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Evaluation of a Produce Prescription Program for Low-Income Adults

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Abstract

Evaluation of a Produce Prescription Program for Low-Income Adults
By Miranda Cook

Despite the proliferation of produce prescription (PRx) programs seeking to address structural barriers to achieving high-quality diets, little evidence exists demonstrating effectiveness in underserved populations, program mechanisms of action, and the role stress plays in these interventions. The objective of this dissertation is to enhance understanding of the role of PRx programs in addressing the relationship between food insecurity, diet quality, and chronic disease by addressing these critical gaps. We used data collected from the Georgia Food for Health (GF4H) program, a 6-month PRx program implemented in an underserved population in Atlanta, Georgia. GF4H provides vouchers redeemable for produce alongside interactive nutrition and cooking education. Linear mixed models were used to estimate the association between monthly program visits attended (1-6) and health outcomes. Program participation was associated with significant reductions in BMI ($p=0.04$), waist circumference ($p<0.001$), systolic blood pressure ($p<0.001$), and diastolic blood pressure (0.001). Pathway analysis was used to estimate relationships between program intermediate educational outcomes and primary ones, revealing improvements in confidence with buying and cooking healthy food on a budget and food resource management practices such as comparing practices were the key drivers of diet change in the GF4H program. Lastly, in-depth interviews with program participants revealed two distinct typologies related to how participants experienced stress related to food insecurity: namely, those who described stress as overwhelming and those who described self-management of stress through internal processes. Regardless of typology, cost was described as a major barrier to acquiring desired amounts of fruits and vegetables. Making unhealthy eating decisions when stressed was described as comforting and precipitated by feelings of exhaustion and internal conflict. Program-related nutrition education and social support were described as facilitators of healthy eating. Collectively, this work demonstrates the association between PRx program participation and improvements in multiple chronic disease risk factors in a vulnerable, low-income population, highlights the importance of activities designed to increase self-efficacy and food resource management skills, and characterizes the lived experience of stress for PRx participants, emphasizing the role of group-education in achieving behavior change.

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Chapter 1: Introduction

Food insecurity, as defined as a household-level economic and social condition of limited or uncertain access to adequate food, remains a challenge in the United States. Despite small declines in prevalence each year since 2011, more than one in ten households still faced food insecurity in 2020.[1] Food insecurity has important implications for diet quality and chronic disease. Among low-income households, those who are food insecure spend less on food, purchase fewer calories overall, and purchase lower quality food compared to food-secure households.[2–5] In turn, low-quality diets increase the risk of developing diet-related chronic diseases.[6,7] Poor diet quality has been estimated to contribute more to morbidity and mortality from chronic diseases than physical inactivity, alcohol, and smoking combined.[8]

Considering the cyclical nature of food insecurity, alternating between periods of adequate food supply and food scarcity can lead to periods of overconsumption and weight gain during times of food adequacy and periods of underconsumption and weight loss during times of food shortage.[9] Depending on severity of food insecurity experienced, individuals may employ compensatory strategies such as skipping meals, reducing portion sizes, and reducing variety in their diets.[9,10] A combination of physiological and behavioral responses to food insecurity and the associated stress have been offered as an additional explanation for the observed relationships between food insecurity, poor quality diets, and chronic disease.[10–12]

Given the importance of high-quality diets for preventing chronic diseases and evidence that food insecure families struggle to achieve diets beneficial for health outcomes, intervention strategies are needed to address these health inequalities. Recognizing this need, there has been a proliferation of interest in interventions incorporating Food is Medicine™ initiatives into

healthcare systems to facilitate access to healthy foods for vulnerable patients.[13–15] One promising approach is the produce prescription (PRx) model, which involves physician or healthcare worker referrals to free or discounted healthy produce for patients identified to be at risk for chronic disease based on low food security status or income and diet-related health risk factors.[14–17] Financial incentive models, including produce Rx programs, are informed by the principles of operant conditioning, whereby behaviors eliciting rewards are repeated.[18,19] Thus, incentives may act as a catalyst to engage in a behavior, and repeated engagement may become intrinsically motivating, facilitating sustained behavior change.[20] Some produce Rx programs additionally incorporate group-based nutrition education and cooking sessions.[21–26] Nutrition education increases knowledge and awareness while hands-on cooking sessions provide skills and increase self-efficacy to engage in the behavior.[27–30] These behaviors are reinforced through educational sessions involving peer and provider support.[16,20,27,31]

There is consistent evidence that produce Rx programs increase food security [25,32–34] and increase mean fruit & vegetable consumption by 0.3-2 servings/day.[22,23,25,34–37] However, few studies have reported on health outcome measures, and overall results have been mixed. A recent meta-analysis estimated that produce Rx programs are associated with decreases in BMI of 0.6 kg/m2 (95% CI: 0.2, 1.1) and HbA1c of 0.8% (95% CI: 0.1, 1.6).[17] However, no significant changes were observed for blood pressure or lipid outcomes. While these results are promising, more evidence is needed to evaluate the effectiveness of produce Rx programs for improving chronic disease risk factors.

Further, there is limited evidence demonstrating how PRx programs achieve behavioral and health outcomes. While nutrition education and environmental supports provided by PRx programs are intended to facilitate behavior change and improve diet quality[16,38], no studies to

date have explored the relationship between intermediate behavioral outcomes such as self-efficacy and attitudes on diet and food security outcomes. For evaluation and program improvement purposes, it is important to understand which intervention components in a program's theory of change impact program outcomes and which fall short of expectations.

Lastly, while robust conceptual theories have been developed explaining the complex relationships between stress, food insecurity, and diet quality[12,39,40], it is unclear how these factors influence how participants' experience PRx programs, whether stress acts as a barrier to behavior change in this context, and if so, what can be done to improve programs to address these issues.

Research Aims

This dissertation intends to evaluate the effectiveness of a produce prescription program in an underserved, largely understudied population, understand program mechanisms of action and areas for program improvement, and to explore the relationships between stress and food security to identify strategies to improve program retention and health outcomes. Each specific aim used data collected from the Georgia Food for Health (GF4H) program implemented in a safety-net health system in Atlanta, Georgia.

Specific Aims

Aim 1: Assess change in health outcomes observed among GF4H participants and explore predictors of health improvements using repeated measures data collected across three years of program implementation in 5 clinic sites.

Aim 2: Determine the relationships between GF4H intermediary education outcomes and primary program outcomes, food security and diet quality using pathway analysis on two years of program data collected across 5 clinic sites.

Aim 3: Characterize experiences of stress and food insecurity among GF4H program participants using in-depth interview techniques on a subset of program participants to understand related facilitators and barriers to behavior change in the program.

References

1. Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A. *Household Food Security in the United States in 2020*.; 2021.
2. Gregory CA, Mancino L, Coleman-Jensen A. *Food Security and Food Purchase Quality among Low-Income Households: Findings from the National Household Food Acquisition and Purchase Survey (FoodAPS)*.; 2019.
3. Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. *The American journal of clinical nutrition*. 2004;79(1):6-16. http://www.ncbi.nlm.nih.gov/pubmed/14684391.
4. United States Department of Agriculture ERS. Food Prices and Spending. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-prices-and-spending/. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-prices-and-spending/. Published November 3, 2021. Accessed November 2, 2021.
5. Gregory CA, Mancino L, Coleman-Jensen A. *Food Security and Food Purchase Quality Among Low-Income Households: Findings From the National Household Food Acquisition and Purchase Survey (FoodAPS)*.; 2019.
6. Dietary Guidelines Advisory Committee. *Scientific Report of the 2020 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Agriculture and the Secretary of Health and Human Services*. Washington, DC; 2020.
7. U.S Department of Agriculture; U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2020-2025*.; 2020.
8. Lim SS, Voz T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2224-2260.
9. Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *New England Journal of Medicine*. 2010.
10. Laraia BA. Food Insecurity and Chronic Disease. *Advances in Nutrition*. 2013.
11. Seligman HK, Laraia BA, Kushel MB. Food Insecurity Is Associated with Chronic Disease among Low-Income NHANES Participants. 2010.
12. Laraia BA, Leak TM, Tester JM, Leung CW. Biobehavioral Factors That Shape Nutrition in Low-Income Populations: A Narrative Review. *American Journal of Preventive Medicine*. 2017.
13. Veldheer S, Scartozzi C, Knehans A, et al. A Systematic Scoping Review of How Healthcare Organizations Are Facilitating Access to Fruits and Vegetables in Their Patient Populations. *The Journal of Nutrition*. 2020.
14. Mozaffarian D, Mande J, Micha R. Food Is Medicine-The Promise and Challenges of Integrating Food and Nutrition into Health Care. *JAMA Internal Medicine*. 2019.
15. Downer S, Berkowitz SA, Berkowitz SA, Harlan TS, Olstad DL, Mozaffarian D. Food is medicine: Actions to integrate food and nutrition into healthcare. *The BMJ*. 2020.
16. Swartz H. Produce RX programs for diet-based chronic disease prevention. *AMA Journal of*

Ethics. 2018.
17. Bhat S, Coyle DH, Trieu K, et al. Healthy Food Prescription Programs and their Impacts on Dietary Behavior and Cardiometabolic Risk Factors: A Systematic Review and Meta-Analysis. *Advances in Nutrition*. 2021:1-13.
18. Skinner BF. *Science and Human Behavior*. Cambridge, MA: Skinner Foundation; 1953.
19. Burns RJ, Donovan AS, Ackermann RT, Finch EA, Rothman AJ, Jeffery RW. A theoretically grounded systematic review of material incentives for weight loss: Implications for interventions. *Annals of Behavioral Medicine*. 2012.
20. Purnell JQ, Gernes R, Stein R, Sherraden MS, Knoblock-Hahn A. A systematic review of financial incentives for dietary behavior change. *Journal of the Academy of Nutrition and Dietetics*. 2014.
21. Burrington CM, Hohensee TE, Tallman N, Gadomski AM. A pilot study of an online produce market combined with a fruit and vegetable prescription program for rural families. *Preventive Medicine Reports*. 2020.
22. Emmert-Aronson B, Grill KB, Trivedi Z, Markle EA, Chen S. Group medical visits 2.0: The open source wellness behavioral pharmacy model. *Journal of Alternative and Complementary Medicine*. 2019.
23. Orsega-Smith E, Slesinger N, Cotugna N. Local Pediatricians Partner with Food Bank to Provide Produce Prescription Program. *Journal of Hunger and Environmental Nutrition*. 2019.
24. Ridberg RA, Bell JF, Merritt KE, Harris DM, Young HM, Tancredi DJ. A Pediatric Fruit and Vegetable Prescription Program Increases Food Security in Low-Income Households. *Journal of Nutrition Education and Behavior*. 2019.
25. Ridberg RA, Marpadga S, Akers MM, Bell JF, Seligman HK. Fruit and Vegetable Vouchers in Pregnancy: Preliminary Impact on Diet & Food Security. *Journal of Hunger and Environmental Nutrition*. 2021.
26. Watt TT erling, Appel L, Lopez V, Flores B, Lawhon B. A Primary Care-Based Early Childhood Nutrition Intervention: Evaluation of a Pilot Program Serving Low-Income Hispanic Women. *Journal of racial and ethnic health disparities*. 2015.
27. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*. 2011.
28. Redding C a, Rossi JS, Rossi SR, Velicer WF, Prochaska JO. Health Behavior Models. *The International Electronic Journal of Health Education*. 2000.
29. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *American Journal of Health Promotion*. 1997.
30. Prochaska JO. Decision making in the transtheoretical model of behavior change. *Medical Decision Making*. 2008.
31. Bellg AJ. Maintenance of Health Behavior Change in Preventive Cardiology: Internalization and Self-Regulation of New Behaviors. *Behavior Modification*. 2003.
32. Ridberg RA, Bell JF, Merritt KE, Harris DM, Young HM, Tancredi DJ. A Pediatric Fruit and Vegetable Prescription Program Increases Food Security in Low-Income Households. *Journal of Nutrition Education and Behavior*. 2019.
33. Aiyer JN, Raber M, Bello RS, et al. A pilot food prescription program promotes produce intake and decreases food insecurity. *Translational Behavioral Medicine*. 2019.
34. Berkowitz SA, O'Neill J, Sayer E, et al. Health Center–Based Community-Supported Agriculture: An RCT. *American Journal of Preventive Medicine*. 2019.
35. Omar J, Heidemann D, Blum-Alexander B, et al. Fresh prescription program: A program to

improve access to fresh products among underserved patients in downtown detroit. *Journal of General Internal Medicine*. 2017;32(2):S7S2.
36. Trapl ES, Smith S, Joshi K, et al. Dietary Impact of Produce Prescriptions for Patients With Hypertension. *Preventing Chronic Disease*. 2018.
37. Freedman DA, Choi SK, Hurley T, Anadu E, Hébert JR. A farmers' market at a federally qualified health center improves fruit and vegetable intake among low-income diabetics. *Preventive Medicine*. 2013.
38. Hager K, Mozaffarian D. The promise and uncertainty of fruit and vegetable prescriptions in health care. *Journal of Nutrition*. 2020.
39. Starcke K, Brand M. Decision making under stress: A selective review. *Neuroscience and Biobehavioral Reviews*. 2012.
40. Koolhaas JM, Bartolomucci A, Buwalda B, et al. Stress revisited: A critical evaluation of the stress concept. *Neuroscience and Biobehavioral Reviews*. 2011.
41. Comerford, B; Doughty, K; Njike, V; Ayettey, R; Weisel, A; Katz, D; Costales V. Impact of a Fruit and Vegetable Prescription Program on Diet Quality and Cardio-Metabolic Risk Factors in Healthy Adults in a Worksite Setting: A Randomized Controlled Trial. *Current Developments in Nutrition*. 2019;13(3):Suppl 1.
42. Chrisinger A, Wetter A. Fruit and Vegetable Prescription Program: Design and Evaluation of a Program for Families of Varying Socioeconomic Status. *Journal of Nutrition Education and Behavior*. 2016.
43. Joshi K, Smith S, Bolen SD, Osborne A, Benko M, Trapl ES. Implementing a Produce Prescription Program for Hypertensive Patients in Safety Net Clinics. *Health Promotion Practice*. 2019.
44. Bryce R, Guajardo C, Ilarraza D, et al. Participation in a farmers' market fruit and vegetable prescription program at a federally qualified health center improves hemoglobin A1C in low income uncontrolled diabetics. *Preventive Medicine Reports*. 2017.
45. Slagel N, Newman T, Sanville L, et al. The Effects of a Fruit and Vegetable Prescription Program (FVRx)® for Low-Income Individuals on Fruit and Vegetable Intake and Food Purchasing Practices. *Journal of Nutrition Education and Behavior*. 2018;50(7):S103.
46. Luu, Catherine; Andersen N. Pharmacy to farm prescriptions pilot program in New York City - Baseline survey findings. *Journal of Nutrition Education and Behavior*. 2018;50(7):S163-S164.
47. Trapl ES, Joshi K, Taggart M, Patrick A, Meschkat E, Freedman DA. Mixed Methods Evaluation of a Produce Prescription Program for Pregnant Women. *Journal of Hunger and Environmental Nutrition*. 2017.
48. Buyuktuncer Z, Kearney M, Ryan CL, Thurston M, Ellahi B. Fruit and vegetables on prescription: A brief intervention in primary care. *Journal of Human Nutrition and Dietetics*. 2014.
49. Kearney M, Bradbury C, Ellahi B, Hodgson M, Thurston M. Mainstreaming prevention: Prescribing fruit and vegetables as a brief intervention in primary care. In: *Public Health*. ; 2005.
50. S A. Prescribing prevention: fresh fruits and vegetables are just what the doctor orders. *Contemp Pediatr*. 2014;31(6):5-7.
51. Goddu AP, Roberson TS, Raffel KE, Chin MH, Peek ME. Food Rx: A community-university partnership to prescribe healthy eating on the south side of Chicago. *Journal of Prevention and Intervention in the Community*. 2015.
52. Cavanagh M, Jurkowski J, Bozlak C, Hastings J, Klein A. Veggie Rx: An outcome evaluation of a healthy food incentive programme. *Public Health Nutrition*. 2017.

53. Marcinkevage J, Auvinen A, Nambuthiri S. Washington State's Fruit and Vegetable Prescription Program: Improving Affordability of Healthy Foods for Low-Income Patients. *Preventing Chronic Disease*. 2019.
54. de Marchis EH, Torres JM, Benesch T, et al. Interventions addressing food insecurity in health care settings: A systematic review. *Annals of Family Medicine*. 2019.

Chapter 2: Background

The Burden of Diet-related Chronic Diseases

Definition

Chronic diseases are defined as conditions that last one year or more and require ongoing medical attention, limit activities of daily living, or both.[1] Chronic conditions related to nutrition include cardiovascular diseases, metabolic syndrome, type 2 diabetes, overweight and obesity, chronic liver disease, as well as certain types of cancers and dental conditions.[2] These diseases are the result of a complex mix of genetic, biological, behavioral, socioeconomic, and environmental factors.[3]

Current prevalence and consequences of chronic diseases

Globally, nutrition-related chronic diseases are among the leading causes of death and disability.[4] Poor nutrition is attributable for a greater population burden of morbidity and mortality from chronic diseases than tobacco, alcohol, and physical inactivity combined.[5] In the United States, six in ten adults have at least one chronic condition and four in ten have two or more.[6,7] Adults with multiple chronic conditions have lower health-related quality of life, higher health care costs, and increased risk of death, compared with adults without chronic conditions.[7–10]

Historical trends

Efforts to monitor and prevent the development of chronic diseases gained traction in the early twentieth century.[11] Life insurance companies began to cover yearly physical examinations in the hopes of identifying and addressing issues through advice on behavior modifications that could improve health.[11] By the 1960s, evidence from large-scale studies such as the Framingham Heart

Study, the Seven Countries Study, and the British Doctors Study helped to identify the leading causes of chronic diseases.[12,13] As behavioral risk factors such as diet were recognized to contribute to the development and progression of chronic disease, researchers began to investigate interventions that could be used to reduce their impact.[13] Around the same time, more research began to additionally focus on social and economic factors such as occupation, income, and education that increase risk of developing chronic diseases.[13–15] Improvements in diet, detection and treatment of risk factors such as hypertension and dyslipidemia, medical care and treatment have reduced the deaths attributable to heart disease and stroke since the 1960s.[13]

However, cardiovascular diseases still currently represent the leading cause of death, both globally and in the United States.[16,17] Further, obesity rates have increased substantially over time (Figure 2).[18] In 1960-1962, prevalence of obesity among U.S. adults was estimated to be 13.4%.[19] By 2017-2018, obesity prevalence was 42.4%.[20] Obesity increases the risk of developing other chronic conditions such as type 2 diabetes and coronary heart disease and may make disease management more challenging.[21] While the causes of increased obesity prevalence are complex, many researchers point to changes that have occurred in food consumption over time.[13,22]

Health risks and benefits related to diet

Globally, suboptimal diets were estimated to be attributable for 11 million deaths and 255 million disability-adjusted life years in 2017.[23] High intakes of sodium and low intakes of whole grains and fruits were the leading dietary risk factors identified.[23]

Diet & Cardiovascular diseases: Cardiovascular diseases are the leading cause of death, both globally and in the United States.[24,25] High blood pressure, or hypertension, is the predominant risk factor for cardiovascular disease and the residual lifetime risk for developing hypertension is

90%.[26–28] In addition to genetic factors that may predisposition some people to develop hypertension, obesity, high sodium intake, sedentary lifestyle, and excessive alcohol consumption can increase blood pressure.[29–38] Consistently high intakes of saturated and trans-fat can additionally increase risks of developing cardiovascular disease.[39–43] Dietary approaches to reducing hypertension and preventing cardiovascular diseases largely focus on reducing sodium intake while emphasizing fruits and vegetable intake.[44] Fruits and vegetables are nutrient & fiber-dense and low in calories; eating more fruits and vegetables helps to meet nutrient requirements without exceeding caloric recommendations.[45–47] Diets rich in fiber specifically help to reduce cardiovascular risks as certain types of fiber bind to bile acids in the gastrointestinal tract and are excreted, prompting the body to create additional bile acids from circulating cholesterol, which can lower the total amount in the body over time.[48,49] Overall, diets rich in fruits, vegetables, and whole grains can reduce cardiovascular risks.

Diet & Cancer: Cancer is the 2nd leading cause of death in the United States.[25] An estimated 20-30% of cancers are attributable to diet and physical inactivity.[50] However, the role of diet in cancer development is complex and involves environmental and genetic interactions that affect cancer risks.[45] Obesity has been associated with increased risk of developing 13 types of cancer including those of the esophagus, breast, colon and rectum, uterus, gallbladder, kidneys, and liver, just to name a selection.[51–53] High-fat diets have been associated with increased risks of developing cancers of the colon, rectum, prostate, and endometrium.[54,55] High intakes of red meat and processed meat are additionally associated with some types of colorectal cancer while consumption of leaner proteins like fish and poultry are associated with reduced risks.[54,56–58]

Diet & Type-2 Diabetes Mellitus: While family history of type-2 diabetes is one of the strongest risk factors for developing the disease, dietary risks include excess fat intake, low fruit,

vegetable, and fiber intakes, and physical inactivity.[59–65] Obesity additionally increases risks of developing type-2 diabetes.[66,67]

Diet & Metabolic Syndrome: Metabolic syndrome is a cluster of at least three risk factors for heart disease including hypertriglyceridemia, low HDL cholesterol, hyperglycemia, hypertension, and excess abdominal fat.[68] Individuals with metabolic syndrome are at an increased risk for both cardiovascular disease and type-2 diabetes.[69] In the United States, 35% of adults meet the criteria for metabolic syndrome.[70] Poor diet and low physical activity in combination with genetic predisposition are the main risk factors.[68]

High quality diets emphasizing fruits and vegetables are known to aid in preventing the development of chronic diseases and reduce risks of all-causes of mortality.[2] The current Dietary Guidelines for Americans recommends consuming nutrient-dense foods and beverages within calorie limits, focusing on vegetables, fruits, whole grains, low-fat or fat-free dairy products, lean proteins, and unsaturated vegetable oils while limiting consumption of added sugars, saturated fat, red and processed meats, sodium, and alcoholic beverages.[3] However, few Americans follow healthy dietary patterns.

Current diets in the United States

The typical diet of American adults falls short of recommendations, particularly for fruits, vegetables, whole grains, and dairy.[2] Underconsumption of these food groups increases results in less than recommended intakes of specific nutrients and increases risks of development or exacerbation of diet-related chronic conditions.[2] Meanwhile, other components are overconsumed including sodium, added sugars, and saturated fats.[2] Overconsumption of these dietary components is associated with displacement of more nutritious foods from the eating pattern, increased risk of hypertension and cardiovascular diseases, as well as excess energy

consumption that results in weight gain.[2] Among U.S. adults, average caloric intake increases with age and intakes are highest among adults ages 19-30 and lowest among adults ages 71 years and older.[2] The mean caloric intake among adult males is 2,463 kcal/day and 1,814 kcal/day among adult females.[2] Due to measurement error for energy intakes, these estimates are likely to be underestimates.

Fruits

Recommended intakes for fruit ranges from 1-2.5 cup equivalents per day, depending on caloric needs.[2] Mean intake among individuals age 2 or older is 0.9 cup equivalents per day and the majority of the U.S. population do not meet recommendations (81%).[2] Approximately two-thirds of fruit consumption is whole fruit and one-third is 100% fruit juice.[2] The top five sources of fruit intake for adults are whole fruit, 100% fruit juice, sugar-sweetened and diet beverages, desserts and sweet snacks, and breakfast cereals and bars containing dried fruit.[2] Total fruit consumption is not associated with income but lower-income households; however, fruit juice consumption was inversely associated with income level while other fruits (e.g. apples, bananas, grapes) and citrus, melons, and berries consumption were positively associate with income.[2]

Vegetables

Depending on the calorie level of the diet, recommendations for vegetables range from 1-4 cup equivalents per day.[2] The majority of U.S. adults do not meet these recommendations (90%), reporting a mean daily intake of 1.4-1.7 cup equivalents per day.[2] Most vegetables are consumed as part of other foods and more than a quarter of total vegetables consumed are white potatoes.[2] Intakes of dark green, red, and orange vegetables are especially low across all age groups.[2] Total vegetable intake varies by income category, with an average 1.4 cup equivalents per day in the highest income group and 1.27 cup equivalents per day in the lowest income group.[2]

Whole grains

The recommended range for whole grains is 3 - 8 ounce equivalents per day with at least half coming from whole grains (1.5 – 4 ounce equivalents/day).[2] More than one in five adults exceed recommendations for total grains, however the average amount of whole grains consumed is just 0.9 ounce equivalents per day.[2] Only 2% of the population meets whole grain recommendations and 75% of all Americans exceed recommendations for refined grains.[2]

Dairy

For most groups, the recommended range for total dairy foods is 3 cup equivalents per day.[2] Mean total dairy intake among adults age 20 years and older is 1.5 cup equivalents per day.[2] Nearly 10% of Americans exceed recommended intakes; meanwhile 88% fall short.[2] Males are more likely than females to exceed recommendations across all age categories.[2] The major food sources for dairy intake among adults are burgers and sandwiches, followed by higher fat milk, yogurt, and cheese.[2] Among older adults, the top dairy contributors are higher fat milk and yogurt, burgers and sandwiches, desserts and sweet snacks, and low-fat milk and yogurt.[2] Dairy intake does not significantly vary by income level.[2] Total dairy intake is highest among white and Hispanic individuals and lowest among black individuals of all ages.[2]

Solid fats & added sugars

The maximum recommended limit for both solid fats and added sugars is 10% of total calories consumed.[2] The majority of the population exceeds these limits for both solid fats and added sugars.[2] Mean intakes of solid fat among adult males is 360-385 kcal/day and among adult females is 271-280 kcal/day.[2] Meanwhile, added sugars provide 284-334 kcal/day among adult males and 220-254 kcal/day among adult females.[2] The average percent of energy contributed from added sugars was 12.7% for the population ages 1 year and older.[2] Approximately 40% of

adults achieve the goal of consuming less than 10% of total calories from added sugars.[2] Mean intakes of added sugars is lowest among Asian Americans (9.6 tsp equivalent) compared to Hispanic (15.6 tsp equivalents), white (16.6 tsp equivalents), and Black (17.7 tsp equivalents) Americans ages 2 and older.[2] Some of the major sources of solid fats are burgers and sandwiches (12-22% of total solid fat intakes) and desserts and sweet snacks (14-19%).[2] The main sources of added sugars are sugar-sweetened beverages, desserts and sweet snacks, sweetened coffee and tea, and candy.[3]

Sodium

The maximum recommended limit for sodium is 2,300 milligrams per day for adults.[3] The majority of Americans (~90%) exceed recommended intakes, consuming an average of 3,393 mg per day.[2] Males have higher intakes of sodium compared to females, attributable to their higher caloric intakes and resulting in 97% of males and 79% of females reporting intakes exceeding recommended levels.[2]

Interventions to address diet-related chronic disease

Given the importance of healthy diet patterns for preventing and managing chronic disease, a variety of dietary interventions have been introduced at various levels of influence. The most successful of these have been multi-component interventions using the existing social structures of a community to reduce barriers to implementation.[71,72]

Policy & Mass Media Campaigns: The farthest-reaching interventions are implemented at the policy level, such as legislations removing artificial trans fats from the food supply and reducing cardiovascular-related deaths by an estimated 1.3% - 6.4%.[71,73] Mass media campaigns are another far-reaching approach and have been shown to be effective in raising awareness of health messaging.[71] Evidence of their effectiveness in changing diet behaviors is more mixed, with

about 63% the interventions included in one systematic review conducted by the World Health Organization reporting modest positive changes in behavior.[71] The most successful media campaigns targeting diet behaviors are those using a single, simple message such as the various '5 A Day' campaigns promoting increased consumption of fruits and vegetables. However, even the most successful of mass media diet interventions have only led to small increases in diet quality relative to recommendations.[74,75]

School & Workplace Interventions: Interventions implemented in schools and workplace settings have been shown to consistently improve knowledge, attitudes, behaviors, and when tested, physical and clinical outcomes.[72,76] The most effective of these interventions involved curriculum on diet and/or physical activity, a family component, and increased availability of healthy food options through on-site cafeterias or vending machines.[71,72] For example, the Treatwell 5-a-Day Study aimed at increasing fruit and vegetable intake through nutrition education and environmental changes such as including more fruits and vegetables in vending machines and educational posters, videos, and brochures placed in areas where employees eat.[77,78] In Sorenson et al.'s study investigating program effectiveness, they found that involving employees' families through take-home education materials and hosting health events involving families, yielded larger increases in fruit and vegetable intake (19% increase) compared to that of interventions not involving families (7% increase).[77]

Community-based interventions: Community-based interventions typically target adults in a specific community or disadvantaged population, engaging them in classes with curriculum on diet and physical activity with goals to increase knowledge, attitudes, and healthy behaviors. The most successful are multi-component diet education programs targeting high-risk groups.[71] For example, older adults participating in congregate meal programs (programs providing meals to

adults 60+ in community settings) were found to have higher quality diets were less likely to screen positive for depression and food insecurity compared to those who did not participate.[79]

Primary care interventions: Some of the most successful interventions have been conducted in healthcare settings. Successful interventions in healthcare settings target participants based on risk factors for chronic disease, include at least one session with a healthcare professional, goal-setting discussions, follow-ups with a trained professional, targeted information, and coordination with community partner organizations.[71] Among the most successful diet interventions implemented in healthcare settings are the Diabetes Prevention Program (DPP) and the Dietary Approaches to Stop Hypertension (DASH) diet.

The DPP targets individuals at risk for type 2 diabetes and engages them in a 16-session curriculum featuring education on behavioral self-management strategies promoting weight loss and physical activity.[80] Participants in the DPP program have been found to increase diet quality by 4.2 points on the alternative healthy eating index, a significantly greater increase compared to those in metformin (1.2) and placebo groups (1.4).[81] Participants of the DPP program were found to have lower chance of developing type 2 diabetes by 58% compared to participants receiving placebo.[82] At 10-year follow-up, participants of the DPP continued to have delays in diabetes development of 34% and developed diabetes an average of about 4 years later compared to placebo participants.[83] Since the original study, DPP has been implemented in a variety of settings and those conducted in healthcare settings have some of the highest attendance rates (80-96%).[84]

The DASH diet emphasizes fruits, vegetables, low-fat dairy products and limits food high in saturated fat, sugar. In the original clinical trial, consuming the DASH diet was found to reduce systolic blood pressure by 5.5 mmHg and diastolic blood pressure by 3.0 mmHg more

than those on a control diet representing the average American diet.[85] Among subjects with hypertension, reductions were even larger in magnitude, with those consuming the DASH diet experiencing reduced systolic blood pressure of 11.4 mmHg and diastolic blood pressure of 5.5 mmHg above those on the control diet.[85] Further studies have shown the DASH diet in combination with sodium reduction enhanced blood pressure improvements.[44]

Less intensive, minimal contact interventions such as single counselling sessions or information distribution have not been found to be effective, although individual responses vary based on stage of readiness.[71] Across implementation sites and groups targeted, successful interventions were those including multiple components and adapted to the local context. Using existing social structures of a community, such as schools or the weekly meetings of older adults helped to reduce barriers to implementation. However, many interventions addressing the relationship between poor diet quality and chronic disease risks do not account for the complication presented by food insecurity among participants.

Food Insecurity and Chronic Disease

Food insecurity: Definition, Measurement & Trends

Food insecurity is defined as a household-level economic and social condition of limited or uncertain access to adequate food[86] and more than one in ten households in the United States were food insecure between 2017 and 2020.[87] Prevalence of food insecurity decreased significantly each year between 2017 and 2019 but remained unchanged from 2019 to 2020, at 10.5%.[88]

Measurement

Many measurements have been developed to assess food insecurity with some notable examples

including a) the Household Food Insecurity Access Scale which provides a continuous measure of household food inaccessibility in the previous month[89], b) the Household Dietary Diversity Scale, which measures a count of different food groups consumed over the recall period, most commonly ranging from 24 hours to 7 days[90], and c) the Household Hunger Scale, which measures household food deprivation over the past 30 days[91]. These tools were primarily developed for application in low and middle-income countries and to have wording that is universally applicable with only minor adaptations needed based on local contexts.[89–91]

In the United States, national food security is monitored using data collected in the Food Security Supplement to the Current Population Survey (CPS).[92] The 18-item U.S. Household Food Security Survey Module developed by the U.S. Department of Agriculture (USDA) to monitor prevalence and severity of food insecurity is considered to be the most robust and reliable for screening in the U.S.[93] Using a twelve month recall period, it takes a three-stage approach, first asking questions about the general household food situation, then the adults in the household, followed by the children.[94] Affirmative responses to questions are summed to create a raw score and categorized into four categories of food security status: high food security (raw score:0), marginal food security (raw score: 1-2), low food security (raw score: 3-7), and very low food security (raw score: 8-18).[94] Surveys are conducted in early December each year, improving the ability to interpret annual changes, as prevalence has been noted to vary from month to month across a given year.[92]

A shorter 10-item tool, the U.S. Adult Food Security Survey Module, is a subset of the 18-item tool that excludes questions related to children's food security.[93] The even-shorter Six-Item Short Form of the Food Security Survey Module contains a subset of questions included in the 18-item core module and has been shown to reliably capture the three main categories of

food security with minimal bias relative to the longer modules.[95] Although the 6-item tool presents less respondent burden compared to the longer 18-item and 10-item modules, it does not assess the most severe levels of food insecurity or conditions of children in the household.[96]

The Hunger Vital Sign™ two-question screening tool was developed to rapidly identify food insecurity in clinical settings and was found to be sensitive (97%), specific (83%), and have strong convergent validity with indicators of child health risk factors.[97] It is among the most widely used tools for food insecurity in medical and community-based settings and has been recommended for use by the American Academy of Pediatrics[98] and is embedded into one of the most widely-used Electronic Medical Record systems, Epic.[99]

The definition of food security in the US comprises four levels of severity: high, marginal, low, and very low food security.[86] The definition of marginal food security includes worry about food resources sufficiency and there is evidence that households categorized as marginally food secure face health risks similar to those experienced by families with low and very low food security.[100] While households with low food security experience reduced quality, variety, or desirability of diet, there is little or no indication of reduced food intake. Households with very low food security experience disruptions in normal eating patterns and report food intake below adequate levels.[86] Year-to-year declines in prevalence of very low food security were not statistically significant.[101] However, prevalence in 2020 (3.9%) was significantly lower than the prevalence in 2018 (4.3%).[101]

Prevalence of Food Insecurity by Respondent Characteristics

Prevalence of food insecurity varies by social and economic circumstance. Demographic and geographic differences in food security partially reflect differences in income across these groups due to strong associations between food security and income.[102] In 2020, rates of food insecurity

were significantly higher than the national average of 10.5% among households with children (14.8%), especially those with children under age six (15.3%), and those headed by a single parent (27.7% for households headed by a single woman, 16.3% for households headed by a single man).[102] Households with a non-Hispanic Black reference person (21.7%) or a Hispanic reference person (17.2%) were more likely to experience food insecurity compared to those with a non-Hispanic White reference person (7.1%).[102]

Across the United States, prevalence of food insecurity is higher in principal cities of metropolitan areas (12.7%) and nonmetropolitan rural areas (11.6%) compared to suburban and other metropolitan areas outside principal cities (8.8%).[102] Regionally, prevalence in the South (12.3%) is significantly higher than the national average and all other individual regions respectively.[102]

State-level characteristics including average wages, cost of housing, and state-level policies influence prevalence of food insecurity.[103,104] In the period between 2018 and 2020, the prevalence of food insecurity was significantly higher than the national average in 9 states (AL, KY, LA, MS, NM, OK, TN, TX, and WV).[102] In Georgia, food insecurity has declined significantly at each reporting period (2015-2017, 2018-2020) since the great recession peak in 2008-2010 when prevalence reached 16.9%.[102,105] The most recent data from 2018-2020 estimates household food insecurity prevalence in Georgia at 10.0%.[102] The Map the Meal Gap study conducted by Feeding America in 2019, estimates prevalence of child food insecurity in Georgia at 15.1%. At the county level, household food insecurity in Fulton county was estimated at 11.3% and 10.5% for Dekalb county, while child food insecurity was estimated at 13.9% for Fulton county and 15.5% for Dekalb.[106]

Food Insecurity & Diets

Among low-income households, those who are food insecure spend less on food, purchase fewer calories overall, and purchase lower quality food compared to food-secure households.[107–110] In 2019, households in the lowest income quintile on average spent 36% of their disposable income on food (an average of $4,400), much more than the average 8% for households in the highest income quintile (average $13,987).[109] To examine differences in spending more granularly, researchers from the Economic Research Service used data from the USDA National Household Food Acquisition and Purchase Survey, a nationally representative survey detailing food purchases and acquisitions from grocery stores, restaurants, work, school, food assistance programs, and other sources.[110] They found that low-income (<130% of the poverty line), food-insecure households spent nearly $13 less per adult equivalent per week on food at home and acquired 5,170 fewer calories per week compared to low-income, food-secure households.[110] After controlling for individual and household-level characteristics, low-income food-secure households' Healthy Eating Index (HEI) scores were significantly higher than that of food-insecure households (49 points compared to 45 points).[110] For every 1,000 calories acquired, food-secure households acquired more total fruit, whole fruit, total protein, as well as seafood and plant proteins compared to food-insecure households.[110] While these studies are helpful for understanding nutritional differences in food acquired, they may not fully capture differences in consumption since not all food purchased is ultimately consumed. Additionally, the study could not fully account for difference in shopping practices such as shopping based on what is in season or on sale and buying in bulk and storing for later use.

Individuals experiencing food insecurity may employ additional compensatory strategies such as skipping meals, reducing portion sizes, and reducing the variety in their diets.[111,112] Additional coping mechanisms identified among households with very low food security include

delaying or strategically timing bill payments, discontinuing services such as telephones, selling or pawning possessions, and sending children to other houses for meals.[113] Often in discussions of these compensatory strategies, it is suggested that households experiencing food insecurity buy lower-cost, more energy-dense, and nutritionally-poor food items compared to food secure households.[108,111,114–117]

Since food items with more refined grains, added sugars, fats, and sodium tend to cost less than nutritionally rich foods like fruits and vegetables, it is hypothesized that households anticipating running out of food will attempt to stretch their food budgets by concentrating their funds on purchasing these low-cost, nutritionally poor foods.[108,111,114–120] There is strong evidence suggesting an association between food insecurity and lower consumption of fruits and vegetable as well as lower intakes of calcium, magnesium, and zinc.[113,121–127] Additionally, a number of studies report intakes of vitamin A and vitamin B-6 are lower among food insecure women.[124–129] However, evidence that food insecure households purchase more processed foods or empty calories is mixed. A number of studies have found no association between food insecurity and grain consumption, carbohydrates or protein intake.[121,124,129,130] Further, there is only limited evidence of an association between food insecurity and total fat, saturated fat, and fiber intake.[121,122,124,131] On the other hand, studies using National Health and Nutrition Examination Survey (NHANES) data have observed associations between food insecurity and higher intakes of added sugars and empty calories.[132,133] As Morales and Berkowitz have previously pointed out, the dichotomous definition of food insecurity encompasses a range of severities, therefore it is likely that studies report conflicting results due to the heterogeneity of circumstances captured in the study populations.[134] It is likely that food insecurity can simultaneously result in reduced caloric and nutrient intake, increased caloric and nutrient intake,

or no change in either, depending on the severity, duration, and frequency of food insecurity experienced.[134]

The Cyclical Relationship between Food Insecurity, Toxic Stress and Chronic Disease

Food insecurity is temporal and often cyclical. On average, households that experience food insecurity at some point during the year are food insecure during 7 months over the year.[102] Even within individual months, it is common to have enough food at the beginning of the month and a shortage by the end.[112] On average, SNAP households redeem more than 75% of their benefits by the middle of the month and more than half have exhausted their benefits in those first two weeks.[135]

Alternating between an adequate food supply and food scarcity can lead to periods of overconsumption and weight gain during times of food adequacy and periods of underconsumption and weight loss during times of food shortage.[111] These repeated periods of weight loss and regain form a pattern known as weight cycling and may increase the risk of developing cardiovascular diseases and type II diabetes beyond that of the risks associated with remaining consistently overweight or obese.[136,137] Although the exact mechanisms influencing this increased risk profile are not fully understood, researchers hypothesize that weight cycling leads to the release of inflammatory cytokines from adipose tissue, increasing inflammation to a greater extent than consistent overweight or obesity and sustained inflammation has been associated with increased risks of cardiovascular disease and diabetes.[138–140]

The experience of food insecurity is both psychologically and physically stressful. Exposure to household food insecurity has been associated with stress, depression, anxiety, and suicidal ideation.[141–144] Some have argued that those who perceive greater levels of stress are more vulnerable to negative mental health outcomes.[145] Individual factors are thought to

influence perceived stress. Prior adverse life experiences, especially those experienced during childhood, can increase both perceived stress and susceptibility to associated deleterious mental health outcomes.[145,146] Further, perceived stress may differ by gender and role in the household, with the person primarily involved in managing meals, often women, bearing the brunt of the psychological burden in protecting family members from food insecurity.[147–149]

Additional factors thought to influence the relationship between food insecurity and mental health outcomes include perceived community belonging and level of social support.[145] In qualitative studies, individuals experiencing food insecurity have reported distress, frustration, and despair in the context of insufficient food access.[150–152] Some described limiting social engagements due to lack of food (*"If there is no money to invite someone to your house, how do you make a friend?"; Runnels et al., 2011, p.164)* while others report that family and friends help them get enough food during difficult situations.[150] These informal resources such as eating meals with family members are thought to play an important role in the way individuals perceive stress and may potentially modify the relationship between food insecurity and negative mental health outcomes.[145]

In reaction to sustained stressors, the hypothalamic-pituitary-adrenal axis is activated, releasing cortisol.[112,153] Inhibition of corticotrophin-releasing hormone by cortisol increases orexigenic neuropeptide Y (NPY), which is known to both increase appetite and reduce stress via negative feedback mechanisms resulting in reduced psychological impact of stressors.[154] In the long term, high levels of cortisol are associated with leptin resistance, which will cause leptin to fail to downregulate NPY, resulting in increased appetite, suppresses energy expenditure, and contributes to weight gain.[155,156] Cortisol additionally increases fat deposition into visceral regions.[157,158] Chronically high levels of cortisol are associated with abdominal obesity and can

also cause insulin resistance.[159,160] Further, high levels of circulating insulin interact with cortisol to both promote fat deposition and reduce lipolysis.[156,161]

Simultaneously, reward and memory pathways are activated, increasing hedonic hunger, or hunger resulting from the anticipation of eating palatable food.[162] In animal models, subjects subjected to stress quickly showed preference for high-fat, high-sugar foods and sought that food again even in lower-stress scenarios.[112,153] These pathways are thought to work similarly in humans, with comfort eating triggered by stress hormones and neuropeptides through pathways that increase preference for highly palatable foods.[112,153,163] There is additionally evidence that dopamine receptors are downregulated in response to chronic stress, resulting in the need for greater stimulation to compensate. This has been referred to as a 'reward deficiency syndrome' and has been observed in studies of individuals addicted to cocaine and alcohol as well as in individuals with obesity.[164] However, subsequent studies have found no difference in BMI between those exhibited downregulated dopamine receptor phenotypes and those without.[165] In the long-term, these disruptions in the hypothalamic food intake regulation pathways and increased hedonic hunger can increase risk of abdominal obesity, type II diabetes, and cardiovascular diseases due to alterations in metabolism and food preferences.[112,138–140,153,166]

Scarcity Mindset

These biological responses additionally contribute to a mentality of scarcity, or the diminished cognitive capacity to manage challenges, which can alter decision-making ability and adversely affect diet quality.[167–172] Persistent scarcity and uncertainty limits mental bandwidth, diminishes cognitive capacity, and can cause conflict between immediate and long-term goals.[163,173,174] Constant-trade-off decisions can deplete mental capacity, leading to reduced self-control in a phenomenon known as decision fatigue.[175,176] This scarcity-induced decision fatigue can

additionally lead to discounting of future costs – focusing on the immediate instead of the future and reducing impulse control.[169,177,178] All of these factors can ultimately result in impulsive or comfort eating and the selection of highly palatable foods over more nutritious choices.[112,168,169,179]

Scarcity has been described as "more than just the displeasure of having very little. It changes how we think. It imposes itself on our minds".[167] It is the presence of an unmet need that can become all consuming, as demonstrated in the Minnesota Starvation Experiment. During World War II, volunteers were subjected to starvation in an experiment aimed to observe the body's reaction to hunger and the most effective way to provide rehabilitation afterwards.[180,181] The participants in the study became preoccupied with food, comparing prices of fruits and vegetables from one newspaper to the next and planning future careers in agriculture and restaurants.[181]Hunger had captured their thinking and attention.

Another, later experiment sought to explore how hunger can capture the mind by presenting words close to the threshold of conscious perception, hypothesizing that hungry participants would be more likely to perceive food-related words than sated ones.[182] The participants arrived fasted for at least three hours and half were given a chance to eat lunch while the other half were not. They were then asked to identify 80 words, 20 of which were food-related. The word appeared for 33 milliseconds on the screen, followed by a 33 millisecond blank screen, and a 67 millisecond postmask (i.e., "&&&&&&"). Participants were then asked to rate the visibility of the word before choosing between two words, one being the target and the other a similar foil (ie. Cake-Sake) which was used to create a perceptual sensitivity index (d'). A greater d' indicates greater perceptual processing of the stimuli. Hunger did not affect the reported visibility of neutral words, $t(40) = 0.48$, n.s., but the fasted participants rated the

visibility of the food-related words higher (M = 5.48, SD = 1.42) than the satiated participants (M = 4.52, SD = 1.51), t(40) = 2.06, p <0.05. Similarly, there was no effect of hunger on the perceptual processing of neutral words t(40) = 0.39, n.s., but fasted participants had a greater awareness of food-related words (M = 0.63, SD = 0.14) than the satiated participants (M = 0.51, SD = 0.20), t(40) = 2.27, p<0.05. Their results imply that the stimuli were processed unconsciously and the stimuli most relevant to participants' goals were most likely to be selected to reach consciousness.[182] This may, in part, explain how scarcity can cause intrusive thoughts and capture attention and energy.

In a scarcity state, where needs are unmet, trade-off decisions must be made. Households served by the Feeding America network reported having to choose between paying for food and paying for medical care (65.9%), utilities (69.3%), housing (57.1%), or transportation (66.5%) at some point in the last 12 months.[183] Recent studies have shown that when people make choices, they draw from a finite pool of executive resources, or mental energy.[184–188] This concept, known as decision fatigue, is offered as an explanation for impaired decision making in situations where people are forced to make many trade-off decisions.[189] In a state of decision fatigue, self-regulation is impaired, which can lead to poor dietary choices and lack of exercise.[188,190]

Food Security Interventions

Recognizing the important links between food security and health, a variety of programs and policies have been developed to address the issue. These interventions can generally be classified into three groups: federal nutrition programs, food banks and food pantries, and community food programs.[191] In the United States, the largest federal response to food insecurity is the Supplemental Nutrition Assistance Program (SNAP), which distributed an average of $154.81 for food purchases to approximately 40 million people every month during 2020.[192] Additional

federal nutrition programs include the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC program), the National School Lunch program, and The Emergency Food Assistance Program, all of which target specific populations at risk of nutritional inadequacy.[191] In contrast to these broad federal programs, food banks and food pantries are more localized organizations that provide free groceries to people seeking their assistance.[191] These are often run as non-profit community- or faith-based organizations and, although clients may use them regularly, they are largely viewed as a resource for emergency food provision.[191] Community food programs are more varied but typically aim to address food insecurity by teaching skills to stretch limited budgets and increasing access to food through price discounts, providing space to grow food, and/or food box programs.[191]

SNAP: A Brief History

Since 1939, the U.S. has run food-specific social security programs in various forms.[193] The first iteration of SNAP began as part of the New Deal, introducing Food Stamps as a solution to growing agricultural surpluses and widespread food insecurity.[193] Low-income individuals could purchase orange stamps equivalent to their typically food purchases and would receive a corresponding number of blue stamps (at a ratio of 2:1), which could then be used to purchase surplus food such as beans, flour, corn meal, eggs, and fresh vegetables.[193] While this original program was discontinued in 1943 during a period of economic prosperity, it was later reintroduced with John F. Kennedy's 1st Executive Order in 1961, establishing several food stamp pilot programs.[193] This was later cemented with the Food Stamp Act of 1964.[193]

The program continued to evolve over time, with funding following political cycles. With the Food Stamp Act of 1977, the requirement to purchase stamps was eliminated and eligibility standards were set nationwide.[193] By 1981, participation in the program hit a record high of 22.4

million people.[193] Despite the growth of the program, major budget cuts and additional eligibility criteria were introduced in 1981 & 1982.[193] As food insecurity rates increased, the number of food stamp participants decreased to 18.6 million in 1988. Recognizing this issue, improvements were introduced to the program in 1988 & 1990 including the reinstatement of categorical eligibility, increases to benefits, and the introduction of optional outreach and nutrition education activities for states.[193] Uptake of this program was slow, with just seven states establishing such programs by 1992. It wasn't until nearly twenty years later, in 2004, that all 50 states began conducting nutrition education programs.[193]

In the late 1990s to early 2000s, physical food stamps were phased out in favor of Electronic Benefits Transfer (EBT) cards that work similarly to credit and debit cards, transferring government benefits from a federal account to the retailer.[193] This not only improved ease of use for program participants, but it also helped to decrease stigma associated with using food stamps for purchases since the cards are more discreet than the physical stamps. The 2008 Farm Bill introduced the modern name of the program: SNAP, increased funding for the program including increases to the minimum benefit and an expansion of eligibility criteria, and introduced nutrition incentive programs.[193] These incentive programs began as pilots to study the use of incentives to encourage the purchase of healthy foods with SNAP benefits.[193] The modern form of these incentive programs fall under the Gus Schumacher Nutrition Incentive Program (GusNIP), providing funding to conduct and evaluate projects providing incentives to increase consumption of fruits and vegetables for low-income individuals.[194] GusNIP funds two types of nutrition incentive projects: 1) point-of-purchase incentives such as programs that double the value of SNAP dollars at farmers markets and 2) produce prescription programs which offer vouchers redeemable for fruits and vegetables alongside nutrition education.[194]

Throughout its history, SNAP has sought to provide a social safety net and alleviate food insecurity for households and individuals in need.[193] Despite fluctuations related to political shifts, the program has been shown to be effective at improving food security, improving children's health and academic performance, supporting economic growth, and lifting people out of poverty.[195,196]

SNAP & Food Insecurity Patterns Among Recipients

SNAP is a means-tested program, meaning eligibility is limited to individuals and families whose incomes and assets fall below pre-set thresholds. Current criteria require households have no more than $2,500 in assets and savings, a gross monthly income at or below 130% of the poverty line (~$28,550 per year for a family of 3), and a net income at or below the poverty line (~$21,960 for a family of 3).[197] Given these strict criteria, it is no surprise that food insecurity rates are high among SNAP recipients. However, not all food insecure households participate. About 55% of food insecure households surveyed in the Community Population Survey reported participating in SNAP or other federal nutrition assistance programs.[92] However, by some estimates, prevalence of food insecurity is twice as high among SNAP recipients compared to non-participating households with qualifying incomes.[198] Feeding America estimates that just 41% of their affiliate food bank clients receive SNAP benefits when more than 88% may be eligible.[183] Households facing greater financial hardships and more severe food insecurity are more likely to join the program.[198,199]

Despite these self-selection effects, studies have shown that participation in SNAP is associated with significant declines in food insecurity, ranging from 19% to 33%.[200] Ratcliffe & McKernan reported receiving SNAP benefits reduces the likelihood of being food insecure by approximately 30%.[201] Additionally, severity of food insecurity is reduced among those who

remain food insecure despite receiving benefits, with the receipt of SNAP benefits reducing the likelihood of being very food insecure by 20%.[201]

Although SNAP participation is associated with reductions in food insecurity, rates of food insecurity among SNAP recipients remain elevated beyond that of the overall population, even after excluding new recipients. This potentially suggests that the levels of support offered by the program falls short of providing food security. A 2018 USDA study revealed that 88% of SNAP participants reported facing at least one barrier to achieving a healthy diet throughout the month, with the most common being the affordability of healthy foods (61%).[202] Further, more than 80% of SNAP benefits are spent within the first two weeks of receipt.[203]

Recently, the USDA conducted a reevaluation of the Thrifty Food Plan, which estimates the minimum cost of a weekly basket of foods and beverages that can be purchased to support a healthy diet through nutritious meals and snacks at home.[204] This plan is used to calculate the amount of benefits SNAP participants receive. The reevaluation concluded that the cost of a nutritious, practical, and cost-effective diet is 21% higher than the previous Thrifty Food Plan had estimated.[205] In response, SNAP benefits were permanently increased by $36.24 per person per month.[205] This figure is excluding additional funds provided as part of pandemic relief which temporarily increased benefits by 15% and is set to expire in fiscal year 2022.[205]

While this increase in benefits is helpful, more work can be done to improve access to and uptake of the program. The Robert Wood Johnson Foundation identified a series of steps to further strengthen SNAP including a focus on ensuring that all eligible people can access the program, especially immigrants, people of color, and rural residents.[206] Additionally, they suggest expanding eligibility to cover more people, expanding nutrition incentive programs to help participants stretch their SNAP dollars and make healthy food purchases, and eliminating

lifetime bans on SNAP participation for convicted drug felons.[206]

Food Banks & Food Pantries

In contrast to the large national programs that address food insecurity like SNAP, food banks and food pantries are localized, charitable organizations addressing food needs in communities. In the US, food banks and food pantries serve over 46.5 million people each year.[183] They aim to prevent people from going hungry, whether in the short or the long term. Unsurprisingly, food insecurity rates are high among those making use of food banks. Feeding America's Hunger in America National Report estimated that 84% of clients accessing their partner distribution agencies were food insecure.[183]

Systematic reviews have reported associations between food bank use and improvements in food security, diet, cooking skills, health literacy, nutrition knowledge, and/or health outcomes.[207,208] However, a lack of consistency in measurements and outcomes between studies precluded the authors' ability to conduct meta-analyses.[207,208] Some evidence suggests that a client-choice model wherein food bank clients select food from an offering of goods is more effective at meeting clients' needs and improves food security beyond that of a traditional pre-selected provision of food model.[209]

The nutritional quality and quantity of foods provided from food banks varies widely. A review of studies examining nutritional quality of foods provided by food banks reported insufficient amounts of fruits and vegetables and milk products along with insufficient amounts of calcium, vitamin A, and vitamin C.[191,210] Further, multiple studies among food bank users have reported feelings of shame related to food bank usage.[128,191,211] Other research indicates households consider food banks a last resort, with some reporting to go without food rather than

turn to charity.[212]

While food banks play an important role in providing an immediate solution to severe food deprivation, cumulatively, studies on food banks' charitable food provision suggest inherent limitations in their ability to meet the needs of food insecure populations. Issues with unreliable sourcing of foods, potentially limited nutritional value of distributed foods, lack of social acceptability among some food insecure individuals, and the complications of evaluating the effectiveness of efforts present challenges for food banks.[191] However, they fill a critical gap for many households who rely on them and are able to provide food quicky when it is needed. In addition to filling these important gaps for communities, food pantries are an ideal setting for offering additional services to highly vulnerable populations.

Food Security Interventions in Healthcare Settings

Within the last ten years, interest has grown in identifying & addressing food insecurity in the healthcare setting. Many professional medical societies now recommend the integration of food security screening and resource referrals into standard care. Many hospitals and clinics have integrated routine food security screening using the Children's HealthWatch Hunger Vital Sign tool.[97] This two-question tool is based on the USDA's household food security scale and asks the following questions:

- "Within the past 12 months, we worried whether our food would run out before we got money to buy more." Was that often true, sometimes true or never true for your household?
- "Within the past 12 months, the food we bought just didn't last, and we didn't have money to get more." Was that often true, sometimes true or never true for your household?

Using Grady Health System as an example, routine food security screening is currently conducted in 10 clinics across the system. The system's goal is to have all clinics routinely screening by 2022. When a patient screens positive for food insecurity, providers receive a Best Practice Alert, a pop-up screen that appears in the patient's medical record, until a referral is made connecting the patient to food resources. A list of resources is available in the medical record that can be provided to patients screening positive. Some of these resources are community-based such as food pantries and SNAP application assistance, while others are provided through the health system itself. The Fresh Food Cart is one such program, providing 20 lbs. of fresh produce and healthy recipes for pick-up up to twice per month. Patients with additional health risk factors (HbA1c > 9% or blood pressure > 140/90 mmHG) are eligible for a more intensive program that provides nutrition education and cooking classes in addition to free produce available for pick up every two weeks for up to one year.

Across studies reporting on referral-based interventions in healthcare settings, rates of patients receiving referrals range from 30% - 75%.[213] Three studies across diverse populations (one in rural South Carolina, one in Michigan, and the other in California) reported moderate increases in patients' use of food resources (pooled standardized mean difference (SMD): 0.54, 95% CI: 0.31, 0.78). Results from 2 randomized control trials (RCT)s indicate that providers were more likely to refer patients to resources if screening is conducted before the patient is seen, such as through a self-completed form or by a medical assistant earlier in the visit (SMD: 1.42, 95% CI: 0.76, 2.08 & SMD: 0.67, 95% CI: 0.36, 0.98).[213] In a separate RCT, there was no reported difference in interest or use of food resources between patients who received referrals as needed and those who received additional navigational support with referrals (SMD: 0.18, 95% CI: -0.08, 0.43).[213]

Despite the proliferation of routine food security screening in healthcare settings, the two studies reporting on food security outcomes did not use a validated screening tool to assess food insecurity after referrals. One such study reported that 58% of patients (n=7) reported their food-related concerns had been resolved and a separate qualitative study found that caregivers of pediatric patients (n=32) reported improved access to and consumption of fresh fruits & vegetables after the clinic introduced an on-site farmers market and began distributing food vouchers to shop at the market.[213–215] Other studies reporting on changes in fruit & vegetable consumption after referral interventions showed no intervention effect when pooled (pooled SMD: -0.03, 95% CI: -0.66, 0.61).[213] Potentially the dose or duration of the intervention was insufficient to influence consumption or follow-up periods were too long or too short to observe changes.

Few studies have reported on health or healthcare utilization outcomes and, of those, reported effect sizes are small and variability in outcome measures across studies preventing pooling.[213] However, interventions targeting patients with greater health risks (such as uncontrolled diabetes or hypertension) and offering more services such as nutrition education and vouchers for free produce have reported modest reductions in Hba1c (-0.71%; p=0.001) and BMI (-0.74 kg/m^2; p= 0.02).[213,216,217] These programs, often referred to as produce prescription programs, are among the most intensive food-related interventions offered in healthcare settings.

Produce Prescription Programs

Produce prescription (PRx) programs are designed to address the relationship between food insecurity and chronic disease by providing free fruits and vegetables. While implementation of these programs varies widely, most often incorporate nutrition education and some offer additional supports such as cooking classes. Patients are typically referred to the program by a

healthcare provider who identifies patients based on food insecurity and/or chronic disease risks factors such as diabetes, obesity, and/or hypertension. Produce provision varies across programs as well, with uptake options typically including redemption of vouchers at local food stores or farmers markets, directly at the healthcare center, or through home-delivery.

PRx programs operate through a partnership model of care that involves a healthcare provider, typically the referring clinician, rewarding and positively reinforcing repeated health-seeking behaviors.[218–220] Financial incentive models, including PRx programs, are informed by the principles of operant conditioning, whereby behaviors eliciting rewards are repeated.[221,222] Thus, incentives may act as a catalyst to engage in a behavior, and repeated engagement may become intrinsically motivating, facilitating sustained behavior change.[219] Some produce Rx programs additionally incorporate group-based nutrition education and cooking sessions.[223–228] Nutrition education increases knowledge and awareness while hands-on cooking sessions provide skills and increase self-efficacy to engage in the behavior.[229–232] These behaviors are reinforced through educational sessions involving peer and provider support.[218,219,229,233]

Food security and diet outcomes: There is consistent evidence that produce Rx programs increase food security ranging from 18% -94% relative to baseline [225,227,234–237] and increase mean fruit & vegetable consumption by 0.3-2 servings/day across studies.[224,225,227,236,238–240] A recent meta-analysis estimated that produce Rx programs are associated with increases in fruit and vegetable consumption by 22%, corresponding to an increase of 0.8 daily servings.[241] However, among the studies reporting on these outcomes, the majority used a pre-post study design and did not include a comparison group. There are two notable exceptions.[227,236] One program, Vouchers 4 Veggies, was conducted in a population of pregnant WIC participants

in San Francisco, offering $40 vouchers redeemable for fruits and vegetables in addition to the standard WIC benefit of $11 per month for fruits and vegetables.[227] Comparing 592 Vouchers 4 Veggies participants to 108 non-pregnant women participating in WIC at the same clinics, the authors found that among those who were food insecure at baseline, a significantly greater proportion of the intervention group compared to the comparison group were food secure at follow-up (23% vs. 14%, p=0.04).[227] A difference-in-differences analysis showed Vouchers 4 Veggies participants increased mean produce intake frequency above controls by 0.19 (95% CI: -0.11, 0.49) times per day for fruit and by 0.59 (95% CI: 0.16, 1.02) times per day for vegetables.[227]

Another study by Berkowitz et al. used a randomized control trial design wherein individuals with BMI > 25 kg/m^2 recruited from a community health center in Massachusetts were randomized to either receive subsidized community-supported agriculture (CSA) memberships for 24 weeks (lasting a growing season) or healthy eating information and equivalent financial incentives to that of the CSA group ($300).[236] Among those who received the CSA, food security increased by 65%.[236] In comparison, food security among controls increased by 24%.[236] Adjusting for baseline security, the authors calculated a risk ratio of food insecurity among CSA participants compared to controls of 0.68 (95% CI: 0.48, 0.96).[236] Those who received the CSA increased mean Healthy Eating Index score beyond that of the control group (4.3 points higher, 95% CI: 0.5, 8.1; p=0.03).[236]

While these two studies robustly demonstrate improvements in food security and diet outcomes after participation in PRx programs, neither intervention studied included lessons on nutrition education. Future work exploring these outcomes should investigate the added benefit, or lack thereof, of including additional components such as nutrition education and cooking

classes. Further, many of these studies included patient populations recruited from the Northeast region of the U.S., primarily Massachusetts, Delaware, Maine, Rhode Island, and New York, indicating potential issues with generalizability of the collective research on PRx programs. Just four studies reporting on food security or diet outcomes were identified including primarily non-white populations: one, a study implemented in Ohio with a primarily black population,[239] another, a study of three programs implemented in primarily black populations in Georgia,[237] another, including a primarily black population in South Carolina,[240] and the last, implemented in a primarily Hispanic population in Texas.[235] More research is needed to understand the applicability and transportability of PRx programs to diverse populations and what augmentations to program design or content are needed to ensure cultural appropriateness.

Health Outcomes: Few studies have reported on health outcome measures and overall results have been mixed. A recent meta-analysis pooled outcomes from 2 studies reporting on plasma lipids, 3 reporting on BMI, 4 reporting on blood pressure, and 5 reporting on HbA1c.[241] Their analysis estimated that produce Rx programs are associated with decreases in BMI of 0.6 kg/m2 (95% CI: 0.2, 1.1) and HbA1c of 0.8% (95% CI: 0.1, 1.6).[241] In this meta-analysis, no significant changes were observed for blood pressure or lipid outcomes. However, individual studies have reported significant changes in blood pressure outcomes.[224,236–238] Berkowitz et al. reported a significantly greater reduction in diastolic blood pressure among CSA members compared to controls of 3.66 mmHg (95% CI: -6.27, -1.05).[236] The authors did not observe significant differences in other anthropometric measures examined including BMI, systolic blood pressure, HbA1c, or plasma lipids.[236] Emmert-Aronson et al., used repeated measures to evaluate their clinic-based Open Source Wellness model involving 16 weeks of weekly two-hour meetings

including physical activity, mindfulness mediation, interactive health and nutrition lessons, small-group coaching over a meal, and the provision of vouchers worth $10 redeemable for produce at the on-site Food Farmacy.[224] Participants with hypertension in this study experienced significant reductions in systolic blood pressure of 4.04 mmHg ($p<0.01$) but not diastolic blood pressure. Participants showed statistically significant but clinically marginal reductions in BMI of 0.19 kg/m^2 ($p=0.05$).[224]

While more published evidence supports findings related to BMI and HbA1c, studies reporting on blood pressure and other health indicators have reported mixed results. Stronger evidence is needed to demonstrate effectiveness of PRx programs for improving chronic disease risk factors. Similar to studies reporting on food security and diet outcomes, those reporting on health outcomes have largely been conducted in homogenous white populations. A few exceptions worth noting include one conducting in Detroit, Michigan including a largely Hispanic sample,[216] another conducted in Albany, New York among a 54% black population,[217] and the last, previously mentioned, conducted across three sites in Georgia including a predominantly black population.[237]

Large variations between program implementation make it difficult to compare results across studies. While some programs provide nutrition incentives only, others, such as the Open Source Wellness model include a variety of program components. As programs continue to expand and more research focuses on best practices for populations based on geographic and demographic characteristics, it will be useful to understand which program components are most effective and the populations most likely to benefit from their incorporation into existing offerings.

Barriers and Facilitators to Participation: In addition to diet and health outcomes, a number of studies have included a qualitative research component, with most focusing on understanding barriers and facilitators to participation and program implementation.[242–249] Multiple studies reported themes related to structural barriers to patient participation in PRx programs including lack of access to transportation and less often, lack of equipment to store and cook food at home.[242,244,245,248,249] Sustainability of changes adopted during the program were a concern identified in multiple studies and participants discussed affordability of healthy food items as a continued barrier to diet behavior change.[242,243,248] These insights indicate the potential benefit of follow-on programs for improving sustainability of adopted diet behavior change. A few studies identified themes related to social interaction within the program, with many discussing how a supportive group of peers enhanced program experience.[243,247,249] Further research is needed to understand how flexibility in program model, follow-on programs supporting sustainability of behavior change, and social support provided by PRx programs can improve the participant experience and enhance ability to adopt healthy eating behaviors.

While PRx programs show promise in improving food security, diet, and health outcomes, additional research is needed to understand how and for whom they work. More evidence is needed to evaluate the effectiveness of PRx programs for improving chronic disease risk factors. Among studies reporting health outcomes, only one used longitudinal data[224] and none to our knowledge has used multiple years of program data. Further, no studies including health outcomes have been conducted in the Southeastern U.S. or with predominantly black participants. Additionally, to our knowledge, no study has performed pathway analyses investigating the mechanism of action by which these programs operate, nor performed qualitative analyses exploring the role of stress in program adoption and implementation.

References

1. Centers for Disease Control and Prevention; National Center for Chronic Disease Prevention and Health Promotion; About Chronic Diseases. https://www.cdc.gov/chronicdisease/about/index.htm. Accessed August 2, 2021.
2. Dietary Guidelines Advisory Committee. *Scientific Report of the 2020 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Agriculture and the Secretary of Health and Human Services*. Washington, DC; 2020.
3. U.S Department of Agriculture; U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2020-2025*.; 2020.
4. World Health Organization. *Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020*.; 2013.
5. Lim SS, Voz T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2224-2260.
6. Centers for Disease Control and Prevention; National Center for Chronic Disease Prevention and Health Promotion; Chronic Diseases in America. https://www.cdc.gov/chronicdisease/resources/infographic/chronic-diseases.htm. Accessed August 2, 2021.
7. Boersma P, Black LI, Ward BW. Prevalence of multiple chronic conditions among US adults, 2018. *Preventing Chronic Disease*. 2020.
8. Agborsangaya CB, Lau D, Lahtinen M, Cooke T, Johnson JA. Health-related quality of life and healthcare utilization in multimorbidity: Results of a cross-sectional survey. *Quality of Life Research*. 2013.
9. Partnership for Solution. Chronic Conditions : Making the Case for Ongoing Care. *Johns Hopkins University*. 2004.
10. Lee TA, Shields AE, Vogeli C, et al. Mortality rate in veterans with multiple chronic conditions. In: *Journal of General Internal Medicine*. ; 2007.
11. Weisz G. *Chronic Disease in the Twentieth Century: A History*. Johns Hopkins University Press; 2014.
12. Foody JAM, Mendys PM, Liu LZ, Simpson RJ. The utility of observational studies in clinical decision making: Lessons learned from statin trials. *Postgraduate Medicine*. 2010.
13. Remington PL, Brownson RC, Centers for Disease Control. Fifty years of progress in chronic disease epidemiology and control. *MMWR Surveillance summaries : Morbidity and mortality weekly report Surveillance summaries / CDC*. 2011.
14. Marmot MG, Rose G, Shipley M, Hamilton PJS. Employment grade and coronary heart disease in British civil servants. *Journal of Epidemiology and Community Health*. 1978.
15. Berkman LF, Kawachi I, Glymour MM. *Social Epidemiology Second Edition*.; 2014.
16. Kochanek K, Xu J, Arias E. *Mortality in the United States, 2019*.; 2019.
17. World Health Organization. Cardiovascular diseases (CVDs). https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds). Accessed August 2, 2021.
18. Fryar CD, Carroll MD, Afful J. Prevalence of Overweight, Obesity, and Severe Obesity Among

Adults Aged 20 and Over: United States, 1960–1962 Through 2017–2018. *National Center for Health Statistics*. 2020.
19. Ogden CL, Carroll MD. *Prevalence of Overweight, Obesity, and Extreme Obesity Among Adults: United States, Trends 1960-62 Through 2007-2008*.; 2010.
20. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of Obesity and Severe Obesity Among Adults: United States, 2017-2018. *NCHS data brief*. 2020.
21. U.S. Department of Health and Human Services. Managing Overweight and Obesity in Adults: Systematic Evidence Review from the Obesity Expert Panel. *National Heart, Lung, and Blood Institute*. 2013.
22. Glickman D, Parker L, Sim LJ, del Valle Cook H, Miller EA. *Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation*.; 2012.
23. Afshin A, Sur PJ, Fay KA, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2019.
24. World Health Organization. Cardiovascular diseases (CVDs). Fact Sheets. https://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds). Published 2021.
25. National Center for Health Statistics, Centers for Disease Control and Prevention. Leading Causes of Death. FastStats. https://www.cdc.gov/nchs/fastats/leading-causes-of-death.htm. Published 2021.
26. Chobanian A V., Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: The JNC 7 Report. *Journal of the American Medical Association*. 2003.
27. Fuchs FD, Whelton PK. High Blood Pressure and Cardiovascular Disease. *Hypertension*. 2020.
28. Vasan RS, Beiser A, Seshadri S, et al. Residual lifetime risk for developing hypertension in middle-aged women and men: The Framingham Heart Study. *Journal of the American Medical Association*. 2002.
29. Myers RH, Kiely DK, Cupples LA, Kannel WB. Parental history is an independent risk factor for coronary artery disease: The Framingham Study. *American Heart Journal*. 1990.
30. Williams RR, Hunt SC, Hasstedt SJ, et al. Are there interactions and relations between genetic and environmental factors predisposing to high blood pressure? *Hypertension*. 1991.
31. Krauss RM, Winston M, Fletcher BJ, Grundy SM. Obesity: Impact on Cardiovascular Disease. *Circulation*. 1998;98(14):1472-1476.
32. Luft FC, Weinberger MH. Sodium Intake and Essential Hypertension. *Hypertension*. 1982.
33. Karppanen H, Mervaala E. Sodium Intake and Hypertension. *Progress in Cardiovascular Diseases*. 2006.
34. Grillo A, Salvi L, Coruzzi P, Salvi P, Parati G. Sodium intake and hypertension. *Nutrients*. 2019.
35. Lelong H, Blacher J, Baudry J, et al. Combination of healthy lifestyle factors on the risk of hypertension in a large cohort of french adults. *Nutrients*. 2019;11(7).
36. Beilin LJ, Puddey IB, Burke V. Lifestyle and hypertension. *American Journal of Hypertension*. 1999;12(9 I).
37. Husain K, Ansari RA, Ferder L. Alcohol-induced hypertension: Mechanism and prevention. *World Journal of Cardiology*. 2014;6(5).
38. Puddey IB, Mori TA, Barden AE, Beilin LJ. Alcohol and Hypertension—New Insights and Lingering Controversies. *Current Hypertension Reports*. 2019;21(10).
39. Khosla I, Khosla GC. Saturated fats and cardiovascular disease risk: A review. *Journal of Clinical and Preventive Cardiology*. 2017;6(2).

40. Siri-Tarino PW, Sun Q, Hu FB, Krauss RM. Meta-analysis of prospective cohort studies evaluating the association of saturated fat with cardiovascular disease. *American Journal of Clinical Nutrition*. 2010;91(3).
41. Hooper L, Martin N, Jimoh OF, Kirk C, Foster E, Abdelhamid AS. Reduction in saturated fat intake for cardiovascular disease. *Cochrane Database of Systematic Reviews*. 2020;2020(8).
42. Siri-Tarino PW, Sun Q, Hu FB, Krauss RM. Saturated fat, carbohydrate, and cardiovascular disease. *American Journal of Clinical Nutrition*. 2010;91(3).
43. Ganguly R, Pierce GN. Trans fat involvement in cardiovascular disease. *Molecular Nutrition and Food Research*. 2012;56(7).
44. Juraschek SP, Miller ER, Weaver CM, Appel LJ. Effects of Sodium Reduction and the DASH Diet in Relation to Baseline Blood Pressure. *Journal of the American College of Cardiology*. 2017.
45. Insel P, Ross D, McMahon K, Bernstein M. *Nutrition*. Sixth. Burlington, Massachusetts: Jones & Bartlett Learning; 2017.
46. van Duyn MAS, Pivonka E. Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: Selected literature. *Journal of the American Dietetic Association*. 2000;100(12).
47. Slavin JL, Lloyd B. Health benefits of fruits and vegetables. *Advances in Nutrition*. 2012;3(4).
48. Stipanuk MH, Caudill MA. *Biochemical, Physiological, and Molecular Aspects of Human Nutrition*. Third. St. Louis, Missouri: Elsevier Inc.; 2013.
49. Ferrier DR. *Lippincott's Illustrated Reviews, Biochemistry*. Sixth. (Harvey RA, ed.). Baltimore, Maryland: Lippincott Williams & Wilkins, Wolters Kluwer; 2014.
50. Behrens G, Gredner T, Stock C, Leitzmann MF, Brenner H, Mons U. Cancers Due to Excess Weight, Low Physical Activity, and Unhealthy Diet. *Deutsches Aerzteblatt Online*. 2018.
51. Division of Cancer Prevention and Control C for DC and P. Obesity and Cancer.
52. Vucenik I, Stains JP. Obesity and cancer risk: Evidence, mechanisms, and recommendations. *Annals of the New York Academy of Sciences*. 2012;1271(1).
53. Avgerinos KI, Spyrou N, Mantzoros CS, Dalamaga M. Obesity and cancer risk: Emerging biological mechanisms and perspectives. *Metabolism: Clinical and Experimental*. 2019;92.
54. Key TJ, Bradbury KE, Perez-Cornago A, Sinha R, Tsilidis KK, Tsugane S. Diet, nutrition, and cancer risk: What do we know and what is the way forward? *The BMJ*. 2020;368.
55. Bojková B, Winklewski PJ, Wszedybyl-Winklewska M. Dietary fat and cancer—which is good, which is bad, and the body of evidence. *International Journal of Molecular Sciences*. 2020;21(11).
56. Zhao Z, Feng Q, Yin Z, et al. Red and processed meat consumption and colorectal cancer risk: A systematic review and meta-analysis. *Oncotarget*. 2017;8(47).
57. Hur SJ, Yoon Y, Jo C, Jeong JY, Lee KT. Effect of Dietary Red Meat on Colorectal Cancer Risk—A Review. *Comprehensive Reviews in Food Science and Food Safety*. 2019;18(6).
58. Aykan NF. Red meat and colorectal cancer. *Oncology Reviews*. 2015;9(1).
59. Fuchsberger C, Flannick J, Teslovich TM, et al. The genetic architecture of type 2 diabetes. *Nature*. 2016;536(7614).
60. Mambiya M, Shang M, Wang Y, et al. The Play of Genes and Non-genetic Factors on Type 2 Diabetes. *Frontiers in Public Health*. 2019;7.
61. Schnurr TM, Jakupović H, Carrasquilla GD, et al. Obesity, unfavourable lifestyle and genetic risk of type 2 diabetes: a case-cohort study. *Diabetologia*. 2020;63(7).
62. Khazrai YM, Defeudis G, Pozzilli P. Effect of diet on type 2 diabetes mellitus: A review.

Diabetes/Metabolism Research and Reviews. 2014;30(S1).
63. Wake AD. Antidiabetic effects of physical activity: How it helps to control type 2 diabetes. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*. 2020;13.
64. Hamasaki H. Daily physical activity and type 2 diabetes: A review. *World Journal of Diabetes*. 2016;7(12).
65. Petermann F, Díaz-Martínez X, Garrido-Méndez Á, et al. Association between type 2 diabetes and physical activity in individuals with family history of diabetes. *Gaceta Sanitaria*. 2018;32(3).
66. Al-Goblan AS, Al-Alfi MA, Khan MZ. Mechanism linking diabetes mellitus and obesity. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*. 2014;7.
67. Barnes AS. The epidemic of obesity and diabetes: Trends and treatments. *Texas Heart Institute Journal*. 2011;38(2).
68. Kaur J. A comprehensive review on metabolic syndrome. *Cardiology Research and Practice*. 2014;2014.
69. Kendall DM, Harmel AP. The metabolic syndrome, type 2 diabetes, and cardiovascular disease: Understanding the role of insulin resistance. *American Journal of Managed Care*. 2002;8(20 SUPPL.).
70. Hirode G, Wong RJ. Trends in the Prevalence of Metabolic Syndrome in the United States, 2011-2016. *JAMA - Journal of the American Medical Association*. 2020;323(24).
71. World Health Organization. "Best buys" and other recommended interventions for the prevention and control of noncommunicable diseases. *World Health Organisation*. 2017;17(9).
72. World Health Organization. *Interventions on Diet and Physical Activity: What Works?*; 2009.
73. Downs SM, Bloem MZ, Zheng M, et al. The impact of policies to reduce trans fat consumption: A systematic review of the evidence. *Current Developments in Nutrition*. 2018;1(12).
74. Thomson CA, Ravia J. A Systematic Review of Behavioral Interventions to Promote Intake of Fruit and Vegetables. *Journal of the American Dietetic Association*. 2011.
75. Rekhy R, McConchie R. Promoting consumption of fruit and vegetables for better health. Have campaigns delivered on the goals? *Appetite*. 2014;79.
76. World Health Organization. *Tackling NCDs - Best Buys*.; 2017.
77. Sorensen G, Stoddard A, Peterson K, et al. Increasing fruit and vegetable consumption through worksites and families in the Treatwell 5-a-Day study. *American Journal of Public Health*. 1999;89(1).
78. Steyn NP, Parker W, Lambert E v., Mchiza Z. Nutrition interventions in the workplace: Evidence of best practice. *South African Journal of Clinical Nutrition*. 2009;22(3).
79. Mabli J, Gearan E, Cohen R, et al. *Evaluation of the Effect of the Older Americans Act Title III-C Nutrition Services Program on Participants' Food Security, Socialization, and Diet Quality*.; 2017.
80. The Diabetes Prevention Program (DPP): Description of lifestyle intervention. *Diabetes Care*. 2002;25(12).
81. Allaire BT, Tjaden AH, Venditti EM, et al. Diet quality, weight loss, and diabetes incidence in the Diabetes Prevention Program (DPP). *BMC Nutrition*. 2020;6(1).
82. Diabetes Prevention Program Research Group. Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin. *New England Journal of Medicine*. 2002.
83. Diabetes Prevention Program Research Group. 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. *The Lancet*. 2009;374(9702).
84. Whittemore R. A systematic review of the translational research on the Diabetes Prevention

Program. *Translational Behavioral Medicine*. 2011;1(3).
85. Appel LJ, Moore TJ, Obarzanek E, et al. A Clinical Trial of the Effects of Dietary Patterns on Blood Pressure. *New England Journal of Medicine*. 1997;336(16).
86. United States Department of Agriculture, Economic Research Service. Definitions of Food Security. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx. Published 2021.
87. United States Department of Agriculture, Economic Research Service. Trends in U.S. food security. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/interactive-charts-and-highlights/#trends. Published 2021.
88. United States Department of Agriculture Economic Research Service. Food security in the U.S.: Key statistics and graphics.
89. Swindale A, Bilinsky P. Development of a universally applicable household food insecurity measurement tool: Process, current status, and outstanding issues. *Journal of Nutrition*. 2006;136(5).
90. Swindale A, Bilinsky P. Household Dietary Diversity Score (HDDS) for measurement of household food access: Indicator guide. *Food and Nutrition Technical Assistance …*. 2006.
91. Deitchler, M. Ballard, T. Swindale, A. & Coates J. Introducing a Simple Measure of Household Hunger for Cross-Cultural Use. *Washington, DC: Food and Nutrition …*. 2011;(2010).
92. Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A. *Household Food Security in the United States in 2020*.; 2021.
93. Bickel G, Nord M, Price C, Hamilton W, Cook J. Measuring Food Security in the United States Guide to Measuring Household Food Security Revised 2000. *United States Department of Agriculture*. 2000.
94. Economic Research Service, USDA. U.S. Household Food Security Survey Module: Three-Stage Design, With Screeners. 2012.
95. Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the household food security scale. *American Journal of Public Health*. 1999.
96. Blumberg J, Bialostosky K, Hamilton WL, Briefel RR. *U.S. Household Food Security Survey Module: Six-Item Short Form*.; 1999.
97. Hager ER, Quigg AM, Black MM, et al. Development and validity of a 2-item screen to identify families at risk for food insecurity. *Pediatrics*. 2010.
98. Food Research & Action Center, American Academy of Pediatrics. Screen and Intervene: A Toolkit for Pediatricians to Address Food Insecurity. 2021.
99. Nitkin K. A New Way to Document Social Determinants of Health. *BestPractice News*. 2019.
100. Gundersen C, Ziliak JP. Food insecurity and health outcomes. *Health Affairs*. 2015;34(11).
101. United States Department of Agriculture, Economic Research Service. Food Security in the U.S.: Key Statistics and Graphics. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics/. Published 2021.
102. Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A. *Household Food Security in the United States in 2020*.; 2021.
103. Bartfeld J, Dunifon R. State-level predictors of food insecurity among households with children. *Journal of Policy Analysis and Management*. 2006.
104. Bartfeld J, Men F. Food insecurity among households with children: The role of the state economic and policy context. *Social Service Review*. 2017.
105. United States Department of Agriculture, Economic Research Service. Interactive Charts and Highlights. Food Security in the United Sates: How do States compare?

https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/interactive-charts-and-highlights/#States. Published 2021.
106. Feeding America. Map the Meal Gap Interactive Map. Food Insecurity in Georgia: Before COVID-19. https://map.feedingamerica.org/county/2019/overall/georgia. Published 2021.
107. Gregory CA, Mancino L, Coleman-Jensen A. *Food Security and Food Purchase Quality among Low-Income Households: Findings from the National Household Food Acquisition and Purchase Survey (FoodAPS).*; 2019.
108. Drewnowski A, Specter SE. Poverty and obesity: the role of energy density and energy costs. *The American journal of clinical nutrition*. 2004;79(1):6-16. http://www.ncbi.nlm.nih.gov/pubmed/14684391.
109. United States Department of Agriculture ERS. Food Prices and Spending. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-prices-and-spending/. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-prices-and-spending/. Published November 3, 2021. Accessed November 2, 2021.
110. Gregory CA, Mancino L, Coleman-Jensen A. *Food Security and Food Purchase Quality Among Low-Income Households: Findings From the National Household Food Acquisition and Purchase Survey (FoodAPS).*; 2019.
111. Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *New England Journal of Medicine*. 2010.
112. Laraia BA. Food Insecurity and Chronic Disease. *Advances in Nutrition*. 2013.
113. Tarasuk VS. Household food insecurity with hunger is associated with women's food intakes, health and household circumstances. In: *Journal of Nutrition*. Vol 131. ; 2001.
114. Darmon N, Drewnowski A. Does social class predict diet quality? *American Journal of Clinical Nutrition*. 2008;87(5):1107-1117.
115. Drewnowski A, Darmon N. The economics of obesity: dietary energy density and energy cost. *The American journal of clinical nutrition*. 2005;82(1 Suppl).
116. Darmon N, Drewnowski A, James WP, et al. Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. *Nutrition reviews*. 2015;73(10):643-660. http://www.ncbi.nlm.nih.gov/pubmed/26307238%5Cnhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4586446.
117. Drewnowski A, Darmon N. Food Choices and Diet Costs: an Economic Analysis. *The Journal of Nutrition*. 2005;135:900-904. http://jn.nutrition.org/content/135/4/900.full.pdf+html.
118. Monsivais P, Drewnowski A. The Rising Cost of Low-Energy-Density Foods. *Journal of the American Dietetic Association*. 2007;107(12):2071-2076.
119. Drewnowski A, Darmon N. Food Choices and Diet Costs: an Economic Analysis. *The Journal of Nutrition*. 2005;135:900-904. http://jn.nutrition.org/content/135/4/900.full.pdf+html.
120. Rehm CD, Monsivais P, Drewnowski A. The quality and monetary value of diets consumed by adults in the United States. *American Journal of Clinical Nutrition*. 2011;94(5):1333-1339.
121. Hanson KL, Connor LM. Food insecurity and dietary quality in US adults and children: A systematic review. *American Journal of Clinical Nutrition*. 2014.
122. Kendall A, Olson CM, Frongillo EA. Relationship of hunger and food insecurity to food availability and consumption. *Journal of the American Dietetic Association*. 1996;96(10).
123. Bruening M, MacLehose R, Loth K, Story M, Neumark-Sztainer D. Feeding a family in a recession: Food insecurity among Minnesota parents. *American Journal of Public Health*.

2012;102(3):520-526.
124. Cristofar SP, Basiotis PP. Dietary intakes and selected characteristics of women ages 19–50 years and their children ages 1–5 years by reported perception of food sufficiency. *Journal of Nutrition Education*. 1992;24(2).
125. Dixon LB, Winkleby MA, Radimer KL. Dietary intakes and serum nutrients differ between adults from food-insufficient and food-sufficient families: Third National Health and Nutrition Examination Survey, 1988-1994. *Journal of Nutrition*. 2001;131(4).
126. Rose D, Oliveira V. Nutrient intakes of individuals from food-insufficient households in the United States. *American Journal of Public Health*. 1997;87(12).
127. Bhattacharya J, Currie J, Haider S. Poverty, food insecurity, and nutritional outcomes in children and adults. *Journal of Health Economics*. 2004;23(4).
128. Tarasuk VS, Beaton GH. Household food insecurity and hunger among families using food banks. *Canadian Journal of Public Health*. 1999;90(2).
129. Champagne CM, Casey PH, Connell CL, et al. Poverty and Food Intake in Rural America: Diet Quality Is Lower in Food Insecure Adults in the Mississippi Delta. *Journal of the American Dietetic Association*. 2007;107(11).
130. Basiotis PP, Lino M. *Food Insufficiency and Prevalence of Overweight Among Adult Women.*; 2002. http://www.cnpp.usda.gov/Publications/NutritionInsights/Insight26.pdf.
131. Zizza CA, Duffy PA, Gerrior SA. Food insecurity is not associated with lower energy intakes. *Obesity*. 2008;16(8).
132. Nguyen BT, Shuval K, Bertmann F, Yaroch AL. The supplemental nutrition assistance program, food insecurity, dietary quality, and obesity among US adults. *American Journal of Public Health*. 2015;105(7).
133. Leung CW, Epel ES, Ritchie LD, Crawford PB, Laraia BA. Food Insecurity Is Inversely Associated with Diet Quality of Lower-Income Adults. *Journal of the Academy of Nutrition and Dietetics*. 2014.
134. Morales ME, Berkowitz SA. The Relationship Between Food Insecurity, Dietary Patterns, and Obesity. *Current Nutrition Reports*. 2016;5(1).
135. Castner L, Wakar B, Wroblewska K, Trippe C, Cole N. *Benefit Redemption Patterns in the Supplemental Nutrition Assistance Program in Fiscal Year 2017*.; 2020.
136. Strohacker K, Carpenter KC, McFarlin BK. Consequences of Weight Cycling: An Increase in Disease Risk? *International journal of exercise science*. 2009.
137. Hill AJ. Does dieting make you fat? *British Journal of Nutrition*. 2004.
138. Lopez-Candales A, Hernández Burgos PM, Hernandez-Suarez DF, Harris D. Linking Chronic Inflammation with Cardiovascular Disease: From Normal Aging to the Metabolic Syndrome. *Journal of nature and science*. 2017.
139. Wellen KE, Hotamisligil GS. Inflammation, stress, and diabetes. *Journal of Clinical Investigation*. 2005.
140. Tsalamandris S, Antonopoulos AS, Oikonomou E, et al. The role of inflammation in diabetes: Current concepts and future perspectives. *European Cardiology Review* . 2019.
141. Weaver LJ, Hadley C. Moving beyond hunger and nutrition: A systematic review of the evidence linking food insecurity and mental health in developing countries. *Ecology of Food and Nutrition*. 2009;48(4).
142. Pourmotabbed A, Moradi S, Babaei A, et al. Food insecurity and mental health: A systematic review and meta-analysis. *Public Health Nutrition*. 2020;23(10).
143. Davison KM, Marshall-Fabien GL, Tecson A. Association of moderate and severe food

insecurity with suicidal ideation in adults: national survey data from three Canadian provinces. *Social Psychiatry and Psychiatric Epidemiology*. 2015;50(6).
144. Pryor L, Lioret S, van der Waerden J, Fombonne É, Falissard B, Melchior M. Food insecurity and mental health problems among a community sample of young adults. *Social Psychiatry and Psychiatric Epidemiology*. 2016;51(8).
145. Martin MS, Maddocks E, Chen Y, Gilman SE, Colman I. Food insecurity and mental illness: Disproportionate impacts in the context of perceived stress and social isolation. *Public Health*. 2016.
146. McLaughlin KA, Conron KJ, Koenen KC, Gilman SE. Childhood adversity, adult stressful life events, and risk of past-year psychiatric disorder: A test of the stress sensitization hypothesis in a population-based sample of adults. *Psychological Medicine*. 2010;40(10).
147. Carter KN, Kruse K, Blakely T, Collings S. The association of food security with psychological distress in New Zealand and any gender differences. *Social Science and Medicine*. 2011;72(9).
148. McIntyre L, Glanville NT, Raine KD, Dayle JB, Anderson B, Battaglia N. Do low-income lone mothers compromise their nutrition to feed their children? *CMAJ*. 2003;168(6).
149. Olson C. Food Insecurity in Women: A Recipe for Unhealthy Trade-offs. *Topics in clinical nutrition*. 2005;20(4).
150. Runnels VE, Kristjansson E, Calhoun M. An Investigation of Adults' Everyday Experiences and Effects of Food Insecurity in an Urban Area in Canada. *Canadian Journal of Community Mental Health*. 2011;30(1).
151. Puddephatt JA, Keenan GS, Fielden A, Reaves DL, Halford JCG, Hardman CA. 'Eating to survive': A qualitative analysis of factors influencing food choice and eating behaviour in a food-insecure population. *Appetite*. 2020;147.
152. Meza A, Altman E, Martinez S, Leung CW. "It's a Feeling That One Is Not Worth Food": A Qualitative Study Exploring the Psychosocial Experience and Academic Consequences of Food Insecurity Among College Students. *Journal of the Academy of Nutrition and Dietetics*. 2018.
153. Dallman MF, Pecoraro N, Akana SF, et al. Chronic stress and obesity: A new view of "comfort food." *Proceedings of the National Academy of Sciences of the United States of America*. 2003;100(20).
154. Heilig M. The NPY system in stress, anxiety and depression. *Neuropeptides*. 2004;38(4).
155. Zakrzewska KE, Cusin I, Sainsbury A, Rohner-Jeanrenaud F, Jeanrenaud B. Glucocorticoids as counterregulatory hormones of leptin: Toward an understanding of leptin resistance. *Diabetes*. 1997;46(4).
156. Björntorp P. Do stress reactions cause abdominal obesity and comorbidities? *Obesity Reviews*. 2001;2(2).
157. LUNDHOLM K, REBUFFE-SCRIVE M, BJC-RNTORP P. Glucocorticoid hormone binding to human adipose tissue. *European Journal of Clinical Investigation*. 1985;15(5).
158. Epel ES, McEwen B, Seeman T, et al. Stress and body shape: Stress-induced cortisol secretion is consistently greater among women with central fat. *Psychosomatic Medicine*. 2000;62(5).
159. Incollingo Rodriguez AC, Epel ES, White ML, Standen EC, Seckl JR, Tomiyama AJ. Hypothalamic-pituitary-adrenal axis dysregulation and cortisol activity in obesity: A systematic review. *Psychoneuroendocrinology*. 2015;62.
160. Brillon DJ, Zheng B, Campbell RG, Matthews DE. Effect of cortisol on energy expenditure and amino acid metabolism in humans. *American Journal of Physiology - Endocrinology and Metabolism*. 1995;268(3 31-3).
161. Dallman MF, la Fleur SE, Pecoraro NC, Gomez F, Houshyar H, Akana SF. Minireview:

Glucocorticoids - Food intake, abdominal obesity, and wealthy nations in 2004. *Endocrinology*. 2004;145(6).
162. Espel-Huynh HM, Muratore AF, Lowe MR. A narrative review of the construct of hedonic hunger and its measurement by the Power of Food Scale. *Obesity Science and Practice*. 2018;4(3).
163. Laraia BA, Leak TM, Tester JM, Leung CW. Biobehavioral Factors That Shape Nutrition in Low-Income Populations: A Narrative Review. *American Journal of Preventive Medicine*. 2017.
164. Grant KA, Shively CA, Nader MA, et al. Effect of social status on striatal dopamine D2 receptor binding characteristics in cynomolgus monkeys assessed with positron emission tomography. *Synapse*. 1998;29(1).
165. Benton D, Young HA. A meta-analysis of the relationship between brain dopamine receptors and obesity: A matter of changes in behavior rather than food addiction. *International Journal of Obesity*. 2016;40(S1).
166. Bermúdez-Millán A, Wagner JA, Feinn RS, et al. Inflammation and Stress Biomarkers Mediate the Association between Household Food Insecurity and Insulin Resistance among Latinos with Type 2 Diabetes. *Journal of Nutrition*. 2019;149(6).
167. Mullainathan S. Scarcity: Why Having Too Little Means So Much | Sendhil Mullainathan. *Harvard University*. 2013.
168. Alonso-Alonso M, Pascual-Leone A. The right brain hypothesis for obesity. *Journal of the American Medical Association*. 2007.
169. C. K, H. P, R.N. A. Rational snacking: Young children's decision-making on the marshmallow task is moderated by beliefs about environmental reliability. *Cognition*. 2013.
170. Lattimore P, Maxwell L. Cognitive load, stress, and disinhibited eating. *Eating Behaviors*. 2004.
171. Ward A, Mann T. Don't mind if I do: Disinhibited eating under cognitive load. *Journal of Personality and Social Psychology*. 2000.
172. Friese M, Hofmann W, Wänke M. When impulses take over: Moderated predictive validity of explicit and implicit attitude measures in predicting food choice and consumption behaviour. *British Journal of Social Psychology*. 2008.
173. Kassam KS, Koslov K, Mendes WB. Decisions under distress: Stress profiles influence anchoring and adjustment. *Psychological Science*. 2009.
174. Loewenstein G. Emotions in Economic Theory and Economic Behavior. *American Economic Review*. 2000.
175. Baumeister R. The psychology of irrationality: Why people make foolish, self-defeating choices. *The psychology of economic decisions*. 2003;1:3-16.
176. Baumeister R, Tierney J. *Willpower: Rediscovering the Greatest Human Strength*. Penguin; 2012.
177. Starcke K, Brand M. Decision making under stress: A selective review. *Neuroscience and Biobehavioral Reviews*. 2012.
178. Zauberman G, Lynch JG. Resource slack and propensity to discount delayed investments of time versus money. *Journal of Experimental Psychology: General*. 2005.
179. Richardson AS, Arsenault JE, Cates SC, Muth MK. Perceived stress, unhealthy eating behaviors, and severe obesity in low-income women. *Nutrition Journal*. 2015.
180. Kalm LM, Semba RD. They Starved So That Others Be Better Fed: Remembering Ancel Keys and the Minnesota Experiment. *The Journal of Nutrition*. 2005.
181. Fuhrman FA, B. M, Keys A, et al. The Biology of Human Starvation. *The American Journal of Psychology*. 1951.

182. Radel R, Clément-Guillotin C. Evidence of motivational influences in early visual perception: Hunger modulates conscious access. *Psychological Science*. 2012.
183. Feeding America. *Hunger in America 2014*.; 2014.
184. Bruyneel S, Dewitte S, Vohs KD, Warlop L. Repeated choosing increases susceptibility to affective product features. *International Journal of Research in Marketing*. 2006.
185. Levav J, Heitmann M, Herrmann A, Iyengar S. Order in product customization decisions: Evidence from field experiments. *Journal of Political Economy*. 2010.
186. Pocheptsova A, Amir O, Dhar R, Baumeister RF. Deciding without resources: Resource depletion and choice in context. *Journal of Marketing Research*. 2009.
187. Vohs KD, Baumeister RF, Schmeichel BJ, Twenge JM, Nelson NM, Tice DM. Making Choices Impairs Subsequent Self-Control: A Limited-Resource Account of Decision Making, Self-Regulation, and Active Initiative. *Journal of Personality and Social Psychology*. 2008.
188. Vohs KD, Nelson N, Rawn C. Why do choices tax self-regulatory resources? Three tests of candidates to explain decision fatigue. *ACR North American Advances*. 2009.
189. Spears D. Economic decision-making in poverty depletes behavioral control. *BE Journal of Economic Analysis and Policy*. 2011.
190. Baumeister RF. Ego Depletion and Self-Control Failure: An Energy Model of the Self's Executive Function. *Self and Identity*. 2002.
191. Loopstra R. Interventions to address household food insecurity in high-income countries. In: *Proceedings of the Nutrition Society*. ; 2018.
192. Food and Nutrition Service, United States Department of Agriculture. SNAP Data Tables: National Level Monthly Data.
193. U.S. Department of Agriculture. A Short History of SNAP. A Short History of SNAP.
194. National Institute of Food and Agriculture, United States Department of Agriculture. Gus Schumacher Nutrition Incentive Program.
195. Center on Budget and Policy Priorities. *Chart Book: SNAP Helps Struggling Families Put Food on the Table*.; 2019.
196. Carlson S, Keith-Jennings B. SNAP Is Linked with Improved Nutritional Outcomes and Lower Health Care Costs. *Center on Budget and Policy Priorities*. 2018.
197. Food and Nutrition Service, United States Department of Agriculture. SNAP Eligibility. 2021.
198. Wilde PE. Measuring the effect of food stamps on food insecurity and hunger: Research and policy considerations. *Journal of Nutrition*. 2007;137(2).
199. Nord M, Golla AM. Does snap decrease food insecurity? Untangling the self-selection effect. In: *SNAP's (Supplemental Nutrition Assistance Program) Role in Poverty Reduction and Increased Food Security*. ; 2012.
200. Furman J, Munoz C, Black S. *Long-Term Benefits of the Supplemental Nutrition Assistance Program*. Washington, DC; 2015.
201. Ratcliffe C, McKernan SM, Zhang S. How much does the supplemental nutrition assistance program reduce food insecurity? *American Journal of Agricultural Economics*. 2011.
202. Gearing M, Dixit-Joshi S, May L. *Barriers That Constrain the Adequacy of Supplemental Nutrition Assistance Program (SNAP) Allotments*.; 2021.
203. Rosenbaum D, Dean S, Neuberger Z. *The Case for Boosting SNAP Benefits in Next Major Economic Response Packag*.; 2020.
204. U.S. Department of Agriculture. *Thrifty Food Plan*.; 2021.
205. Dean S. Thrifty Food Plan Re-evaluation Puts Nutrition in Reach for SNAP Participants.
206. Robert Wood Johnson Foundation. *Federal Policy Recommendations to Advance Health Equity*

from the Robert Wood Johnson Foundation .; 2021.
207. Bazerghi C, McKay FH, Dunn M. The Role of Food Banks in Addressing Food Insecurity: A Systematic Review. *Journal of Community Health*. 2016;41(4).
208. An R, Wang J, Liu J, Shen J, Loehmer E, McCaffrey J. A systematic review of food pantry-based interventions in the USA. *Public Health Nutrition*. 2019;22(9).
209. Martin KS, Colantonio AG, Picho K, Boyle KE. Self-efficacy is associated with increased food security in novel food pantry program. *SSM - Population Health*. 2016.
210. Simmet A, Depa J, Tinnemann P, Stroebele-Benschop N. The Nutritional Quality of Food Provided from Food Pantries: A Systematic Review of Existing Literature. *Journal of the Academy of Nutrition and Dietetics*. 2017;117(4).
211. Garthwaite K. Stigma, shame and "people like us": An ethnographic study of foodbank use in the UK. *Journal of Poverty and Social Justice*. 2016;24(3).
212. Loopstra R, Tarasuk V. The relationship between food banks and household food insecurity among low-income Toronto Families. *Canadian Public Policy*. 2012;38(4).
213. de Marchis EH, Torres JM, Benesch T, et al. Interventions addressing food insecurity in health care settings: A systematic review. *Annals of Family Medicine*. 2019.
214. Hassan A, Scherer EA, Pikcilingis A, et al. Improving Social Determinants of Health: Effectiveness of a Web-Based Intervention. *American Journal of Preventive Medicine*. 2015;49(6).
215. Saxe-Custack A, Lofton HC, Hanna-Attisha M, et al. Caregiver perceptions of a fruit and vegetable prescription programme for low-income paediatric patients. *Public Health Nutrition*. 2018.
216. Bryce R, Guajardo C, Ilarraza D, et al. Participation in a farmers' market fruit and vegetable prescription program at a federally qualified health center improves hemoglobin A1C in low income uncontrolled diabetics. *Preventive Medicine Reports*. 2017.
217. Cavanagh M, Jurkowski J, Bozlak C, Hastings J, Klein A. Veggie Rx: An outcome evaluation of a healthy food incentive programme. *Public Health Nutrition*. 2017.
218. Swartz H. Produce RX programs for diet-based chronic disease prevention. *AMA Journal of Ethics*. 2018.
219. Purnell JQ, Gernes R, Stein R, Sherraden MS, Knoblock-Hahn A. A systematic review of financial incentives for dietary behavior change. *Journal of the Academy of Nutrition and Dietetics*. 2014.
220. Adams J, Giles EL, McColl E, Sniehotta FF. Carrots, sticks and health behaviours: a framework for documenting the complexity of financial incentive interventions to change health behaviours. *Health Psychology Review*. 2014.
221. Skinner BF. *Science and Human Behavior*. Cambridge, MA: Skinner Foundation; 1953.
222. Burns RJ, Donovan AS, Ackermann RT, Finch EA, Rothman AJ, Jeffery RW. A theoretically grounded systematic review of material incentives for weight loss: Implications for interventions. *Annals of Behavioral Medicine*. 2012.
223. Burrington CM, Hohensee TE, Tallman N, Gadomski AM. A pilot study of an online produce market combined with a fruit and vegetable prescription program for rural families. *Preventive Medicine Reports*. 2020.
224. Emmert-Aronson B, Grill KB, Trivedi Z, Markle EA, Chen S. Group medical visits 2.0: The open source wellness behavioral pharmacy model. *Journal of Alternative and Complementary Medicine*. 2019.
225. Orsega-Smith E, Slesinger N, Cotugna N. Local Pediatricians Partner with Food Bank to Provide

Produce Prescription Program. *Journal of Hunger and Environmental Nutrition*. 2019.
226. Ridberg RA, Bell JF, Merritt KE, Harris DM, Young HM, Tancredi DJ. A Pediatric Fruit and Vegetable Prescription Program Increases Food Security in Low-Income Households. *Journal of Nutrition Education and Behavior*. 2019.
227. Ridberg RA, Marpadga S, Akers MM, Bell JF, Seligman HK. Fruit and Vegetable Vouchers in Pregnancy: Preliminary Impact on Diet & Food Security. *Journal of Hunger and Environmental Nutrition*. 2021.
228. Watt TT erling, Appel L, Lopez V, Flores B, Lawhon B. A Primary Care-Based Early Childhood Nutrition Intervention: Evaluation of a Pilot Program Serving Low-Income Hispanic Women. *Journal of racial and ethnic health disparities*. 2015.
229. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*. 2011.
230. Redding C a, Rossi JS, Rossi SR, Velicer WF, Prochaska JO. Health Behavior Models. *The International Electronic Journal of Health Education*. 2000.
231. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *American Journal of Health Promotion*. 1997.
232. Prochaska JO. Decision making in the transtheoretical model of behavior change. *Medical Decision Making*. 2008.
233. Bellg AJ. Maintenance of Health Behavior Change in Preventive Cardiology: Internalization and Self-Regulation of New Behaviors. *Behavior Modification*. 2003.
234. Ridberg RA, Bell JF, Merritt KE, Harris DM, Young HM, Tancredi DJ. A Pediatric Fruit and Vegetable Prescription Program Increases Food Security in Low-Income Households. *Journal of Nutrition Education and Behavior*. 2019.
235. Aiyer JN, Raber M, Bello RS, et al. A pilot food prescription program promotes produce intake and decreases food insecurity. *Translational Behavioral Medicine*. 2019.
236. Berkowitz SA, O'Neill J, Sayer E, et al. Health Center–Based Community-Supported Agriculture: An RCT. *American Journal of Preventive Medicine*. 2019.
237. Cook M, Ward R, Newman T, et al. Food Security and Clinical Outcomes of the 2017 Georgia Fruit and Vegetable Prescription Program. *Journal of Nutrition Education and Behavior*. 2021.
238. Omar J, Heidemann D, Blum-Alexander B, et al. Fresh prescription program: A program to improve access to fresh products among underserved patients in downtown detroit. *Journal of General Internal Medicine*. 2017;32(2):S7S2.
239. Trapl ES, Smith S, Joshi K, et al. Dietary Impact of Produce Prescriptions for Patients With Hypertension. *Preventing Chronic Disease*. 2018.
240. Freedman DA, Choi SK, Hurley T, Anadu E, Hébert JR. A farmers' market at a federally qualified health center improves fruit and vegetable intake among low-income diabetics. *Preventive Medicine*. 2013.
241. Bhat S, Coyle DH, Trieu K, et al. Healthy Food Prescription Programs and their Impacts on Dietary Behavior and Cardiometabolic Risk Factors: A Systematic Review and Meta-Analysis. *Advances in Nutrition*. 2021:1-13.
242. Allison Schlosser, Kakul Joshi, Samantha Smith, Anna Thornton, Shari Bolen ET. "The coupons and stuff just made it possible": economic constraints and patient experiences of a produce prescription program. *Translational Behavioral Medicine*. 2019;9(5):875-883.
243. Allison Schlosser, Samantha Smith, Kakul Joshi, Anna Thornton, Erika Trapl SB. "You Guys Really Care About Me…": a Qualitative Exploration of a Produce Prescription Program in Safety Net Clinics. *Journal of General Internal Medicine*. 2017.

244. Trapl ES, Joshi K, Taggart M, Patrick A, Meschkat E, Freedman DA. Mixed Methods Evaluation of a Produce Prescription Program for Pregnant Women. *Journal of Hunger and Environmental Nutrition*. 2017.
245. George DR, Manglani M, Minnehan K, et al. Examining Feasibility of Mentoring Families at a Farmers' Market and Community Garden. *American Journal of Health Education*. 2016.
246. Goddu AP, Roberson TS, Raffel KE, Chin MH, Peek ME. Food Rx: A community-university partnership to prescribe healthy eating on the south side of Chicago. *Journal of Prevention and Intervention in the Community*. 2015.
247. Friedman DB, Freedman DA, Choi SK, et al. Provider Communication and Role Modeling Related to Patients' Perceptions and Use of a Federally Qualified Health Center-Based Farmers' Market. *Health Promotion Practice*. 2014.
248. Newman T, Lee JS. Strategies and Challenges: Qualitative Lessons Learned From Georgia Produce Prescription Programs. *Health Promotion Practice*. 2021.
249. Cahill E. Investigating the barriers of a healthy diet among low-income individuals who suffer from diet-related illnesses living in Atlanta, GA. 2018.

Chapter 3: Methods

Methods

This dissertation evaluates the Georgia Food for Health program, a produce prescription program implemented in Atlanta, Georgia between 2016 & 2020.

Intervention overview

The Georgia Food for Health (GF4H) program was a 6-month long PRx program implemented in Atlanta, Georgia. The program was the product of a multi-partner collaboration that aimed to improve food access and provide experiential nutrition and cooking education.

Description of partners & their roles in the intervention

Partners included Grady Health System, Open Hand Atlanta, Wholesome Wave Georgia, The Georgia Common Market, Community Farmers Markets, and Emory University. Grady health system serves vulnerable populations in Fulton and Dekalb counties who have limited or no health insurance. Grady served as the healthcare partner and implementation site for the program. Open Hand Atlanta is a community-based organization that served as the cooking education partner and provided funding for produce. Wholesome Wave Georgia is a community-based organization that provided administrative support and funding for produce. The Georgia Common Market, a local food distributor, provided produce for the program. Community Farmers Markets administers the Fresh MARTA Markets, which are produce stands located in train stations in metro Atlanta and served as produce redemption sites for the program. Emory University is a research institution and served as the research and evaluation partner.

Recruitment

Participants were referred by healthcare providers from five clinics within the Grady Health System including 3 primary care clinics, a diabetes clinic, and an infectious disease clinic. Eligibility requirements included a positive screen for food insecurity in the previous 12 months using a validated 2-item food insecurity screener. Participants were 18 years or older, patients of the Grady Primary Care Centers, and expressed commitment to the 6-month program.[1] Recruitment strategies varied somewhat by year and clinic. In 2017, clients were referred directly by their healthcare providers during clinic visits and followed-up by registered dietitians for enrollment into the program. In 2018 and 2019, participants from four of the five clinics were recruited from a pool of patients who were attending group nutrition education sessions offered at the clinics by registered dietitians. At the fifth clinic, participants were referred directly during clinic visits by their healthcare providers and followed-up by registered dietitians for enrollment.

Intervention Methods

Over the first six weeks, six hands-on cooking classes were taught by a Registered Dietitian from Open Hand Atlanta using Cooking Matters™, an evidence-based curriculum.[2] Classes included resource management tips, with the goal of teaching participants to prepare healthy meals on a limited budget. At each weekly cooking skills class, seasonal produce was provided according to participant household size. Concurrently, participants attended monthly Eat Well, Live Well wellness courses for the duration of the 6-month GF4H program. The education content of the Eat Well, Live Well nutrition sessions varied somewhat by clinic site, covering portion control tips, exercise demonstrations, and gardening sessions. At each monthly Eat Well, Live Well nutrition session, vouchers were distributed worth $1 per family member per day. These were redeemable at local retail locations such as Fresh Marta farmers markets located in train stations in participants' communities. See Figure 1 for a schematic of the overall program.

Graduation

Participants were considered graduates if they attended 4 out of 6 of both the Cooking Matters classes and Eat Well, Live Well sessions. Starting in 2017, 43 participants were enrolled in the program across two cohorts and 34 of those participants graduated (79% graduation rate). In 2018, the program expanded, adding additional cohorts with 115 participants enrolled. Of those, 91 graduated (79% graduation rate). In 2019, 173 participants were enrolled and 157 graduated (91% graduation rate).

Measures collected

The primary measures collected in the GF4H program included survey data capturing demographics, attitudes, confidence, and behaviors and health measures including height, weight, blood pressure, and waist circumference.

The survey tool used in the program included core indicators captured in the Cooking Matters for Adults (CMA) survey (described in detail below) in addition to sociodemographic information, a modified dietary recall, food security screener, and questions on emergency room visits in the past 6 months, and prescribed medication adherence.

Surveys were administered at baseline, at the final Cooking Matters session six weeks later, and at the end of the program 6 months following baseline. Surveys were self-administered by participants with evaluators present to assist with questions, verbally administer surveys as needed, and check for survey completion.

Cooking Matters for Adults survey tool

CMA survey questions assess a) attitudes and perceptions of access and affordability as well as enjoyment of cooking and eating healthy foods, b) confidence in ability to cook and eat healthy foods, c) frequency of using food resource management practices, d) frequency of making

healthy purchasing decisions, and e) frequency of consumption of various diet components. Survey questions on eating habits query typical frequency of consumption of fruit, green salads, dark greens, other non-fried vegetables, fried potatoes, other white potatoes, beans, and meals purchased from restaurants. Additional questions assess typical frequency of drinking fruit juices, sodas or other sugar-sweetened beverages such as sweet-tea and sports drinks, and water. Response options include 'Not at all', 'Once a week or less', 'More than once a week', 'Once a day', and 'More than once a day.' Questions assessing attitudes and beliefs assessing attitudes queried agreement with statements on access and affordability of fruits and vegetables, willingness to try new foods, enjoyment of eating fruits and vegetables, and attitudes towards cooking. Response options used a 3-point Likert scale for 'Never', 'Sometimes', and 'Always'. Questions assessing confidence asked about confidence with using the same healthy ingredient in different recipes, choosing the best-priced form of fruits and vegetables (between fresh, frozen, or canned varieties), using basic cooking skills, as well as buying and cooking health foods for their family on a budget, and helping friends and family eat healthier. Response options used a 5-point Likert scale ranging from '0-Not at all confident' to ''4-Very confident".

Food resource management practices were assessed via questions on frequency of comparing prices when shopping, planning meals ahead of time, using shopping lists, cooking meals at home, and adjusting meals to include more budget-friendly ingredients. Questions assessing healthy shopping practices query frequency of selecting low-fat milk, low-fat dairy products, whole grain products, low-sodium options, low-fat proteins, and selecting healthy options at fast food or sit-down restaurants. Response options for both food resource management practices and healthy shopping practices used a 5-point Likert scale ranging from '0-Never' to '4-Always'.

Validation of the CMA survey was conducted using cognitive interviewing and psychometric testing to ensure both that participants interpret questions as intended and that items have satisfactory construct and internal validity.[3] First, the study authors conducted cognitive interviews with 21 low-income adults from various community sites in Omaha, Nebraska to evaluate the content, design, and layout of the CMA survey. These interviews resulted in changes to the survey including layout improvements, alterations to response options to better align with how questions were interpreted, the addition of descriptions of what is meant by healthy foods, and the removal of questions that were ambiguous or generated biased responses.

After cognitive testing, 19 psychosocial items in the survey were tested using data from a purposive convenience sample of 250 individuals geographically distributed across 10 CMA program sites (3 in western states, 2 in midwestern states, 2 in southern states, and 4 in northeastern states). Construct validity of items was assessed with exploratory factory analysis and internal reliability was assessed with Cronbach's alpha. The factor analysis resulted in 4 constructs: cooking barriers, cooking confidence, healthy food preparation, and food resource management. The internal consistency of survey items were satisfactory, with reported Cronbach alpha values ranging from 0.7-0.88 for all constructs with the exception of food resource management, which had a low Cronbach's alpha ($\alpha = 0.62$). The study authors analyzed food resource management items individually for this reason.

Sociodemographic Information

Sociodemographic information collected at baseline included sex, age in years (dichotomized to 18-49 & $\geq$ 50 years), ethnicity (Hispanic or Latino: Yes/No), race (Asian/Asian American, American Indian/Alaskan Native, Black/African American or Caribbean American,

Hawaiian/Pacific Islander, White/Caucasian, & Other/Multi-racial), highest level of education (Less than high school degree, High school or GED certificate, Two-year college or technical school degree, Some college/technical school, but have not graduated, Four-year college or technical school degree, & More than four-year college degree), employment status (Working full-time, Working part-time, Retired, Not employed/Homemaker, Student, On disability, & Other), health insurance status (Uninsured, Insured by Medicaid, Medicare or other public insurance, Insured through employer, Insured through private insurance, & Other), annual household income (Less than $25,000, $25,000-$34,999, $35,000-$49,999, & $50,000 or greater), and household size including non-relatives living in the home.

Food Security

At enrollment, 6-weeks of participation, and the end of the program, participants completed the 6-item United States Department of Agriculture Household Food Security Survey Module[4] with a 30-day recall to assess recent food security status and change over time. The 6-item module was chosen over the longer 18-item USDA module to avoid unduly increasing participant burden.[5] Food security was categorized using the scoring guide with categories including: high or marginal food security, low food security, and very low food security.[4]

Biometric Data

At each program visit, clinical staff from Grady collected height, weight, blood pressure, and waist circumference for all participants prior to program education sessions. Height was collected using ScaleTronix stadiometers, weight using ScaleTronix scales, blood pressure using Omron Blood Pressure Monitor Model BP742N, and waist circumference using retractable measuring tape. BMI was derived from monthly height and weight variables as weight in pounds divided by height in inches squared and multiplied by 703.[6]

Analytical approach & rationale for study aims

Aim 1: Estimate the association between program visits attended and changes in clinical indicators of chronic disease risk using linear mixed models

For study aim 1, we set out to estimate change in chronic disease risk indicators over the 6-month GF4H program using data collected from 2017 to 2019 across five clinic sites. Health indicators including blood pressure, weight, and waist circumference were collected monthly from enrollment to graduation, allowing the use of repeated measures methods to examine changes over the course of the program. Linear mixed models were used to estimate the association of monthly program visits attended (range 1-6) with change in BMI, weight, waist circumference, systolic blood pressure, and diastolic blood pressure. Estimation used restricted maximum likelihood and models controlled for program site, year, and participant sex and age. We included random slopes and intercepts for individual participants and site of participation. Month of program (1-6) was specified as the time variable.

Linear mixed models are an extension of simple linear models that allow for both fixed and random effects.[7] Fixed effects are parameters that do not vary over time and allow for estimation of systematic interindividual differences.[7] Random effects, in contrast, are expected to differ across some level of aggregation of interest.[7] For this reason, mixed models with random effects are commonly used to estimate relationships in data with some hierarchical structure, such as in our case, where patients participated in a program across different clinic sites. Incorporating random slopes and intercepts for clinic site and individual patients allows for the

estimation of each levels' own unique regression relationship, only informed by the grand mean where more specific information is missing.[8] Given that clinic sites varied in specialty (primary care, infectious disease prevention, and diabetes) and that each patient entered the program at different levels of health, incorporating random intercepts into the model allowed us to capture these differences in starting point. Additionally, we might expect changes throughout the program to vary across clinic site and individual (i.e., slopes are not parallel). Incorporating random slopes into the model allows us to estimate individual slopes for each hierarchical level.[8]

Aim 2: Investigate mechanisms of action in the GF4H program using pathway analysis

In order to investigate mechanisms of action in the program and how improvements in intermediate outcomes like attitudes, confidence, healthy purchasing behaviors, and food resource management practices affect primary program outcomes such as food security and diet quality, we used measured variable path analysis. Path analysis is a structural equation modeling technique used to evaluate causal models by examining the relationships between variables whose variation is explained by factors not in the model (exogenous variables) and those whose variation is explained, at least in part, by other variables in the model (endogenous variables).[9] Correlations between these variables can be used to estimate magnitude and significance of both direct and indirect (mediated) effects to aid in understanding mechanisms of action, how closely a program aligns with hypothesized logic models or theory of change, and to identify areas for program improvement.[9] As Pedhazur noted, "Path analysis is intended not to discover causes but to shed light on the tenability of the causal models a researcher formulates based on knowledge and theoretical considerations."[10] Our original hypothesized model was informed by the GF4H program theory of change (Appendix 1). Based on model fit statistics and adjustments to the model in consideration of sample size, multiple iterations of this model were tested.

When conducting a path analysis, relationships within the model can only be interpreted when the estimated model appropriately fits the data. To determine model fit, we used five indices commonly reported in the literature: Root Mean Squared Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Squared Residual (SRMR). RMSEA < 0.08, CFI > 0.95, TLI >0.95, and SRMR < 0.08 are the criteria for consideration of good fit.[11] Modification indices were used to adjust model fit where appropriate based on theory and understanding of the program.

As a rule of thumb, pathway analysis requires 20 observations for every path estimated. Given the limited sample size for this analysis (n=178), index scores were created as a method of data reduction. Creating an index score is a way of compiling one score from a collection of measures representing a single concept.[12] Typically, composite variables such as index scores are used to address issues with multicollinearity in related measures, control for type 1 error rates in situations where sample size is insufficient for multiple comparisons testing, and as a way to organize highly correlated variables into more interpretable, easily digestible information.[13,14] To allow for estimation of intermediary and ultimate outcomes within a relatively small sample size for pathway analysis, composite variables were created using a simple averaging approach. A detailed description of how these index measures were created are provided in Chapter 5. We combined survey items based on previously reported construct grouping used in the CMA survey tool development.[3] A simple averaging approach to creating composite variables is an easily interpretable data reduction technique when sample size precludes the ability to use more robust methods such as factor analysis.[14]

The use of composite variables has a few notable limitations. First, if individual items included in our composite variables are not sensitive to change in the program, their inclusion

can dilute observed effects or associations in the data.[13] This would result in a bias towards a null result and underestimation of construct effects. Second, if a composite variable does not capture all aspects of a construct it is meant to represent, it must be recognized as an imperfect measure of that construct.[14] This is true for all attempts to mathematically represent factors that cannot be directly and objectively measured. Variations in methods used to create composite variables from study-to-study result in fluctuations and limit comparability.[15] For this reason, using the simplest additive approach can be beneficial due to ease of interpretation and replicability across research groups. Despite these limitations, composite variables are useful for managing model complexity and facilitating general conclusions by representing complex constructs.

Aim 3: Characterize experiences of stress and food insecurity among GF4H program participants

We used qualitative research methods to gain a better understanding of how stress and food insecurity potentially impact the experience of program participation. Qualitative research adds context and expands understand of existing knowledge and for patient-centered work, aids us to put the patient experience in the forefront.[16] In program evaluation and implementation research especially, qualitative methods can reveal easy wins in program improvement by simply asking the experts, those who have experience the program firsthand.[17]

Given that the hypotheses for this study aim were informed by an existing conceptual framework, a thematic approach, which focuses on examining themes or patterns of meaning within data, was deemed most appropriate for data analysis.[18] It is a flexible approach that can be used to explore lived experiences, behaviors, and practices within the context of existing conceptual frameworks.[19,20] Alternative analytical approaches were considered, namely phenomenology, for interpretation of data that did not correspond with characterizations of experiences captured within existing conceptual frameworks. Phenomenological approaches focus

on inductive description of lived experiences with no pre-existing hypothesis to capture the meaning participants assign to their experiences.[21–23]

Taking a primarily thematic approach, qualitative analysis was conducted in MAXQDA 2020, following Braun and Clarke's Six Phases of Thematic Analysis.[24] Deductive codes were developed based on the key topics addressed in interviews (program experience, experiences of stress, coping strategies, stress & decision making) and the framework presented by Larai et al. on biobehavioral factors influencing nutrition in low-income populations.[25] For data that could not be interpreted in the context of existing frameworks or theories of behavior change, all interpretation was drawn directly from the data, following a phenomenological approach. However, full meaning saturation was not achieved, limiting our ability to interpret experiences described more broadly.[26] Additional questions remain that could not be answered in the data collected, regardless of analytical approach. While the goal of this study was not to develop a theory explaining how stress relates to diet, but rather to expand our understanding and provide additional context to the robust existing theories, our inductive findings can be seen as hypothesis-generating for additional future work.

References

1. Hager ER, Quigg AM, Black MM, et al. Development and validity of a 2-item screen to identify families at risk for food insecurity. *Pediatrics*. 2010.
2. Cooking Matters National. *Cooking Matters Curriculum*. SNAP-Ed Strategies & Interventions Toolkit, USDA SNAP-Ed Connection; 2016.
3. Pinard CA, Uvena LM, Quam JB, Smith TM, Yaroch AL. Development and testing of a revised cooking matters for adults survey. *American Journal of Health Behavior*. 2015;39(6).
4. Blumberg J, Bialostosky K, Hamilton WL, Briefel RR. *U.S. Household Food Security Survey Module: Six-Item Short Form*.; 1999.
5. Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the household food security scale. *American Journal of Public Health*. 1999.
6. CDC. Defining adult overweight and obesity. Centers for Disease Control and Prevention.
7. Singer JD, Willett JB. *Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence*.; 2009.
8. Huber C. Multilevel Linear Models in Stata, Part 2: Longitudinal Data. *The Stata Blog*. 2013.
9. Kline RB. *Principles and Practice of Structural Equation Modeling: Third Edition*.; 2011.
10. Pedhazur EJ. Multiple Regression in Behavioral Research; Explanation and Prediction. *Journal of the American Statistical Association*. 1997.
11. Hooper D, Coughlan J, Mullen MR. Structural equation modelling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods*. 2008.
12. Ley P. *Quantitative Aspects of Psychological Assessment: An Introduction*.; 1972.
13. Song MK, Lin FC, Ward SE, Fine JP. Composite variables: When and how. *Nursing Research*. 2013;62(1).
14. Grace JB, Bollen KA. Representing general theoretical concepts in structural equation models: The role of composite variables. *Environmental and Ecological Statistics*. 2008;15(2):191-213.
15. Dialga I, Thi Hang Giang L. Highlighting Methodological Limitations in the Steps of Composite Indicators Construction. *Social Indicators Research*. 2017;131(2).
16. Thorne S. The Great Saturation Debate: What the "S Word" Means and Doesn't Mean in Qualitative Research Reporting. *The Canadian journal of nursing research = Revue canadienne de recherche en sciences infirmieres*. 2020;52(1).
17. Freudenberg N. *Lessons from Evaluating Community Food Programs*.; 2017.
18. Daly J, Kellehear A, Gliksman M. The public health researcher: A methodological approach. *Sexual Deviance Theory Assessment and Treatment*. 1997.
19. Braun V, Clarke V, Hayfield N, Terry G. Thematic analysis. In: *Handbook of Research Methods in Health Social Sciences*. ; 2019.
20. Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*. 2013.
21. Vagle MD, Vagle MD. Phenomenological Research Methodology. In: *Crafting Phenomenological Research*. ; 2019.

22. Creswell JW, Poth CN. *Qualitative Inquiry & Research Design; Choosing among Five Approach*.; 2018.
23. Reid K, Flowers P, Larkin M. Exploring lived experience: An introduction to Interpretative Phenomenological Analysis. *The Psychologist*. 2005.
24. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative Research in Psychology*. 2006.
25. Laraia BA, Leak TM, Tester JM, Leung CW. Biobehavioral Factors That Shape Nutrition in Low-Income Populations: A Narrative Review. *American Journal of Preventive Medicine*. 2017.
26. Hennink MM, Kaiser BN, Marconi VC. Code Saturation Versus Meaning Saturation: How Many Interviews Are Enough? *Qualitative Health Research*. 2017.

Chapter 4: Participation in a produce prescription program was associated with reductions in chronic disease risk factors in a low-income, urban population

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Introduction

Poor diet quality is attributable for a greater population burden of morbidity and mortality from chronic diseases than tobacco, alcohol, and physical activity combined.[1] Consumption of diets including high proportions of fruits and vegetables are associated with reduced risks of developing cardiovascular diseases, type 2 diabetes, and cancer.[2] However, the majority of U.S. adults consume less than the recommend amounts.[3,4] This is especially true for individuals facing food insecurity, the limited or uncertain ability to acquire adequate food due to insufficient money and other resources.[5–9] Given the important roles of poor diet quality and food insecurity in chronic disease, there has been a proliferation of interest in interventions incorporating Food is Medicine™ initiatives into healthcare systems to facilitate access to healthy foods for vulnerable patients.[10–12] One promising approach is the produce prescription model, which involves physician or healthcare worker referrals to free or discounted healthy produce for patients identified to be at risk for chronic disease based on low food security status or income and diet-related health risk factors.[11–14]

Produce prescription (Produce Rx) programs use a partnership model of care that involves a healthcare provider, typically the referring clinician, rewarding and positively

reinforcing repeated health-seeking behaviors.[13,15,16] Financial incentive models, including produce Rx programs, are informed by the principles of operant conditioning, whereby behaviors eliciting rewards are repeated.[17,18] Thus, incentives may act as a catalyst to engage in a behavior, and repeated engagement may become intrinsically motivating, facilitating sustained behavior change.[15] Some produce Rx programs additionally incorporate group-based nutrition education and cooking sessions.[19–24] Nutrition education increases knowledge and awareness while hands-on cooking sessions provide skills and increase self-efficacy to engage in the behavior.[25–28] These behaviors are reinforced through educational sessions involving peer and provider support.[13,15,25,29]

There is consistent evidence that produce Rx programs increase food security [22,23,30,31] and increase mean fruit & vegetable consumption by 0.3-2 servings/day.[20,21,23,31–34] However, few studies have reported on health outcome measures, and overall results have been mixed. A recent meta-analysis estimated that produce Rx programs are associated with decreases in BMI of 0.6 kg/m2 (95% CI: 0.2, 1.1) and HbA1c of 0.8% (95% CI: 0.1, 1.6).[14] No significant changes were observed for blood pressure or lipid outcomes. While these results are promising, more evidence is needed to evaluate the effectiveness of produce Rx programs for improving chronic disease risk factors. Among studies reporting health outcomes, only one used longitudinal data[20] and none to our knowledge has used multiple years of program data. Further, no studies including health outcomes have been conducted in the Southeastern U.S. or with predominantly black participants.

To address these needs, we evaluated the Georgia Food for Health (GF4H) program, a produce Rx program implemented in Atlanta, Georgia. GF4H is a multi-partner collaboration that aims to improve food access and provide experiential nutrition and cooking education.[35,36]

Partners include Grady Health System, Open Hand Atlanta, Wholesome Wave Georgia, The Georgia Common Market, and Emory University.

Located in inner-city Atlanta, Grady Health System is a safety-net hospital that served as the healthcare partner and implementation site for the program. Grady health system serves vulnerable populations in Fulton and Dekalb counties who have limited or no health insurance. Data collected from the Grady Health System Primary Care Center suggests that the majority of patients experience poverty (90% report annual family incomes < $20,000), multiple chronic health conditions (two-thirds have ≥ 4 chronic diseases), and demonstrate low patient activation (60% report low knowledge and confidence to take action in self-management of health). Open Hand Atlanta is a community-based organization that served as the cooking education partner and provided funding for produce. Wholesome Wave Georgia is a community-based organization that provided administrative support and funding for produce. The Georgia Common Market, a local food distributor, provided produce for the program. Emory University is a research institution and served as the research and evaluation partner.

The six-month GF4H program provided vouchers worth $1 per household member per day, redeemable weekly for fresh produce at retail locations throughout Atlanta. Additionally, participants received monthly group-based nutrition education and hands-on cooking classes for the first six weeks of the program. The purpose of this study was to evaluate chronic disease risk factor changes and health outcomes among graduates of the GF4H program. We evaluated longitudinal program data collected from 2017-2019 by program partners.

Methods

Recruitment

Participants were referred by healthcare providers from five clinics within the Grady Health

System including 3 primary care clinics, a diabetes clinic, and an infectious disease clinic. Eligibility requirements included a positive screen for food insecurity in the previous 12 months using a validated 2-item food insecurity screener.[37,38] Participants were 18 years or older, patients of the Grady Primary Care Centers, and expressed commitment to the 6-month program.[37] Recruitment strategies varied somewhat by year and clinic. In 2017, clients were referred directly by their healthcare providers during clinic visits and followed-up by registered dietitians for enrollment into the program. In 2018 and 2019, participants from four of the five clinics were recruited from a pool of patients who were attending group nutrition education sessions offered at the clinics by registered dietitians. At the fifth clinic, participants were referred directly during clinic visits by their healthcare providers and followed-up by registered dietitians for enrollment.

Intervention

Over the first six weeks, six hands-on cooking classes were taught by a Registered Dietitian from Open Hand Atlanta using Cooking Matters™, an evidence-based curriculum.[39] Classes included resource management tips, with the goal of teaching participants to prepare healthy meals on a limited budget. At each weekly cooking skills class, seasonal produce was provided according to participant household size. Concurrently, participants attended monthly Eat Well, Live Well wellness courses for the duration of the 6-month GF4H program. The education content of the Eat Well, Live Well nutrition sessions varied somewhat by clinic site, covering portion control tips, exercise demonstrations, and gardening sessions. At each monthly Eat Well, Live Well nutrition session, vouchers were distributed worth $1 per family member per day. These were redeemable at local retail locations such as Fresh Marta farmers markets located in train stations in participants' communities. See Figure 1 for a schematic of the overall program.

Graduation

Participants were considered graduates if they attended 4 out of 6 of both the Cooking Matters classes and Eat Well, Live Well sessions. Starting in 2017, 43 participants were enrolled in the program across two cohorts and 34 of those participants graduated (79% graduation rate). In 2018, the program expanded, adding additional cohorts with 115 participants enrolled. Of those, 91 graduated (79% graduation rate). In 2019, 173 participants were enrolled and 157 graduated (91% graduation rate).

Evaluation

Program evaluation used a longitudinal, repeated measures, single-arm approach to estimate the association between the number of monthly program visits attended (1-6) and changes in body mass index (BMI), blood pressure, and waist circumference among graduates of the GF4H program using program data from 2017-2019. This project was deemed exempt from review by Emory University IRB and approved by Grady Health System's Office of Research Administration.

Measures

Surveys were administered at baseline, at the final Cooking Matters session six weeks later, and at the end of the program 6 months following baseline. Surveys were self-administered by participants with evaluators present to assist with questions, verbally administer surveys as needed, and check for survey completion.

Sociodemographic information collected at baseline included sex, age in years (dichotomized to 18-49 & ≥ 50 years), ethnicity (Hispanic or Latino: Yes/No), race (Asian/Asian American, American Indian/Alaskan Native, Black/African American or Caribbean American, Hawaiian/Pacific Islander, White/Caucasian, & Other/Multi-racial), highest level of education (Less than high school degree, High school or GED certificate, Two-year college or technical

school degree, Some college/technical school, but have not graduated, Four-year college or technical school degree, & More than four-year college degree), employment status (Working full-time, Working part-time, Retired, Not employed/Homemaker, Student, On disability, & Other), health insurance status (Uninsured, Insured by Medicaid, Medicare or other public insurance, Insured through employer, Insured through private insurance, & Other), annual household income (Less than $25,000, $25,000-$34,999, $35,000-$49,999, & $50,000 or greater), and household size including non-relatives living in the home.

At enrollment, 6-weeks of participation, and the end of the program, participants completed the 6-item United States Department of Agriculture Household Food Security Survey Module[40] with a 30-day recall to assess recent food security status and change over time. The 6-item module was chosen over the longer 18-item USDA module to avoid unduly increasing participant burden.[41] Food security was categorized using the scoring guide with categories including: high or marginal food security, low food security, and very low food security.[40]

At each monthly Eat Well, Live Well visit, clinical staff collected height, weight, blood pressure, and waist circumference for all participants prior to program education sessions. Height was collected using ScaleTronix stadiometers, weight using ScaleTronix scales, blood pressure using Omron Blood Pressure Monitor Model BP742N, and waist circumference using retractable measuring tape. BMI was derived from monthly height and weight variables as weight in pounds divided by height in inches squared and multiplied by 703.[42]

Blood pressure was categorized as normal if systolic blood pressure (SBP) was < 120 mmHg and diastolic blood pressure (DBP) was < 80 mmHg, elevated if SBP was 120 – 129 mmHg and DBP was < 80 mmHg, hypertensive stage 1 if SBP was 130-139 mmHg or DBP was 80-89 mmHg, and hypertensive stage 2 if SBP was ≥ 140 mmHg or DBP was ≥ 90 mmHg.[43]

Blood pressure improvement was defined as 'yes' if the participant's blood pressure category at the last visit attended was lower than that at the first visit and 'no' otherwise.

Weight loss of 5% or greater was defined as 'yes' if the participant's last visit weight was less than 95% of the first visit weight. Waist circumference reduction of 5% or greater was defined as 'yes' if the participant's last visit waist circumference was less than 95% of the first visit waist circumference. These thresholds represent clinically-relevant changes.[44–48]

Redeemed vouchers were collected by the individual markets at the time of redemption and reported to Wholesome Wave Georgia. Household per-capita redemption was calculated as the dollar amount of vouchers redeemed divided by household size.

Analytic Sample

Participants who were enrolled but did not complete the program (n=49) were excluded from the analysis. The overall graduation rate across all three years was 83%, resulting in a final analytical sample of 282.

Statistical Methods

We used descriptive analyses, including means and frequencies to characterize study participants and paired t-tests to test the significance of change in values for continuous outcomes. Longitudinal approaches were used to analyze repeated measurements.

We used linear mixed models to estimate the association of monthly program visits attended (range 1-6) with change in BMI, weight, waist circumference, SBP and DBP. Estimation used restricted maximum likelihood and models controlled for program site, year, and participant sex and age. Random effects included intercepts and slopes for participants and site of participation. Month of program (1-6) was specified as the time variable. Estimates are presented with 95% confidence intervals (95% CI).

We used multivariate logistic regression to estimate the association between individual and programmatic factors and odds of improving categorical blood pressure, achieving 5% or greater weight loss, and achieving 5% or greater waist circumference reduction. Individual and programmatic factors in these models included sex, age (18-49 years or 50 years or older), annual household income level (<25k, 25-35k, and >35k), SNAP benefits status, baseline food security, food security improvement from first to last visit, household size, per-person total voucher redemption, and number of program visits attended.

Some data were missing for 55 of the program graduates (0.7 – 3.2% of observations). Additionally, blood pressure information was missing for 0.5% of observations, BMI was missing for 0.3%, and waist circumference was missing for 0.4%. All analyses were conducted in STATA version 15.0.[51] Statistical significance was determined at $p<0.05$.

Results

Demographics

Demographic characteristics of program graduates are presented in Table 1. The large majority of participants were black (93.1%), female (71.6%), and aged 40 y or older (91.9%). Most participants received health insurance through Medicaid, Medicare, or some other public insurance (65.3%) and had a household income of less than $25,000 annually (86.6%). Most were retired (24.3%) and/or receiving disability benefits (40.2%). At baseline, the majority of participants were characterized as having low or very low food security (60.4%) and received SNAP benefits (59.4%).

Clinical outcomes

At baseline, program graduates had a mean BMI of 36.5 (95% CI: 35.5, 37.6) kg/m^2, a mean weight of 227 (95% CI: 220, 233) lbs., a mean waist circumference of 45.3 (95% CI: 44.5,

46.1) inches, mean systolic blood pressure of 140.4 (95% CI: 138.1, 142.6) mmHg, and mean diastolic blood pressure of 82.8 (95% CI: 80.4, 83.2) mmHg. We observed significant reductions in mean BMI, weight, waist circumference, systolic and diastolic blood pressure from the first program visit attended to the last program visit attended (Table 2).

After controlling for program site, year of implementation, and participant sex, each program visit was associated with a 0.1 (95% CI: -0.1, -0.0) kg/m^2 reduction in BMI, a 0.4 (95% CI: -0.6, -0.2) lb. reduction in weight, a 0.4 (95% CI: -0.4, -0.3) inch reduction in waist circumference, a 0.4 (95% CI: -0.7, -0.2) mmHg reduction in diastolic blood pressure, and a 1.0 (95% CI: -1.4, -0.6) mmHg reduction in systolic blood pressure (Table 3). We used multivariate imputation by chained equations (MICE) method to estimate observed outcomes in the scenario of no missing data (See Supplemental Materials).[49,50] Estimates using imputed data were consistent with those from the original dataset. However, blood pressure estimates were slightly lower in magnitude when using the imputed data (Supplemental Table 1).

Overall, individual and programmatic factors were not strongly predictive of experiencing clinical improvements over the course of the program (Supplemental Tables 2-4). Some exceptions were noted, however. Participants receiving SNAP benefits were 2.5 times more likely to experience categorical blood pressure improvement compared to those not receiving benefits (OR: 2.5; 95% CI: 1.1, 5.7). Participants with 3-4 household members were 3.8 times more likely to experience categorical blood pressure improvement compared to participants with 1-2 household members (OR: 3.8; 95% CI: 1.6, 9.1). Females were more likely to experience 5% or greater weight loss compared to males (OR: 6.1; 95% CI: 1.3, 27.3). No individual or programmatic factors were significantly associated with odds of achieving a 5% or greater waist circumference reduction.

Discussion

Among graduates of the GF4H program, the number of program visits attended was associated with modest but statistically significant reductions in BMI, weight, waist circumference, and blood pressure measures. Most published studies on evaluations of similar programs report increases in fruit and vegetable consumption and improvements in food security but do not report health outcomes. [19,30,32,33,52–56] A recent meta-analysis pooling results of 3 studies reporting BMI, 4 reporting blood pressure, and 5 reporting HbA1c estimated that produce Rx programs were associated with modest decreases in BMI by 0.6 kg/m^2 (95% CI: -2.8, -0.3), and HbA1c by 0.8% (95% CI: -1.6, -0.1) across studies.[14] No significant changes in blood pressure or plasma lipid measurements were observed. The results of the GF4H program are generally comparable in magnitude to the few evaluations of produce Rx programs examining health outcomes. However, heterogeneity in program duration and implementation, participant characteristics, and study design limits the ability to make direct comparisons between programs. For example, other programs range in duration from 13 weeks[57,58] to 6 months[31] and involve a variety of program components such as mindfulness meditation and physical activity.[20] Nutrition education components varied substantially across programs, with one program providing healthy eating information handouts[31], others involving one-on-one nutrition counseling sessions[32,58], and another providing hour-long group-based sessions over a meal.[20] Although many programs incorporate recipes and cooking demonstrations,[32,57] there are no published studies of produce Rx programs that include hands-on cooking education. Further, to our knowledge, this is the first paper to report on health outcomes using repeated measures collected over multiple years of program implementation.[10]

Produce Rx programs are designed to improve chronic disease risk factors by increasing food

security and diet quality.[12] The combination of increased access to high-quality food and nutrition education supports participants' engagement in healthy shopping and eating practices throughout the program.[12,13,59] By practicing these behaviors, participants gain confidence in their skills and ability to acquire and cook healthy food on a budget, improving ability to maintain these behaviors after the program has ended.[60,61] Sustained improvements in diet quality reduce the risk of chronic disease risk factor progression and exacerbation of existing conditions.[4] Further studies are needed to examine the long-term benefits of these programs and to better understand the impacts of individual program components.

Limitations

This study has several limitations. Data were not available for those who were lost to follow-up, limiting our findings to those who completed the program. However, graduation rates across the three years of the program were relatively high at 83%, comparable to those observed in published evaluations of similar programs.[20,31,57] Nevertheless, our conclusions are generalizable only to people who are likely to remain engaged. For some clinics, participants were recruited from a pool of patients who had completed four introductory group nutrition classes, so those enrolled likely differed from the general patient population in that they had enough schedule flexibility to participate in the six-month program involving both group education sessions and weekly market visits for produce voucher redemption. It is also possible that those who graduated the program remained engaged due to their perceived benefits of participation, indicating potential for reverse causality. However, the findings from this study remain useful for understanding the potential among motivated patients for chronic disease risk factor improvement after participation in a produce Rx program.

We do not have information on why participants dropped out of the program or were lost

to follow-up. Implementation of a process for routinely collecting and recording this information would be helpful for understanding the barriers to participation and generating ideas on how to address them to better retain participants who are facing challenges due to competing life events.

Another limitation is the lack of a comparison group in evaluation. It is possible that changes observed in this study were related to factors outside of the intervention. Additional investigations involving control groups and randomized study design are needed to strengthen our understanding of the potential of produce Rx programs for achieving health outcome improvements.

Additionally, some missing data was present due to skipped questions in surveys or, in some cases, participants missing data collection days. While the proportion of missing data was low, analysis of a dataset created using multiple imputation was performed and compared to the results of complete-case analysis. Estimates of clinical change over the course of the program were similar and help to confirm the validity of the findings presented here.

Strengths

The major strengths of this evaluation include the inclusion of three years of program data from multiple sites of implementation and longitudinal data with objective biometric measures. This program was implemented in an urban, safety net health system context, with low-income participants. These populations face the highest barriers to participation in an in-person program. However, we observed high graduation rates (83.0% graduated across all years) and graduation improved with each year of program implementation (from 79.1% in 2017 and 2018 to 90.8% in 2019). Improvements in program graduation are likely related to increased communication between program partners over time, resulting in greater clarity of goals and a more cohesive and flexible program structure for participants. The GF4H program managed to

address many of the challenges participants face with participating by offering assistance with transportation, allowing participants to bring children to group sessions, and offering the opportunity to make up missed group sessions with one-on-one meetings with providers when needed (D. Denton, A mixed methods analysis to explore retention in the Fruit and Vegetable Prescription program (FVRx) from Grady Hospital, Open Hand, and Wholesome Wave Georgia, 2021).

Conclusions

Overall, our findings support the hypothesis that increased access to fresh produce and education in nutrition, cooking, and food resource management techniques is associated with improved chronic disease risk factors over the course of a six-month intervention in a low-income, urban population. Results of this evaluation indicate that waist circumference and blood pressure changes are the most sensitive to change through the program and small reductions in weight and BMI are achievable. These findings can help with participant and program staff goal setting and inform realistic outcomes from participation in similar programs.

References

1. Lim SS, Voz T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2224-2260.
2. Boeing H, Bechthold A, Bub A, et al. Critical review: Vegetables and fruit in the prevention of chronic diseases. *Eur J Nutr*. 2012.
3. Dietary Guidelines Advisory Committee. *Scientific Report of the 2020 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Agriculture and the Secretary of Health and Human Services*. Washington, DC; 2020.
4. U.S Department of Agriculture; U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2020-2025*.; 2020.
5. Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A. *USDA ERS - Household Food Security in the United States in 2019*.; 2020.
6. Seligman HK, Laraia BA, Kushel MB. Food Insecurity Is Associated with Chronic Disease among Low-Income NHANES Participants. 2010.
7. Leung CW, Epel ES, Ritchie LD, Crawford PB, Laraia BA. Food Insecurity Is Inversely Associated with Diet Quality of Lower-Income Adults. *J Acad Nutr Diet*. 2014.
8. Laraia BA. Food Insecurity and Chronic Disease. *Adv Nutr*. 2013.
9. Hanson KL, Connor LM. Food insecurity and dietary quality in US adults and children: A systematic review. *Am J Clin Nutr*. 2014.
10. Veldheer S, Scartozzi C, Knehans A, et al. A Systematic Scoping Review of How Healthcare Organizations Are Facilitating Access to Fruits and Vegetables in Their Patient Populations. *J Nutr*. 2020.
11. Mozaffarian D, Mande J, Micha R. Food Is Medicine-The Promise and Challenges of Integrating Food and Nutrition into Health Care. *JAMA Intern Med*. 2019.
12. Downer S, Berkowitz SA, Berkowitz SA, Harlan TS, Olstad DL, Mozaffarian D. Food is medicine: Actions to integrate food and nutrition into healthcare. *BMJ*. 2020.
13. Swartz H. Produce RX programs for diet-based chronic disease prevention. *AMA J Ethics*. 2018.
14. Bhat S, Coyle DH, Trieu K, et al. Healthy Food Prescription Programs and their Impacts on Dietary Behavior and Cardiometabolic Risk Factors: A Systematic Review and Meta-Analysis. *Adv Nutr*. 2021:1-13.
15. Purnell JQ, Gernes R, Stein R, Sherraden MS, Knoblock-Hahn A. A systematic review of financial incentives for dietary behavior change. *J Acad Nutr Diet*. 2014.
16. Adams J, Giles EL, McColl E, Sniehotta FF. Carrots, sticks and health behaviours: a framework for documenting the complexity of financial incentive interventions to change health behaviours. *Health Psychol Rev*. 2014.
17. Skinner BF. *Science and Human Behavior*. Cambridge, MA: Skinner Foundation; 1953.

18. Burns RJ, Donovan AS, Ackermann RT, Finch EA, Rothman AJ, Jeffery RW. A theoretically grounded systematic review of material incentives for weight loss: Implications for interventions. *Ann Behav Med*. 2012.
19. Burrington CM, Hohensee TE, Tallman N, Gadomski AM. A pilot study of an online produce market combined with a fruit and vegetable prescription program for rural families. *Prev Med Reports*. 2020.
20. Emmert-Aronson B, Grill KB, Trivedi Z, Markle EA, Chen S. Group medical visits 2.0: The open source wellness behavioral pharmacy model. *J Altern Complement Med*. 2019.
21. Orsega-Smith E, Slesinger N, Cotugna N. Local Pediatricians Partner with Food Bank to Provide Produce Prescription Program. *J Hunger Environ Nutr*. 2019.
22. Ridberg RA, Bell JF, Merritt KE, Harris DM, Young HM, Tancredi DJ. A Pediatric Fruit and Vegetable Prescription Program Increases Food Security in Low-Income Households. *J Nutr Educ Behav*. 2019.
23. Ridberg RA, Marpadga S, Akers MM, Bell JF, Seligman HK. Fruit and Vegetable Vouchers in Pregnancy: Preliminary Impact on Diet & Food Security. *J Hunger Environ Nutr*. 2021.
24. Watt TT erlin., Appel L, Lopez V, Flores B, Lawhon B. A Primary Care-Based Early Childhood Nutrition Intervention: Evaluation of a Pilot Program Serving Low-Income Hispanic Women. *J racial Ethn Heal disparities*. 2015.
25. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implement Sci*. 2011.
26. Redding C a, Rossi JS, Rossi SR, Velicer WF, Prochaska JO. Health Behavior Models. *Int Electron J Health Educ*. 2000.
27. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *Am J Heal Promot*. 1997.
28. Prochaska JO. Decision making in the transtheoretical model of behavior change. *Med Decis Mak*. 2008.
29. Bellg AJ. Maintenance of Health Behavior Change in Preventive Cardiology: Internalization and Self-Regulation of New Behaviors. *Behav Modif*. 2003.
30. Aiyer JN, Raber M, Bello RS, et al. A pilot food prescription program promotes produce intake and decreases food insecurity. *Transl Behav Med*. 2019.
31. Berkowitz SA, O'Neill J, Sayer E, et al. Health Center–Based Community-Supported Agriculture: An RCT. *Am J Prev Med*. 2019.
32. Omar J, Heidemann D, Blum-Alexander B, et al. Fresh prescription program: A program to improve access to fresh products among underserved patients in downtown detroit. *J Gen Intern Med*. 2017;32(2):S7S2.
33. Trapl ES, Smith S, Joshi K, et al. Dietary Impact of Produce Prescriptions for Patients With Hypertension. *Prev Chronic Dis*. 2018.
34. Freedman DA, Choi SK, Hurley T, Anadu E, Hébert JR. A farmers' market at a federally qualified health center improves fruit and vegetable intake among low-income diabetics. *Prev Med (Baltim)*. 2013.
35. Wholesome Wave. *Fruit & Vegetable Prescription Programme Fact Sheet*.; 2017.
36. Wholesome Wave Georgia. Georgia Food for Health (GF4H). https://www.wholesomewavegeorgia.org/gf4h. Published 2018.
37. Hager ER, Quigg AM, Black MM, et al. Development and validity of a 2-item screen to identify families at risk for food insecurity. *Pediatrics*. 2010.

38. Gundersen C, Engelhard EE, Crumbaugh AS, Seligman HK. Brief assessment of food insecurity accurately identifies high-risk US adults. *Public Health Nutr*. 2017.
39. Cooking Matters National. *Cooking Matters Curriculum*. SNAP-Ed Strategies & Interventions Toolkit, USDA SNAP-Ed Connection; 2016.
40. Blumberg J, Bialostosky K, Hamilton WL, Briefel RR. *U.S. Household Food Security Survey Module: Six-Item Short Form*.; 1999.
41. Blumberg SJ, Bialostosky K, Hamilton WL, Briefel RR. The effectiveness of a short form of the household food security scale. *Am J Public Health*. 1999.
42. CDC. Defining adult overweight and obesity. Centers for Disease Control and Prevention.
43. American Heart Association. Understanding Blood Pressure Readings. https://www.heart.org/en/health-topics/high-blood-pressure/understanding-blood-pressure-readings. Published 2021.
44. National Institutes of Health. The practical guide: identification, evaluation, and treatment of overweight and obesity in adults. *US Dep Heal Hum …*. 2000.
45. Stevens J, Truesdale KP, McClain JE, Cai J. The definition of weight maintenance. *Int J Obes*. 2006.
46. Verweij LM, Terwee CB, Proper KI, Hulshof CT, Mechelen W Van. Measurement error of waist circumference: Gaps in knowledge. *Public Health Nutr*. 2013.
47. Jensen MD, Ryan DH, Donato KA, et al. Executive summary: Guidelines (2013) for the management of overweight and obesity in adults. *Obesity*. 2014.
48. Williamson DA, Bray GA, Ryan DH. Is 5% weight loss a satisfactory criterion to define clinically significant weight loss? *Obesity*. 2015.
49. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. *Stat Med*. 2011.
50. Lee KJ, Carlin JB. Multiple imputation for missing data: Fully conditional specification versus multivariate normal imputation. *Am J Epidemiol*. 2010.
51. Stata Corp. *StataCorp. 2017*.; 2017.
52. Buyuktuncer Z, Kearney M, Ryan CL, Thurston M, Ellahi B. Fruit and vegetables on prescription: A brief intervention in primary care. *J Hum Nutr Diet*. 2014.
53. Luu, Catherine; Andersen N. Pharmacy to farm prescriptions pilot program in New York City - Baseline survey findings. *J Nutr Educ Behav*. 2018;50(7):S163-S164.
54. Comerford, B; Doughty, K; Njike, V; Ayettey, R; Weisel, A; Katz, D; Costales V. Impact of a Fruit and Vegetable Prescription Program on Diet Quality and Cardio-Metabolic Risk Factors in Healthy Adults in a Worksite Setting: A Randomized Controlled Trial. *Curr Dev Nutr*. 2019;13(3):Suppl 1.
55. Marcinkevage J, Auvinen A, Nambuthiri S. Washington State's Fruit and Vegetable Prescription Program: Improving Affordability of Healthy Foods for Low-Income Patients. *Prev Chronic Dis*. 2019.
56. Joshi K, Smith S, Trapl E, Bolen S. Implementing a clinic-community partnership to promote fruit and vegetable consumption among food insecure patients with hypertension in safety net clinics. *J Gen Intern Med*. 2016.
57. Bryce R, Guajardo C, Ilarraza D, et al. Participation in a farmers' market fruit and vegetable prescription program at a federally qualified health center improves hemoglobin A1C in low income uncontrolled diabetics. *Prev Med Reports*. 2017.
58. Cavanagh M, Jurkowski J, Bozlak C, Hastings J, Klein A. Veggie Rx: An outcome evaluation of a healthy food incentive programme. *Public Health Nutr*. 2017.

59. Hager K, Mozaffarian D. The promise and uncertainty of fruit and vegetable prescriptions in health care. *J Nutr*. 2020.
60. Pooler JA, Morgan RE, Wong K, Wilkin MK, Blitstein JL. Cooking Matters for Adults Improves Food Resource Management Skills and Self-confidence Among Low-Income Participants. *J Nutr Educ Behav*. 2017.
61. Adedokun OA, Plonski P, Aull M. Food Resource Management Mediates the Relationship Between Participation in a SNAP-Ed Nutrition Education Program and Diet Quality. *J Nutr Educ Behav*. 2021.

Table 1. Demographic characteristics of Georgia Food for Health (GF4H) program graduates, 2017-2019

Characteristic	2017 (n=34) %	2018 (n=91) %	2019 (n=157) %	Overall (n=282) %
Sex				
Female	75.8	72.7	70.1	71.6
Male	24.2	27.3	29.9	28.4
Age in years				
18-29	6.5	2.4	1.9	2.6
30-39	6.5	5.9	5.1	5.5
40-49	35.5	29.4	7.6	17.6
50-59	38.7	45.9	40.8	42.1
60+	12.9	16.5	44.6	32.2
Race & Ethnicity				
Black	90.9	93.0	93.6	93.1
White	0.0	1.2	1.9	1.5
Hispanic	6.1	0.0	2.6	2.2
Other/Multi-racial	3.0	5.8	1.9	3.3
Education				
<HS degree	12.1	11.5	14.2	13.1
HS or GED	18.2	33.3	40.0	35.3
Some college	39.4	40.2	18.1	27.6
College degree	15.2	8.1	16.8	13.8
> college degree	15.2	6.9	11.0	10.2
Health insurance				
Uninsured	21.2	23.9	19.2	20.9
Public insurance	69.7	58.0	68.6	65.3
Insured through employer	3.0	4.6	1.9	2.9
Private insurance	0.0	3.4	2.6	2.5
Other	6.1	10.2	7.7	8.3
Yearly income				
< 25k	93.9	90.8	82.7	86.6
25-35k	6.1	5.8	7.7	6.9
> 35k	0.0	3.5	9.6	6.5
Employment				
Not employed	12.1	11.5	10.3	10.9
On disability	60.6	36.8	37.8	40.2

Working full-time	3.0	9.2	6.4	6.9
Working part-time	9.1	10.3	12.8	11.6
Retired	15.2	21.8	27.6	24.3
Student	0.0	2.3	0.6	1.1
Other	0.0	8.1	4.5	5.1
Food Security				
Food insecure	77.1	53.9	59.7	60.4
SNAP participation				
	69.7	61.6	56.1	59.4

Table 2. Mean changes in clinical indicators between first and last visit attended, among Georgia Food for Health (GF4H) program graduates, 2017-2019

Indicator	N	Mean at first visit (95% CI)	Mean at last visit (95% CI)	Mean Difference (95% CI)	T-Test P-Value
BMI (kg/m^2)	281	36.5 (35.4, 37.5)	36.2 (35.2, 37.2)	-0.3 (-0.5, -0.0)	**0.02**
Weight (lbs)	281	226.4 (219.7, 233.1)	224.8 (218.0, 231.5)	-1.6 (-3.0, -0.2)	**0.03**
Waist circumference (inches)	281	44.9 (44.1, 45.8)	43.4 (42.6, 44.3)	-1.5 (-1.9, -1.1)	**<0.001**
Systolic blood pressure (mmHg)	280	141.0 (138.4, 143.5)	135.8 (133.7, 137.9)	-5.2 (-7.6, -2.8)	**<0.001**
Diastolic blood pressure (mmHg)	280	82.2 (80.7, 83.7)	79.7 (78.3, 81.0)	-2.6 (-4.0, -1.2)	**<0.001**

Table 3. Estimated association of monthly program visits attended (1-6) with change in clinical measures among Georgia Food for Health (GF4H) program graduates, 2017-2019

Measure	**$N_{participants}$**	**Nobs**	**Mean obs per participant**	**Baseline Mean (95% CI)**	**Unadjusted Model (95% CI)**	**Adjusted Model‡ (95% CI)**
BMI (kg/m^2)	273	1,464	5.4	36.80 (33.88, 39.72)	-0.06 (-0.11, 0.00)	-0.06 (-0.11, -0.00)
Weight (lbs)	273	1,464	5.4	227.66 (213.29, 242.02)	-0.31 (-0.68, 0.05)	-0.33 (-0.71, 0.04)
Waist circumference (inches)	273	1,461	5.4	45.10 (43.16, 47.05)	-0.36 (-0.47, -0.25)	-0.36 (-0.47, -0.26)
Systolic blood pressure (mmHg)	273	1,460	5.3	139.79 (137.33, 142.24)	-0.97 (-1.39, -0.55)	-1.01 (-1.44, -0.58)
Diastolic blood pressure (mmHg)	273	1,460	5.3	81.73 (78.50, 84.96)	-0.42 (-0.67, -0.17)	-0.44 (-0.69, -0.18)

All estimates produced from linear mixed models including random intercepts and slopes for participants and site of participation

‡Adjusted models include fixed effects: year, sex, and age

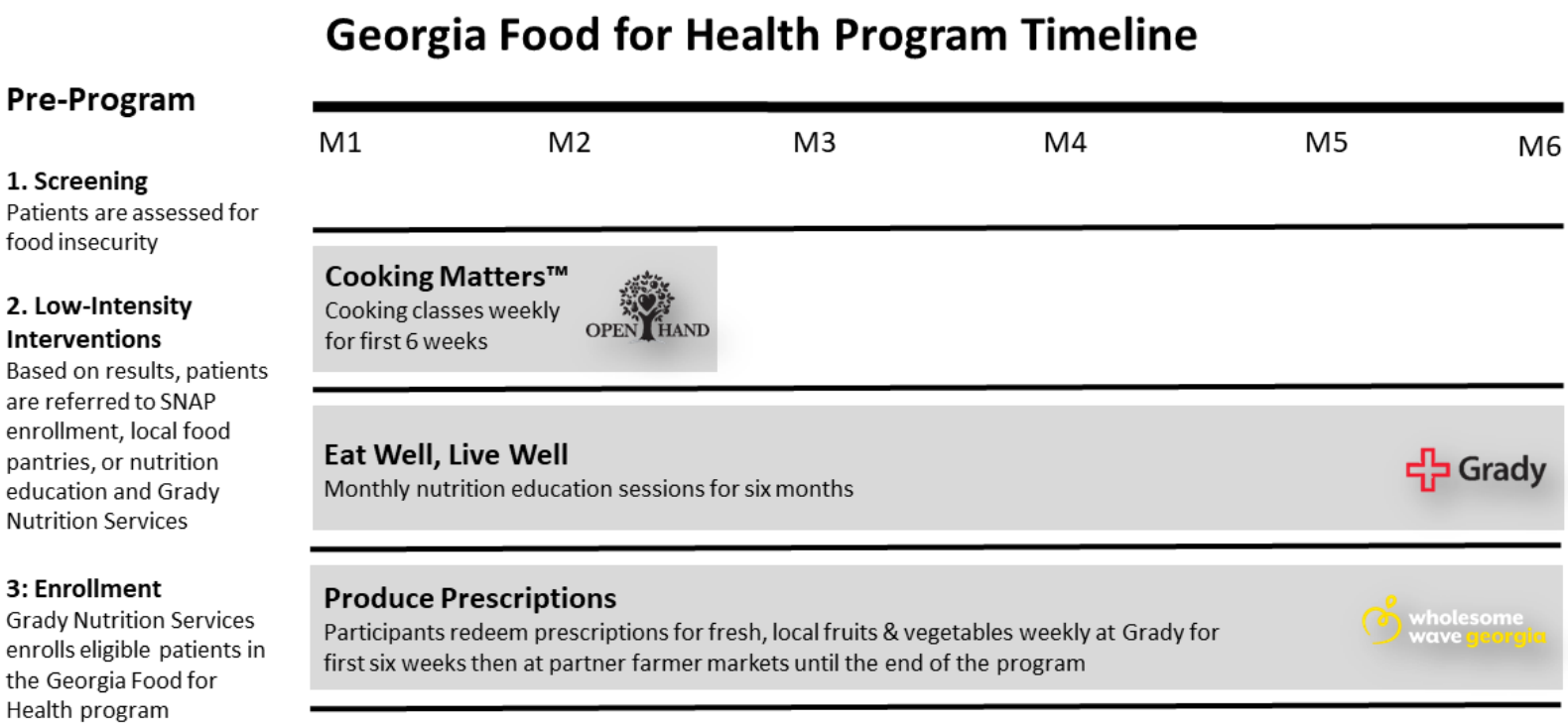
Supplemental Table 1. Estimated association of monthly program visits attended (1-6) with change in clinical measures after multiple imputation among Georgia Food for Health (GF4H) program graduates, 2017-2019

Measure	**$N_{participants}$**	**N_{Obs}**	**Mean obs per participant**	**Baseline Mean (95% CI)**	**Unadjusted Model (95% CI)**	**Model 2ǂ**
BMI (kg/m2)	282	1,510	5.4	36.79 (33.88, 39.69)	-0.06 (-0.11, -0.00)	-0.06 (-0.12, -0.00)
Weight (lbs)	282	1,513	5.4	227.52 (213.30, 241.74)	-0.33 (-0.70, 0.04)	-0.36 (-0.74, 0.01)
Waist circumference (inches)	282	1,513	5.4	45.10 (43.16, 47.03)	-0.36 (-0.47, -0.25)	-0.36 (-0.47, -0.26)
Systolic blood pressure (mmHg)	282	1,513	5.4	139.63 (137.17, 142.10)	-0.94 (-1.36, -0.52)	-0.95 (-1.37, -0.53)
Diastolic blood pressure (mmHg)	282	1,513	5.4	81.64 (78.43, 84.85)	-0.40 (-0.66, -0.15)	-0.40 (-0.65, -0.15)

All estimates produced from linear mixed models including random intercepts and slopes for participants and site of participation

ǂAdjusted models include fixed effects: year, sex, and age

Figure 1. Georgia Food for Health (GF4H) program diagram



Supplemental Table 2. Association between programmatic and individual factors and odds of categorical blood pressure improvement (yes/no), Georgia Food for Health (GF4H) 2017-2019

	Total	**Improved**	**Unimproved**	**OR (95% CI)**	**OR adjusted (95% CI)**
Predictors					
Sex					
Female	197 (71.4%)	37 (18.8%)	160 (81.2%)	Reference	Reference
Male	79 (28.6%)	15 (19.0%)	61 (81.0%)	1.0 (0.5, 2.0)	1.0 (0.4, 2.2)
Age in years					
18-49	68 (25.1%)	21 (30.9%)	47 (69.1%)	Reference	Reference
50+	203 (74.9%)	31 (15.3%)	172 (84.7%)	0.4 (0.2, 0.8)	0.7 (0.3, 1.6)
Income					
<25k	237 (86.5%)	46 (19.4%)	191 (80.6%)	1.2 (0.3, 4.3)	0.7 (0.2, 3.1)
25-35k	19 (6.9%)	2 (10.5%)	17 (89.5%)	0.6 (0.1, 4.1)	0.2 (0.0, 1.8)
>35k	18 (6.6%)	3 (16.7%)	15 (83.3%)	Reference	Reference
SNAP					
Not receiving benefits	112 (40.9%)	16 (14.3%)	96 (85.7%)	Reference	Reference
Receiving benefits	162 (59.1%)	36 (22.2%)	126 (77.8%)	1.7 (0.9, 3.3)	**2.5 (1.1, 5.7)**
Food Security Improvement					
Did not improve	172 (65.7%)	33 (19.2%)	139 (80.8%)	Reference	Reference
Improved	90 (34.4%)	17 (18.9%)	73 (81.1%)	1.0 (0.5, 1.9)	1.3 (0.6, 2.7)
Household Size					

1-2 household members	167 (60.1%)	24 (14.4%)	143 (85.6%)	Reference	Reference
3-4 household members	72 (25.9%)	24 (33.3%)	48 (66.7%)	**3.6 (1.8, 7.3)**	**3.8 (1.6, 9.1)**
5+ household members	39 (14.0%)	5 (12.8%)	34 (87.2%)	0.9 (0.3, 2.7)	0.5 (0.1, 1.9)
Per-person total redemption					
$1 - $50	64 (23.8%)	19 (29.7%)	45 (70.3%)	**2.8 (1.1, 7.1)**	2.7 (0.9, 8.2)
$51-$100	57 (21.2%)	14 (24.6%)	43 (75.4%)	2.2 (0.8, 5.7)	2.0 (0.6, 6.1)
$101-$150	86 (32.0%)	9 (10.5%)	77 (89.5%)	0.8 (0.3, 2.2)	0.4 (0.1, 1.3)
>$150	62 (23.1%)	8 (12.9%)	54 (87.1%)	Reference	Reference
Number of visits attended					
3-4 visits	45 (16.1%)	9 (20.0%)	36 (80.0%)	Reference	Reference
5-6 visits	235 (83.9%)	44 (18.7%)	191 (81.3%)	0.9 (0.4, 2.3)	0.9 (0.3, 2.6)

CI indicates confidence interval; OR, odds ratio; SNAP, *Supplemental Nutrition Assistance Program*.

Note: Values are as n (%) or odds ratio (95% CI).

Supplemental Table 3. Association between programmatic and individual factors and odds of 5% or greater weight loss (yes/no), Georgia Food for Health (GF4H) 2017-2019

	Total	**Improved**	**Unimproved**	**OR (95% CI)**	**OR adjusted (95% CI)**
Predictors					
Sex					
Female	198 (71.2%)	28 (14.1%)	170 (85.9%)	Reference	Reference
Male	80 (28.8%)	3 (3.8%)	77 (96.3%)	**0.2 (0.1, 0.8)**	**0.2 (0.0, 0.7)**
Age					
18-49	70 (25.6%)	11 (15.7%)	59 (84.3%)	Reference	Reference
50+	203 (74.4%)	20 (9.9%)	183 (90.2%)	0.6 (0.3, 1.3)	0.6 (0.2, 1.8)
Income					
<25k	239 (86.6%)	28 (11.7%)	211 (88.3%)	0.7 (0.2, 2.4)	0.8 (0.2, 3.3)
25-35k	19 (6.9%)	0 (0.0%)	19 (100.0%)	-	-
>35k	18 (6.5%)	3 (16.7%)	15 (83.3%)	Reference	Reference
SNAP					
Not receiving benefits	112 (40.6%)	8 (7.1%)	104 (92.9%)	Reference	Reference
Receiving benefits	164 (59.4%)	23 (14.0%)	141 (86.0%)	2.2 (0.9, 5.3)	1.4 (0.5, 3.8)
Food Security Improvement					
Did not improve	172 (65.4%)	19 (11.1%)	153 (89.0%)	Reference	Reference
Improved	91 (34.6%)	11 (12.1%)	80 (87.9%)	1.1 (0.5, 2.5)	1.2 (0.5, 3.0)
Household Size					
1-2 household members	168 (60.2%)	16 (9.5%)	152 (90.5%)	Reference	Reference
3-4 household members	71 (25.5%)	6 (8.5%)	65 (91.6%)	0.9 (0.3, 2.3)	0.8 (0.3, 2.5)

5+ household members	40 (14.3%)	9 (22.5%)	31 (77.5%)	**2.8 (1.1, 6.8)**	2.3 (0.7, 7.1)
Per-person total redemption					
$1 - $50	66 (24.4%)	4 (6.1%)	62 (93.9%)	0.7 (0.2, 2.9)	0.7 (0.1, 3.6)
$51-$100	56 (20.7%)	9 (16.1%)	47 (83.9%)	2.2 (0.7, 7.0)	2.0 (0.5, 7.9)
$101-$150	86 (31.9%)	10 (11.6%)	76 (88.4%)	1.5 (0.5, 4.6)	1.1 (0.3, 4.1)
>$150	62 (23.0%)	5 (8.1%)	57 (91.9%)	Reference	Reference
Number of visits attended					
3-4 visits	45 (16.0%)	3 (6.7%)	42 (93.3%)	Reference	Reference
5-6 visits	236 (84.0%)	28 (11.9%)	208 (88.1%)	1.9 (0.5, 6.5)	2.2 (0.5, 10.8)

CI indicates confidence interval; OR, odds ratio; SNAP, *Supplemental Nutrition Assistance Program*.

Note: Values are as n (%) or odds ratio (95% CI).

Supplemental Table 4. Association between programmatic and individual factors and odds of 5% or greater reduction in waist circumference (yes/no), Georgia Food for Health (GF4H) 2017-2019

	Total	**Improved**	**Unimproved**	**OR (95% CI)**	**OR adjusted (95% CI)**
Predictors					
Sex					
Female	197 (71.1%)	86 (43.7%)	111 (56.4%)	Reference	Reference
Male	80 (28.9%)	32 (40.0%)	48 (60.0%)	1.0 (0.6, 1.8)	1.0 (0.5, 1.9)
Age					
18-49	69 (25.4%)	32 (46.4%)	37 (53.6%)	Reference	Reference
50+	203 (74.6%)	85 (41.9%)	118 (58.1%)	0.7 (0.4 1.2)	0.6 (0.3, 1.2)
Income					
<25k	238 (86.6%)	104 (43.7%)	134 (56.3%)	1.4 (0.5, 3.7)	2.2 (0.7, 6.7)
25-35k	19 (6.9%)	6 (31.6%)	13 (68.4%)	0.9 (0.2, 3.7)	1.1 (0.3, 5.2)
>35k	18 (6.6%)	7 (38.9%)	11 (61.1%)	Reference	Reference
SNAP					
Not receiving benefits	111 (40.4%)	50 (45.1%)	61 (55.0%)	Reference	Reference
Receiving benefits	164 (59.6%)	68 (41.5%)	96 (58.5%)	1.0 (0.6, 1.7)	0.9 (0.5, 1.7)
Food Security Improvement					
Did not improve	172 (65.4%)	77 (44.8%)	95 (55.2%)	Reference	Reference
Improved	91 (34.6%)	39 (42.9%)	52 (57.1%)	0.9 (0.6, 1.6)	1.0 (0.6, 1.8)
Household Size					
1-2 household members	167 (59.9%)	65 (38.9%)	102 (61.1%)	Reference	Reference
3-4 household members	72 (25.8%)	36 (50.0%)	36 (50.0%)	1.4 (0.8, 2.5)	1.2 (0.6, 2.3)
5+ household members	40 (14.3%)	18 (45.0%)	22 (55.0%)	1.2 (0.6, 2.5)	1.4 (0.5, 3.4)
Per-person total redemption					
$1 - $50	65 (24.1%)	27 (41.5%)	38 (58.5%)	1.8 (0.8, 4.0)	1.6 (0.6, 4.4)
$51-$100	57 (21.1%)	19 (33.3%)	38 (66.7%)	0.8 (0.4, 1.8)	0.9 (0.3, 2.1)

$101-$150	86 (31.9%)	44 (51.2%)	42 (48.8%)	1.6 (0.8, 3.1)	1.8 (0.8, 3.8)
>$150	62 (23.0%)	25 (40.3%)	37 (59.7%)	Reference	Reference
Number of visits attended					
3-4 visits	45 (16.0%)	11 (24.4%)	34 (75.6%)	Reference	Reference
5-6 visits	236 (84.0%)	108 (45.8%)	128 (54.2%)	2.1 (1.0, 4.5)	2.1 (0.7, 5.9)

CI indicates confidence interval; OR, odds ratio; SNAP, *Supplemental Nutrition Assistance Program*.

Note: Values are as n (%) or odds ratio (95% CI).

Chapter 5: Changes in confidence & food resource management skills drive diet change in a produce prescription program: A multivariate pathway analysis

Introduction

Produce prescription (PRx) programs are increasingly popular approaches to improving access to and consumption of fresh produce for patients experiencing food insecurity and chronic disease. These programs use a partnership model of care combining health clinics, community-based organizations, farmers markets, and research institutions.[1] In this model, patients are recruited based on chronic disease status or risk factors and food insecurity. Once enrolled, patients are provided vouchers or "prescriptions" redeemable for produce and engage in nutrition education sessions.

Evaluations of PRx programs report improvements in food security ranging from 18% to 94% relative to baseline.[2–5] A recent meta-analysis estimated that PRx programs increase fruit and vegetable consumption by 22%, corresponding to an increase of 0.8 daily servings.[6] While these results are promising, there is limited evidence on the mechanisms of action operating within these programs. Multiple activities are conducted simultaneously within PRx programs including nutrition and health education, the provision of free produce, and other activities such as cooking education, exercise, and group-based health discussions, depending on the specific program.[7] The goals of nutrition education in these programs are also multi-factorial, focusing on improving knowledge, attitudes, and confidence related to buying and cooking healthy foods on a budget,[8–11] healthy purchasing and cooking practices,[2,4,5,8–15] and dietary disease self-management strategies,[11,15–20] just to name a few.

Nutrition education and environmental supports in PRx programs are intended to

facilitate behavior change and improve diet quality.[21] Key factors influencing behavior change readiness include attitudes and self-efficacy.[22–26] Improvements in these factors, in turn, have been demonstrated to improve intentions and health behaviors.[27] Nutrition education programs such as SNAP-Education (SNAP-Ed) have been demonstrated to be effective at improving food security and diet quality.[28–31] However, the distinct and combined effects of intermediate behavioral outcomes such as self-efficacy and attitudes on diet and food security outcomes are unclear. Interventions targeting food insecure populations often additionally include education on food resource management (FRM) practices, which are techniques promoting cost-effective shopping and selection of healthy foods. FRM strategies include shopping sales, comparing prices while shopping, shopping with a list, and planning meals ahead of time. Improvements in FRM skills have been associated with improvements in food security[31,32] and diet quality.[33–36]

For evaluation and program improvement purposes, it is important to understand which intervention components in a program's theory of change impact program outcomes, which fall short of expectations, and how various intermediate outcomes affect primary program outcomes like food security and diet quality. Measured variable path analysis, a structural equation modeling technique, is an approach used to investigate relationships in a theory of change and determine how well a hypothesized model applies to observed data.[37] Path models include variables whose variation is explained by factors not in the model (exogenous variables) and variables whose variation is explained, at least partially, by other variables in the model (endogenous variables).[38] Correlations between these variables can be used to estimate direct and indirect (mediated) effects to understand mechanisms of action, how closely an intervention maps to hypothesized logic models, and to identify areas for program improvement.

We hypothesized that PRx programs operate by increasing food security, attitudes, and

confidence, which in turn, improve food resource management & healthy purchasing behaviors, and ultimately increase fruit and vegetable consumption.[39,40] Additionally, we hypothesized that changes in resource score and purchase score would covary, since many of the behaviors captured in the resource score would be expected to coincide with behaviors captured in the purchase score. Logically, food purchasing behaviors are considered a mediator between the food environment and eating behaviors.[41] Although similar research has been conducted evaluating programs such as SNAP-Ed, to our knowledge, this is the first pathway analysis applied to evaluate mechanisms of action in a PRx program.

Methods

Program Description

To investigate mechanisms of action in PRx programs, we used data collected from two years of implementation of the Georgia Food for Health program (GF4H). GF4H is a PRx program implemented at Grady Health System community health clinics in the metro Atlanta area. GF4H represents a partnership between Grady Health system as the clinic partner, Open Hand Atlanta as a funding and cooking instruction partner, Wholesome Wave Georgia as a coordinating and funding partner, Georgia Common Market and Community Farmers Market's Fresh MARTA Market as produce supplier and redemption site partners, and Emory University as the research and evaluation partner.

Recruitment

Participants were recruited by providers from five clinics within the Grady healthcare system. Three clinics are primary care clinics, one is a specialty clinic for patients with diabetes, and one is an infectious disease specialty clinic. Participants from four of the five clinics were recruited from a pool of patients who were attending group nutrition education sessions offered at the

clinics by registered dietitians. At the fifth clinic, participants were referred directly during clinic visits by their healthcare providers and followed-up by registered dietitians for enrollment. Eligibility requirements included a positive screen for food insecurity in the previous 12 months using a validated 2-item food insecurity screener.[42,43] All participants were 18 years or older, patients of the Grady Primary Care Centers, and expressed commitment to the 6-month program.

Intervention

For the first six weeks of the course, nutrition education and cooking classes were administered by a registered dietitian according to Project Open Hand's Cooking Matters for Adults curriculum.[44] Class topics covered include food resource management strategies with an emphasis on making healthy purchase decisions on a budget. At each weekly meeting, seasonal produce was provided according to participant household size. Following completion of the Cooking Matters course, participants moved to a once-monthly meeting schedule. At each of these monthly sessions, nutrition education was provided along with vouchers worth $1 per family member per day, redeemable once weekly at local retail locations such as the Fresh Marta farmers markets located in train stations around metro Atlanta.

Data Collection

Surveys were administered at the enrollment meeting prior to the first Cooking Matters course, at the final Cooking Matters course six weeks later, and at the end of the program (6 months following baseline).[45] The surveys captured sociodemographic information, food security, attitudes, confidence, as well as food resource management practices, health purchasing practices, and diet. Demographic information collected includes age in years (dichotomized around the median to <50 years, ≥ 50 years), sex (male, female), race & ethnicity (black or African-American, white, Hispanic, & other/multi-racial), and household size. Food security was

measured using the USDA 6-item food security screener at baseline, six weeks, and endline.[46]

Survey questions assess a) attitudes and perceptions of access and affordability as well as enjoyment of cooking and eating healthy foods, b) confidence in ability to cook and eat healthy foods, c) frequency of using food resource management practices, d) frequency of making healthy purchasing decisions, and e) frequency of consumption of various diet components. More specifically, questions assessing attitudes queried agreement with statements on access and affordability of fruits and vegetables, willingness to try new foods, enjoyment of eating fruits and vegetables, and attitudes towards cooking. Response options used a 3-point Likert scale for 'Never', 'Sometimes', and 'Always'. Questions assessing confidence asked about confidence with using the same healthy ingredient in different recipes, choosing the best-priced form of fruits and vegetables (between fresh, frozen, or canned varieties), using basic cooking skills, as well as buying and cooking health foods for their family on a budget, and helping friends and family eat healthier. Response options used a 5-point Likert scale ranging from '0-Not at all confident' to ''4-Very confident". Food resource management practices were assessed via questions on frequency of comparing prices when shopping, planning meals ahead of time, using shopping lists, cooking meals at home, and adjusting meals to include more budget-friendly ingredients. Purchasing practices were assessed through questions on frequency of purchasing low-fat milk (skim or 1%), low-fat dairy, lean meat, whole grains, low-sodium foods, and reading nutrition labels when selecting food. Responses on these questions used a 5-point Likert scale ranging from '0-Never', to '4- Always', and 'Not applicable'. Diet was also assessed through questions on usual frequency of consuming fruit, green salads, dark leafy greens, other non-fried vegetables, fried potatoes, non-fried white potatoes, beans, food prepared and purchases away from home (such as from restaurants, carry-out, drive-thru, or delivery), and

consuming food from each food group every day. Response options included ‘Not at all’, ‘Once a week or less’, ‘More than once a week’, ‘Once a day’, and ‘More than once a day’.

Creation of Index Measures

Food security scores were created following the USDA 6-item food security scoring guide. Measures collected from survey data were combined into indices capturing attitudes, confidence, food resource management practices, healthy purchasing practices, and healthy food consumption using methodology previously developed by Obrutu.[47]

The diet score combined total responses on frequency of consumption of fruits, salads, dark green vegetables, other green vegetables, non-fried potatoes, fried potatoes, and consuming food from all food groups every day.[47] All measured diet components except fried potatoes were categorized as desirable. Positive scores were assigned to desirable food components, ranging from 0 to 4, with 0 representing a response of “never” or “not at all” and 4 representing a response of “always” or “more than once a day.” These scores were inverted for undesirable food components, with a score of 0 representing a response of “always” or “more than once a day” and 4 representing a response of “never” or “not at all”.[47]

Healthy purchase scores were similarly created by combining responses of participants reported frequency of purchasing low fat milk, low fat dairy, lean meat, whole grains, low-sodium foods, and looking at nutrition labels when purchasing foods. All purchasing practices were considered desirable and scores were assigned 0-4, with 0 representing a response of ‘never’ and 4 representing a response of ‘always’.

Resource management scores were created by combining responses of participants reported frequency of comparing prices when shopping, planning meals ahead of time, using shopping lists, cooking meals at home, and adjusting meals to include more budget-friendly

ingredients. All resource management practices assessed were considered desirable and scores were assigned 0-4, with 0 representing a response of 'never' and 4 representing a response of 'always'.

Attitude scores were created by combining responses of participants' reported agreement with statements on access and affordability of fruits and vegetables, willingness to try new foods, enjoyment of eating fruits and vegetables, and attitudes towards cooking. Three statements about cooking were considered negative: *It takes too much time to cook, Cooking is frustrating*, and *It is too much work to cook*. One statement about cooking was considered positive: *I think cooking is fun.* All other statements were considered positive and scores were assigned 0-2, with 0 representing 'Never' and 2 representing 'Always'. Scores were inverted for negative attitudes, with a score of 0 representing 'Always' and a score of 2 representing 'Never'.

Confidence scores were created by combining responses of participants' reported confidence in using the same healthy ingredient in different recipes, choosing the best-priced from of fruits and vegetables, using basic cooking skills, as well as buying and cooking healthy foods for their family on a budget, and helping family and friends eat healthier. Scores were assigned 0-4, with 0 representing 'Not at all confident' and 4 representing 'Very confident'.

Total scores are represented as a proportion of the total attainable score multiplied by 10 to put all score variables on the same scale.[47] Descriptive statistics and summaries for score variables are presented in Table 4.

To capture change in each component over the course of the program, baseline measures were subtracted from endline measures. Food security change was then reverse coded so that a higher score would indicate an improvement in food security from baseline to endline.

Analysis

These index score measures were used to fit a path model estimating the relationships between change in program components and change in outcomes over the course of the program. Covariates in models included age and sex of participant as well as site and year of program participation. Due to homogeneity in the study sample, race was not included as a covariate and age was dichotomized around the median to <50 & ≥ 50 years old. Our hypothesized model is presented in Figure 1.

Due to missing endline data for participants who did not complete the program (n=37), this analysis was restricted to graduates of the program (n=248). Sample sizes for path analysis are recommended to contain at least twenty observations for every parameter estimated.[38] After excluding those with missing data for variables used in analysis (n=70), our sample included 178 participants, with 30% from the 2018 program year and 70% from the 2019 program year (ranging 20-55 per clinic site). A sample of 178 allowed for estimation of approximately 9 parameters.

Estimates of direct effects were calculated and reported both unstandardized with statistical error and standardized. Estimates of indirect effects were bootstrapped, or resampled 500 times, in line with recommendations for estimation of indirect effects and reported standardized.[38,48,49] Model fit was interpreted based on the following indices: Root Mean Squared Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Squared Residual (SRMR). RMSEA < 0.08, CFI > 0.95, TLI >0.95, and SRMR < 0.08 are the criteria for consideration of good fit.[50] Modification indices were used to adjust model fit where appropriate based on theory.

Frequencies and means with 95% confidence intervals were calculated to describe the

study sample. Paired t-tests were used to compare differences in study outcomes from the baseline to endline. Stata version 15.0 software was used for data management procedures and descriptive statistics while the lavaan package version 0.6-3 within R software was used for pathway analysis.[51–53]

Results

The majority of participants were Black or African-American women over the age of 50 (Table 5). Over half of participants reported receiving SNAP benefits (56%) and 63% reported a monthly household income of ≤ $1,300. The average household size was 2.5, ranging from 1 to 9. Most participants were insured through Medicare or Medicaid (63%) or uninsured (23%). The average number of monthly program visits attended was 5.6, ranging from 3 to 6. The average amount of produce vouchers redeemed per-person in household was $126.90 and ranged from $0 to $351.71.

Proposed Model

Several models were examined to better understand the relationship between changes in attitudes, confidence, purchase and food resource management behaviors, food security, and diet. Originally, we hypothesized that the number of program visits attended would have direct effects on attitude and confidence change as well as on the total amount of vouchers redeemed in the program, given that vouchers were distributed at program visits. We hypothesized that the total amount of vouchers redeemed would have direct effects on food security change and diet change. We additionally hypothesized that food security change would have a direct effect on diet change. We hypothesized direct effects from confidence change to food resource management change and diet change, in addition to a direct effect from food resource management change to both food security and diet change. We hypothesized direct effects from

attitude change to purchase change and diet change in addition to a direct effect from purchase change to diet change (Figure 2).

Final Model

Model fit statistics indicate that the final model fit was good (χ^2: 0.544, CFI:1.000, TLI: 1.209, RMSEA < 0.001, & SRMR: 0.014). Standardized estimates of direct effects are presented in Figure 3 and Table 6. After controlling for sex and age of participant as well as site and year of program participation, change in confidence score had moderate direct effects on change in purchase score (β=0.201, $p<0.01$) and change in food resource management score (β=0.310, $p<0.001$). Change in attitude score additionally had a direct effect on change in food resource management score (β=0.151, $p=0.04$), which had a moderate significant direct effect on change in diet score (β=0.184, $p=0.02$). No other significant direct or indirect effects were observed in the model.

Discussion

This study examined the pathways by which PRx programs are expected to improve food security and diet, with findings revealing that increased confidence in ability to buy and cook healthy foods on a budget and increased use of food resource management techniques such as comparing prices while shopping were most impactful on observed improvements in healthy eating scores.

The results of this study align with previous work conducted by Adedokun et al. indicating that improvements in food resource management skills mediate the relationship between participation in a SNAP-Ed nutrition education program and diet quality improvements.[29] While few studies have conducted pathway or mediation analyses, the relationship between improvements in food resource management and increases in diet quality

have been well-documented.[33–36,54] Further, it has been previously reported that self-efficacy in managing food resources was significantly associated with food security among food pantry clients, confirming the importance of emphasizing food resource management practices in food security interventions.[32]

It was assumed that the provision of free produce would improve food security and increase consumption of fruits and vegetables. While we observed significant improvements in food security over the course of the program (34%; $p<0.001$), our results indicate that these improvements were not directly associated with the collected measures of program engagement: number of sessions attended and total voucher redemption. Eicher-Miller et al. previously reported that SNAP-Ed participation directly improved food security with no observed mediation or moderation effects from participation in food assistance programs such as SNAP, WIC, or food pantries.[28] Although these programs differed from the PRx program model, their results indicated that SNAP-Ed improved food security directly rather than magnifying improvements related to economic food assistance. Further, they found no association between the magnitude of change in food security and program characteristics such as number of lessons attended, delivery format, or SNAP-Ed educator.[28] In their study, participation in more than the minimum four sessions did not result in greater improvements in food security.[28] Collectively, these results could indicate that participation in the minimum SNAP-Ed sessions alone is sufficient to improve food security. However, not all participants of food assistance programs participate in SNAP-Ed programs and a myriad of research shows participation in SNAP increases food security and improves nutrition outcomes.[55–57] Further research is needed to better understand the distinct and combined effects of economic nutrition assistance and nutrition education for improving food security.

While this study expands knowledge of how intermediary educational outcomes are associated with food insecurity and diet outcomes, it is not without limitations. Firstly, educational outcomes were assessed via a survey, introducing the potential for both recall and social desirability biases, which could overestimate effects, as well as measurement error, which could underestimate effects. While these limitations are true for all self-reported data, the survey tool used in this study has been previously validated through both cognitive interviewing and psychometric testing and provides satisfactory internal consistency and construct validity among a diverse population of low-income adults.[58] Second, due to program design, there was limited heterogeneity in the measured program components available for analysis. Participants were required to complete four of six weekly cooking classes and four of six monthly nutrition education sessions to graduate, creating a limited range of number of program visits attended. Similarly, participants were required to redeem produce vouchers at least once a month to remain in the program; as such little variation exists in total voucher redemption among graduates. Ultimately, these program components were excluded from the final model due to this lack of variation and the prioritization of other study variables, given the small sample size, which limited the ability to examine more than 9 pathways. However, this study made use of multiple years of program data collected across multiple cohorts and with validated measurements of intermediary educational outcomes that, to our knowledge, have not been reported on previously in the PRx literature.

Strengths

A major strength of this study was the use of index scores to summarize intermediary outcomes including attitudes, confidence, purchase behaviors, and food resource management practices. This allowed for the use of more of the available data within the constraints of a small sample

size for pathway analysis. While index scores can underestimate effects when individual items included in the index are not sensitive to change, potentially diluting other effects observed in the data, they are nevertheless useful for estimating relationships between constructs and managing model complexity.[59–61] Without composite variables like index scores, complex models can become highly specific, which ultimately limits the ability to put findings to practical use in community programs.[59] For these reasons, index scores represent a compromise between using all available data to explore meaningful questions and over-specifying a model beyond applicable utility. Few evaluations of PRx programs have reported on diet outcomes beyond fruits and vegetables, despite the recognition that other dietary components such as whole grains, beans, and lean meat are also important for health.[6] Index scores allowed for the consideration of all dietary components including those that should be consumed in moderation, such as fried potatoes. For investigations of mechanisms of action, pathway analysis has several strengths.

This method allows for assessment of both direct and indirect relationships, which is useful for understanding how intermediary outcomes work in tandem to produce observed changes in ultimate outcomes, or perhaps identify where interventions fall short of achieving change in ultimate outcomes. In that way, pathway analysis is not only useful for identifying mechanisms of action, but also for identifying areas for program improvement and cost-savings.

Future work should focus on aggregating data across similar interventions with variation in program implementation in order to compare program components in addition to these intermediary educational outcomes. Greater heterogeneity in program components and sites of implementation as well as a larger sample size will allow for broader multilevel modeling capabilities to better explain how these programs operate in context, highlight the most effective program components, and identify areas for program improvement.

Conclusions

This study highlights the components of nutrition education that are likely “active ingredients” needed to improve diet quality. Improvements in confidence with buying and cooking healthy food on a budget and food resource management practices such as comparing prices show promise as key drivers of diet change in a six-month PRx program. Confidence-promoting activities and education on food resource management techniques should continue to be prioritized in similar interventions.

References

1. Swartz H. Produce RX programs for diet-based chronic disease prevention. *AMA Journal of Ethics*. 2018.
2. Ridberg RA, Bell JF, Merritt KE, Harris DM, Young HM, Tancredi DJ. A Pediatric Fruit and Vegetable Prescription Program Increases Food Security in Low-Income Households. *Journal of Nutrition Education and Behavior*. 2019.
3. Aiyer JN, Raber M, Bello RS, et al. A pilot food prescription program promotes produce intake and decreases food insecurity. *Translational Behavioral Medicine*. 2019.
4. Ridberg RA, Marpadga S, Akers MM, Bell JF, Seligman HK. Fruit and Vegetable Vouchers in Pregnancy: Preliminary Impact on Diet & Food Security. *Journal of Hunger and Environmental Nutrition*. 2021.
5. Berkowitz SA, O'Neill J, Sayer E, et al. Health Center–Based Community-Supported Agriculture: An RCT. *American Journal of Preventive Medicine*. 2019.
6. Bhat S, Coyle DH, Trieu K, et al. Healthy Food Prescription Programs and their Impacts on Dietary Behavior and Cardiometabolic Risk Factors: A Systematic Review and Meta-Analysis. *Advances in Nutrition*. 2021:1-13.
7. Rodriguez ME, Drew C, Bellin R, Babaian A, Ross D. *Produce Prescription Programs: US Field Scan Report: 2010-2020*.
8. Orsega-Smith E, Slesinger N, Cotugna N. Local Pediatricians Partner with Food Bank to Provide Produce Prescription Program. *Journal of Hunger and Environmental Nutrition*. 2019.
9. Slagel N, Newman T, Sanville L, et al. A Pilot Fruit and Vegetable Prescription (FVRx) Program Improves Local Fruit and Vegetable Consumption, Nutrition Knowledge, and Food Purchasing Practices. *Health Promotion Practice*. 2021.
10. Slagel N, Newman T, Sanville L, et al. The Effects of a Fruit and Vegetable Prescription Program (FVRx)® for Low-Income Individuals on Fruit and Vegetable Intake and Food Purchasing Practices. *Journal of Nutrition Education and Behavior*. 2018.
11. Cook M, Ward R, Newman T, et al. Food Security and Clinical Outcomes of the 2017 Georgia Fruit and Vegetable Prescription Program. *Journal of Nutrition Education and Behavior*. 2021.
12. Burrington CM, Hohensee TE, Tallman N, Gadomski AM. A pilot study of an online produce market combined with a fruit and vegetable prescription program for rural families. *Preventive Medicine Reports*. 2020.
13. Paolantonio L, Kim SY, Ramirez J, et al. Food Purchasing Behavior of Food Insecure Cancer Patients Receiving Supplemental Food Vouchers. *Supportive Care in Cancer*. 2020;28(8).
14. Bryce R, Guajardo C, Ilarraza D, et al. Participation in a farmers' market fruit and vegetable prescription program at a federally qualified health center improves hemoglobin A1C in low income uncontrolled diabetics. *Preventive Medicine Reports*. 2017.
15. Trapl ES, Smith S, Joshi K, et al. Dietary Impact of Produce Prescriptions for Patients With Hypertension. *Preventing Chronic Disease*. 2018.
16. Friedman DB, Freedman DA, Choi SK, et al. Provider Communication and Role Modeling Related to Patients' Perceptions and Use of a Federally Qualified Health Center-Based Farmers' Market. *Health Promotion Practice*. 2014.
17. Omar J, Heidemann D, Blum-Alexander B, et al. Fresh prescription program: A program to improve access to fresh products among underserved patients in downtown detroit. *Journal of General Internal Medicine*. 2017;32(2):S7S2.
18. Cavanagh M, Jurkowski J, Bozlak C, Hastings J, Klein A. Veggie Rx: An outcome evaluation of a healthy food incentive programme. *Public Health Nutrition*. 2017.

19. Joshi K, Smith S, Trapl E, Bolen S. Implementing a clinic-community partnership to promote fruit and vegetable consumption among food insecure patients with hypertension in safety net clinics. *Journal of General Internal Medicine*. 2016.
20. Marcinkevage J, Auvinen A, Nambuthiri S. Washington State's Fruit and Vegetable Prescription Program: Improving Affordability of Healthy Foods for Low-Income Patients. *Preventing Chronic Disease*. 2019.
21. Contento IR, Koch PA. *Nutrition Education: Linking Research, Theory, and Practice*. Jones & Bartlett; 2020.
22. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *American Journal of Health Promotion*. 1997.
23. Prochaska JO, Redding CA, Evers KE. The Transtheoretical Model and Stages of Change. In: *Health Behavior and Health Education*. ; 2008.
24. Prochaska JO. Decision making in the transtheoretical model of behavior change. *Medical Decision Making*. 2008.
25. Bandura A. Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*. 1977.
26. Bandura A. Health promotion from the perspective of social cognitive theory. *Psychology and Health*. 1998.
27. Sheeran P, Maki A, Montanaro E, et al. The impact of changing attitudes, norms, and self-efficacy on health-related intentions and behavior: A meta-analysis. *Health Psychology*. 2016.
28. Eicher-Miller HA, Rivera RL, Sun H, Zhang Y, Maulding MK, Abbott AR. Supplemental nutrition assistance program-education improves food security independent of food assistance and program characteristics. *Nutrients*. 2020.
29. Adedokun OA, Plonski P, Aull M. Food Resource Management Mediates the Relationship Between Participation in a SNAP-Ed Nutrition Education Program and Diet Quality. *Journal of Nutrition Education and Behavior*. 2021.
30. Rivera RL, Maulding MK, Abbott AR, Craig BA, Eicher-Miller HA. SNAP-Ed (supplemental nutrition assistance program-education) increases long-term food security among Indiana households with children in a randomized controlled study. *Journal of Nutrition*. 2016.
31. Kaiser L, Chaidez V, Algert S, et al. Food Resource Management Education With SNAP Participation Improves Food Security. *Journal of Nutrition Education and Behavior*. 2015.
32. Martin KS, Colantonio AG, Picho K, Boyle KE. Self-efficacy is associated with increased food security in novel food pantry program. *SSM - Population Health*. 2016.
33. Wiig K, Smith C. The art of grocery shopping on a food stamp budget: Factors influencing the food choices of low-income women as they try to make ends meet. *Public Health Nutrition*. 2009.
34. Dubowitz T, Cohen DA, Huang CY, Beckman RA, Collins RL. Using a Grocery List Is Associated With a Healthier Diet and Lower BMI Among Very High-Risk Adults. *Journal of Nutrition Education and Behavior*. 2015.
35. Kim SY, Nayga RM, Capps O. The Effect of Food Label Use on Nutrient Intakes: An Endogenous Switching Regression Analysis. *Journal of Agricultural and Resource Economics*. 2000.
36. Crawford D, Ball K, Mishra G, Salmon J, Timperio A. Which food-related behaviours are associated with healthier intakes of fruits and vegetables among women? *Public Health Nutrition*. 2007.
37. Pedhazur EJ. Multiple Regression in Behavioral Research; Explanation and Prediction. *Journal*

of the American Statistical Association. 1997.
38. Kline RB. *Principles and Practice of Structural Equation Modeling: Third Edition*.; 2011.
39. Mello, Jennifer; Gans, Kim; Risica, Patricia; Kirtania, Usree; Strolla, Leslie; Fournier L. How is food insecurity associated with dietary behaviors? An analysis with low income, ethnically diverse participants in a nutrition intervention study. *Journal of the American Dietetic Association*. 2010;110(12):1906-1911.
40. Brug, J; Lechner, L; De Vries H. Psychosocial determinants of fruit and vegetable consumption. *Appetite*. 1995;25(3):285-296.
41. Appelhans BM, French SA, Tangney CC, Powell LM, Wang Y. To what extent do food purchases reflect shoppers' diet quality and nutrient intake? *International Journal of Behavioral Nutrition and Physical Activity*. 2017.
42. Hager ER, Quigg AM, Black MM, et al. Development and validity of a 2-item screen to identify families at risk for food insecurity. *Pediatrics*. 2010.
43. Gundersen C, Engelhard EE, Crumbaugh AS, Seligman HK. Brief assessment of food insecurity accurately identifies high-risk US adults. *Public Health Nutrition*. 2017.
44. Cooking Matters National. *Cooking Matters Curriculum*. SNAP-Ed Strategies & Interventions Toolkit, USDA SNAP-Ed Connection; 2016.
45. Cooking Matters. Share our Strength Cooking Matters for Adults Survey. 2017.
46. Blumberg J, Bialostosky K, Hamilton WL, Briefel RR. *U.S. Household Food Security Survey Module: Six-Item Short Form.*; 1999.
47. Obrutu O. Evaluation of the impact of Grady FVRx program on dietary practices and food security status of low-income patients with chronic disease risk. 2020.
48. Nevitt J, Hancock GR. Performance of bootstrapping approaches to model test statistics and parameter standard error estimation in structural equation modeling. *Structural Equation Modeling*. 2001.
49. Yung Y-F, Bentler PM. Bootstrapping techniques in analysis of mean and covariance structures. In: *Advanced Structural Equation Modeling: Issues and Techniques*. ; 1996.
50. Hooper D, Coughlan J, Mullen MR. Structural equation modelling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods*. 2008.
51. Stata Corp. *StataCorp. 2017*.; 2017.
52. Team RC. R: A Language and Environment for Statistical Computing. *Vienna, Austria*. 2019.
53. Rosseel Y. Lavaan: An R package for structural equation modeling. *Journal of Statistical Software*. 2012.
54. Hersey J, Anliker J, Miller C, et al. Food shopping practices are associated with dietary quality in low-income households. *Journal of Nutrition Education and Behavior*. 2001.
55. Keith-Jennings B, Llobrera J, Dean S. Links of the supplemental nutrition assistance program with food insecurity, poverty, and health: Evidence and potential. *American Journal of Public Health*. 2019.
56. Carlson S, Keith-Jennings B. SNAP Is Linked with Improved Nutritional Outcomes and Lower Health Care Costs. *Center on Budget and Policy Priorities*. 2018.
57. Ratcliffe C, McKernan SM, Zhang S. How much does the supplemental nutrition assistance program reduce food insecurity? *American Journal of Agricultural Economics*. 2011.
58. Pinard CA, Uvena LM, Quam JB, Smith TM, Yaroch AL. Development and testing of a revised cooking matters for adults survey. *American Journal of Health Behavior*. 2015.
59. Grace JB, Bollen KA. Representing general theoretical concepts in structural equation models: The role of composite variables. *Environmental and Ecological Statistics*. 2008;15(2):191-213.

60. Dialga I, Thi Hang Giang L. Highlighting Methodological Limitations in the Steps of Composite Indicators Construction. *Social Indicators Research*. 2017;131(2).
61. Song MK, Lin FC, Ward SE, Fine JP. Composite variables: When and how. *Nursing Research*. 2013;62(1).

Figure 2. Hypothesized model representing relationships between program components, intermediate educational outcomes, food security and diet, GF4H 2018-2019

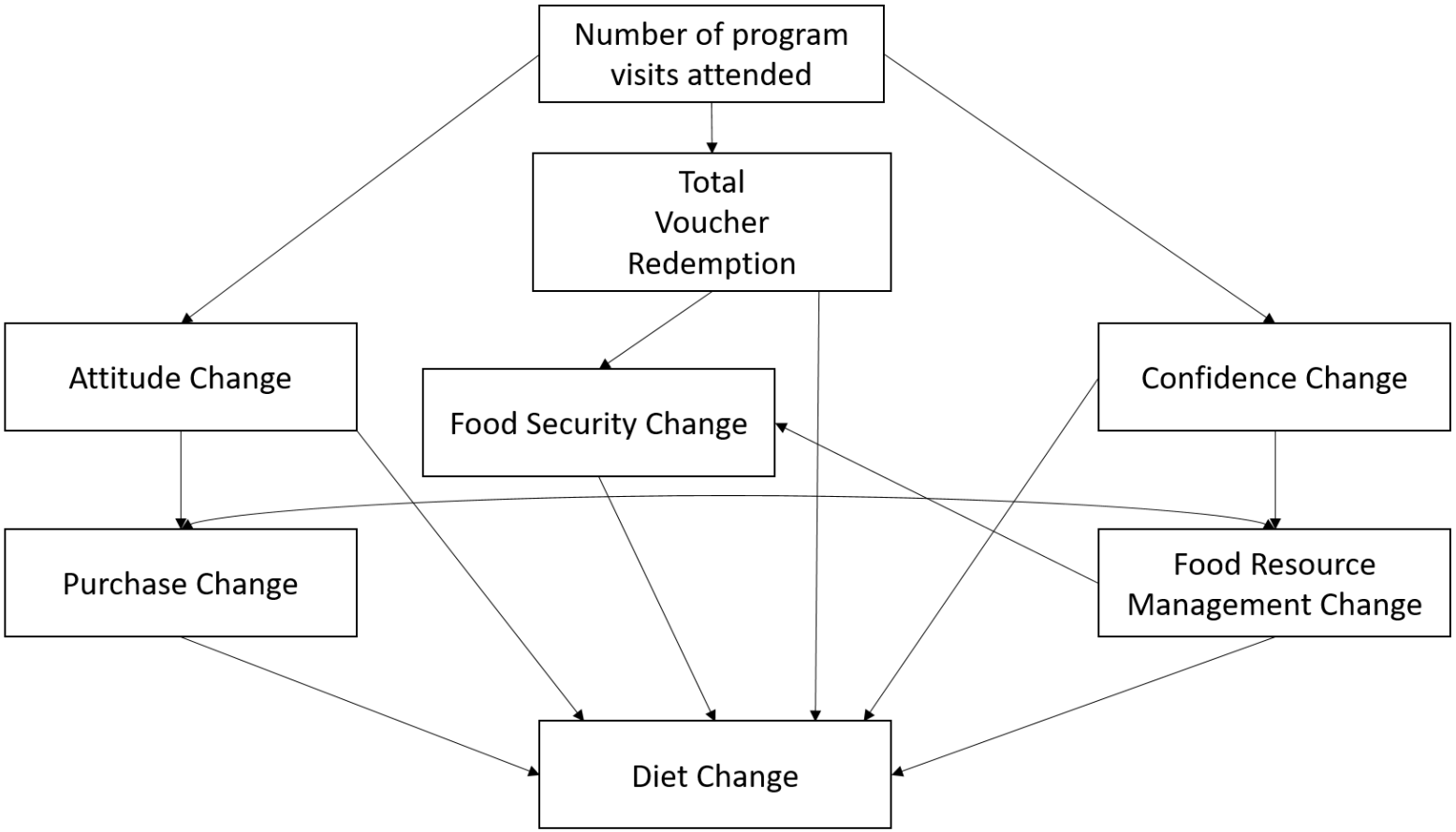
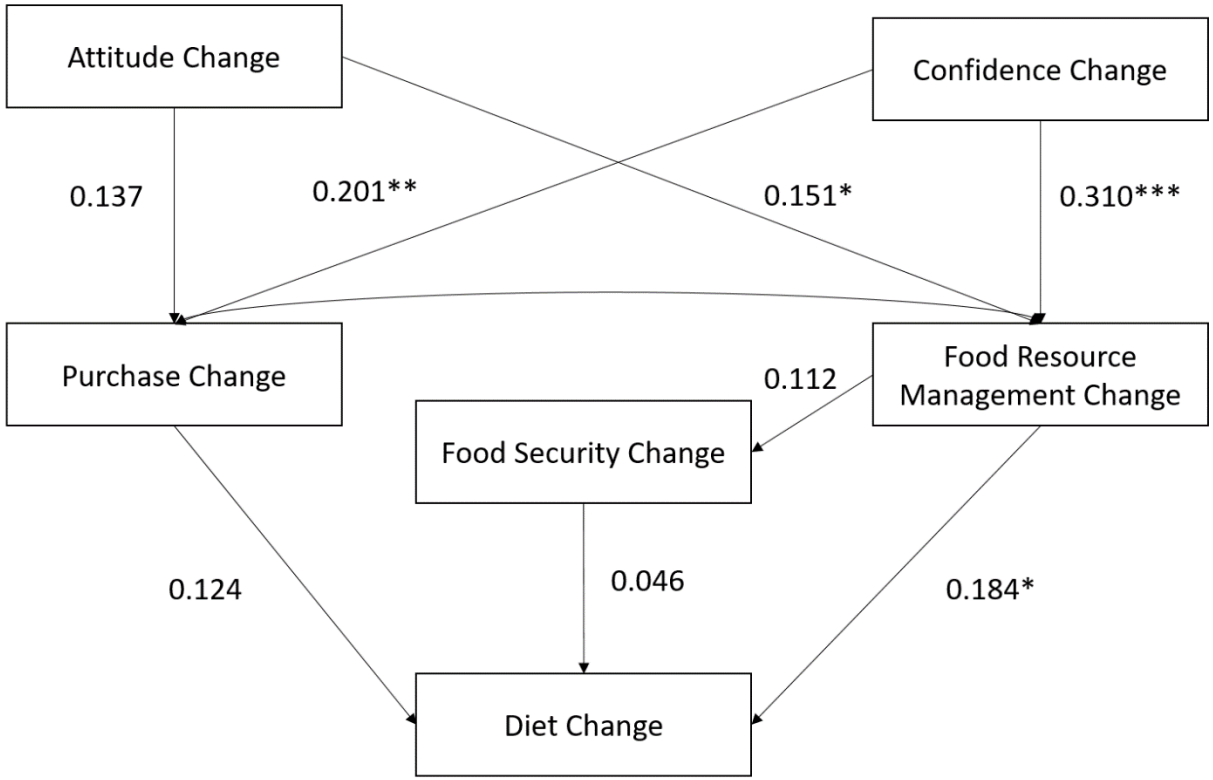


Figure 3. Diagram of direct standardized path coefficient from intermediate educational outcomes to food security and diet change, GF4H 2018-2019 (n=178)



Model fit: $\chi 2$: 0.544, CFI: 1.000, TLI: 1.209, RMSEA: <0.001, SRMR: 0.014
Model controls for age & sex of participant, site & year of program implementation
*p<0.05; **p<0.01; ***p<0.001

Table 4. Score variable definitions and descriptive statistics, GF4H graduates 2018-2019 (N = 178)

Score	*Components*	*Possible Score Range*	*Population Score Range*	*Mean (95% CI)*
Attitude Score	Perceptions of access and affordability of fruits and vegetables, willingness to try new foods, enjoyment of eating fruits and vegetables, and attitudes towards cooking. A higher score indicates more positive attitudes towards buying, cooking, and eating fruits and vegetables.	0-10	BL: 0-10	BL: 7.4 (7.2, 7.7)
			EL: 1.7 - 10	EL: 8.0 (7.8, 8.2)
Confidence Score	Level of confidence in using the same healthy ingredient in different recipes, choosing the best-priced form of fruits and vegetables, using basic cooking skills, buying and cooking healthy foods on a budget, and helping friends and family eat heathier. A high score indicates a greater level of confidence.	0-10	BL: 0.4-10	BL: 8.1 (7.8, 8.4)
			EL: 0-10	EL: 8.8 (8.6, 9.0)
Food Resource Management Score	Frequency of comparing prices when shopping, planning meals ahead of time, using shopping lists, cooking meals at home, and adjusting meals to include more budget-friendly ingredients. A higher score indicates greater use of resource management practices.	0-10	BL: 0 - 7.5	BL: 4.1 (3.8, 4.3)
			EL: 0 - 7.5	EL: 4.5 (4.3, 4.8)
Purchase Score	Frequency of purchasing low fat milk, low fat dairy, lean meat, whole grains, low-sodium foods, and looking at nutrition labels when purchasing foods. A higher score represents healthier purchasing practices.	0-10	BL: 0 - 7.5	BL: 3.3 (3.1, 3.5)
			EL: 0 - 7.5	EL: 4.2 (4.0, 4.5)
Diet Score	Frequency of consumption of fruits, salads, dark green vegetables, other green vegetables, non-fried potatoes, fried potatoes, and consuming food from all food groups every day. A higher score represents a healthier diet.	0-10	BL: 1.3 - 8.4	BL: 3.9 (3.6, 4.1)
			EL: 0.6 – 8.4	EL: 4.3 (4.1, 4.5)

BL: Baseline; EL: Endline

Table 5. Demographic and programmatic characteristics of study sample, GF4H 2018-2019 (n=178)

Characteristic	**N**	**Frequency or mean (95% CI)**
Age in years		
18-29	3	1.7%
30-39	9	5.1%
40-49	26	14.6%
50-59	76	42.7%
60+	64	36.0%
Sex		
Female	126	70.8%
Male	52	29.2%
Race		
Black or African-American	166	93.3%
White	3	1.7%
Hispanic	3	1.7%
Other or multi-racial	6	3.4%
Household Size	178	2.5 (2.2, 2.7)
Site of Participation		
Site 1	32	18.0%
Site 2	55	30.9%
Site 3	20	11.2%
Site 4	24	13.5%
Site 5	47	26.4%
Year of Participation		
2018	53	29.8%
2019	125	70.2%
Number of program visits attended (1-6)	178	5.6 (5.5, 5.7)
Total voucher redemption per-person in household (in U.S. dollars)	178	128.2 (116.1, 140.2)

Table 6. Unstandardized, standardized, and significance level for estimates in pathway model, GF4H 2018-2019 (n=178)

Parameter Estimate	**R2**	**Unstandardized (SE)**	**Standardized**	**P-Value**
Food Resource Management Score Change	0.162			
Attitude Change		0.141	0.151	**0.04**
Confidence Change		0.226	0.310	**<.001**
Sex		-0.204	-0.059	0.41
Site 1		0.269	0.059	0.56
Site 2		0.475	0.117	0.28
Site 3		0.266	0.079	0.50
Site 4		0.764	0.216	0.05
Age		-0.222	-0.058	0.42
Year		-0.189	-0.056	0.45
Purchase Score Change	0.077			
Attitude Change		0.115	0.137	0.07
Confidence Change		0.131	0.201	**0.01**
Sex		-0.220	-0.072	0.34
Site 1		0.604	0.15	0.16
Site 2		0.000	0.000	1.00
Site 3		0.214	0.071	0.56
Site 4		0.286	0.091	0.44
Age		-0.160	-0.047	0.54
Year		0.039	0.013	0.87
Diet Score Change	0.080			
Food Resource Management Score Change		0.175	0.19	**0.01**
Purchase Score Change		0.128	0.124	0.10
Sex		0.171	0.054	0.47
Site 1		-0.325	-0.077	0.47
Site 2		-0.066	-0.017	0.88
Site 3		-0.278	-0.089	0.47
Site 4		-0.088	-0.027	0.82
Age		0.26	0.074	0.33
Year		0.259	0.082	0.29
Bootstrapped Indirect Effects				
Confidence change -> Purchase change -> Diet change			0.025	0.33
Confidence change -> FRM change -> Diet change			0.059	0.07
Attitude change -> Purchase change -> Diet change			0.017	0.37
Attitude change -> FRM change -> Diet change			0.029	0.19

Chapter 6: Stress & food insecurity among participants of a clinic-based produce prescription program: Characterizing lived experiences.

Introduction

More than one in ten households in the United States experience limited or uncertain ability to acquire enough food.[1] Household food insecurity is associated with stress, disordered eating patterns, poor diet, and the development and exacerbation of diet-related chronic diseases.

Explanations for these relationships suggest that limited or uncertain access and affordability of healthy foods induces a biobehavioral cascade of stress responses that act to alter metabolism to increase efficiency of energy storage, increase preference for highly palatable foods, and diminish cognitive capacity via effects to executive function, leading to increased impulsivity and selection of poor dietary choices.[2–6] In addition to health risks imposed by low quality diets, stress-induced metabolic changes in the long-term increase abdominal fat and insulin resistance, further exacerbating risks for chronic diseases such as type 2 diabetes.[6–8]

It is often assumed that food insecurity is an inherently stressful experience.[2,8,9] However, individual factors can affect the extent to which one perceives stress. Prior adverse life experiences, especially those that occurred during childhood, can increase both perceived stress and susceptibility to associated deleterious mental health outcomes.[10,11] Further, perceived stress may differ by gender and role in the household, with the person primarily involved in managing meals, often women, bearing the brunt of the psychological burden in protecting family members from food insecurity.[12–14] Perceived community belonging and level of social support can additionally modify perceptions of and responses to stress.[11] In qualitative studies, individuals experiencing food insecurity have reported distress, frustration, and despair in the context of

insufficient food access.[15–17] Participants in some studies described limiting social engagements due to lack of food (*"If there is no money to invite someone to your house, how do you make a friend?" Runnels et al., 2011, p.164)* while others report that family and friends help them get enough food during times of scarcity.[15] These informal resources such as eating meals with family members are thought to play an important role in the way individuals perceive stress and may potentially modify the relationship between food insecurity and negative mental health outcomes.[11]

Research also confirms the deleterious impacts of chronic stress on executive function with associated reductions in impulse control[18]. Thus, individual stress responses may be an important predictor of the effectiveness of nutrition interventions. Despite abundant research documenting how stress impacts dietary decision-making and how nutrition interventions can improve mental health outcomes, there are relatively few studies that document how stress modifies the effects of interventions on behavior and diet changes.[18] To explore relationships between stress and diet changes within a nutrition intervention, we interviewed former participants of a multi-site produce prescription program implemented in Atlanta, Georgia.

Methods

Intervention

The Georgia Food for Health (GF4H) program is a multi-partner collaborative that aims to improve food security and diet quality by providing vouchers redeemable for fruits and vegetables alongside nutrition education and cooking classes. In 2019, GF4H was implemented in five clinics within an urban safety net hospital system in Atlanta GA, including 2 primary care clinics, 1 specialty diabetes clinic, and 1 infectious disease prevention clinic. Patients were eligible to participate if they were 18 years or older, patients of one of the participating clinics,

and screened positive for food insecurity in the previous 12 months using a validated 2-item food insecurity screener.[19,20] For all but one site, patients were recruited from a pool of patients who had previously attended group nutrition education sessions held at the clinics. At the infectious disease clinics, participants were referred directly during clinic visits by their healthcare providers and followed-up by registered dietitians for enrollment.

Over the first six weeks, hands-on two-hour cooking lessons were taught weekly by a Registered Dietitian from Open Hand Atlanta using Cooking Matters for Adults™, an evidence-based curriculum emphasizing food resource management skills to prepare healthy meals on a limited budget.[21] At each cooking skills class, seasonal produce was provided according to participant household size. Participants additionally attended monthly wellness courses for the duration of the 6-month GF4H program. The education content of the monthly nutrition sessions varied somewhat by clinic site based on participant input but included for example, topics related to portion control, physical activity, and gardening. At each monthly nutrition session, vouchers were distributed worth $1 per family member per day. These were redeemable at local farmers' markets, including markets co-located in transit stations in participants' communities. To be considered program graduates, participants attended 4 out of 6 of both the Cooking Matters and the monthly nutrition classes. In the 2019 program year, 91% of participants graduated (n=157).

Qualitative Study Design

We aimed to understand facilitators and barriers to program participation and examine in detail participants experiences with food insecurity and stress. Interview questions were informed by both program components and the conceptual framework developed by Larai et al. which proposes a mentality of scarcity and reduced healthy food purchasing power as a mediator between stress and poor diet quality.[2] Participants were asked questions around program

structure, stress sources, stress management techniques, and how they make decisions around eating while stressed (Table 7).

All participants provided verbal consent to participate and have the conversation recorded. This research was approved by the Emory University Institutional Review Board and the Grady Health System Research Oversight Committee.

Sample and Recruitment

A total of 17 semi-structured in-depth interviews were conducted with participants of the 2019 program year. Recruitment occurred in May – June 2020, approximately 6 months after the end of the 2019 program year. A stratified, criterion-based recruitment approach was used to recruit 3-4 participants from each of the five clinic sites participating in the 2019 program year. Both participants that completed the program and those who were lost to follow-up were eligible to participate. Recent program participants were first contacted by clinic staff to inform them about the study and ask permission to be contacted by the research team. Those who granted permission were invited to participate in the study. For clinic sites where phone calls to potential participants presented challenges, fliers were distributed directly to eligible participants, who then contacted the research team directly to express interest in participating. Replacement sampling was used as participants refused to participate or were unable to be contacted or scheduled for an interview. Participants were provided $20 gift cards to their choice of two local grocery stores.

Attempts to contact participants who did not graduate the program were unsuccessful. Program staff provided a list of participants who were lost to follow-up to be contacted for interviews. For each of these participants, a maximum of three calls were made to invite them to schedule interviews. Due to changed or disconnected numbers, lack of response, or inability to

schedule an interview, we were not able to recruit anyone from this participant pool. The issue remained after expanding criteria to include participants lost to follow-up from previous years' cohorts.

Data analysis

Interviews were approximately one hour in length, were conducted over the phone, and recorded using the Cube ACR app. Interview recordings were transcribed verbatim. One interview could not be transcribed due to poor recording quality and detailed notes were used in analyses in lieu of verbatim transcripts. A thematic analysis approach was used to analyze interview transcripts for both deductive and inductive codes. Deductive codes were developed based on the key topics addressed in interviews (program experience, experiences of stress, coping strategies, stress & decision making) and the framework presented by Larai et al. on biobehavioral factors influencing nutrition in low-income populations.[2] Inductive codes were developed from analysis of transcripts. One investigator developed a preliminary code book based on an initial review of the transcripts. This was further refined based on research team feedback resulting in greater precision of code definitions and the combination of similar codes. A separate investigator independently coded 30% of the interviews, capturing interviews from each clinic site. Inter-rater agreement was 74%. The investigators discussed discrepancies before finalizing the codebook and adjusting coded sections of all transcripts.

Data were additionally analyzed for differences in descriptions of stress and diet decisions by food security status and level of social support described by participants. All analyses were conducted using MAXQDA Plus 2020.

Results

Participant characteristics are shown in Table 8. Characteristics of interview participants were

largely similar to that of the overall sample population. Four key themes were identified related to 1) participants' response to stress, 2) emotional experiences of different food procurement strategies, 3) comfort eating as a response and cause of stress and 4) social support and nutrition education as stress mitigators.

Participants' responses to stress: "weighed down" vs "managed"

Participants discussed several key sources of stress including stressors related to health, family situations, finances, and acute situational stressors such as being stuck in traffic. The most frequently mentioned stressors were related to family and financial situations. Many participants described overlap in family and financial stressors, such as worrying about negative impacts of economic constraints on children, as one participant described, saying: *"I don't want her to have to work two jobs while she's in college … knowing that she don't have the financials that she needs it bothers me."*

Two participant typologies for stress responsiveness emerged – namely, those who became "overwhelmed" by stress and those that "managed" their stress. Interestingly, the prevalence of food insecurity differed among these two typologies, with 7 out of 8 (88%) of those who became overwhelmed by stress screening positive for food insecurity and 1 out of 9 (11%) of those who managed their stress doing so.

Approximately half of participants (n=8) described their experiences of stress as overwhelming, uncomfortable, and as a feeling of *"being weighed down."* For these participants, stress involved mental worrying and rumination. Other manifestations included headaches and body tension, difficulty sleeping, bouts of crying, and less frequently, feelings of anger and loneliness. The most-often discussed stress reduction practices were reaching out to social networks for support and engaging in religious activities such as prayer. Other commonly

mentioned stress reduction practices among this group included distracting activities such as watching television, exercise, and breathing or other mindfulness practices.

The remaining group of participants (n=9) discussed staying calm in stressful situations, not just through coping mechanisms such as calling on social networks for support, but also through an internal process of recognizing a stressful situation and choosing not to get upset about it. The recognition of negative health impacts of stress was frequently mentioned as a motivator and facilitator for these participants to avoid internalizing stress. One participant described it:

> *"I've learned how to deal with stress so – so it won't impact me so much. Because I realized that of all things, stress is some of the worst thing on your body."*

Participants in this group further explained their strategies to avoid internalizing stress as involving proactive management of situations as they arise: *"I try not to let it get to me. I try to exercise more and do things to occupy my mind."* One participant in this group described stress as an expectation, *"it's chronic … something expected to be lived for as a part of my life,"* requiring active management to avoid negative health effects. This participant went on to say:

> *"Recently I want to say it has not affected my health, because it's managed. Like I say, you know, I get help. I believe if it was unmanaged, if it was festering, if this was, you know .... I dealt with it on a daily basis, but I dealt with it productively. I dealt with it [by] getting assistance. I dealt with it – it didn't get a chance to take its toll or effect on me."*

Financial barriers to healthy eating

Regardless of stress typology and food security status, nearly all participants described healthy food as expensive and discussed economic limitations as a barrier to healthy eating, discussing the need to make multiple trade-off decisions, and imparting a heavy mental toll. One participant

described his experience shopping for healthy food both in and outside of the program, saying:

> *"When I go to the grocery store, it's not in and out. It's not just walking down the aisle and pulling off the shelf. No, there's a serious cost evaluation for every item that I pick up."*

The high cost of certain fruits and vegetables in contrast to the relatively low cost and long shelf-life of processed foods was frequently noted as a temptation to purchase the less healthy food items, despite a desire to prioritize fruits and vegetables in their diets. Participants discussed strategies they use to shop and cook healthy foods on limited budgets including shopping for items on sale, comparing prices between stores and brands, and buying items in bulk when they are in season or on sale and freezing for later use, decreasing variety of produce purchased, and buying frozen or canned vegetables when fresh ones are unaffordable.

Among these strategies, participants additionally discussed using community and social resources to meet their food needs. For many, community resources were described as necessary but not always the healthiest option, as one participant discussed, saying: *"I mean sometimes you have to go to these food places. … And pretty much they're going to bring you cans and boxed stuff. … it's definitely not healthy choices."* Another participant, recognizing the types of foods she typically received from community sources, discussed how she strategically planned her shopping trips to purchase foods to supplement and create healthy meals for her family, saying:

> *" I use a lot of churches, you know, to – you know, to make up the difference and stuff like that. I use a lot of different resources to get extra food. You know, but I still cook stuff that's healthy for the kids. … When I go to the grocery store, I would buy vegetables because I would get meats and canned goods from the church"*

Despite the recognized benefits of strategically using community resources, for many, they are seen as a strategy of last resort due to feelings of stigma related to their use. Other strategies such as strategic timing of bill payments and borrowing money from or eating meals with family members were used before community resources. Participants discussed making trade-off decisions between paying a bill and buying food as a juggling act, wherein a bill with consequences such as the power being turned off if it's not paid takes priority over food purchases, as one participant described, saying:

> *"If I need to pay that bill or there's some consequences with that bill, I will sacrifice the food. … I either ask my sister, like borrow money from my sister or I will pay another bill late that has no consequences and buy food. … Okay, bump the groceries. We're going to keep these lights on, but you know, if I can go one more month with the water bill, okay, that water bill waits, and I get the groceries."*

Financial strain and the need to make constant trade-off decisions carried a heavy emotional toll for participants. One participant described how persistent lack of resources to buy the healthy types of food she preferred saying,

"*It's very emotional when I run out of stuff and I don't have money to go buy it. … I just don't have any money for all the stuff like that, so (sighs) it kind of makes me depressed"*

Use of social and community resources were also described as distressing and evoking feelings of shame and regret for past choices made, with participants emphasizing personal choice and responsibility while downplaying structural and economic barriers, with one participant exemplifying this sentiment, saying:

"*You feel bad because you feel like you're eating off of somebody else instead of maybe being responsible enough to get your own food. It takes you back to, well, I should have made a better decision when I was younger and I wouldn't be in this situation."*

While social and community resources were described as necessary to make ends meet and as a facilitator to healthier eating, some participants discussed avoiding their use as much as possible to evade these feelings of shame, guilt, and stigma.

Comfort eating – a response to and source of stress

The majority of participants with the "overwhelmed" response to stress described patterns of comfort eating (7 out of 8; 88%). Those with the "managed" response were much less likely to describe this pattern (2 out of 9; 22%). When asked about the decision-making process when making unhealthy eating decisions while stressed, participants with this "overwhelmed" typology discussed convenience as a major driving factor. Many described fast-food or take-out as *"the easier choice"* due to both the relative low cost and time needed to acquire the food in comparison to buying and preparing a meal at home. For some participants, especially those with the "overwhelmed" typology of stress response, the decision to make less healthy choices was described in tandem with feelings of exhaustion.

One participant described her motivation for choosing to eat fast food after a long day of work as the director of a daycare, saying: *"That's being exhausted from trying to balance everything."* Another participant discussed how her motivation to cook is diminished in times of stress, making her more likely to order take-out food, saying:

" when I'm stressed like this, it takes away my passion, and when the passion goes, it's like that desire to cook and eat, … it takes that away to the point that you're like oh, let's just go get some chicken wings and be done with it, because of the convenience of it."

Participants additionally discussed "being of two minds" when making diet decisions in stress states, with their internal goals in conflict between motivating factors related to health and setting an example for family members on one hand and the convenience, relatively lower cost, and anticipated pleasure of eating favorite food items on the other. One participant described this conflict between health goals and the cost and shelf life of two different snacks, saying:

> *"I actually split, you know, two ways in my mind knowing that I want to be healthy…I really need the cherries because of the health [benefits] … But financially-wise, my money can get me the honey buns that'll be just as satisfying as the cherry, but I know it's an unhealthy choice."*

Others described it as an internal struggle between habits developed over time and willpower to make healthier decisions, emphasizing self-control and internal motivation, as one participant described, saying, "*your mind might say, ooh, you know you want that, you know you want that. But then you have that willpower have to kick in because you don't want that."* For some, the decision to make a less healthy choice was described as a breaking point in their willpower.

Despite strong motivation to make healthy decisions, in times of stress those motivations are overcome. Long-term health consequences were described as less relevant in situations of stress. One participant described this breaking point in willpower, saying:

> *"P: Some days I do [eat unhealthy foods] more, then I have to catch myself and say okay, this is not going to work. Once this is over that I'm going to regret the decisions that I've made, and it's not going to be good.*
>
> *I: Yeah. So what do you think the difference is on the days when you're not able to say, hey, I'm going to regret this? What changes in those days when you do kind of make those choices?*

P: I don't care. You know, and that's the attitude that I take. I don't give a damn because I'll, you know, -- I'm not going back to the doctor for a while, so I'll be okay. I'm going to work it back down before I go back. That's the thinking mentality that I have a lot of times, you know?"

For many participants, health was described as a strong motivating factor to cook and eat healthy foods. However, stress habits developed over time, and the combined temptation of low cost, convenient, highly palatable foods were described by some as precipitating factors to make less healthy eating decisions. Some participants described feelings of exhaustion, reduced self-control, and discounting of long-term health goals, focusing instead on the immediate, resulting in patterns of comfort eating. Participants additionally discussed anticipation of regretting eating decisions and feelings of guilt after making what they considered to be unhealthy choices, such as one participant who described laying awake at night worrying:

"*It keeps you up at night. It really does. … And when you do … eat something like chicken wings, it bothers me whether or not it's going to affect my health, whether I'm going to be in pain or not, whether or not my joints are going to hurt."*

Social support buffers food insecurity & propensity for comfort eating

Participants who screened negative for food insecurity at the time of the interview were more likely to describe having many people they can reach out to for help or support. Some described receiving help acquiring groceries through their social network while others described calling on their social network for emotional support or advice, such as one participant who described:

"I'm going to pick up the phone and reach out and say, hey, you know, I'm feeling overwhelmed, hey, I'm stressed out. Somebody helps me, whether it be offering advice, offering assistance, or pointing me in the right direction."

By contrast, participants who screened positive for food insecurity described relatively lower social support compared to those who were food secure. Among this group, some described a reluctance to talk to others about their situation for various reasons including avoiding judgment or pity and a distrust of others no to maintain their privacy. One participant described it, saying:

> *"Talk to someone to get it off your chest so that it won't be filled up and cause you more problems. But then it's going to be spread all over the place. … Basically they put your business out on the street … so you have to be careful what you say to people."*

The way participants described dietary decision-making when stressed varied by food security and degree of social support, with those experiencing food insecurity and describing low social support describing making unhealthy choices with more emotional intensity compared to those who were food secure with high social support. Participants with high social support and food security did not discuss patterns of comfort eating as often and, when they did, were more likely to describe motivating factors such as boredom. One participant with high levels of social support and food security described the relationship between stress and diet, saying:

> *"It [stress] makes you eat … makes you nibble more, you know? … You'd be sitting around your apartment .. and you done looked at the television just about all day, and straightened up as much as you can or you know, did something. Next thing you do, you nibbling."*

By contrast, those who were experiencing food insecurity and described relatively low social support discussed making unhealthy choices under stress more frequently and with more emotional intensity.

Some participants in this group described a propensity to comfort eating as filling a void and a response to feelings of loneliness, saying, "*It [food] fills a void, just – it becomes a friend to me.*

It's like – it's just my friend." Similarly, another participant discussed eating unhealthy foods as filling a void and linked her behavior with food to her past behaviors with drugs and alcohol, saying:

> *"If I'm stressed out, I eat a lot of things I'm not supposed to eat. Yeah, I eat chips, candy. I just eat stuff that I know is not good for me. … I don't do anything that I used to do. … As opposed to when I got stressed, I would go drink or do drugs. I don't do that anymore. … Just filling a void. … When I first stopped getting high, I used to binge on a lot of candy and stuff like that because that was filling the void."*

She went on to similarly draw a parallel to comfort eating and loneliness, saying:

> *"I did a lot of drugs because I was stressed. I would drink alcohol as a means to not deal with stuff. I would do drugs as a substitute for being around other people and not being around my family. Does that make some sense?*
>
> *I: Yeah. And then what about food?*
>
> *P: Food is a comfort. Food is a comforting – is a comfort for me, you know? Yeah, I mean, I could – some days I just – I won't even be hungry and I'll eat"*

While eating unhealthy foods in response to negative emotions was described across nearly all participants, those experiencing food insecurity and low social support simultaneously were more likely to describe their experience as self-soothing or *"filling a void."* These participants additionally linked their proclivity for comfort eating with feelings of loneliness. In contrast, participants who described higher levels of social support tended to discuss comfort eating as a response to boredom. Level of social support was varied somewhat by stress response typology in our data, with 4 out of the 9 (44%) participants describing a "managed" response describing

high levels of social support compared to 1 out of 8 (13%) of those with the "overwhelmed" stress response.

Nutrition education & program social supports serve as a facilitator of healthy eating

Nearly all participants interviewed emphasized education and awareness of the importance of a healthy diet as motivators to make healthy decisions. They discussed how the nutrition education provided by the program raised awareness of the health benefits of a high-quality diet, exposed them to new fruits and vegetables they had previously never tried, and taught them new strategies to safely store and cook healthy foods. Participants described their experience with the program as changing the way they think about food, as one participant described, saying:

> *"Once you really learn about nutrition and what things can do to your body, I think what happens is you tend to look at food differently."*

Many participants emphasized the exposure to new fruits and vegetables they had never tried before as a facilitator to adopting new diet habits. Some described how the produce provided by the program facilitated trying new items normally avoided due to a reluctance to deviate from known foods for fear of wasting money, as one participant described:

> *"I started to eat certain vegetables that I had not been eating like kale. I've never really been a kale eater. … because we could go there and shop I tried it, you know?"*

Participants frequently discussed their new approaches to eating in contrast to previous behaviors. For many, eating decisions prior to their involvement with the program were described as driven largely by convenience, price, and taste, whereas, after engaging in the program, they are described in relation to strategies to avoid making unhealthy decisions and motivations related to health. One participant described this contrast in her approach to nutrition:

> *"I just ate for the pleasure of eating and the taste of it. As opposed to now, I'm looking*

and I'm saying, oh my God, how much sodium is in this. Oh my God, it's going to run my sugar up, you know what I'm saying. Or it's going to make my blood pressure go sky high, you know. I start to think about those things now. When I'm looking at a box now, I'm looking at it and saying okay, how much sodium is in this right here. Okay, how many more grams do I have to go. I didn't -- I had no regard for that."

Participants additionally discussed how the people they met through the program serve to motivate them, acting as accountability partners, further inspiring them to make healthy decisions. One participant discussed how the relationships formed in the program served as a motivator to stay engaged:

"One thing that would make them feel more comfortable are their fellow participants who I know, the stronger their connection they have with them, then that's just one more extra thing that will keep them coming back … I definitely think that the relationship development aspect was very powerful, and it was definitely very, very clear."

Nearly all participants interviewed mentioned that they are still in contact with friends they made in the program and talk regularly, discussing recipes and healthy eating strategies together. One participant described his connection with those he met in the program:

"P: We keep in contact with each other. We get together every now and then and go out eat lunch or something, you know, so yes.

I: Awesome. What kind of things do you guys talk about?

P: Nutrition. What are you eating? What did you eat today? Sometimes we'll get together maybe once every two weeks, and we – you know, we'll meet and go, you know, to a grocery store and we'll shop together and stuff like that, so – And then we get on the telephone and talk about how we cooking our food, what we're using to cook the food,

how we're cooking and so forth."

Discussion

Our findings underscore the complexity of decision-making that low-income families navigate to obtain food in times of financial scarcity. Aligning with the conceptual framework put forth by Laraia et al., for some, economic constraints are compounded by high levels of stress that are described as lowering bandwidth and decreasing willpower, making less healthy options "the easier choice." The mental toll of multiple trade-off decisions has been described as inducing "decision fatigue" which may reduce willpower and explain, at least in part, our findings related to exhaustion, conflicts in goals, and decreased willpower.[22–26]

Despite descriptions of economic constraints, individual motivation and responsibility were emphasized by participants, potentially increasing feelings of guilt and shame related to making less healthy decisions, reducing propensity to use community and social resources available, and perpetuating cycles of stress response and comfort eating patterns. However, not all participants described comfort eating, especially those who experienced high levels of social support. Participants with lower social support discussed eating as comforting and "filling a void," often in response to feelings of loneliness. For some, recognizing negative health impacts of stress served as a facilitator to avoid internalizing a stressful situation. The nutrition education provided by the program served to increase awareness of the positive health benefits of high quality diets and change the way participants view food decisions. The social aspects of the program additionally served as a motivating factor, with many participants reporting to make friends from the program that they continue to connect with to discuss healthy eating strategies, acting as accountability partners.

Results of this study are consistent with previous work reporting socioeconomic barriers to maintaining a healthy diet. Our data adds context to these descriptions by exploring the nuanced decision-making processes low-income families navigate in times of economic scarcity. Our findings deepen our understanding of how participants experience produce prescription programs and the role stress plays in adopting behavior change within these interventions. Although participants described significant economic barriers to acquiring healthy foods, many viewed accessing community resources as a last resort, only to be used when absolutely necessary. Explanations for this reluctance to use resources emphasized feelings of regret for past choices made, echoing findings reported by Schlosser et al. wherein participants underscored personal choice, self-control, and discipline while downplaying socioeconomic barriers to achieving healthy eating behaviors.[27] Future work should explore how to encourage the use of existing resources without undermining patients' dignity and feelings of self-worth. Many food banks encourage strategic use, educating patients to not wait until the end of the month when other individual resources like cash and SNAP benefits have been exhausted, but rather to come at the beginning of the month and use these remaining resources to purchase items to supplement what they receive from the pantry. However, if stigma continues to prevent the use of these resources except as a last resort, such strategic resource management education will likely be unsuccessful. Further, our findings on comfort eating both a response to and source of stress, may have troubling implications as a negative outcome of nutrition education in that achieving greater knowledge and awareness of the important of healthy eating could increase feelings of shame in situations where participants cannot meet healthy eating recommendations.

While qualitative studies of similar produce prescription programs have reported that participants struggle to sustain behavior changes after the end of the program when the provision

of free produce is discontinued, we did not observe these themes in our data.[27–29] Participants discussed using strategies adopted through the program and strategies learned from their peers in the program to sustain behavior change with participants describing adopted strategies as a "lifestyle change." Cahill et al. had previously reported similar findings from interviews with the original pilot participants of the Georgia Food for Health program. In their study, participants reported to continue to eat a variety of fruits and vegetables and use lessons learned in the program when making food choices.[30] However, in our data, many participants discussed participating in additional food security programs offered by the health system in response to the ongoing COVID-19 pandemic, including one program which offers gift cards for produce purchases redeemable at major retailers and another program that offers 20 lb. produce boxes available for pick-up 1-2 times a month at community health clinics. These additional nutrition programs increasing access to fresh produce likely serve to increase the sustainability of behavior changes adopted during the 6-month Georgia Food for Health program for participants who engage with them. Further research into these ongoing programs that may act as a "sustainability phase" of more intensive nutrition interventions is needed to understand the duration and dose needed to support sustained behavior change, a sentiment that has been echoed across implementation science research.[31,32]

Our findings have implications for the implementation of similar programs, especially findings related to comfort eating in response to social isolation and feelings of loneliness. Loneliness has been associated with increased odds of experiencing food insecurity among older adults (OR: 1.356, p=0.005).[33] Additionally, loneliness has been associated with increased risk of depression, which, in turn, has been associated with poor eating habits.[34] In an attempt to avoid feelings of embarrassment or shame, individuals experiencing food insecurity may withdraw

further, exacerbating their social isolation and increasing risk or severity of food insecurity.[33] Many diet interventions are already implemented in group settings, offering an ideal setting to increase social interaction. Programs that encourage and support socializing throughout diet interventions are likely to be more successful, especially among older adults, as they intervene on the bidirectional relationships between food insecurity, diet, and social support.[33] While friendships and social networks evolved organically in the Georgia Food for Health program, additional research on the effectiveness of more formalized approaches to encourage social interaction in nutrition interventions could allow for greater transportability between similar programs. Validated tools such as the Multidimension Scale of Perceived Social Support and the Perceived Stress Scale could additionally be incorporated into program evaluation measures and would allow for deeper exploration into the effectiveness of group-based nutrition interventions to improve social support and stress.[35,36]

Limitations

This research should be interpreted in context of its limitations. First, attempts to recruit participants who did not meet graduation criteria were unsuccessful. Those who withdrew from the program potentially faced greater barriers to participation such as family obligations or health complications that prevented their continued involvement. Survey data collected at enrollment show that those lost to follow-up and those who graduated were similar in terms of demographics, socioeconomic status, and food security. However, those who withdrew from the program were slightly younger on average than those who graduated (48% of those lost to follow up were < 50 years old compared to 26% of those who graduated; $p<0.002$). Withdrawal was unlikely to be related to work obligations as no differences in reported employment status were observed. Graduation rates were high for the 2019 program year (91%), leaving only 16

participants who did graduate available for recruitment. Nevertheless, our findings likely capture the experience of those patients with flexibility in their schedules to attend sessions, reliable transportation and phone service, and those most engaged with the program. Efforts to recruit patients who withdraw from the program could be made more successful if participants are invited to interviews at the time of withdrawal. Insights provided by these participants will help to identify barriers to participant and areas for program improvement.

Second, although we reached code saturation within the collected interviews, we did not achieve meaning saturation for all concepts discussed in interviews, namely, those related to eschewing stress.[37] While the goal of this study was not to develop a theory explaining how stress relates to diet, but rather to expand our understanding and provide additional context to the robust existing theories, additional exploration is nevertheless warranted.[38] Understanding predictors of common traits and shared experiences of those with this stress response pattern as well as a greater understanding of the pattern itself could aid in identifying promising stress management techniques that could potentially increase effectiveness of nutrition interventions.

Conclusions

Our findings highlight the complexity of experience for patients of food security interventions. Participants are juggling multiple responsibilities and a variety of stressors. Increased nutrition knowledge and higher levels of social support may buffer deleterious effects of stress on diet quality. There is potential for group-based nutrition interventions to bolster social support, increasing effectiveness of programs intended to intervene on relationships between food insecurity, diet, and health.

References

1. Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A. *Household Food Security in the United States in 2020*.; 2021.
2. Laraia BA, Leak TM, Tester JM, Leung CW. Biobehavioral Factors That Shape Nutrition in Low-Income Populations: A Narrative Review. *American Journal of Preventive Medicine*. 2017.
3. Starcke K, Brand M. Decision making under stress: A selective review. *Neuroscience and Biobehavioral Reviews*. 2012.
4. Lattimore P, Maxwell L. Cognitive load, stress, and disinhibited eating. *Eating Behaviors*. 2004.
5. Björntorp P. Do stress reactions cause abdominal obesity and comorbidities? *Obesity Reviews*. 2001;2(2).
6. Dallman MF, Pecoraro N, Akana SF, et al. Chronic stress and obesity: A new view of "comfort food." *Proceedings of the National Academy of Sciences of the United States of America*. 2003;100(20).
7. Bermúdez-Millán A, Wagner JA, Feinn RS, et al. Inflammation and Stress Biomarkers Mediate the Association between Household Food Insecurity and Insulin Resistance among Latinos with Type 2 Diabetes. *Journal of Nutrition*. 2019;149(6).
8. Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *New England Journal of Medicine*. 2010.
9. Laraia BA. Food Insecurity and Chronic Disease. *Advances in Nutrition*. 2013.
10. McLaughlin KA, Conron KJ, Koenen KC, Gilman SE. Childhood adversity, adult stressful life events, and risk of past-year psychiatric disorder: A test of the stress sensitization hypothesis in a population-based sample of adults. *Psychological Medicine*. 2010;40(10).
11. Martin MS, Maddocks E, Chen Y, Gilman SE, Colman I. Food insecurity and mental illness: Disproportionate impacts in the context of perceived stress and social isolation. *Public Health*. 2016.
12. Carter KN, Kruse K, Blakely T, Collings S. The association of food security with psychological distress in New Zealand and any gender differences. *Social Science and Medicine*. 2011;72(9).
13. McIntyre L, Glanville NT, Raine KD, Dayle JB, Anderson B, Battaglia N. Do low-income lone mothers compromise their nutrition to feed their children? *CMAJ*. 2003;168(6).
14. Olson C. Food Insecurity in Women: A Recipe for Unhealthy Trade-offs. *Topics in clinical nutrition*. 2005;20(4).
15. Runnels VE, Kristjansson E, Calhoun M. An Investigation of Adults' Everyday Experiences and Effects of Food Insecurity in an Urban Area in Canada. *Canadian Journal of Community Mental Health*. 2011;30(1).
16. Puddephatt JA, Keenan GS, Fielden A, Reaves DL, Halford JCG, Hardman CA. 'Eating to survive': A qualitative analysis of factors influencing food choice and eating behaviour in a food-insecure population. *Appetite*. 2020;147.
17. Meza A, Altman E, Martinez S, Leung CW. "It's a Feeling That One Is Not Worth Food": A Qualitative Study Exploring the Psychosocial Experience and Academic Consequences of Food Insecurity Among College Students. *Journal of the Academy of Nutrition and Dietetics*. 2018.
18. Scherr RE, Laugero KD, Graham DJ, et al. Innovative techniques for evaluating behavioral nutrition interventions. *Advances in Nutrition*. 2017;8(1).

19. Hager ER, Quigg AM, Black MM, et al. Development and validity of a 2-item screen to identify families at risk for food insecurity. *Pediatrics*. 2010.
20. Gundersen C, Engelhard EE, Crumbaugh AS, Seligman HK. Brief assessment of food insecurity accurately identifies high-risk US adults. *Public Health Nutrition*. 2017.
21. Cooking Matters National. *Cooking Matters Curriculum*. SNAP-Ed Strategies & Interventions Toolkit, USDA SNAP-Ed Connection; 2016.
22. Baumeister R. The psychology of irrationality: Why people make foolish, self-defeating choices. *The psychology of economic decisions*. 2003;1:3-16.
23. Baumeister RF. Ego Depletion and Self-Control Failure: An Energy Model of the Self's Executive Function. *Self and Identity*. 2002.
24. Baumeister R, Tierney J. *Willpower: Rediscovering the Greatest Human Strength*. Penguin; 2012.
25. Pocheptsova A, Amir O, Dhar R, Baumeister RF. Deciding without resources: Resource depletion and choice in context. *Journal of Marketing Research*. 2009.
26. Vohs KD, Baumeister RF, Schmeichel BJ, Twenge JM, Nelson NM, Tice DM. Making Choices Impairs Subsequent Self-Control: A Limited-Resource Account of Decision Making, Self-Regulation, and Active Initiative. *Journal of Personality and Social Psychology*. 2008.
27. Allison Schlosser, Kakul Joshi, Samantha Smith, Anna Thornton, Shari Bolen ET. "The coupons and stuff just made it possible": economic constraints and patient experiences of a produce prescription program. *Translational Behavioral Medicine*. 2019;9(5):875-883.
28. Newman T, Lee JS. Strategies and Challenges: Qualitative Lessons Learned From Georgia Produce Prescription Programs. *Health Promotion Practice*. 2021.
29. Allison Schlosser, Samantha Smith, Kakul Joshi, Anna Thornton, Erika Trapl SB. "You Guys Really Care About Me…": a Qualitative Exploration of a Produce Prescription Program in Safety Net Clinics. *Journal of General Internal Medicine*. 2017.
30. Cahill E, Schmidt SR, Henry TL, et al. Qualitative research study on addressing barriers to healthy diet among low-income individuals at an urban, safety-net hospital. *BMJ Nutrition, Prevention and Health*. 2020.
31. Glasgow RE, Vinson C, Chambers D, Khoury MJ, Kaplan RM, Hunter C. National institutes of health approaches to dissemination and implementation science: Current and future directions. *American Journal of Public Health*. 2012;102(7).
32. Baumann AA, Cabassa LJ. Reframing implementation science to address inequities in healthcare delivery. *BMC Health Services Research*. 2020;20(1).
33. Burris M, Kihlstrom L, Arce KS, et al. Food Insecurity, Loneliness, and Social Support among Older Adults. *Journal of Hunger and Environmental Nutrition*. 2021;16(1).
34. Leung CW, Epel ES, Willett WC, Rimm EB, Laraia BA. Household food insecurity is positively associated with depression among low-income supplemental nutrition assistance program participants and income-eligible nonparticipants. *Journal of Nutrition*. 2015;145(3).
35. Lee EH. Review of the psychometric evidence of the perceived stress scale. *Asian Nursing Research*. 2012;6(4).
36. Zimet G. Multidimensional scale of perceived social support (MSPSS)-scale items and scoring information. *Johns Hopkins University Press*. 2016;(December).
37. Hennink MM, Kaiser BN, Marconi VC. Code Saturation Versus Meaning Saturation: How Many Interviews Are Enough? *Qualitative Health Research*. 2017.
38. Thorne S. The Great Saturation Debate: What the "S Word" Means and Doesn't Mean in Qualitative Research Reporting. *The Canadian journal of nursing research = Revue canadienne*

de recherche en sciences infirmieres. 2020;52(1).
39. Blumberg J, Bialostosky K, Hamilton WL, Briefel RR. *U.S. Household Food Security Survey Module: Six-Item Short Form.*; 1999.

Table 7. Example participant interview questions

Domain	**Example questions**
Stress experience	What does stress mean to you? What sort of things stress you out?
Relaxation strategies	What sort of relationships do you use for support in tough times? What do you do to relax when you're feeling stressed out?
Stress & Diet	How do you think stress affects your diet? Tell me about the most recent time you were stressed and what sorts of food you bought and ate. Why do you think you chose that?
Coping strategies	What sort of strategies do you use to make your food last between trips to the store? Tell me about a time recently where you had to make a decision or trade-off about what you would spend money on.
Program experience	What drew you to the program? How have your food choices been impacted by the program? What would you change about the program?

Table 8. Characteristics of 2019 GF4H participants

Characteristic (%)	**Overall sample (n=157)**	**Interview sample (n=17)**
African-American	94%	100%
Female	70%	59%
Over 50 years old	85%	88%
High school education or below	54%	65%
Food insecure	60%	47%

Food security presented for the overall sample represents assessment at enrollment while that of the interview sample represents assessment at the time of the interview, both using the USDA 6-item food security screener with a 30-day recall period.[39]

Chapter 7: Discussion

The overall objective of this dissertation was to evaluate the effectiveness of a produce prescription program in an underserved population, understand program mechanisms of action and areas for program improvement, and to explore the relationships between stress and food security to identify strategies to improve program retention and health outcomes. There is consistent evidence that PRx programs are effective interventions to increase food security and diet quality, however, there is a lack of evidence demonstrating robust health improvements after exposure to PRx programs.[1] Further, the majority of published research to date has not included some of the populations most vulnerable to the deleterious effects of food insecurity and poor diet quality. Inequities in nutrition and health are well documented, with consistent evidence that Black and Hispanic households experience disproportionate rates of food insecurity and chronic disease.[2,3] Interventions to address food insecurity and chronic disease must include the populations most affected in order to understand effectiveness for the most vulnerable populations and so that best practices developed are appropriate for all groups.

Using data from the GF4H program, we were able to perform a rigorous evaluation evaluating the association of program participation with health outcomes, investigating drivers of behavior change, and characterizing experiences of stress and food insecurity among program participants. My first contribution to the evaluation of PRx programs examined food security and clinical outcome changes observed over the course of a program implemented in 2017 across three health systems in the state of Georgia. This work found significant improvements in food security and diastolic blood pressure.[4] Building off this preliminary work, we applied similar

methodology to three years of data collected in the GF4H program implemented at Grady Health System clinics. We found that graduation from the program was associated with modest but significant reductions in BMI, weight, waist circumference, and blood pressure. Results were comparable in magnitude to the few evaluations reporting on these health outcomes, indicating the program model remains effective in a primarily black, urban population in the Southeastern U.S.

In addition, we sought to investigate program mechanisms of action using pathway analysis techniques. We found that improvements in confidence in ability to buy and cook healthy foods and increases in the use of food resource management techniques, such as a comparing prices while shopping, had direct effects on observed improvements in healthy eating behaviors. These findings highlight the importance of confidence-promoting activities and food resource management education in diet interventions targeting adults with food insecurity.

Lastly, we explored experiences of stress and food insecurity among participants of the 2019 GF4H program to better understand the role of stress in adopting behavior changes in a PRx program. This study revealed two distinct typologies related to stress experience. While some participants described stress as overwhelming, others described managing this stress through internal mental processes. Regardless of stress typology, cost was discussed as a major barrier to healthy eating. Among those with the "overwhelmed" stress typology, making unhealthy eating decisions when stressed was described as comforting and precipitated by feelings of exhaustion and internal conflict. Nutrition education received and the social relationships developed in the program were described as facilitators of healthy eating by raising knowledge and awareness of healthy eating and forming social support networks with shared healthy eating goals.

Public health implications

Out of more than 100 PRx programs operating in the U.S., just 9 are located in the Southeast.[5] This region has some of the highest rates of food insecurity and chronic disease, indicating a high need for such interventions. Given the high vulnerability and limited access to PRx programs in the South, in addition to the evidence presented in this dissertation illustrating the appropriateness and effectiveness of PRx programs implemented for low-income, urban Southerners, greater expansion of programs operating in these areas is warranted.

Many community programs, including PRx programs, lack capacity to rigorously evaluate program outcomes. Challenges are numerous including difficulty accessing data needed to demonstrate program effectiveness, lack of staff time, and in some cases, skill set, for program evaluation and data analysis. Funders require detailed program outcome data, and rightfully so, as these are not cheap to implement. However, when it is beyond the capacity of an implementing organization to provide such data, it can collapse programs, leaving communities without access to services, eroding trust between the communities and implementing organizations, and causing negative economic impacts for program redemption partners who face the loss of a stable customer base.[5] These interventions are intensive and complex, requiring a great deal of staff time to build community trust and effective partnerships while managing participant recruitment, offering a program model flexible enough for participants who struggle with other structural determinants of health (such as stable transportation and housing), managing program logistics, collecting and analyzing outcome data, and reporting back to funders. It can be an extreme challenge to find funding to refine and expand programs amidst these demands. These issues are further compounded by the fractured and inconsistent sources of funding for these programs. Private sources such as foundation, trust, enterprise, or large-scale

grant support are estimated to be the primary funding source for 46% of all PRx programs in operation between 2010 and 2020.[5] Further, privately funded programs had an average longevity of 3.6 years, highlighting the challenges of sustainability.[5] This not only indicates a need for evaluation capacity-building to support sustainability of programs, it additionally supports the case for classifying PRx programs as preventive health care services reimbursable by health insurance companies.

Embedding the PRx program model within Medicare and Medicaid, classifying it as a preventive health service, and making it eligible for reimbursement would not only assist with issues due to unstable funding. It is estimated that a 30% subsidy on fruits and vegetables for adults in Medicare and Medicaid would prevent 1.93 million cardiovascular events and 0.35 million cardiovascular-related deaths over a lifetime, saving $40 billion in healthcare costs.[6] A more expansive 30% subsidy on several healthy foods including fruits and vegetables, whole grains, nuts & seeds, seafood, and plant oils was estimated to yield even greater health improvements and reductions in healthcare costs.[6]

Limitations

While this collective body of work is among one of the most robust evaluations of a single PRx program to date, it is not without limitations. First, while modest but significant reductions in health indicators were observed, our ability to make causal inference is precluded by the lack of a control group. Future work should prioritize inclusion of comparison groups using medical record data or prospective control study designs. Further, a longer follow-up period for evaluation would increase the ability to answer questions of behavior change sustainability after graduation from the program.

Additionally, just one program was evaluated in this body of work. Although this

analysis included data from multiple clinic sites collected over multiple years with a unique patient population, PRx programs vary widely in implementation and programmatic context. Evidence would be strengthened by replication in other PRx programs and through data-sharing agreements between programs that would allow for detailed evaluation of factors improving study outcomes.

Another limitation of this work is the use of self-report data for measures of food security and diet behaviors, which can be subject to both recall and social-desirability bias, leading to overestimation of effects, as well as measurement error, which can result in underestimation. However, the tools used for evaluation have been validated and are consistent across years of program implementation. Further, the use of more robust methods such as 24-hour recalls for dietary assessment are likely to be overburdensome both for participants and for program staff.

Next, while we qualitatively explored experiences of stress and food insecurity in the program, no data was collected on important indicators of stress and social support. To further explore the role of stress in the program experience and identify areas of program strength and opportunities for program improvement, measures of stress and social support should be collected as part of routine program evaluation.

Strengths and Innovations

This dissertation evaluated a PRx model in an underserved population that has not been explored by any previously published research to our knowledge. Ensuring that nutrition interventions intending to address food insecurity and chronic disease are appropriate for the population most affected by these conditions is imperative to ensure that best practices developed and implemented are culturally appropriate. This research applied techniques little-used in the literature on PRx programs including analysis of repeated health measures and pathway analysis

exploring mechanisms of action, expanding our understanding of how PRx programs achieve behavioral and health outcomes. Additionally, qualitative methods allowed for the characterization of lived experiences of stress and deepened understanding of how stress impacts behavior change in the context of a PRx program.

Conclusions and Future Directions

Overall, this body of work supports evidence that the PRx model including the provision of free produce in combination with experiential cooking and nutrition education has potential to improve food security, diet, and achieve modest health improvements. Further, this research highlights a PRx model tailored for low-income, black southerners while generating new questions for further research.

Future research directions continuing evaluation efforts to refine and improve program should explore questions related to the ideal program duration and dosage, identifying the most effective program components, investigating in more detail the cultural appropriateness of the educational curriculum and recipes included in the program, and identifying best practices for food security screening and resource referrals to nutrition services including PRx programs. While published reports of PRx programs reveal wide variation in the length and intensity of interventions offered, no research has been conducted to explore the most effective program length or frequency of sessions. Similarly, the components of PRx programs differ broadly, with some offering just vouchers for produce while others offer a wide variety of activities including nutrition education, cooking classes, mindfulness mediation, and exercise, just to name a few. A multi-stage optimization trial (MOST) could be used to identify the most effective program components, duration, and dosage by randomizing participants to various versions of the program offering different components and analyzing compiled outcome data.

Further research into the cultural appropriateness of program curriculum in diverse populations is warranted to ensure health equity is embedded in best practices developed as well as in future policy decisions. As GF4H program partners expand operations into new communities, opportunities to explore these research questions should be harnessed strategically to improve tailoring of programs for diverse groups.

Additional research on best practices for food security screening and resource referral will aid in identifying patients who would benefit from PRx programs. These interventions may not be the most appropriate for all individuals experiencing food insecurity, with some requiring more intensive intervention, and others who may be appropriate for less intensive options. This work in combination with research exploring the most effective program components will help identify how and for whom these programs can most effectively operate. Finally, building on the work presented and proposed, explorations into questions of scalability and transportability should be conducted to understand if the PRx model could be applied to low and middle-income countries to address food security in different contexts.

References

1. Bhat S, Coyle DH, Trieu K, et al. Healthy Food Prescription Programs and their Impacts on Dietary Behavior and Cardiometabolic Risk Factors: A Systematic Review and Meta-Analysis. *Advances in Nutrition*. 2021:1-13.
2. Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A. *Household Food Security in the United States in 2020*.; 2021.
3. Dietary Guidelines Advisory Committee. *Scientific Report of the 2020 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Agriculture and the Secretary of Health and Human Services*. Washington, DC; 2020.
4. Cook M, Ward R, Newman T, et al. Food Security and Clinical Outcomes of the 2017 Georgia Fruit and Vegetable Prescription Program. *Journal of Nutrition Education and Behavior*. 2021.
5. Rodriguez ME, Drew C, Bellin R, Babaian A, Ross D. *Produce Prescription Programs: US Field Scan Report: 2010-2020*.
6. Lee Y, Mozaffarian D, Sy S, et al. Cost-effectiveness of financial incentives for improving diet and health through medicare and medicaid: A micro simulation study. *PLoS Medicine*. 2019;16(3).

Appendix Table 1. Georgia Food for Health Theory of Change