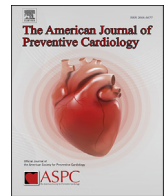


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State-of-the-Art Review

The food pharmacy: Theory, implementation, and opportunities

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ABSTRACT

The food pharmacy is an emerging program model designed to increase the access to and consumption of healthful foods, particularly fruits and vegetables. Existing research on the efficacy of the food pharmacy model shows that these programs have been effective in improving patient understanding of nutrition and removing barriers to healthy eating, and in turn may have a significant impact on diet-related health outcomes. However, efforts to date aiming to evaluate program effectiveness have been small and lack rigorous research methods. More research is needed to adequately assess the longitudinal effects of food pharmacy programs on healthful food intake and diet-related health outcomes. In this review, we outline the strengths and limitations of previous programs and explore possible options to improve the scalability and sustainability of food pharmacy programs.

1. Introduction

The prevalence of obesity in the United States (U.S.) population is a staggering 42%, and rates of nutrition-related chronic disease are climbing across the globe [1]. Ischemic heart disease is the leading cause of death, both in the U.S. and globally, and is the leading cause of disability-adjusted life-years (DALYs) lost globally [1,2]. Despite well-established links between nutrition and chronic disease, the global and U.S. healthcare community has failed to implement effective strategies at-scale to improve dietary intake for the prevention, management, and treatment of nutrition-related chronic diseases. In order to avert lives and DALYs lost, it is imperative that nutrition and public health experts focus on prevention by developing effective ways to affect change in eating patterns and to empower patients to maintain these changes.

The emergence of the food pharmacy concept – an umbrella term for programs designed to increase public access to fruits and vegetables – has the potential to elicit changes in eating patterns, if sustainable and effective methods are developed. Food pharmacy, also coined “food farmacy,” is a component of the “food is medicine” initiative, which aims to integrate or coordinate nutrition interventions with the healthcare system [3], though a number of food pharmacy programs have also been undertaken outside of the healthcare system [4,5]. Food pharmacy programs primarily focus on removing barriers to healthy eating, such as financial constraints, through coupons and financial incentives to promote consumption of healthy foods, particularly fruits and vegetables. Food pharmacy programs may also target a variety of barriers, such as a

lack of knowledge of healthy eating and cooking skills through inclusion of nutrition or culinary education, a lack of household or community support through peer-support components in the program, or a lack of geographic access to fresh produce through transportation assistance or facilitation of establishment of new locations for vendors of healthy foods. The purpose of this review is to explore the food pharmacy concept, demonstrate its current uses, identify implementation strategies that have been successful, and discuss future opportunities for the application of the food pharmacy concept in promotion of public health. A narrative review of the literature was conducted due to the heterogeneity in interventions, incentives, and outcome evaluations in various food pharmacy programs preventing the use of meta-analysis to combine and analyze the results of these studies.

2. Review of the necessity, utilization, and future of food pharmacy

2.1. Nutrition and cardiovascular disease

Over the past 25 years, the prevalence of chronic diet-related diseases, such as obesity [6,7], type 2 diabetes [8], hypertension [9], and certain cancers [10], have increased significantly, and cardiovascular disease (CVD) remains the leading cause of death worldwide [1]. Approximately 50% of American adults have at least one nutrition-related chronic disease [11]. In those with impaired glucose tolerance, lifestyle interventions, including diet and exercise advice, are

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at least as effective as pharmacological therapy for preventing or delaying the onset of type 2 diabetes [12]. Further, studies have shown the cost-effectiveness of dietary interventions for the primary prevention of CVD, with one overview of various strategies finding the estimated costs per life year gained to be \$20 to \$900 for population-based healthy eating compared to \$9,800 to \$18,000 for statin therapy [9,13]. Prevention-focused diet and lifestyle modifications could have a major beneficial impact on health in the U.S. [14].

A higher consumption of fruits and vegetables is associated with improved health. In 2013, an estimated 5.6 to 7.8 million premature deaths worldwide could be attributed to inadequate fruit and vegetable consumption [15]. Studies have shown a 28% reduction in CVD risk and a 27% reduction in CVD mortality in individuals who eat more fruits and vegetables (at least 3 to 5 servings per day) compared to those who eat less fruits and vegetables (fewer than 1.5 servings per day) [16,17]. Dose-response analyses have demonstrated that each 200 g of fruit and vegetable intake per day is associated with an 8–13% CVD risk reduction, and that the reduction in risk increases up to 800 g (approximately 10 servings) per day [15].

The field of nutrition has historically focused on nutrients and food components in relation to health outcomes, with saturated fat, sodium, and cholesterol of particular concern for cardioprotective nutrition. More recently, however, there has been a shift toward focusing on whole foods and dietary patterns, which recognizes the abundance of nutrients and non-nutrients supplied by the food matrix and the potential interactions among those compounds [18,19]. A recent review and meta-analysis by Mozaffarian et al. outlined fruits, vegetables, nuts, fish, shellfish, vegetable oils, minimally-processed whole grains, legumes, and fermented dairy as being especially heart healthy [18]. Among vegetables, green leafy vegetables appear especially protective, with one serving a day conferring an 11% reduction in CVD risk [15,16]. The meta-analysis by Mozaffarian et al. found that refined carbohydrates, processed meat, sodium, and industrially-made trans fats and hydrogenated oils are particularly harmful for cardiovascular health [18].

2.2. Barriers to meeting the recommendations

The American Heart Association and the 2015–2020 Dietary Guidelines for Americans both recommend 4 servings of fruits and 5 servings of vegetables per day [11,20,21]. Although these recommendations for daily fruit and vegetable intakes can be achieved by spending only \$2.10 to \$2.60 per day [22], just 12% of American adults meet the recommended daily intake for fruit and 9% meet the recommended daily intake for vegetables [23–26]. For adults above 31 years of age, the average vegetable intake is less than 2 cup-equivalents of vegetables (approximately 4 servings) per day and less than 1.5 cup-equivalents of fruits (approximately 3 servings) per day [11].

A number of barriers to healthy eating have been described in the literature, including financial and geographical access; knowledge deficit; lack of time, skills, or equipment for cooking; and lack of social support [27–30]. The National Health and Nutrition Examination Survey (NHANES) data has shown strong correlations between both income and education levels and diet quality, leaving no doubt that socioeconomic barriers significantly contribute to insufficient fruit and vegetable intake. People with lower socioeconomic status have lower dietary quality and higher rates of obesity compared to those with higher socioeconomic status [31]. In the U.S., the lowest intakes of vegetables were reported in adults living at or below the poverty level, with only 7% meeting the recommended vegetable intake compared to 11.4% of those at the highest income level [26]. Participants involved in produce prescription programs commonly report that financial constraints and lack of neighborhood availability prevent them from consuming more fruits and vegetables [32–35]. In the Prevention Produce Program in Pennsylvania, the most commonly reported barriers to consuming fruits and vegetables were ‘affordability’ and ‘lack of desire’ [36]. This demonstrates that financial constraints, including the price of fruits and vegetables or the

amount of money the participant or household has to buy food [33], are commonly experienced as barriers to meeting the recommendations. While socioeconomic factors strongly impact food choices, there are clearly additional barriers preventing adequate consumption of fruits and vegetables, exemplified when considering that 89% of adults at the highest income level still do not meet the recommended vegetable intake [37]. Environmental factors, such as geographic access and lack of transportation, are also barriers to fruit and vegetable consumption. Participants in produce prescription programs commonly report that limited access to fresh fruit and vegetables in their neighborhood and limited transportation options prevent them from consuming more fruits and vegetables [32,34,35].

The factors that most influence healthy behavior change and maintenance of healthy behavior change, such as eating more fruits and vegetables, are overlapping and include emotions, knowledge, social support, available transportation, as well as beliefs about the connection between healthy lifestyle and chronic disease risk [38,39]. Patients’ perceived CVD risk is often lower than their true risk [40], so practitioners and curriculum developers should connect dietary behavior change to clinical outcomes [38]. Programs should integrate support of healthy eating using factors that are known to influence health behavior change and maintenance, with special focus on building social support. Programs should promote maintenance of learned and changed health-promoting behaviors, which tend to decrease over time [41]. This can be through inclusion of an educational or knowledge-building component, which is fundamental to the maintenance of changed behaviors and have been shown to influence personal choices and preferences [38] and change beliefs and opinions about the connection between produce intake and chronic disease risk [36].

2.3. Food pharmacy

Based on evidence available in the literature, the food pharmacy concept will be integral in efforts to produce positive and necessary changes in fruit and vegetable intake. Food pharmacies are programs that are designed to increase access to healthful foods, often using financial incentives, such as providing free or discounted produce. Food pharmacy programs may include supplemental components, such as nutrition or culinary education, produce prescriptions, or promotion of fruit and vegetable intake from a healthcare provider. The majority of food pharmacy programs target food insecure populations [42], but have utility for a broad range of audiences. A recent systematic review of 30 studies using pricing interventions to examine changes in food purchases and consumption found that incentivizing purchases of healthy foods, particularly fruits and vegetables, is an effective strategy to elicit positive behavior change. The majority of the included studies targeted low-income populations (n = 18), however, the remaining studies (n = 12) featured diverse socioeconomic backgrounds. While there was a great deal of heterogeneity among the interventions used, all appeared effective in improving food choices, indicating that financial incentives are a valuable tool to improve diet quality across socioeconomic strata [43].

The food pharmacy concept first gained national attention through Wholesome Wave, a non-profit organization that, in 2012, began partnering with healthcare clinics to issue ‘prescriptions’ – good for up to \$1 per day per household member, over a course of 4–5 months – that could be redeemed for produce at participating farmers’ markets [44]. Many variations on the food pharmacy model have since been developed in healthcare settings, including, but not limited to, on-site gardens that patients can help tend, free or reduced-cost produce boxes from local farms (e.g., Community Supported Agriculture [CSA] shares), and food pantries set up on-site at hospitals or clinics.

2.3.1. Financial incentives to promote healthy food consumption

Various approaches exist that utilize financial incentives to promote healthy food consumption, including providing discounted or even free

Table 1
Non-clinic-based food pharmacy programs.

First Author, Year	Population	Sample Size	Design	Total Voucher Value	Voucher Value/ Person/Day	Voucher Redemption Site			Intervention Components					Duration	# EC	Outcome(s)	
						FM	GS	MM	NC	NEM	NES	CEM	CES				GS
Kral, 2016	Adults living in Philadelphia between 40 and 70 years of age and qualified as either a frequent coupon user or a non-coupon user.	N = 54	Randomized controlled trial. Analysis compared pre- and post-intervention values.	\$100 max* not a voucher system	Variable, depending on purchasing habits		X				X				3 mo	1	The incentive group's daily vegetable intake increased over time, while the control groups did not. Both groups improved obesogenic household food availability scores over time.
Sharma, 2016	Low-income parent-child dyads with children enrolled in elementary schools with ≥75% of students receiving free or reduced-price school lunch.	N = 717 dyads	Quasi-experimental non-randomized controlled school-based study in Houston, TX. Data analyzed at baseline, week 8, and study completion (week 16).	\$0, free 50–60 servings of fresh produce per week	N/A				X	X	X	X			16 wk	16	Children in the intervention group had increased intake of fruits, vegetables, and fiber, and decreased intake of added sugar. Parental understanding of nutrition facts labels and using labels to make food purchasing decisions increased in the intervention compared to control group.
Byker, 2014	Head Start preschoolers and their families	N = 51 families	Pre-test/post-test design; pre-test administered 4 weeks prior to intervention. Post-test administered 4 weeks post-intervention.	\$0, free 21 cup equivalents of fresh produce weekly	N/A				X		X				8 wk	0	Increases in fiber, vitamin A, vitamin C, vegetable servings, and combined fruit and vegetable servings over time. On average, participants increased their number of cups of fruits and vegetables per day by 1.4.
Zepeda, 2014	Across 4 sites, racially, ethnic-ally, socioeconomically diverse adults in urban and rural areas	N = 82 across all sites	Convenience sample focus group study design at four sites consisting of both shoppers and non-shoppers of local mobile produce vendors	N/A	N/A			X							N/A	0	Mobile produce market customers, on average, consumed 1.5 more servings of fruits and vegetables per day compared to non-mobile produce market customers. None of the participants met the CDC's recommendation of 9 servings of fruits and vegetables per day.
Gorham, 2015	Low-income parents of children aged 3–13 years recruited at one of 6 mobile produce markets in Rhode Island.	N = 378 parents with children aged 3–13 years	Non-randomized cohort study. Analysis comparing pre- and post- values.	N/A; produce at markets priced 15–25% lower than retail prices.	N/A			X							5 mo	N/A	Children's average fruit, vegetable, and combined fruit and vegetable intake increased by ¼ cup, 1/3 cup, and nearly ½ cup, respectively, from pre- to post-program.

Key: FM: Farmers' Market; GS: Grocery Store; MM: Mobile Market; NC: Nutrition Counseling; NEM: Nutrition Education Materials; NES: Nutrition Education Sessions; CEM: Culinary Education Materials; CES: Culinary Education Sessions; GS: Goal Setting; Number of Educational Contacts: # EC.

foods. Financial incentive programs are gaining national momentum through federal food assistance programs. The WIC Farmers' Market Nutrition Program provides participants with between \$10 and \$30 in vouchers for local farmers' markets to purchase fruits, vegetables, and herbs [45]. In nearly 30 states, recipients of SNAP are eligible for Double Up Food Bucks, a program that increases participants' ability to purchase fruits and vegetables by providing matching credits for every dollar spent on fruits and vegetables, for up to \$20 a day, at participating farmers' markets and grocery stores [46]. SNAP also launched a separate program, known as the Healthy Incentives Pilot (HIP) program, for 14 months to determine whether financial incentives at point-of-sale would increase the purchase of fruits and vegetables. Seven thousand five hundred SNAP participants in Hampden County, Massachusetts, were provided \$0.33 for every \$1 spent on fruits and vegetables at participating retailers [47]. After 1 year of this pilot program, researchers observed a 26% increase in fruit and vegetable intake of HIP participants over non-participants in a 5,000-participant subsample. HIP participants also reported an 8.5% increase in expenditures on fruits and vegetables and purchasing a greater variety of fruits and vegetables compared to non-HIP participants [48]. Though interventions, such as awareness campaigns, provision of detailed instructions, and participant education (e.g., farmers' market tours, cooking demonstrations, produce sampling, nutrition classes on the benefits of fruit and vegetable intake) have been shown to significantly improve participation and efficacy for increasing fruit and vegetable intake, they are unfortunately underutilized [5].

2.3.2. Non-clinic-based fruit and vegetable provision programs

Food pharmacy programs and related programs are not always based out of clinics. Such programs may instead operate through mobile produce markets, schools, or other venues. These programs are typically designed to increase access and reduce barriers to fruit and vegetable consumption. Though they do not always incentivize purchases, they have been shown to be successful at meaningfully increasing fruit and vegetable intake [4,49–52]. Non-clinic-affiliated food pharmacy programs are shown in Table 1.

Mobile produce markets targeting multiple populations have significantly increased their customers' fruit and vegetable intakes from baseline [49]. In a cross-sectional study that compared the reported intake of fruits and vegetables of four mobile produce markets' customers across the U.S., Zepeda and colleagues found mobile produce market customers, on average, consumed 1.5 more servings of fruits and vegetables per day compared to non-mobile produce market customers [50]. In a separate study specifically evaluating fruit and vegetable consumption in 378 parent-child pairs utilizing mobile produce markets, the children's average fruit, vegetable, and combined fruit and vegetable intake increased by $\frac{1}{4}$ cup, $\frac{1}{3}$ cup, and nearly $\frac{1}{2}$ a cup, respectively, over a 5-month period [52]. The mobile produce market design underscores the significant importance of convenience and the impact of geographic access, such as the neighborhood food environment, as a barrier to fruit and vegetable consumption [49,50,52].

School-based programs targeting fruit and vegetable consumption and healthy behavior adaptations have also been shown to be successful for improving diet quality [4,51]. One such program in Texas, Brighter Bites, operated over 16 weeks in Houston-area elementary schools where at least 75% of students received free or reduced-price school lunches. The program provided between 50 and 60 servings of fruits and vegetables per week to families with children attending the schools, along with a health education course for parents and recipe tastings featuring the provided produce. At study conclusion, children and their parents at the intervention school sites consumed more fruits, vegetables, and fiber daily, while consuming less added sugar daily, and demonstrated increased understanding and use of nutrition facts labels, compared to control school sites [4].

Another smaller fruit and vegetable provision program operating through Head Start preschools provided each participating family 21 cup-equivalents of produce per week with recipes utilizing the provided

produce during an 8-week intervention. Similar to children and parents participating in Brighter Bites, these Head Start study participants reported significant increases in combined fruit and vegetable servings, vegetable servings, and fiber intake from baseline to post-intervention follow-up [51]. These results suggest that school-based programs with financial incentives, such as free produce, and culinary education materials, such as recipes, can improve fruit and vegetable intake. The addition of a social support component, such as health education for parents, can improve home cooking habits and understanding of the importance and utility of nutrition facts labels.

Universities have also operated food pharmacy programs in order to study the effect of financial incentivization on grocery purchasing behavior, dietary intake, and diet-related health outcomes. Researchers at University of Pennsylvania conducted a randomized controlled trial through the Center for Weight and Eating Disorders to observe the effect that financial incentivization of healthy grocery purchases had on dietary intake, weight, and the home food environment in 54 adults in Philadelphia. In this study, intervention participants were provided education on reading nutrition facts labels at baseline and received \$1 for every healthy food or beverage they purchased, up to a maximum of \$100 over the 3-month intervention period. At study conclusion, the incentive group's daily vegetable intake had significantly increased, while the control group's did not. However, the difference in daily vegetable intake between groups was not significant. Intriguingly, both groups demonstrated a significant decrease in obesogenic household food availability scores over time, despite the control group's lack of nutrition education or financial incentivization for healthy grocery purchases. The decrease in obesogenic household food availability seen in the control group, as well as the intervention group, suggests that dietary monitoring alone may improve healthy food availability in the household [27].

2.3.3. Clinic-based healthy food prescription with a financial incentive

Healthcare organizations and clinics have partnered with community organizations to prescribe healthy foods, such as fruits and vegetables, and to provide these foods to patients free or at a reduced cost. Clinic-affiliated food pharmacy programs are shown in Table 2. These programs commonly partner with farmers' markets [34,35,44,53,54] as the source of produce, and some programs have partnered with other food retailers, such as grocery stores [33] and small markets [55]. The social reinforcement of physicians or other healthcare providers issuing fruit and vegetable prescriptions enhances participants' motivation to increase consumption of fruits and vegetables [33]. All programs contained a produce prescription with a financial incentive and nutrition counseling, and several also incorporated culinary education materials and visits with a healthcare provider or medical student [34–36].

Adult programs demonstrated effectiveness for improving understanding of the connection between diet and health, shopping habits, and dietary behaviors. The PRxMoms and PRxHTN programs both included nutrition counseling, nutrition and/or culinary education, goal setting, and farmer's market vouchers. The PRxMoms program provided \$160 of vouchers (\$40 per month, \$1.29 per day), to pregnant women. Providers reported that the produce vouchers improved participants' motivation to try new produce varieties, and participants reported that they understood the importance of eating fruits and vegetables more as a result of the program [35]. The researchers of the PRxHTN study provided \$120 of produce vouchers (\$40 per month, \$1.29 per day) to participants with hypertension and food insecurity. After program completion, 88% of participants reported consuming more fruits and vegetables compared to before the program, significantly increasing the mean fruit intake from 1.6 (SD 1.3) to 2.4 (SD 1.2) servings per day and mean vegetable intake from 1.7 (SD 1.1) to 2.5 (SD 1.3) servings per day. Those who completed the program decreased their frequency of fast-food consumption from 1.3 days per week to 0.7 days per week [34].

The Fresh Prescription Program at federally-qualified health centers provided up to \$45 in farmers' market produce vouchers (\$0.48 per day)

Table 2
Clinic-based food pharmacy programs.

First Author, Date	Population	Sample Size	Design	Total Voucher Value	Voucher Value/Person/Day	Voucher Redemption Site						Intervention Components						Duration	# EC	Outcome(s)
						FM	GS	MM	NC	NEM	NES	CEM	CES	GS	NC	NEM	NES			
Buyuktunce, 2014	All patients >16 years	N = 621 enrolled, 84 at T1, 54 at T2	Non-randomized intervention. Analysis comparing pre- and post- values.	€4	\$0.01		X				X						16 wk	0	76% used at least 1 voucher. Increased nutrition knowledge. No change in single day's diet pattern.	
Cavanagh, 2017	Obese, hypertensive, or diabetic	N = 108	Non-randomized controlled intervention. Analysis compared group changes.	\$91-98	\$0.97			X				X					13 wk	1	Intervention group BMI decreased by 0.74 kg/m2 after study.	
Bryce, 2017	Uncontrolled diabetes	N = 65	Non-randomized intervention. Analysis comparing pre- and post- values.	\$45	\$ 0.48	X								X			13 wk	1-4	Decrease in HbA1c (9.54%–8.83%). No significant change in blood pressure or weight.	
Trapl, 2017	Pregnant women	N = 75	Non-randomized intervention. Analysis of post-intervention only.	\$160 (\$40/mo)	\$1.29	X			X	X			X		X		4 mo	1-4	56% of participants used ≥ 1 voucher. 95% found educational material useful.	
Trapl, 2018	Hypertensive food insecure adults	N = 224 enrolled N = 137 at follow up	Non-randomized intervention. Analysis comparing pre- and post- values.	\$120 (\$40/mo)	\$1.29	X			X	X			X		X		3 mo	3	Fruit intake increased from 1.6 (SD 1.3) to 2.4 (SD 1.2) servings/d. Vegetable intake increased from 1.7 (SD 1.1) to 2.5 (1.3) servings/d.	
Ridberg, 2019	Low-income families with overweight or obese children	N = 883 children	Non-randomized intervention. Analysis comparing pre- and post- values.	Variable	\$0.50-\$1.00 per person per day	X			X			X					4-6 mo	3-6	For each additional visit, participants consumed 0.32 more cups of fruits and vegetables/d.	
Marcinkevage, 2019	Low-income patients in clinics and community settings. SNAP participants. Specific populations differed across sites.	N = 144 surveyed	Mixed methods process and outcome evaluation.	\$10	Variable; number of vouchers provided varied across sites			X									Variable		Qualitative findings: Of the participants surveyed, there was a 54% voucher redemption rate. 88% of participants reported eating more fruits and vegetables as a result of the fruit and vegetable prescription. 88.2% (N = 127) reported eating more fruits and vegetables than previously.	
Forbes, 2019	Families at risk for chronic or metabolic disease; food insecure patients expressing difficulty obtaining fruit or vegetables	N = 9	Non-randomized pre-post intervention. Analysis did not include statistical analysis.	\$160	\$5.16	X			X		X	X					1 mo	4	Qualitative findings: fruit and vegetable intake increased post- program (1 mo). There was an increased proportion of participants who tried to include produce at every meal. Improved understanding of connection between produce and chronic disease risk.	
Jones, 2020	Children aged 6 years or younger enrolled in the Navajo FVRx program between May 2018 and September 2018.	N = 122 children	Non-randomized intervention. Analysis comparing pre- and post- values.	\$180 per person; \$900 maximum (family of 5)	\$1; maximum of \$5 per day	X	X		X	X	X		X	X			6 mo	6	BMI decreased over time. Fruit and vegetable consumption increased from 5.2 to 6.8 servings per day. Food security increased from 18% to 35%.	

to 65 patients with uncontrolled type 2 diabetes, defined as hemoglobin A1c (HbA1c) > 6.5%, within 3 months of program initiation. This 13-week program included optional goal setting and, though no cooking demonstrations or nutrition education were provided through the program, cooking demonstrations were commonly available at the farmers' markets where vouchers were redeemed by participants. At the end of the program, participants' HbA1c decreased by 0.71% points, on average. There were no changes observed in the participants' weight or blood pressure [54].

Pediatric programs demonstrated effectiveness for improving dietary behaviors, reducing child obesity, and increasing food security. The Wholesome Wave Fruit and Vegetable Prescription Program (FVRx) and the pediatric Navajo FVRx programs provided health coaching or counseling and nutrition education, and the pediatric Navajo FVRx program additionally provided individualized goal setting. Wholesome Wave implemented the FVRx program in children in Connecticut, Maine, Massachusetts, New Mexico, New York, Rhode Island, and Washington, D.C. Families with one or more child with overweight or obesity received a fruit and vegetable prescription for \$0.50 to \$1.00 per household member per day to be redeemed at a local farmers' market. At the end of the study, participants consumed about 0.32 more cups of fruits and vegetables per day for each additional visit they attended between 3 and 6 visits, bringing the average fruit and vegetable intake from 2.8 (SD 2.2) cups at baseline to 3.1 (SD 2.1) cups at 4–6 months [44]. This program also reported a significant decrease in food insecurity in participating households [53]. The pediatric Navajo FVRx program is a collaborative program operated through 19 healthcare facilities and 25 retailers serving the Navajo community with the goal of improving healthy food access in households with children under 6 years of age. Program participants were enrolled through their healthcare clinic and received vouchers for the purchase of fruits, vegetables, and healthy Dine (Navajo) foods, valued at \$1 per household member per day (up to \$5 per day). While 54% of the children (n = 122) met criteria for overweight/obesity at baseline, 49% met these criteria at program completion. Of the children classified as having overweight/obesity at baseline (n = 58), 38% had BMI percentiles which fell into the healthy range by the end of the program. Additionally, fruit and vegetable intake increased from 5.2 to 6.8 servings per day by program end [56].

The Washington State FVRx program was a collaboration between the Washington State Department of Health; 14 implementation partners, including private and public health care entities, public health agencies, and community organizations; and a supermarket chain with 169 stores. This larger-scale program enrolled SNAP recipients and provided \$10 grocery store vouchers that could be redeemed for fresh, canned, or frozen fruit or vegetables, so long as there was no added sugar, fat, or salt. The voucher regimen varied greatly, with some partners providing only one \$10 voucher and some providing up to weekly \$10 vouchers for 6 months. Neither nutrition or culinary education nor nutrition counseling were included in the program. A post-intervention survey of 144 participants showed perceived improvements in fruit and vegetable consumption, the management of health conditions, and food security as a result of receiving the vouchers [57]. Despite the lack of quantitative data, these findings suggest that large-scale FVRx programs can be effective if implemented strategically.

In New York, Capital Roots partnered with the Whitney M. Young, Jr. Health Center to carry out the Veggie Rx program. In this program, an RDN provided education about the importance of fruits and vegetables and provided coupons for 13–14 weeks of free produce (\$7 per week, \$0.97 per day) to be redeemed at Capital Roots' Veggie Mobile, a mobile produce market that serves low-income urban neighborhoods. Participants, who had either obesity, hypertension, or diabetes, were compared to controls who were matched for age, ethnicity, and co-morbidity status. In the intervention group, BMI decreased after the study by 0.74 kg/m^2 , which was significantly different from the control group, for whom BMI increased [58].

2.4. Characteristics of effective programs

Any intervention that increased nutrition knowledge, increased fruit and/or vegetable intake, or improved a risk factor for CVD, such as BMI or HbA1c, was considered effective. Effective interventions varied in duration, but most were between 3 and 6 months. Across a range of intervention styles, programs were effective at increasing fruit and vegetable intake, improving nutrition knowledge, and decreasing BMI if they were 3–4 months in duration [33,54,58] or offered financial incentives [27,33,34,44,54,56,57]. Participants in these programs reported developing habits to increase fruit intake and feeling more comfortable experimenting with new fruits and vegetables [32]. The food vendors used in effective programs included farmers' markets [35,54], grocers [27,33,56], and mobile vendors [58].

The Fresh Prescription Program included only \$45 (approximately \$0.49/person/day) in farmers' market vouchers and an optional goal-setting worksheet. Still, this program achieved a mean 0.71% point decrease in HbA1c over 13 weeks [54]. Due to the simplicity of this program and the prevalence of diabetes in the U.S., integration of this program into the clinical setting and scaling up across the country could help reduce the burden of diabetes on the population and healthcare system. The PRx programs [32,34,35,42,59] shared a theoretical framework for behavior change that included economic incentives (vouchers), social incentives (provider's recommendation), repeated behaviors (prescriptions at monthly clinic visits), and individualized counseling [35]. Repeated behaviors, such as multiple clinic visits or multiple nutrition counseling sessions, are more effective than single visits, with the magnitude of benefit increasing with more frequent opportunities for reinforcement [44,56]. Social support is thought to be foundational to one's ability to integrate healthy behaviors into their everyday life [38]. Programs that featured inclusive and supportive social structures were generally effective [60]. The PRxHTN program enabled participants to include family members [32], which may have strengthened social support for more healthy behaviors. This practice increased the reach of the program to include spouses and children. One participant from the PRxHTN program reported learning about fruits and vegetables, sharing that information with their family, and cooking for their family, which increased the fruit and vegetable consumption of all members of the household [32]. Similarly, the pediatric Navajo FVRx program encouraged family members to attend health coaching sessions with the primary caregiver and child to strengthen familial dietary and health habits [56]. In so doing, this program also incorporated strong social support for healthy eating habits.

Due to the paucity of well-controlled and randomized trials and the variability of outcomes evaluated in the studies available, it is not possible to compare single component interventions with multi-component interventions in this review. Further research is needed to quantify the magnitude of the change in behaviors, risk factors, and risk of CVD that can be attributed to food pharmacy programs.

2.5. Limitations of current strategies and future opportunities

Design of programs and evaluation methods, poor retention, and sustainability are major limitations of current strategies. The majority of interventions included activities and targets pertaining to a single level of the social ecological model: the level of the individual, which is consistent with previous observations of the health promotion literature. Programs that included provision of vouchers and changes in the neighborhood availability of fruits and vegetables, such as those with a mobile vendor, integrate both the individual and community levels of the social ecological model and therefore have the potential for a synergistic effect between the intervention components. Targeting at least two levels of the social ecological model, including the individual, interpersonal, institutional, community, or policy levels, could improve reach and impact of future programs [61].

Most produce prescription programs allow vouchers to be used only

for fresh produce [34,35]. However, most of the scientific data available for the connection between fruit and vegetable intake and longer-term health outcomes consider total fruit and vegetable intake and do not differentiate between fresh, frozen, or canned fruit and vegetable intake [11]. Inclusion of frozen or canned produce without added salt, sugar, or fat may be a way to further increase the integration of fruits and vegetables into the diet. Furthermore, inclusion of options with a longer shelf-life may help reduce food waste and build dietary habits using fruit and vegetables that are more widely accessible.

Research evaluating food pharmacy programs to date has primarily been pilot studies, and rigorous designs with appropriate control groups and adjustment for covariates have yet to be utilized in evaluation of their impacts [58]. Most studies track participants only during the intervention period and there is a lack of long-term evaluation of impact [39]. Future studies should employ rigorous study designs that include randomization and the use of a control group. While multiple studies evaluated dietary intake, such as fruit and vegetable consumption, none used detailed evaluation methods, such as 24-h recalls or weighed food records. More work is needed to streamline evaluation of the outcomes, so that meta analyses can be performed. Converting findings from trials into cost-benefit analyses would increase buy-in by healthcare organizations and policy makers to support these interventions.

Most of the programs evaluated lack sustainable funding [34,35] and are not easily scalable [57]. Many of these programs rely on short-term funding, such as grants, to support the program and, therefore, are not sustainable. In order to build a sustainable and scalable model, the cost of running the program would need to be offset by a consistent source of income or support. One program, the Washington State Fruit and Vegetable Prescription Program, demonstrated that these programs can be scaled up for use in a variety of settings, so long as there is flexibility in implementation [57]. Sustainability is necessary for participants to maintain healthy behaviors that have been achieved in programs. A recurrent theme across studies is that participants struggled to maintain the habits of buying and eating more produce as a consequence of economic hardship [36,59]. Some participants of farmers' market programs with financial incentives reported that, without the financial assistance, they were not able to purchase produce as much as when they received financial assistance [59]. Sustainable funding mechanisms are imperative to provide continued support for food-insecure individuals to maintain healthy food choices.

Most farmers' markets have limited weekly hours, posing a scheduling challenge for participants to obtain their produce. Further, seasonality challenges the long-term efficacy of farmers' market-based programs, because many farmers' markets close during the winter. It is important that future programs utilize consistent food outlets with broader hours of operation to ensure longevity of program-related behavior change. Utilizing grocery stores can improve maintenance of improved produce consumption [34].

Collaborations between healthcare partners and community organizations can reduce the burden of responsibility for care by clinics, improve patient care, and increase communication about diet and the importance of fruit and vegetable consumption between providers and patients [42]. Integration of food pharmacies into the healthcare system provides the opportunity to offer these programs at scale and benefit from sustainable funding sources, such as insurance reimbursements or government funding. Efforts are already underway to loosen restrictions on the use of healthcare money to pay for food. Nutrition programs and public and private providers, as well as the U.S. government, are exploring options to increase food and nutrition offerings in the context of primary health care [3].

Traditionally—recognized barriers to healthy eating continue to hinder the implementation of healthy lifestyle modifications and the purchase and consumption of fruits and vegetables. Transportation issues continue to limit participation in current programs, exemplified by participants' ongoing reports of difficulty accessing farmers' markets and other program-associated food outlets [35,59]. As such, future programs

should incorporate transportation assistance [59] or partner with food outlets that are easy to access via public transportation.

2.6. Building on past experience to conceptualize and realize the optimal food pharmacy program

The goal of food pharmacy is to empower participants to take charge of their well-being, helping them to achieve long-term health through the prevention or management of CVD and other chronic diseases. Barriers to healthy eating could be eliminated by reducing financial constraints and increasing knowledge of nutrition and food preparation techniques. By doing this, healthcare providers support patients as they integrate positive changes into their everyday dietary habits and lifestyles—going beyond simply making recommendations and increasing the likelihood that patients will achieve sustainable implementation.

Many healthcare institutions have formed on-site food pantries, providing vital access to healthy food for the most at-risk individuals. While there is great value in hospital-based food pantries and all variations of the food pharmacy concept, a novel concept has potential to become a vital component of health institutions—integrating a preventive-cardiology brick-and-mortar market into healthcare. The market would be curated by dietitians and medical staff, offering only heart-healthy options. Healthcare providers would write prescriptions for fruits, vegetables, and other heart-healthy foods that could be redeemed at the market based on patient preferences. Nutrition education would be integrated with the market, with RDNs providing MNT to patients along with grocery store tours and practical education, such as nutrition label tutorials. Culinary education would be provided using foods from the store, with participants leaving with the ingredients needed for featured recipes. Because the market would be within the healthcare system, research opportunities abound, with the ability for purchases and class attendance to be easily tracked.

This model addresses barriers that other food pharmacy models have faced. Healthcare facilities that house food pantries must find continuous sources of external funding, while an integrated market could be open to the public, thus obtaining revenue through retail sales that could support the market. Ideally, the cost-effectiveness data for prescription redemption and cardiovascular events and healthcare costs would be presented to insurance companies with the goal of obtaining partial insurance coverage of the food pharmacy prescription costs. With obesity-related healthcare spending in the U.S. exceeding \$238 billion in 2016, preventive measures and out-of-the-box strategies must be implemented to improve public health [62]. Food pharmacy models that utilize farmers' markets face challenges of limited weekly hours, seasonality, and transportation barriers. Housing a market within a healthcare facility, however, offers a convenient location where patients are already receiving medical care and will follow normal business hours. This food pharmacy model – a grocery store housed within a medical facility – is a truly unique concept that has the potential to revolutionize healthcare, providing nutritious foods, educating patients, and changing dietary habits, ultimately eliciting real change in cardiovascular outcomes.

3. Conclusion

Food pharmacies have a great potential to improve public health by informing people about the importance of healthy eating habits, as well as increasing their access to fruits and vegetables and teaching them how to easily prepare the produce. The programs expand on the traditional one-on-one nutrition counseling model and are positioned to reach a much greater number of people, creating the potential for health improvements on a community scale. While many food pharmacy programs exist, more high-quality research is needed to determine which food pharmacy models are most effective, whether the elicited dietary changes are durable, and which health markers are most impacted. A new model – the market-medical facility hybrid – has potential to overcome many of the barriers previously encountered with other food

pharmacy models, generating health benefits and research opportunities while also being self sustaining. If widely implemented in effective ways, food pharmacies have the potential to reduce rates and complications of chronic diseases by increasing access to, knowledge about, and consumption of fruits and vegetables as well as other beneficial health behaviors.

Authorship statement

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 Investigation JD TS LM.
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 Project administration JD TS.
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 Supervision JD TS.
 Validation NA.
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 Roles/Writing - original draft JD TS LM;
 Writing - review & editing JD TS LM.

Declaration of competing interest

Juliana A. Donohue is an employee of Wild Rose Research. The other authors have no conflicts of interest or financial disclosures to report.

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