition programs or food-is-medicine programs, similar to what is often done for Medicaid enrollment) when they screen positive for food insecurity—screening without an intervention is unlikely to improve any clinical outcomes. This is particularly important since the federal nutrition assistance programs are not fully used (e.g., one in two individuals eligible for WIC and one in five eligible for SNAP do not participate), so efforts such as these could help close the participation gap. To support this process, there is a need for more education about how to conduct food insecurity screenings. One successful example is the American Academy of Pediatrics (AAP) and Share Our Strength committing (as part of the recent White House Conference) to offering training to all 67,000 AAP member pediatricians on both screening for nutrition insecurity and referring patients to federal and community nutrition resources by 2030 (64). This is also a good example of the health care sector and antihunger community coming together; more coalition building like this is needed to support this effort. Philanthropy has and may continue to play an important role in convening thought leaders around food is medicine and providing support for evaluation.

Food insecurity should also inform clinical treatment plans. For example, physicians and health care providers may prescribe medications with a lower risk of hypoglycemia or tailor nutrition counseling to support consumption of healthy, lower-cost items (such as canned or frozen produce with no added sugar or salt) (65).

CONCLUSIONS

Food insecurity and diabetes are linked through multiple, interwoven pathways. Food programs, including both food-is-medicine and federal nutrition assistance programs, offer a promising strategy to simultaneously address food insecurity and reduce health disparities. While there is good evidence that these programs can impact intermediate outcomes (dietary intake and food security), there is less consistent evidence about their capacity to impact BMI, glycemic control, and diabetes complications, particularly for food-is-medicine interventions. Future research efforts should focus on how to design and implement these programs so that they best support people with diabetes and people at high risk of diabetes, with a particular emphasis on attenuating longstanding disparities for historically underserved populations. Policy and practice efforts from a variety of actors are also needed to bring this work to scale.

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