ABSTRACT

Title of Dissertation:	EXPLORING CHALLENGES AND STRATEGIES RELATED TO PLANT-BASED DIETARY PATTERNS IN COMMUNITY-DWELLING OLDER ADULTS WITH HYPERTENSION
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Some of the most pressing global crises faced by society are the rise in chronic diseases and climate change. Plant-based diets (PBDs) have become an important part of the sustainability discussion affecting all four 4 domains: nutrition and health, environment, economics, and society. Due to this, it has been offered as one possible solution to the burden of noncommunicable diseases, environmental concerns, and potential economic stressors. Additionally, the growing older adult population presents further challenges. Although research on PBDs and health has grown in recent decades, studies on older adults, particularly those with chronic conditions, remain scarce despite the potential impact.

Broadly, this research focuses on PBDs in hypertensive older adults as a substudy under the Dietary Approaches to Stop Hypertension-Plus (DASH-Plus) initiative. The DASH-Plus was developed in partnership with the University of

Maryland Extension (UME) system and is a community-based program to help hypertensive, community-dwelling, older adults manage their blood pressure (BP). Using a quasi-experimental design, eight intervention senior centers and eight corresponding control sites were recruited in Maryland and participated in the study. Data was collected at three time points: baseline (week 0), intermediate (week 9), and final (week 24) at participating sites. A total of 212 participants were enrolled in the study.

First, baseline data from the DASH-Plus study was used to examine psychosocial factors and demographic characteristics associated with a healthy PBD consumption among hypertensive older adults (≥60 y), and factors that potentially influence the likelihood of adopting a plant-based dietary pattern in the future were identified. This was followed by assessing readiness to consume a PBD. Using longitudinal data collected at three time points, we evaluated the DASH-Plus program's impact on participants' readiness levels and associated psychosocial factors. We focused particularly on perceived barriers and benefits, as these factors serve as critical variables affecting an individual's decisional balance within the Transtheoretical model (TTM) and represent key constructs in the Health Belief Model (HBM) when discussing dietary behavior changes. In addition, specific perceived benefits and barriers pertaining to this population were identified. Finally, the changes in consumption of healthy plant-based foods were evaluated to assess the effectiveness of the DASH-Plus program in shifting older adults toward a healthy PBD.

Through these investigations, our cross-sectional analysis of baseline data revealed that older adults who lived with family members (spouse/partner and/or children), were in a higher stage of change (action/maintenance stages) to consume a PBD, had fewer perceived barriers, maintained better hypertensive, self-care practices (medication adherence, low-salt diet, physical activity, and smoking), and had fewer chronic conditions were more likely to consume a PBD. When readiness to consume a PBD was more closely examined to understand behavior changes resulting from the DASH-Plus program, perceived barriers and perceived benefits to consuming a PBD were found to be key determinants. The DASH-Plus program effectively elevated PBD readiness at 9 weeks, but these effects diminished at 24 weeks. Similarly, when changes in PBD intake were examined, there were significant increases in plant-based food consumption at 9 weeks, but these were also not sustained at 24 weeks. Increased self-care, higher education levels, lower number of medical conditions, and less PBD barriers were found to be key predictors influencing PBD consumption.

While the DASH-Plus program effectively increased both PBD readiness and consumption in the short term, these effects declined by the 24-week follow-up. The intervention demonstrated the potential to influence dietary shifts toward more plant-based eating patterns among older adults; however, these findings underscore the need for further research to explore strategies for maintaining these changes over the long term. Possible strategies could involve increasing the duration of the intervention, the frequency of sessions, total didactic hours, adding booster sessions, and other supportive measures. Future studies should also consider targeting key factors related to PBD adoption, including reducing perceived barriers, providing

education tailored to various educational levels, and offering additional social support for older adults living alone or with non-family members. These approaches may help older adults with chronic diseases successfully incorporate more healthy plant-based foods into their diets.

EXPLORING CHALLENGES AND STRATEGIES RELATED TO PLANT-BASED DIETARY PATTERNS IN COMMUNITY-DWELLING OLDER ADULTS WITH HYPERTENSION

by

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Dedication

To my loving husband and family for their unwavering support and belief in me.

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List of Abbreviations

ADL - Activities of daily life

BMI - Body mass index

BMR - Basal metabolic rate

BP - Blood pressure

CDC - Centers for Disease Control and Prevention

CKD - Chronic kidney disease

CLM - Cumulative logit model

CLMM - Cumulative link mixed model

CVD - Cardiovascular disease

DBP - Diastolic blood pressure

DGA - Dietary Guidelines for Americans

DH - Diet history

FFQ - Food frequency questionnaire

HBM - Health belief model

hPDI - Healthful plant-based diet index

HTN - Hypertension

LMM - Linear mixed-effects model

MCC - Multiple chronic conditions

MID - Multiple imputation, then deletion

MPS - Muscle protein synthesis

NCD - Non-communicable chronic disease

NHANES - National Health and Nutrition Examination Survey

NNR - Nordic Nutrition Recommendations

OR - Odds ratio

PBD - Plant-based diet

PBP - Plant-based protein

PLP - Pyridoxal 5′-phosphate

SBP - Systolic blood pressure

SES - Socioeconomic status

TTM - Transtheoretical model

UME - University of Maryland Extension

uPDI - Unhealthful plant-based diet index

US - United States

USDA - United States Department of Agriculture

Chapter 1: Introduction

1.1 Problem statement and rationale

Among the rise in chronic diseases, cardiovascular disease (CVD) remains the leading cause of morbidity and mortality in the US and globally.[1] Arterial hypertension is a major risk factor for CVDs such as ischemic heart disease, heart failure, cerebrovascular disease and other comorbidities including end-stage renal disease. Chronically elevated blood pressure (BP) not only represents a significant risk factor for cardiovascular complications but also threatens cognitive functionality and autonomy with senescence.[2] Prevalence is highest in older adults aged 65 or older, the National Health and Nutrition Examination Survey (NHANES) reported that around 66.6% of adults 65 years old or older have hypertension,[4] and during August 2021–August 2023 the US Centers for Disease Control and Prevention's National Center for Health Statistics estimated that the prevalence of hypertension was 71.6% for older adults (≥60 years).[5]

This population is also one of the fastest growing demographics. By 2060, almost 1 in 4 people are projected to be aged ≥65 years old.[6] With increased life expectancy, those aged ≥80 years old will also have tripled by 2050.[7] Furthermore, many non-communicable chronic diseases including cardiovascular disease, arthritis, cancer, and dementia markedly increase with advancing age and disproportionately affect older adults. Almost 95% of older adults (≥60 years) have at least one chronic disease, and close to 80% have two or more.[8] The intersection of an aging population and the rise in chronic diseases poses a complex global challenge to the sustainability of healthcare systems with far-reaching societal consequences. In response to this

urgent concern, the initial approach should prioritize nonpharmacological interventions focused on modifiable lifestyle elements, such as diet, nutritional behavior, and physical activity.

In terms of diet, plant-based diets (PBDs) have been proposed as one solution in the nutrition and health domain, but also across the environmental, economic, and societal sustainability domains. This research presents the findings of a study that aims to provide a better understanding of the psychosocial and demographic characteristics of this population who consume a more PBD, and to assess the DASH-Plus program for its effect on readiness to consume a PBD through decisional balance between perceived barriers and benefits as well as the program's effect on reported PBD consumptions.

1.2 Research objectives

The overall objective of this study was to explore the challenges and strategies related to plant-based dietary patterns in community-dwelling older adults with hypertension in order to preserve this vulnerable population's wellbeing. To achieve this objective, three primary aims were developed:

Aim 1.

Examine the psychosocial factors and demographic characteristics associated with a healthy plant-based diet (PBD) consumption among hypertensive older adults (≥60 y) and identify factors that potentially influence the likelihood of adopting a plant-based dietary pattern in the future.

To provide a better understanding of this population's heterogeneous dietary habits in regard to a PBD, the underlying psychosocial factors and demographic characteristics associated

with a higher PBD consumption were examined. These findings helped identify variables that influenced their dietary behaviors towards a more plant-based dietary pattern.

Aim 2.

Assess the effect of the DASH-Plus intervention on participants' readiness to consume a plant-based diet (PBD) and identify key socioeconomic and psychosocial factors including perceived barriers and benefits that predict readiness levels, using longitudinal data collected at three-time points.

Changing behavior including dietary habits can be challenging. Research has shown that behavior change is deeply influenced by personal perceptions and psychological readiness. The stages of change of the transtheoretical model (TTM) and its auxiliary principle of decisional balance have been shown to modify behavior. The most important perceived barriers and benefits of consuming a PBD for this population were also identified for this population. It was hypothesized that increasing perceived benefits while decreasing perceived barriers will lead to increased readiness to consume a PBD with the DASH-Plus intervention.

Aim 3.

Evaluate the effectiveness of the DASH-Plus program in promoting a plant-based diet (PBD) consumption and identify key predictors influencing adoption outcomes in older adults (≥60 years) with hypertension, utilizing longitudinal data from three time points.

As older adults participated in the DASH-Plus program, their PBD consumption was measured at three time points using a short, validated 15-item questionnaire. This provided their general dietary pattern that differentiated a healthy PBD from an unhealthy one. Using this

survey, the dietary changes among the three time points for each arm (intervention and control) were assessed. Specifically, a focus on the DASH-diet education portion of the DASH-Plus intervention was assessed as a possible strategy to increase plant-based consumption in older adults. Analysis of this data also identified key determinants that influenced a plant-based dietary pattern in older adults. While previously, behavior mediators were analyzed, this study aimed to assess the dietary behaviors more directly. The findings of this study will also help tailor future interventions with the overall goal to help manage chronic diseases including hypertension in older individuals using a PBD.

1.3 Project overview

The research studies contained in this dissertation examined the various factors associated with PBDs in the older adult population (≥60 years old). The baseline data collected for the DASH-Plus project was used to better understand the population's psychosocial and demographic characteristics (e.g. gender, socioeconomic status (SES), education) of individuals consuming a more PBD. Previous research was used to determine the factors most likely to influence the adoption and possible adherence to a PBD in older adults. Conversely, it also provided information about potential groups who were less likely to consume a PBD and the potential challenges (perceived barriers) they faced.

With this general overview of the population and the associated characteristics in terms of PBDs, a closer examination of the determinants into dietary behaviors ensued. Specifically, the stages of change (readiness), which are known to influence behavior change, were examined in conjunction with the associated core principles of decisional balance, the perceived benefits and barriers of consuming a PBD in older people. The strongest perceived benefits and barriers

identified can also inform future strategies to help with dietary modifications toward a more plant-based dietary pattern in this group. These effects were observed in the context of the DASH-Plus program.

Finally, the DASH-Plus program's effect on the consumption of PBD was also assessed. The changes in healthy plant-based foods were measured through a validated food frequency questionnaire (FFQ). At this stage, the possible strategy of using the DASH-Plus to transition older adults safely by examining the effectiveness of the program was the primary focus. Simultaneously, the determinants affecting PBD intake were also determined.

The results from the implementation of the DASH-Plus were encouraging. Although the observed effect of the DASH-Plus program in readiness to consume a PBD and reported PBD consumption was initially significant at 9 weeks (intermediate time point), the changes were not sustained at week 24 (final time point). A difference between the intervention and control was also seen at 9 weeks for readiness to consume a PBD, but not in reported PBD consumption. This dietary shift seen at 9 weeks showed a promising start towards modifying dietary behaviors and increasing plant-based food intake in older adults. These findings suggest that strategies such as booster sessions, increasing the total didactic hours of education, and other supportive measures may be needed. Several useful determinants that can be used to tailor future interventions when influencing dietary behaviors were also identified.

By examining these factors, a deeper insight into the complex interplay among diet, health, and psychosocial influences in hypertensive older adults can be seen. This knowledge can then be used to develop more effective and tailored interventions to address the specific needs of this population, improve public health strategies, and promote healthier dietary behaviors in older individuals with the ultimate goal of preserving the health of this expanding population.

Chapter 2: Literature review

2.1 Shifts in population demographics

In 2019 the Centers for Disease Control and Prevention reported that about 16% of the US population, 54.1 million adults, were 65 years or older and is projected to grow rapidly. By 2040, this number is estimated to increase to 80.8 million and by 2060, the number of older adults is estimated to reach 94.7 million, representing about a quarter of the US population. Particularly, the oldest-old segment of the population who are 80 years or older is projected to grow exponentially, increasing by 137.26% from 16.9 million in 2020 to 40.1 million in 2050. The significant shift in sex ratios after the age of 65 is also worth noting in this population. The sex ratio between the ages of 65 and 79 is less than 0.98, but the gap widens at ≥80 years old where there are 65 or fewer males for every 100 females in most places globally.[9]

2.2 Overview of noncommunicable, chronic diseases in older adults

2.2.1 Chronic conditions in older adults

With this aging demographic, the incidence of chronic diseases is also on the rise and most individuals with at least one chronic condition are between the ages of 60 to 79 years old. The oldest-old (≥80 years) are estimated to have the highest disease burden with an increase of 244.3% for one chronic disease and 202.7% for multimorbidity from 2020 to 2050.[10] Currently, the ten most common chronic conditions for adults 65 years or older are as follows: Hypertension (60%), high cholesterol (51%), arthritis (35%), ischemic coronary/ heart disease

(29%), diabetes (27%), chronic kidney disease (25%), heart failure (15%), depression (16%), Alzheimer's disease or dementia (12%) and chronic obstructive pulmonary disease (11%).[11] Cardiovascular disease (CVD), however, remains the leading cause of morbidity and mortality worldwide including in older adults.[1] Close to 95% of adults aged 60 years and older have at least one chronic disease and almost 80% have two or more. Additionally, around 42% of older adults (aged ≥60 y) are obese, which can increase the risk for certain conditions such as heart disease, type 2 diabetes, and some cancers.[11] When using body mass index (BMI) to categorize obesity, it should be taken into consideration that this method and the ranges used to define each category for older adults in particular are controversial. It has been argued that the optimal BMI for older adults may be slightly higher, 31–32 kg/m^2 for females and 27–28 kg/m^2 for males. Some studies have reported better health outcomes with these ranges.[12,13]

2.2.2 Hypertension in older adults

Historically in pre-industrial times, the measured range of blood pressure (BP) was fairly narrow with an average of around 115/75 mmHg, which may represent the ideal BP in humans.[14] It should be noted, however, that the life expectancy in the pre-industrial age was much lower. Over the last century, life expectancy has risen significantly, and it has been observed that systolic blood pressure (SBP), the pressure the blood exerts on the arterial walls when the heart contracts, increases continuously with age in males and females. This may be due to the accumulating effects of being exposed to environmental factors that increase BP over time including excessive sodium intake, inadequate potassium intake, being overweight and obese, alcohol consumption, and a sedentary lifestyle. Genetics can also play a role in the development of hypertension.[14]

Systemic arterial hypertension, commonly referred to as hypertension (HTN) is one of the most prevalent preventable risk factors for many chronic diseases such as cardiovascular disease, chronic kidney disease (CKD), and cognitive impairment, and is the "leading single contributor to all-cause death and disability worldwide."[14] It has been estimated by NHANES that two-thirds of adults 65 years old or older have HTN [4] and the CDC more recently reported that during August 2021–August 2023, the prevalence of hypertension was 71.6% for adults 60 years and older.[5] However, older adults are often undertreated for this condition. This population has also often been excluded from clinical trials in the past due to reasons concerning frailty, fall risk, and poor renal function among others.[4] More studies using innovative ways to safely include older adults with chronic diseases will be necessary in the future.

According to observational data from the Framingham study, the lifetime risk of developing HTN in older adults aged 55 to 65 years old is >90%. After the age of 60, it has been noted that SBP seems to increase in a majority of individuals, while diastolic blood pressure (DBP) remains stable or seems to decrease spontaneously. The most common cause is due to the progressive stiffening of the walls in arterial vessels. Clinically, it has been suggested that lowering BP in noninstitutionalized older adults with few comorbidities has been beneficial even in the oldest old who are 80 years or older.[2,15]

Hypertension can be divided into two classifications based on etiology: primary or essential HTN, which accounts for 85-95% of cases, and secondary HTN caused by, for example, renal artery stenosis and various endocrine disorders. Most of the HTN in older adults aged 65 or older is considered essential and approximately 10% of cases are secondary.[15] Blood pressure in the elderly is diagnosed using at least 3 different BP measurements that are taken on 2 separate office visits. These rules are the same as for younger patients.[2] The current target BP

for older adults is controversial. The 2017 American Heart Association (AHA)/ American College of Cardiology (ACC) defines older adults as 65 years old and recommends the target blood pressure to be <130/80 mmHg.[2,4,16] The 2018 European Society of Cardiology/European Society of Hypertension (ESC/ESH) guidelines propose a BP goal of <140/90 mmHg for individuals over the age of 65 years.[2,15] To clarify further, the ESC/ESH proposes pharmacologic treatment for all older patients with an SBP of ≥160 mmHg. A SBP therapeutic target of 130-139 mmHg and DBP of 70-79 mmHg can be considered for hypertensive 'elderly' aged above 65 years, but not in the 'very old,' >80 years unless considered fit.[4] The ESC/ESH published newer guidelines in 2023, but have kept the recommended goal of <140/80 mmHg for those between 65 - 79 years old and recommended more aggressive treatment to <130/80 mmHg, if well tolerated. For those 80 years and older, the target goal is 140-150 mmHg for SBP and <80 mmHg for DBP.[17,18]

The American College of Physicians/ American Association of Family Physicians guidelines propose the target goal to be a BP <150/90 mmHg.[2,16] The 2017 Canadian guidelines propose an SBP target goal of <120 mmHg for all individuals over the age of 75 years old. This recommendation is supported by the findings of the Systolic Blood Pressure Intervention Trial (SPRINT) Study, for adults aged >50 years, compared to controlling systolic BP to <140 mmHg targeting SBP to a goal of <120 mmHg had better health outcomes. A more intensive management of SBP reduced cardiovascular events by 25 percent and reduced the overall risk of death by 27 percent.[19] Canada is currently updating its HTN guidelines and will be released sometime this year in 2025. The 2013 European guidelines based on the Hypertension in the Very Elderly Trial (HYVET) criteria recommend beginning antihypertensive treatment strategies for those ≥80 years with a SBP >160 mm Hg and that the target goal should be a SBP

<150 mmHg.[2,20] These discrepancies in recommendations can be confusing and may be due to the considerable demographic, cultural, and biomedical changes that have occurred in the last several decades as well as the variable functionality in older adults.[2]

Due to the complex nature of treating HTN, it has been suggested that absolute cardiovascular risk be assessed. This means that when someone has an elevated BP between 130-139/80-89 mmHg (stage 1 hypertension), the patient's characteristics/ comorbidities will be examined for high-risk factors including: age 65 and older, diabetes, chronic kidney disease, known cardiovascular disease before initiating pharmacotherapy. Without these risks, most individuals with stage 1 hypertension do not qualify for drug therapy. Non-high-risk individuals are recommended to start drug therapy when BP is ≥140/90 mmHg. These guidelines suggest that regardless of frailty, all non-institutionalized, community-dwelling adults aged 65 years and over qualify for drug therapy when their SBP is ≥130 mmHg. However, no DBP threshold for treatment has been identified in a similar manner.[21]

Around 80% of adults aged 65 years or older were being treated for HTN, but only around 55% had their blood pressure under control.[22] This is in line with another study that showed that despite growing evidence of improved outcomes with intensive HTN control in this population, analysis of data from 2008 to 2018 revealed that appropriate intensification occurred only in 30% of ambulatory visits for adults ≥60 years and that this was suboptimal based on the major guidelines. More strategies are needed to prevent this therapeutic stagnation.[23]

HTN in older adults is a complex and heterogeneous condition that does not have a simple one size fits all solution.[2] It is recognized that HTN management in older adults has to be individualized taking into consideration the frailty status, complex medical comorbidities, and psychosocial factors. Physicians will also have to be mindful of issues more prevalent in this

population such as cognitive impairment, competing medical health problems, polypharmacy, orthostatic hypotension, falls, gait speed, medication costs and side effects among others, which can be challenging.[20]

2.2.3 Social and economic considerations

Chronic diseases affect many aspects of life and have a tremendous impact socially and economically. One study examining disability in older adults aged 80 years and older found that individuals with chronic diseases, especially cardiovascular diseases (CVD), cancers, chronic respiratory diseases, and diabetes, known as the 'big four' noncommunicable diseases (NCDs) are at a higher risk of becoming functionally disabled. The onset of disability is also earlier for those with major NCDs. The effect this has on activities of daily life (ADL) is profound. ADLs are found to be lost in two clusters, an early-loss cluster, and a late-loss cluster regardless of chronic health status. The early loss cluster consists of bathing, dressing, and walking while the latter consists of toileting, transferring, and eating.[24] The loss of ADLs could affect autonomy, quality of life, and social interactions.

Economically, a person's health directly affects their finances.[25] Chronic diseases account for 86% of the total medical costs in the US. The average cost of healthcare was 5.5 times higher in elderly patients with multiple chronic conditions (MCC) compared to individuals without multiple comorbidities.[26] In another study that analyzed a large sample of US hospitalizations, 3.5 million discharges in 38 states found that almost 80% had MCC and 10% had 6 or more. In 2012, over half the patients discharged for ambulatory care-sensitive conditions were aged 65 or older. Similar to a previous study, this study also showed higher inpatient healthcare costs for patients with MCCs from longer hospital stays.[27] It has been found that the costliest diseases for older adults when combining treatment and lost wages are Alzheimer's/ dementia ($48,701 per

person per year), cancer ($30,028 per person per year), and diabetes ($20,137 per person per year).[28,29]

Additionally, there are large inequities among the older adult population. Women and people of color are more likely to encounter higher treatment costs and higher lost wages due to chronic conditions. Around 39% of Black and Hispanic older adults' lost wages were due to chronic diseases compared to 17% of Whites. Blacks and Latinos/as/xs aged 60 years or older have $4,000 more in average yearly costs due to NCDs than their White counterparts and have fewer financial resources to cope with these health problems.[25,29]

2.3 Non-pharmacological approaches/ lifestyle interventions to address HTN in older adults

2.3.1 Overview of different types of non-pharmacological approaches

Non-pharmacologic lifestyle interventions are a cornerstone of HTN management.[16,30] A study that investigated whether lifestyle factors could offset the BP effect of genotype reported that healthy lifestyle scores were strongly inversely related to both SBP and DBP regardless of the BP genetic risk. Participants with a favorable lifestyle had a SBP that was on average of 4-5 mmHg lower in all genetic risk cohorts compared to those with poor lifestyle habits. Furthermore, populations in non-westernized parts of the globe with low rates of HTN and very low prevalence of age-related HTN also support the role of lifestyle approaches in the prevention of HTN.[16]

Current guidelines include increased physical activity, a modified diet, weight management, smoking cessation, stress reduction, and restraint from excessive alcohol consumption.[15,16,20,30] Of special note, although cigarette smoking increases the risk of CVD and

smoking cessation is often encouraged for health reasons, no direct causal relationship has been found between cigarette smoking and the risk of HTN, and is still being determined. It does, however, have an acute hypertensive effect. The ESC/ESH guidelines recommend smoking cessation to prevent and manage hypertension, but the ACC/AHA guidelines do not.[16] Another study decided not to include smoking cessation as a nonpharmacologic intervention because the existing randomized control studies RCTs using this method in hypertensive and prehypertensive participants were not truly intervened.[30]

Among non-pharmacological interventions for hypertensive older adults, a systematic review and meta-analysis determined that self-management education was the most effective at lowering SBP and DBP. Using the theoretical framework of HTN self-management, a self-management education program was developed with two components: repeated group education and individual counseling. This type of intervention with repeated group education and individual counseling that was specifically tailored towards older adults that addresses personal needs and preferences was shown to be more effective compared to one-time interventions. Using these types of approaches helped them significantly increase their adherence to lifestyle changes and even a short-term, six-week educational intervention was shown to significantly reduce BP.[31]

After self-management education, the authors reported that moderate-intensity aerobic exercise was ranked second in effectively lowering SBP and DBP in older adults. This level of physical activity exercised at least three days per week reaching 64% to 77% of the maximum heart rate also helped decrease body fat, improve maximal oxygen uptake, and reduce the risk of acute cardiovascular incident. Low-intensity aerobic exercise was less effective.[31] Similarly, another review described the BP-lowering effects of physical activity with moderate- to high-

intensity aerobic exercise (at least 3 days a week for 30 minutes each time and achieving 60% to 90% of the maximum heart rate).[30] The American College of Sports Medicine recommends that older adults aim for a minimum of 150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity aerobic activity per week. Additionally, two or more non-consecutive days of moderate-intensity strengthening activities with 8 to 10 exercises that involve major muscle groups and 8 to 12 repetitions of each exercise are also recommended.[20] Moderate-intensity resistance training has also been shown to lower SBP effectively but has had inconsistent results for DBP.[31] Over time, physical activity has proven to be an effective non-pharmacological intervention to lower BP.[15,16,20,30]

2.3.2 Dietary interventions

Modified diets are another important non-pharmacologic lifestyle intervention. The DASH, low carbohydrate, vegetarian, plant-based, and Mediterranean diets have all been recommended for heart health and positive effects on BP.[16,20,30–32] A study examining 22 nonpharmacologic interventions concluded that the DASH was the most effective intervention in lowering BP in prehypertensive and hypertensive adults (SBP: weighted mean difference, 6.97 mm Hg; 95% credible interval, 4.50–9.47 and DBP: weighted mean difference, 3.54 mm Hg; 95% credible interval, 1.80–5.28). In this analysis, the DASH diet intervention was followed by aerobic exercise, isometric training, low-sodium, and high-potassium salt, and then comprehensive lifestyle modifications.[30] This study did not include self-management education as one of the interventions. The DASH diet is rich in fruits, vegetables, whole grains, and low-fat dairy products, which are naturally low in sodium, saturated, and total fat content. The diet also contains other nutrients that may help lower BP and decrease total cholesterol and low-density

lipoprotein (LDL).[30] Many studies specifically mention the DASH diet as one of the most effective approaches to manage HTN.[15,16,31]

Possible therapeutic effects of low sodium intake, increased potassium (1500 to > 3000 mg), calcium and magnesium supplementation, intake of probiotic-rich foods, fiber, flaxseed, and increased protein intake have been shown to help HTN in the elderly. Consumption of garlic, dark chocolate, tea, coffee, and fish oil has also been suggested as possible non-pharmacologic antihypertensives as well.[20] However, dietary fiber, polyphenols, flaxseed, coffee, tea, and vitamins are still controversial lifestyle interventions when trying to lower BP and need more research.[16]

2.3.3 Stress management interventions

Stress management approaches are another lifestyle intervention that helps with managing BP in this population. Activities such as transcendental meditation, yoga, Tai Chi, and biofeedback have shown some decreasing BP effects.[15,20] One review noted that Tai Chi did not have high-quality evidence and removed it from their recommendations, but due to the possible BP-lowering effects, more RCTs were encouraged.[30] Another study in a non-pharmacological intervention review reported that the BP benefits were enhanced if meditation or mental relaxation were combined with breathing techniques from yoga sessions (mean decrease of 11 mm Hg in SBP and 6 mm Hg in DBP). However, more studies are needed to strengthen the evidence behind the positive effects of these types of stress management techniques.[16]

2.3.4 Approaches regarding circadian rhythm and sleep

Lastly, circadian rhythm has been found to be relevant to cardiovascular health. Blood pressure, cardiac output, and heart rate seem to have a marked circadian pattern and a disruption

to this rhythm, especially for BP, has been associated with an increased risk of CVD. Nighttime ambulatory BP has been found to be a better predictor of cardiac risk than daytime ambulatory BP. In healthy individuals, a drop in BP of >10% has been observed from daytime to nighttime. When the circadian rhythm becomes dysfunctional the nighttime BP may remain elevated, and this increased 24-h BP has been associated with a higher risk of CVD, morbidity, and mortality. Exercise and mealtimes can also affect the circadian rhythm so it may be advisable to align meals to earlier times in the day. Sleep is closely associated with circadian rhythm and has been shown to affect hypertension. Blood pressure decreased by 10 - 20% on average during sleep so less sleep can increase the average 24-h BP and sleep deprivation has been associated with obesity, which can then indirectly affect HTN. Therefore, adequate sleep with proper circadian maintenance through a regular sleep-wake schedule, mealtimes, and managing light exposure may also help manage HTN.[16]

It should be mentioned, however, that some of these types of non-pharmacological interventions may not be appropriate for hypertensive individuals ≥80 years old. For example, weight reduction in this age group easily leads to sarcopenia, unwanted muscle loss, and even cachexia unless appropriate physical training and adequate protein are supplied. Excessive salt reduction may also cause hyponatremia, malnutrition, and orthostatic hypotension with an increased risk of falls.[2]

2.4 Nutritional considerations for older adults

2.4.1 General considerations for nutrition in older adulthood

With senescence, physiological, psychological, and social changes affect the dietary habits of older adults. Nutrition is a primary determinant of the quality of life during aging.[33] Dietary practices are often modified as physiological changes in the central nervous system, body composition, and mobility occur. Aging is associated with impaired micronutrient absorption and synthesis, anabolic resistance, bone demineralization, and muscle atrophy among others. Lower energy requirements are needed, but insufficient intake can lead to macro- and micronutrient deficiencies. Older adults often lack adequate energy and protein intake.[33,34] Additionally, many older adults suffer from constipation so dietary fiber is an important component in their diet.[34] Therefore, several dietary requirements should be carefully considered when working with older adults.

Frequently, an inadequate intake due to low appetite and other alterations from aging such as loss of smell and taste, dental issues, and changes in cognitive function can lead to nutritional and physical frailty as well as sarcopenia.[7] Age-related chronic diseases and treatment with polypharmacy can interfere with the ingestion, absorption, and metabolism of food. Furthermore, psychosocial factors such as socioeconomic status often dictate an older person's financial ability to buy medications and meet their nutritional requirements. Loneliness and the likelihood of dining alone can also influence dietary choices. It has been shown that eating with company helps older adults consume more than eating alone.[33] Depression is common in the older adult population and is another strong determinant of inadequate nutritional intake.[33,35]

Finally, food insecurity is another important aspect of diet and nutrition in older adults. Food security is defined by the Food and Agricultural Organization as "all people, at all times,

have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." Four dimensions have been identified under this definition: 1) availability of food 2) accessibility to food 3) ability to utilize the food and 4) the stability of the first three dimensions long-term. Older adults are at a greater risk of economic food insecurity due to reduced financial assistance from Social Security, the increasing cost of health care, and the rising rate of poverty in those aged ≥65.[35]

In addition to economic reasons, physical food insecurity was also found to be important. Older adults can have trouble accessing food due to physical limitations that negatively impact their ability to shop for groceries or prepare meals. Those who were ≥75 years of age were reported to have the highest proportion of physical food insecurity. Data from NHANES showed that >5% of aging adults experienced economic and physical food insecurity and that a high proportion of this group dealt with more challenges in regard to income, depression, and chronic diseases. Individuals in this population also had the lowest total Healthy Eating Index-2015 score, suggesting that their diets were least likely to resemble the recommendations of the Dietary Guidelines of Americans (DGA). In a 2018 study, a sample of US adults aged ≥50, almost half of those who had more than 2 chronic conditions were economically food insecure compared to 9.3% in those who had less than 2 chronic illnesses. Lastly, this study also found that older adults who experienced economic and physical barriers to food security are at a higher risk of poor physical and mental health.[35]

2.4.2 Micronutrients

The 2015-2020 US Dietary Guidelines for Americans (DGA) identified an inadequate intake of vitamins A, C, D, and E across all populations and both the 2010 and 2015-2020 DGA reported a deficiency of vitamin D as a public health issue.[36] According to the MyPlate United

States Department of Agriculture (USDA) website based on the 2020-2025 DGA, older adults may need to pay extra attention to vitamin B12, potassium, calcium, vitamin D, and dietary fiber. The following have also often been identified as deficient in older adults by national surveys and observational studies: protein, n-3 fatty acids, carotenoids, magnesium, vitamin B6, and vitamin E.[7] Moreover, it has been found that older adults' need for vitamin E, B6, and zinc may exceed the current recommendations for immune system regulation and fighting infection.[7,36] A few of these notable vitamins are highlighted below.

Vitamin B12

Vitamin B12 insufficiency has been described in the elderly population. Also known as cobalamin, this vitamin is essential in DNA synthesis and for hematological processes and is a key factor in cognitive functions. Inadequate levels of vitamin B12 have been associated with impaired cognition and neurological diseases such as dementia, depression, and megaloblastic anemia. Older adults may be particularly at risk of B12 deficiency due to decreased gastric acid production, atrophic gastritis,[34] and loss of intrinsic factor production, which can lead to pernicious anemia.[33] Based on the 2020-2025 DGA absorption can also be affected by pharmacotherapies, which is common with increased age.[37] For example, long-term use of antacids may contribute to the development of vitamin B12 deficiency.[7]

Vitamin B6

Aging and vitamin B6 deficiency have been connected to neurological pathologies, impaired immune functions, and cardiovascular diseases. Lower B6 consumption, prevalence of subclinical chronic inflammation and increased activity of alkaline phosphatase may result in lower pyridoxal 5′-phosphate (PLP) concentrations in older adults. One longitudinal study over 18 years in Germany concluded that vitamin B6 levels did not decline from age 60 to 90 years

old. At baseline, 37% of the participants showed a PLP level <30 nmol/L and more than half failed to meet the dietary recommendations. The analyses found that age, use of supplements, and protein intake were positive determinants of PLP concentrations, while adiposity showed a negative effect. Intake of vitamin B6, sex, nor lifestyle factors such as physical activity and smoking affected B6 concentrations long-term.[38] This study refutes the notion that B6 declines further with aging.

Vitamin D

Older adults are at an increased risk of vitamin D deficiency. Data from NHANES reported that as high as 84% of males and 91% of females in the aging adult population may have inadequate levels of vitamin D. This vitamin plays a significant role not only in calcium metabolism but is associated with pathological conditions such as muscle weakness, depression, cognitive impairment and with higher incidence of all-cause, cardiovascular, and cancer mortality.[33] Vitamin D has also been shown to help epithelial cells function in the eyes and the intestinal tract. It is involved in antimicrobial peptide expression in epithelial cells of the respiratory tract and helps protect the lung from infection. Additionally, it helps balance Th1 and Th2 T cells in adaptive immunity, which has been theorized to help regulate autoimmune responses. Clinically, low vitamin D status has also been associated with increased COVID-19 risk. One analysis of 212 cases of individuals with COVID-19 showed that people with a vitamin D deficiency had a 19.61-fold higher risk of an adverse critical outcome compared with those with sufficient serum levels of vitamin D ($p<0.001$).[36] This is of particular interest for older adults as they are also at higher risk for COVID-19 and infections in general.[39]

Vitamin E

One study found that 800 IU of vitamin E per day for 1 month in healthy older adults >60 years old had decreased levels of lipid peroxisomes and improved their immune functionality. Vitamin E supplementation (200 IU/day of dl-α-tocopherol) was also found to enhance the efficacy of hepatitis B and tetanus vaccines in older adults. This kind of supplementation has also shown salubrious effects in older adults suffering from respiratory infections.[36]

Zinc

Zinc acts as a cofactor for many enzymes in the body and is an important part of the antioxidant defense system protecting cells from oxidative damage. It is also a key part of the immune system. Older adults are more susceptible to impaired immune functions from microbiome alterations, higher medication intake, thymic degeneration and lower T cell production as well as multiple health conditions. Zinc deficiency is highly prevalent in older adults. Around 10-45 mg of zinc/ day has been effective in strengthening several aspects of the immune system in older adults.[36]

Calcium

Calcium was named as one of the "shortfall nutrients" in the 2015 DGA for adults ≥70 years old.[7] This is one of the minerals that is of interest in older adults as it plays an important role in bone health, but also affects vascular tone regulation, skeletal muscle contraction, nerve transmission, intracellular signaling, and hormone secretion. The most prevalent condition involving calcium along with vitamin D in old age is bone loss, and osteopenia that can eventually progress to osteoporosis. This condition greatly increases the risk of fractures, which leads to mortality, morbidity, and decreased quality of life. Older adults are at a higher risk of inadequate calcium intake as the absorption of this mineral decreases significantly after the age

of 60. Adults between the ages of 70 and 90 absorb nearly one-third less calcium than younger adults. This is due to achlorhydria, decreased stomach acid production and reduced glomerular filtration rate in the elderly leads to less efficient renal calcium absorption.[33]

Iron

Iron is another important nutrient that helps physical performance, immunity, cognitive development and function, temperature regulation, and thyroid metabolism. It was reported that 10% of community-dwelling older adults and 46% of institutionalized adults aged >65 years are anemic. Anemia in this population can increase the risk of mortality, loss of independence, physical decline, falls, fractures, frailty, cardiovascular incidences, and cognitive impairment.[33] Adequate iron has also been associated with increased gait speed in older adults.[34] Although iron storage does increase with age, absorption of iron from food is impaired. This can be due to atrophic gastritis, celiac disease, helicobacter pylori, and certain drugs among others. Poor dietary habits are another possible reason for low iron levels.[33]

2.4.3 Macronutrient: Addressing protein concerns in older adults

Protein

There has been much attention on the protein requirements of older adults. As previously mentioned, older adults may suffer from sarcopenia, where skeletal muscles atrophy with aging and lead to a general decrease in muscle strength. Sarcopenia has been found to increase the risk of falls, fractures, dependent living, morbidity, and mortality.[40] Almost all studies reviewed by Dorrington et al [34] showed an inverse relationship between protein intake and loss of muscle mass and strength even with disclosed limitations such as over or under-reporting among others. The authors added that having reduced muscle mass and strength affects functionality needed for food accessibility, preparation, and choice making it a vicious cycle. Due to this, it has been

suggested that older adults increase their protein intake to 1.2 g of protein/kg of body weight/day, which is above the current recommendation of 0.8 g of protein/kg of body weight/day.[34,40] This recommendation may change after the new dietary reference intake review with the updated DGA. It has also been recommended that a special focus be placed on the amino acid leucine since it has been shown to increase muscle protein synthesis (MPS) rates.[40]

In terms of PBD, it has been reported that plant-based proteins are less bioavailable with lower digestibility and contain lower leucine content. It has been argued, however, that with sufficient protein intake, the source is less important.[40] Further, a recent study found that a higher adherence to the healthy plant-based diet index (hPDI) was associated with lower frailty risk in a cohort of community-dwelling older adults in Spain and an inverse relationship between vegetable oil and frailty was also found. Contrastingly, higher adherence to the unhealthful plant-based diet index (uPDI) was associated with higher frailty risk. Data analysis pooled from several European studies (Seniors ENRICA-1, 3C Bordeaux, and AMI) showed an inverse relationship between consumption of fruits and vegetables and frailty.[41] Similar results were found in a study of US women >60 years old.[42] These findings help reinforce the differences between healthy plant-based foods and unhealthy plant-based foods. Moreover, it sheds light on the controversy regarding protein sufficiency in PBD in older adults. A possible mechanism is the antioxidant effects from vitamins C, E, carotenoids, and selenium from fruit and vegetables protect the muscle tissues from oxidative stress reducing sarcopenia.[41]

It should also be noted that the "most potent approach to enhance the sensitivity of skeletal muscle is physical activity."[43] This suggests that strategies for sarcopenia and frailty prevention should include more than a dietary approach. Both resistance and aerobic activity

performed before protein intake increased the utilization of amino acids for de novo MPS in older adults. Furthermore, it has been shown that 8 weeks of *n*-3 PUFA, EPA (1.9 g) more than DHA (1.5 g), demonstrated enhanced MPS response in middle-aged and older adults. This supplementation has not yet been investigated with plant-based protein in older adults.[43] However, if similar results are found, this can be used to amplify MPS when using plant-based protein.

Although the advantages of animal protein have been argued and demonstrated when comparing animal and plant protein sources,[44–46] some studies have also shown similarities between the two. One study that compared a cohort on an omnivorous diet to a group on a lacto-ovo-vegetarian diet for changes in muscle mass after 12 weeks of resistance training showed that older men in the vegetarian group did not gain fat-free mass, but the individuals in the omnivorous group gained an average of 1.7 kg of fat-free mass. When investigated further, it was found that the omnivorous group was consuming 1.0 g of protein/kg of body weight/day and the vegetarian group was consuming a lower amount of protein, 0.8 g of protein/kg of body weight/day. However, when consuming 1.2 g of protein/kg of body weight/day, the muscle mass gained through resistance training did not differ between the vegetarian and omnivorous diets.[43] Another study also found no difference in cross-sectional thigh muscle mass between animal or plant-based protein intake with an average intake of 0.9 g of protein/kg of body weight/day in a cohort of elderly adults after 5 years. This study suggests that the source of the protein is not a primary factor in sarcopenia. It should be noted, however, that this may be due to the method of using a food frequency questionnaire, which the authors explained is unable to distinguish between the protein sources from a variable dietary pattern over an extended period. Given that high levels of animal consumption increase saturated fats, are low in fiber, and are associated

with numerous chronic diseases such as obesity, heart disease, metabolic syndrome etc. health benefits may favor plant-based proteins in this sense.[47]

Based on these studies, diets with sufficient plant protein sources have the potential to support muscle mass with aging.[41] A strategy to overcome the fact that any one source of plant-based protein may not be a complete protein containing all nine essential amino acids is to consume a variety of plant-based proteins.[47,48] Other strategies include supplementing plant-based proteins with specific essential amino acids, selective breeding, and mixing plant proteins with animal proteins.[48] Given the findings above, it is important to consider overall protein intake as well as micronutrient intake for the older adult population when considering a change in their dietary patterns.

2.4.4 Additional considerations

An insufficient consumption of nutrient-dense foods was found to be the primary reason for undernutrition in community-dwelling adults. In line with this research finding, the typical American diet that older adults consume lacks adequate intakes of many plant-based foods such as fruits, vegetables, legumes, whole grains, nuts, seeds as well as lean meat, poultry, and low-fat dairy products. This population also consumes refined grains such as white bread and white rice, processed meats, fried foods, solid fats, sodium from canned and processed foods, and added sugars in excess from soft drinks, for example. This type of dietary pattern is strongly associated with many non-communicable diseases as well as obesity.[7]

Older people in the US population that meet the recommended number of fruits and vegetable servings is greater than in younger individuals. However, despite this encouraging trend, less than a third of older adults meet the recommended intake of vegetables, and less than half reach the recommended fruit intake. Another relevant factor of vegetable consumption is

variety, which was found to be relatively low in this age group. Living alone limited access to groceries and the frequency of grocery shopping also decreased as well. Characteristics that improved adherence to healthful dietary patterns in older adults included younger age within the elderly population, living with company rather than alone, a higher education level, and more physical activity.[33]

As a primarily plant-based diet, the DASH diet's inclusion of higher amounts of fruits, vegetables, low-fat dairy, whole grains, and high protein with reduced red meat helps address many micronutrient and macronutrient deficiencies discussed in older adults. This diet is low in saturated and trans fats, sodium, and sugar and is high in potassium, magnesium, calcium, dietary fiber, and protein. It is also high in folate, vitamin E, carotenoids, and other antioxidant nutrients. To be effective several education sessions are needed to help older adults make the necessary behavior changes.[33] Finally, one study demonstrated that combining food with dietary supplements helped reduce 100% of the Recommended Dietary Allowance and Adequate Intake inadequacies for at least nine nutrients and was associated with a lower prevalence of inadequacies for most of the 15 micronutrients including vitamins A, C, E, and zinc, except for vitamin D.[36] This is another strategy that can be employed to help reduce deficiencies in this population regardless of specific diets.

2.5 Psychosocial aspects related to PBD in older adults with hypertension/ chronic diseases

2.5.1 The health belief model for behavior change

There has been growing evidence that numerous psychosocial factors affect the onset and prognosis of hypertension.[49] The health belief model (HBM) is a theoretical model that uses

psychosocial variables applied to health behavior changes. It was developed in the early 1950s by social scientists at the US Public Health Service who wanted to understand why some individuals failed to adhere to disease prevention behaviors or screening tests for early detection of conditions. Later, this framework was also used to study compliance with medical treatments. The HBM proposes that a person's perceptions and beliefs about the disease and the effectiveness of the lifestyle behaviors recommended can predict the likelihood that a person will take the necessary actions to adopt a behavior change. A limitation is the exclusion of other important attitudes, beliefs, and determinants of health behavior. For example, it does not take into account habit-forming behaviors that may influence decision-making such as smoking. It also does not consider environmental or economic factors. Finally, there is an assumption that information about the disease is equally accessible to everyone.[50]

The model includes demographic, social, structural, and personal factors to predict the probability of behavior change and adoption. Specifically, the model emphasizes six constructs: perceptions of disease susceptibility and severity (perceived threat), benefits of healthy behavior, barriers to healthy behaviors, cues to action, and self-efficacy to enact healthy lifestyle behaviors. Using hypertension as an example, an individual may see themselves as vulnerable to hypertension (perceived susceptibility), anticipate major or minor consequences (perceived severity), believe that specific behaviors will help prevent or manage the condition (perceived benefit), are cued to action by a family member, and have high confidence in their ability to adhere to self-care behaviors (self-efficacy), despite any challenges to behavior changes like adopting a new diet or physical activity in their routine (perceived barriers). A recent study of 527 patients with hypertension recruited from Zarandieh, Iran showed that all components of the HBM and social support were significant predictors of self-care behaviors, and that self-efficacy

was the strongest predictor. In descending order, this study also found that perceived barriers, social support, perceived threat and perceived benefits were found to influence behavior change and maintenance.[51]

The World Health Organization (WHO) also endorses that hypertension is a condition that can be controlled using self-care behaviors such as adherence to treatment and a low salt diet, weight control, regular BP monitoring, smoking cessation, regular exercise, and the avoidance of alcohol. Self-care is defined as "conscious, learned, and purposeful actions and activities performed by individuals to maintain their life and promote the health and well-being of themselves and their families." Drug therapy is therefore not possible without self-care. For older adults to adopt self-care behaviors, they need to believe that they are vulnerable to the disease (perceived susceptibility), the disease could have various complications and consequences (perceived severity), self-care has benefits and surmountable barriers, with cues to action from media, healthcare providers, family members, and others who encourage self-care behaviors (cues to action). Lastly, they should believe that they are capable of managing their hypertension through self-care behaviors (self-efficacy).[52]

In a study of 106 hypertensive older adults, (52.83% male with an average age of 63.91 ± 4 years in the intervention group and 64 ± 3.95 in the control group) all constructs in the HBM scores improved after the education program. The intervention consisted of two sessions that lasted 45 to 60 minutes and were held a few weeks apart. Each session consisted of a lecture followed by a question-and-answer session. An educator taught the sessions using a validated booklet titled Self-Care Education for Older Adults that was developed using the HBM and the educational needs of the participants. The control group received routine services normally

provided by the health centers' providers and staff. This study showed the efficacy of HBM-education sessions in improving self-care behaviors in older adults.[52]

Among hypertensive patients in Nepal, one qualitative study reported that patients had difficulties in participating and maintaining the recommended physical exercise because they did not experience many symptoms, so their perceived threat of cardiovascular disease was lower. Lack of support from their family, physicians, workplace, or other social groups was also identified as one of the key barriers in managing and sustaining a healthy lifestyle.[53] Another study showed that satisfaction in communication between a physician and hypertensive patient had a significant positive impact on self-care and pharmaceutical adherence. Higher satisfaction in hypertensive patients regarding communication reflected higher adherence to medical recommendations.[54] Additionally, a hypertensive patient's lack of belief in their ability to participate in and maintain lifestyle behaviors when faced with various challenges such as time constraints is an important barrier as well.[53]

2.5.2 Self-efficacy

Positive associations between self-care behaviors and psychological constructs like self-efficacy have generally been acknowledged.[54] Self-efficacy, an individual's beliefs about their capabilities to execute a behavior change resulting in desired health outcomes, and outcome expectancies are major constructs of the Social Cognitive Theory. Individuals with higher self-efficacy have a greater ability to engage in behavior changes even when facing barriers compared to those with lower self-efficacy. Moreover, self-efficacy is positively associated with health behaviors such as physical activity through environmental factors and social support. Self-efficacy had small-to-large relationships with physical activity (r=0.02-0.46) and dietary adherence (r=0.06-0.79) depending on the assessed domain and country.[53] Self-efficacy was

reported to be significantly related to at least one self-management behavior including physical activity, healthy diet, adherence to medication, blood glucose testing, and foot care.[54]

Outcome expectancy can also affect lifestyle behaviors. This refers to the individual's belief in the likelihood of a behavior leading to a desired outcome. For example a low-sodium diet and regular exercise leading to effective blood pressure management. In one study a positive association between outcome expectancy and moderate-to-vigorous physical activity was not seen in older hypertensive patients (>60 years). Older adults may have more difficulty participating in physical activity due to concerns about safety, frailty, and other chronic conditions.[53]

2.5.3 Effects of social environments

Social support is another construct that can influence hypertensive patients' adherence to lifestyle changes including diet and exercise. There are two dimensions to this construct: (1) structural support which consists of the number and types of connections within a person's social network and (2) functional social support, which involves emotional, informational, and instrumental support from family, peers, or others. One review found a small relationship between social support and physical activity and dietary adherence.[53] Social support played a bigger role in medication adherence and was strongly correlated with following medical prescriptions. The importance of the perception of social support and quality has also been highlighted. A more positive perception of medication-specific social support produces better treatment adherence, but also higher levels of self-efficacy.[54]

Adverse health effects from chronic racial and ethnic discrimination and other social experiences have been associated with negative health effects. Chronic discrimination is more

consistently related to ambulatory BP than to resting clinic BP. Furthermore, discrimination was positively associated with difficulties sleeping, insomnia, and fatigue, which can affect HTN risk. Finally, internalized racism and stereotypes have also been identified as another mechanism that could negatively affect health. Stereotype threat can trigger increased levels of anxiety and impair decision-making and self-regulation processes. It can indirectly affect HTN through weight changes by overeating and by modulating the neural hormonal system. It can also lead to a delay in seeking medical care, poor patient-provider relationships, and low adherence to recommended treatments. Finally, occupational stress is associated with an increased risk of HTN. Occupational stress can come from a hostile work environment, work insecurity, time pressures, and work hazards among others. Jobs that provide low control, but high demand such as servers or clerks are higher among ethnic minorities.[49]

Emotional states such as high levels of anxiety and depression are common in adults with chronic conditions with comorbidities such as HTN. This can have a negative impact on a person's health and quality of life.[49] Depression is one of the most common mental health disorders among those with chronic diseases. The factors associated with hypertensive adults who were also depressed were age, educational status, employment status, SES, physical activity, and family history of HTN.[55] One study demonstrated that individuals with depressive symptoms had a 42% increased risk of HTN. Although more studies are needed, anxiety was suggested to be an independent risk factor for incidents of HTN.[49] A study in Ghana found that older hypertensive patients (8.4%) had nearly twice the prevalence of depression compared to younger patients (4.5%), but no significant differences between older males and females were observed. A depression rate as high as 60% in older hypertensive adults has been reported. Additionally, young and older hypertensive adults who were widowed or separated from their

spouses had higher risks of depression. Hypertensive adults with no religious affiliation and those who rated their health status as bad were 3 times more likely to be depressed than those who marked their health status as good. Participants who experienced hunger every month were also approximately 5 times as likely to report depressive incidences.[55] Other emotions such as anger and hostility are also associated with increased HTN risk. Conversely, positive psychological well-being such as optimism, life satisfaction, and emotional vitality is related to health behaviors such as physical activity that affect HTN and cardiovascular incident risk. More studies in this research area are needed.[49]

Social relationships and networks serve as a source of emotional support including empathy, informational support and instrumental support. These beneficial connections have been shown to support health and reduce the negative effects of stressful experiences on health and resilience.[49] Social support is important for the wellbeing of older adults and individuals without such support have shown to be more susceptible to depression and other psychological problems.[55] Evidenced by The National Health Interview Survey, both emotional support and social integration were independently associated with decreased odds of HTN. It also helped protect against the adverse effects of low SES on HTN. Marital status can have both positive and negative effects on health and HTN in particular depending on the relationship.[49]

2.5.4 Theory of planned behavior

The Theory of Planned Behavior (TPB) is a theory used to predict intention to perform a behavior. There are three constructs used in this theory: attitude (behavioral beliefs), social norms (normative beliefs) and perceived behavioral control (control beliefs). Attitude describes the positive or negative consequences associated with engaging in the behavior. Social norms are about the significance that an individual places towards the opinions of others and the perception

of social pressure to adopt (or not) a behavior. Lastly, perceived behavioral control indicates factors that facilitate or hinder the adoption of the behavior. This theory was used to examine eating behaviors of older adults' consumptions.[56] Plant-based protein and whole grain consumption in older adults was examined.

Under attitudes, the advantages of consuming plant-based protein (PBP) most frequently mentioned were related to health benefits such as cardiovascular health and weight management. This was reported in a higher proportion by women. Good nutrient content and taste of legumes was also mentioned numerous times. Those who consumed PBP twice a week or more (C-group) also mentioned the environment as an advantage of consuming PBP. Individuals who did not consume PBP twice a week or more (NC-group) mentioned health related disadvantages to consuming PBP such as intestinal discomfort (gas and bloating) associated with legumes and the lack of some nutrients. Some in the NC-group felt that PBP could lead to inadequate protein intake, minerals such as iron and calcium, and vitamin B12. Some barriers were the difficulty of cooking PBP as well as the taste of PBP such as tofu or processed products. Those in the C– group also mentioned that having company over for dinner with PBP was challenging and often prepared alternative choices. Finally, others reported that nuts and processed products were more expensive. Many also felt judged about consuming PBP.[56] Low-income older adults were interviewed about their whole grain consumption. Similar to PBP, older adults mentioned the health benefits especially on bowel or gastrointestinal health. Cardiovascular, bone, brain, eye health, diabetes, and weight management were also listed as health benefits. Second to health benefits, some described taste as an advantage. However, taste was also mentioned as a disadvantage, and some described the appearance of whole grains as unappealing.[57]

For social norms, at least one person approved of their consumption of PBP. Usually they mentioned a family member, children/grandchildren or spouse followed by friends. The participants also reported that overall women tended to approve PBP more and that those who disapproved were often male. However, most older adults did not particularly care whether others approved of their choices except when it came from their spouses. In this way social norms are less predictive of behaviors in the older adult population.[56] For whole grains, most people felt that the media, family members and healthcare providers encouraged the consumption of whole grains. Some mentioned that individuals who were less educated and knowledgeable would sometimes discourage whole grain consumption.[57]

Finally for perceived behavioral control, most participants felt that having simple, quick, tasty recipes for PBP would help facilitate increased intake. Some mentioned being more informed about PBP, for instance, the range of products, where to buy them, the benefits of consuming them, and ways to avoid digestive issues would help them purchase PBP. Many reported that animal products are too pervasive in society and that it was often promoted over plant-based foods. Main barriers reported in a higher proportion by males were laziness, inertia (tendency to do nothing and remain unchanged), and unwillingness to put in the effort needed to change habits. Perception of good health at the time of the interview also added to the reluctance to change. In the NC-group, they mentioned that lack of knowledge on how to cook PBP, spousal resistance to change dietary habits, and living alone were all barriers to change. When describing digestive issues associated with PBP, the symptoms described were severe and resembled an allergic reaction.[56] For whole grains, a common barrier that was mentioned was age-related physical changes such as dental problems. For instance, whole wheat bread is harder to chew, and seeds can get stuck under dentures.[57]

Increasing knowledge such as how to prepare PBP may help to reduce barriers. One study used an 8-month cooking class as an intervention with older men that suggested that it could help improve cooking skills and the use of new products. This also helped prevent social isolation. Another study that combined information and culinary skills improved older adults' nutrition knowledge, dietary habits, confidence in eating healthy meals that meet the daily nutritional requirements, and increased variety. These types of interventions may help to lower some of the barriers with PBP.[56]

Psychosocial aspects related to plant-based diets have not been explored much especially in older adults in general. It has also not been thoroughly examined in hypertensive older adults or those with other chronic diseases.

2.6 Plant-based Diets: Definition and Types

Currently, the term "plant-based diet" (PBD) encompasses a wide array of definitions, and many related terms are used both in research and in the media. In general, this type of dietary pattern focuses on plant-based foods such as fruits, vegetables, whole grains, legumes, nuts and seeds, while limiting or excluding animal-derived products including eggs, meat and dairy.[58–60] Sometimes, the term "PBD" is used interchangeably with vegetarianism or veganism. An overview of the various definitions is provided here.

In general, vegetarian diets usually exclude meat, fish, and other animal products and consist mostly of plant-based foods (fruits, vegetables, nuts, legumes, cereal etc.). To help identify specifically which foods are included, there are several subgroups of vegetarianism: lacto-vegetarian (includes dairy products), ovo-vegetarian (includes eggs), and ovo-lacto-vegetarian (includes eggs and dairy products). The vegan diet is more exclusive and eliminates

all animal-derived products including honey.[61] Additionally, there are whole food vegans that exclude processed foods in addition to all animal-based products and whole food, low-fat vegans who are vegans, but further exclude processed as well as high fat plant-based foods such as avocados, oils, nuts etc. Lastly, there are raw vegans who eliminate any cooked plant-based foods.[58]

There are also diets that allow some meat in a mostly vegetarian diet. For example, the pesco-vegetarian/ pescatarian diet excludes meats except for fish.[62] The flexitarian/ semi-vegetarian diet allows for reduced consumption of meat and fish.[61] However, the type and the amount of animal foods included in the diet may differ. For example, some flexitarians specify an acceptable quantity of animal-based foods per month or the inclusion of white meats such as poultry and fish, but exclude red meats.[58,60] Table 2.1 below describes all definitions provided here and other diets adapted from the Kent et al study.[58] Approximately 5% of the US follow a vegetarian diet while 2% of Americans identify as vegans.[63]

Table 2.1. Definitions of plant-based diets

Plant-based diets	**Definition** – all include plant-based foods: fruits, vegetables, grains, nuts, seeds, beans, pulses in addition to the components listed below for each diet	
Vegetarian diets	**Includes**	**Excludes**
Lacto-vegetarian	dairy	meat, fish, and eggs
Ovo-vegetarian	eggs	meat, fish, and dairy
Lacto-ovo-vegetarian	dairy and eggs	meat and fish
Vegan diets	**Excludes all animal and animal-derived products including honey**	
	Includes	**Excludes**
Whole food vegan	unprocessed fruits, vegetables, grains, nuts, seeds, beans, and pulses	all animal and animal-derived products and processed foods
Whole food low-fat vegan	unprocessed and low-fat fruits, vegetables, grains, beans and pulses	all animal and animal-derived products and processed and high-fat plant foods (oils, avocado, nuts, etc.)

Raw vegan	uncooked fruits, vegetables, grains, nuts, seeds, beans, and pulses	all animal and animal-derived products and cooked foods
Plant-based diets	**Includes some animal products**	
	Includes	**Excludes**
Pescatarian/ pesco-vegetarian	fish, dairy and eggs	other meats
Semi-vegetarian flexitarian	fruits, vegetables, grains, nuts, seeds, beans, pulses and fish, dairy, eggs and meat (on some but not all days of the week)	restrictions on meats
Portfolio diet	A primarily vegetarian diet with the inclusion of 4 core food components: 42 g nuts (tree nuts or peanuts); 50 g plant protein from soy products or dietary pulses such as beans, peas, chickpeas, and lentils; 20 g viscous soluble fiber from oats, barley, psyllium, eggplant, okra, apples, oranges or berries; and 2 g plant sterols initially provided in a plant sterol-enriched margarine.	
Mediterranean-style diet	Moderate meat and dairy and emphasis on certain plant-based components, such as olive oil, olives, nuts and moderate red wine intake.	
Dietary approaches to stop hypertension (DASH) diet	Fat-free/low-fat dairy over full-fat dairy products. Poultry and fish in place of red and processed meats. Limited sugar-sweetened foods and beverages and sodium.	
Healthy US-style diet	Based on recommendations from the USDA DGA. Moderate dairy, mostly low-fat or fat-free. Protein sources from seafood, lean meats, poultry, eggs, soy products, nuts and seeds. Limited saturated fats, sodium and added sugars.	
Planetary health diet	Moderate seafood, poultry and dairy (if included at all). Limit red meat, processed meat, added sugar, refined grains, starchy vegetables and highly processed foods.	
Nordic-style diet	Rich in fruits and berries, vegetables, rye, low-fat dairy products and fish. Emphasis on local foods. Fats are from canola oils.	

Previously, some people in the research community have defined the term plant-based diet by excluding all animal products including red meat, poultry, fish, eggs, and dairy products.[64] Some excluded all oils when defining a PBD.[65] Others advocated for a more inclusive definition of a PBD, “An eating pattern dominated by fresh or minimally processed plant foods and decreased consumption of meat, eggs and dairy products. Compared to meat-centered diets,

it involves increased consumption of a variety of grains (including whole grains), fruits, vegetables, legumes, nuts and seeds. This does not necessarily mean a vegetarian diet."[59]

About 50% of researchers used the term 'plant-based diet' interchangeably with veganism, ~33% included dairy products and 20% of interventions encouraged a semi-vegetarian diet. Given these varied definitions, a consensus of the term could help prevent confusion. In the meantime, a plant-based dietary intervention reporting checklist has been created.[62] Additionally, with the increasing popularity of PBD, various terminologies to describe this type of diet have also emerged, "plant-centered, plant-predominant, plant-rich, plant-focused, plant-forward etc."[58]

Using the definition given by Lea et al,[60] some people categorize the DASH diet, the Mediterranean diet, and the Nordic-style diet as plant-based diets. Considering that it is often easier to make gradual incremental changes for most things, with diet being no exception this latter definition was used in these studies. Furthermore, even reductions in animal products instead of a complete elimination when combined with higher consumption of plant-foods is associated with a lower risk of coronary heart disease.[66]

2.7 PBD indices

Several plant-based diet indices have been created for different dietary patterns depending on which foods are incorporated and to what extent animal foods are excluded. These dietary indices can be used to differentiate among the plant-based dietary patterns and quantify their health associations. An overall plant-based diet index (PDI) was created from repeated semi-quantitative FFQ data, where a positive score was given to all plant foods and reverse scores to animal foods. This index does not differentiate plant-foods by nutritional content.[66]

Higher PDI scores have been associated with lower risk of chronic diseases including coronary heart disease.[67]

To differentiate between healthful and unhealthful plant foods, a healthful plant-based index (hPDI) and an unhealthful plant-based diet index (uPDI) were also created. The hPDI consists of healthy plant foods such as whole grains, fruits, vegetables, nuts/legumes, oils, tea/coffee that received positive scores, while less healthy plant foods such as juices/sweetened beverages, refined grains, potatoes/fries, sweets and animal products received reverse scores. To create the uPDI, positive scores were given to the less-healthy plant foods while animal and healthy plant foods received reverse scores. Diets with higher hPDI score are associated with lower risk of CHD and diabetes type 2.[66] Conversely, diets with high uPDI scores have been associated with higher risks of CHD compared with healthy plant foods.[67] Finally, the alternative healthy eating index (AHEI), which has higher scores for healthy plant-based foods as well as for some animal-sourced foods such as fish are also associated with lower risk of chronic diseases.[68]

2.8 DASH diet

The Dietary Approaches to Stop Hypertension (DASH) diet was developed in the 1990s. In 1992, the National Institute of Health funded several research studies to investigate different dietary interventions and their effects on hypertension.[32] The year 2017 marked the 20th anniversary for the DASH diet. It began as a 4-site, randomized controlled feeding study that emphasized protein, fiber, potassium, magnesium and calcium while limiting foods with a high saturated fat and sugar content. Compared to a typical American diet that was used as the control, the DASH diet reduced systolic blood pressure (SBP) by 5.5 mmHg and the diastolic

blood pressure (DBP) by 3.0 mmHg. These results were apparent starting just 2 weeks after baseline across various subgroups of ethnicities, races, and genders in both hypertensive and prehypertensive participants. It also became evident that reducing sodium enhanced the positive results of the DASH diet on hypertension.[69]

The following table has the specific recommendations of the DASH diet. Please see Table 2.2 below:

Table 2.2 Components of the DASH diet

	Number of servings	**Example**
Grains	6 to 8 servings a day	One serving is one slice bread, 1 ounce dry cereal, or 1/2 cup cooked cereal, rice or pasta.
Vegetables	4 to 5 servings a day	One serving is 1 cup raw leafy green vegetable, 1/2 cup cut-up raw or cooked vegetables, or 1/2 cup vegetable juice.
Fruits	4 to 5 servings a day	One serving is one medium fruit, 1/2 cup fresh, frozen or canned fruit, or 1/2 cup fruit juice.
Fat-free or low-fat dairy products	2 to 3 servings a day	One serving is 1 cup milk or yogurt, or 1 1/2 ounces cheese.
Lean meats, poultry, and fish	six 1-ounce servings or fewer	One serving is 1 ounce cooked meat, poultry or fish, or 1 egg.
Nuts, seeds, or dry beans and peas	4 to 5 servings a week	One serving is 1/3 cup nuts, 2 tablespoons peanut butter, 2 tablespoons seeds, or 1/2 cup cooked dried beans or peas, also called legumes.
Fats and oils	2 to 3 servings a day	One serving is 1 teaspoon soft margarine, 1 teaspoon vegetable oil, 1 tablespoon mayonnaise or 2 tablespoons salad dressing.
Sweets and added sugars	5 servings or fewer a week.	One serving is 1 tablespoon sugar, jelly or jam, 1/2 cup sorbet or 1 cup lemonade.

Additionally, the standard DASH diet limits sodium intake to 2300 mg while a reduced sodium version limits it further to 1500 mg.[70]

PBDs such as the DASH diet will help address the shortages in micronutrients from a lack of plant-based foods and will encourage foods that are naturally low in sodium chloride. Lastly, since the DASH diet does not eliminate meats or dairy completely from the diet, but may reduce meat intake, this could be an effective and safe way to transition to a healthier plant-based diet. This would be an easier and safer method than trying to completely eliminate all meat at once and possibly becoming deficient in protein and other nutrients that the meat provided, especially in an older individual.

Chapter 3: Methods

3.1 Conceptual framework

The examination of psychosocial variables associated with PBD consumption through the DASH-Plus program draws primarily from the HBM and the TTM. The HBM theoretical framework has been widely applied in behavior changes related to health outcomes.[71,72] Specifically, the perceived benefits and barriers constructs influencing behavior change were included in the conceptual framework. Among the constructs of the HBM, research has shown that perceived barriers are the strongest predictor of behavior change.[73–75] To assess changes in readiness to consume a PBD using the DASH-Plus intervention, the TTM model was also incorporated. Decision balance is an important aspect of this theoretical framework that also involves considering the perceived barriers and perceived benefits. As perceived barriers decreased and perceived benefits to consuming a PBD increased, it was hypothesized that individuals would progress to a higher stage of change. Increased readiness is a mediator for dietary behavior change and was chosen to demonstrate changes in PBD consumption of participants.

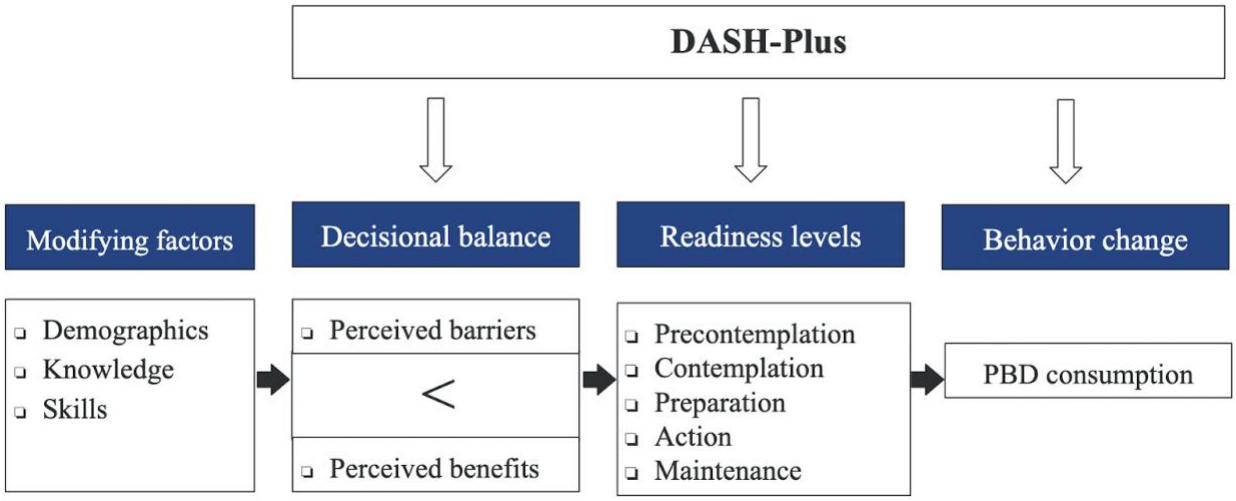

Figure 1. Conceptual framework of PBD consumption through the DASH-Plus program

3.2 Study overview

The overall goal is to better understand the characteristics of older adults who have adopted a more PBD and investigate how to facilitate a successful transition to a more plant-based diet using the DASH diet. To that end, the first study aims to understand the demographic and psychosocial characteristics of hypertensive older adults in relation to a PBD and identify factors that potentially influence the likelihood of adopting a plant-based dietary pattern in the future. Individuals on a PBD diet were identified using their calculated PBD scores based on the hPDI as measured by the administered FFQ. Secondly, the next study assessed the effect of the DASH-Plus intervention on participants' readiness to consume a plant-based diet (PBD) and identified key socioeconomic and psychosocial factors including perceived barriers and benefits that predict readiness levels, using longitudinal data collected at three-time points. Changes in key constructs such as perceived PBD barriers and benefits were measured. Finally, the last study evaluated the effectiveness of the DASH-Plus program in promoting PBD and identified

key predictors in older adults (≥60 years) with hypertension, utilizing longitudinal data from three time points.

3.2.1 Study Design and Setting

These studies were conducted as sub-studies under the DASH-Plus initiative. The DASH-Plus project is a 3-year hypertension management program guided by community-based participatory research in partnership with the University of Maryland Extension (UME) system. As the name suggests, the DASH-Plus program integrates the Dietary Approaches to Stop Hypertension (DASH) diet with physical activity to help community-dwelling, older adults who have hypertension manage their condition. The DASH-Plus intervention consists of three core components: (1) Eight weekly DASH-plus education sessions (Dietary Approaches to Stop Hypertension diet with exercise and HTN self-care skills), (2) weekly produce delivery to increase produce accessibility and (3) self-measured blood pressure (BP) monitoring for 24 weeks. Additionally, the DASH-Plus project also included educational opportunities for students not described here. The overall objective of DASH-plus is to establish a sustainable platform for research and education pertaining to hypertension management for older adults. Using a quasi-experimental design, the project was conducted in the following eight counties across Maryland where an Extension Educator is present to teach: Allegany, Baltimore, Cecil/ Kent, Montgomery, Queen Anne's, Wicomico, and Carroll County. In each county, an intervention and control site were chosen by the respective Extension Educator responsible for that county. A total of 212 participants were recruited.

3.2.2 Recruitment, screening and enrollment

Originally, the research team had planned to employ a cluster randomization method to recruit study sites, participants, and test the effectiveness of the intervention. However, with the uncertainty from the continuing effects of COVID-19 during the implementation phase, a quasi-experimental design was used as a feasible way forward. Eight experienced Extension educators recruited two sites in their respective counties, an intervention site and a corresponding control site. Each prospective site was invited to host the DASH-Plus program as part of the study. Once the study sites officially joined the study, supplemental recruitment material such as flyers were sent to help with participant recruitment. The onsite director and staff also directly spoke with community members as part of the recruitment process.

Potential participants went through an initial screening process during the baseline data collection (week 0) using a 6-item Mini-Mental State Examination (MMSE) and blood pressure was measured three times by trained research staff. Those who met the eligibility criteria and passed the screening process proceeded with enrollment, after which a trained data interviewer administered the remainder of the survey in a standardized process. The number of enrolled participants varied at each site. A study protocol was developed to ensure the fidelity of data collections, and an onsite project manager oversaw the interview process at each site. Written informed consent was obtained from all participants, and the project was approved by the University of Maryland, College Park's Institutional Review Board.

3.2.3 Subjects

Inclusion criteria: The inclusion criteria for participants are: (1) ≥60 years of age, (2) attends OAANP or other community sites for seniors regularly (at least three times per week),

and (3) has systolic blood pressure (SBP) of 140–170 mm Hg and/or diastolic blood pressure (DBP) of 80–100 mm Hg or is taking anti-hypertensive medication(s).

Exception criteria: The following individuals were not included in the study: (1) having an acute and/or terminal condition such as terminal cancer, renal disease, and/or high alcohol consumption (>14 alcoholic drinks per week), (2) having a psychiatric diagnosis precluding participation, such as cognitive impairment as measured by the 6-item Mini Mental State Exam, and (3) being underweight (BMI 18.5 kg/m^2) or class 3 obese (BMI 45.0 kg/m^2).

3.3 Intervention

1) *8-week DASH-plus education*: The educational portion of the DASH-Plus intervention consisted of eight interactive modules. See Table 3.1 below for a brief description of each module. Each session was 60 - 75 minutes long and taught once a week by experienced UME educators for a total of 8 weeks. It was strongly recommended that participants come to all 8 sessions and attendance was recorded. Each session began with a welcome statement introducing the module topic, followed by 5 – 10 minutes of voluntary physical activities such as stretching or light strength training adapted from the National Institute of Aging. Then the educational materials with interactive activities embedded throughout were presented. Towards the end of each session, a summary of the module called “Putting it altogether” was discussed and the sessions concluded with a short cooking demonstration video with a relevant hypertension friendly recipe.

Table 3.1 Summary of DASH-Plus Modules

Sessions	Focus
Module 1: Introduction to DASH-plus & Hypertension	Provides background information about hypertension, the DASH diet, and physical activity component. Includes recipe at the end with cooking demo video clip.
Module 2: Sodium	Addresses the amount of sodium included in the DASH diet, common sources of sodium, and how to reduce sodium. Includes recipe at the end with cooking demo video clip.
Module 3: Grains	Define grains, explains the difference between refined and whole grains, and serving sizes. Includes recipe at the end with cooking demo video clip.
Module 4: Fruit and Vegetables	Discusses benefits of fruits and vegetables: decrease blood pressure, fiber, vitamins, and minerals. Encourages 4 -5 servings of fruits and vegetables. Includes recipe at the end with cooking demo video clip.
Module 5: Meats and other protein	Defines what proteins are, explains how much protein is needed, and meat alternatives. Includes recipe at the end with cooking demo video clip.
Module 6: Dairy	Explains healthy dairy choices, dairy substitutes, benefits of dairy, and cautions against sodium in certain dairy products. Includes recipe at the end with cooking demo video clip.
Module 7: Fats and Sweets	Different types of fats introduced: saturated, unsaturated, trans fats. Encourages reducing added sugar to <10g. Includes recipe at the end with cooking demo video clip.
Module 8: Shopping and Budgeting	Teaches how to grocery shop on a budget, read “sell by,” “use by,” and “best if used by” dates and labels. Includes recipe at the end with cooking demo video clip.

2) *Weekly produce box for 24 weeks:* Additionally, the participants received a weekly produce box of fruits and vegetables for all 24 weeks.

3) *Self-measured blood pressure monitoring*: Every intervention participant received their own individual blood pressure (BP) monitor for them to keep and measure their BP at home. A BP log was provided and detailed instructions on how to measure their BP accurately was covered in the introduction section.

4) *Peer supporter*: A peer supporter was also recruited at the intervention site, who acted as a wellness champion to support and encourage the participants. This role was filled by a participant, a staff member, or a volunteer involved with the project.

5) *Hypertension- friendly recipe booklet*: Intervention participants received a DASH-Plus tote bag, a hypertension-friendly cookbook, and a binder with the slides of each session printed out.

3.4 Control Sites

The control sites received four non-diet related, pre-existing Extension programs that were collectively advertised as Wellness-Plus. See Table 3.2 for a brief discussion of each module. UME educators taught approximately 60-minute sessions biweekly (every other week) for a total of 8 weeks, running concurrently with the intervention modules at the matching site. These participants did not receive an individual BP monitor, weekly produce baskets, a cookbook, or a tote bag. They were, however, given a small promotional item such as a food thermometer, microwave cover etc. as compensation and to encourage attendance. They also received binders with associated handouts where applicable. Once the 24-week study period was concluded at the paired intervention and control site, the control site received a delayed intervention. This provided control participants an opportunity to learn the DASH-Plus approach but without additional incentives (BP monitors, weekly produce etc.). Lastly, if permitted by the control center, a BP measuring station was set up.

Table 3.2 Summary of Wellness-Plus Modules

Sessions	Focus
Module 1: Capture the flavor	Provides fun facts, histories, and information on how to use different herbs and spices. Excluded mentioning replacing sodium and benefits to hypertension.

Module 2: Food safety tips	Delivered in a trivia format, participants learned about different food safety tips by answering questions in teams.
Module 3: Green cleaning	Participants learned different ways household products such as vinegar can be used to create non-toxic disinfectants to reduce allergies and avoid using stronger detergents such as chlorine and ammonia. Created their own green cleaning sprays during class.
Module 4: How to talk to your doctor and health professionals	Helped participants learn to communicate more effectively with their providers. Included a binder with materials discussed during the session.

3.5 Data collection

Data was collected at three different time points by trained data collectors for the DASH-Plus study and sub-studies. First, the baseline questionnaire was administered a week prior to either the intervention DASH-Plus or the control Wellness-Plus programs were implemented at the respective sites. This was considered week 0. The week the intervention modules started was considered week 1 of the study. After 8 weeks of educational sessions at the intervention site and 4 biweekly sessions at the control site, the following week (week 9), an intermediate questionnaire was completed. Finally, at the end of study period (24-weeks), a third questionnaire was completed around week 25. See Table 3.3 below for variables included in each survey.

3.5.1 Baseline data collection

Baseline data was collected through a structured questionnaire that included sociodemographic characteristics such as age, gender, ethnicity, race, marital status, education

level, annual household income, and self-perceived general health status (physical and mental). In addition, the following measures were also collected.

3.5.2 Blood pressure measurements

Blood pressure was measured three times and then averaged at each time point. Participants were asked to sit with their backs supported by the chair, legs uncrossed, with their left arm at the level of their heart (right arm was used if needed) in a relaxed manner. A trained research staff member then measured their BP using an automated blood pressure cuff with a minute rest period between measurements.

3.5.3 Hypertensive self-care

Hypertensive self-care was assessed using the self-care activity level effects (H-Scale) survey.[76] It consists of four activities: medication adherence (3 items), low-salt diet (9 items), physical activity (2 items), and smoking (2 items, one inquires about smoking status yes/no). Participants were asked, "How many of the past 7 days did you (insert activity): from 0-7 days, except for the smoking status question. For example, "Take your blood pressure pills?", "Salt your food at the table?" and "Do at least 30 minutes total of physical activity?" were activities listed in the questionnaire. Each of the 4 sections resulted in a score that was averaged by the number of items answered. A final composite score was totaled to represent the individual's amount of self-care. Higher scores represented more self-care behaviors with a score range from 0 - 105.

3.5.4 Psychosocial factors

Perceived barriers to consuming a PBD were assessed using a list of 10 items compiled from earlier studies that included a significant proportion of the older adult population in their

sample.[59,77] A 5-point Likert scale (strongly agree to strongly disagree) was used with a score ranging from 1 to 5. For example, the perceived barrier, "I don't want to change my eating habit or routine" was measured from strongly agree to strongly disagree in the same manner used previously and the top nine perceived barriers from that study were included in the present study.[59] Additionally, other papers reported that the enjoyment of meat was one of the main barriers, so this was included as the tenth perceived barrier to adopting a PBD.[77,78] (Cronbach's alpha: baseline = 0.65; 9 weeks = 0.72; 24 weeks = 0.80). A summative PBD barriers score was then averaged by the number of items answered by each participant to account for missing values. Higher scores were indicative of higher perceived barriers.

Perceived benefits to consuming a PBD for older adults were measured using a list of ten items gathered by conducting a literature review using a 5-point Likert scale (strongly agree to strongly disagree).[59,78,79] For instance, perceived benefits such as, "Decrease my saturated fat intake" and "Improve my digestion" were included. A score range of 1 to 5 points was assigned to each response where higher scores indicated a greater number of perceived benefits for consuming a PBD (Cronbach's alpha: baseline = 0.88; 9 weeks = 0.92; 24 weeks = 0.93). These scores were then totaled and averaged by the number of items answered by each participant to account for missing items.

Participants' readiness to consume a PBD was determined using one question with choices that corresponded to the five stages of change of the transtheoretical model. This approach has been used previously.[80–83] The responses were categorized as: precontemplation stage ("I am not thinking about eating a PBD"), contemplation stage ("I am thinking about eating more PBD…planning to start within 6 months"), preparation stage ("I am definitely planning to eat a more PBD in the next month)," action stage ("I am trying to eat a more PBD now"), and

maintenance stage ("I am already eating a PBD"). A score range of 1 to 5 was used where higher scores suggested more readiness to consume a PBD.

PBD knowledge was assessed by adapting a questionnaire from a study that surveyed medical providers (11 items) using a 3-point Likert scale (agree, not sure, disagree).[84] Due to the lack of a single definition of PBDs, ambiguous and controversial questions were omitted from the scoring. For example, "Dairy is encouraged in a PBD" and "Fish is a necessary part of a healthful diet" were excluded from the PBD knowledge scores as the answers to these questions depends on the definition of a PBD being used (DASH diet, Mediterranean diet, lacto-vegetarian diet, vegan etc.). A score of 1 was used for correct answers and 0 for not sure and incorrect answers (Cronbach's alpha = 0.57). The total scores of PBD knowledge scores were then averaged by the number of items answered by participants to account for missing values.

3.5.5 Food Frequency Questionnaire (FFQ)

The analyses in the first and third studies are based on an individual's healthy PBD score computed to represent PBD consumption. A validated, short 15-item FFQ was used to collect dietary intake. Starting with some background information about this FFQ, this survey was designed as a screening tool that could be administered by personnel who may not have a nutrition background. It is used to assess the diet quality based on the dietary recommendations of the Nordic Nutrition Recommendations (NNR).[85] At the time of the study, the most recent version of the NNR was developed from 2012-2013 and published in 2014. The next edition was published in June 2023.[86] The Nordic diet is similar to the Mediterranean diet and is rich in plant-based foods such as vegetables, fruits, legumes etc., but most of the fat intake comes from canola oil instead of olive oil.[87] The original 15-item FFQ study was conducted in middle-aged

adults and able to predict cardiovascular risk.[88] It was then validated in older adults aged 70-years old using an accepted method known as diet history (DH) for comparison. To gather the DH of individuals, a dietitian conducts a semi-structured interview one-on-one that usually takes about 60-90 minutes. During this time, the habitual dietary pattern is captured by estimating the inventory of food intake over the last three months. This method has been validated and is comparable to the heart rate method, activity diary, doubly labeled water, and the method that calculates the ratio between energy intake and basal metabolic rate (BMR). The dietary intake had 1810 different food items that were categorized into 35 food groups and was recorded as grams of food item usually consumed per day/ week/ month to calculate the individual intake.[85]

The validated 15-FFQ was chosen in this study for several reasons. First, it was chosen for the relatively short length to reduce the response burden and fatigue since the population of interest in this study is older adults. Although response burden is not simply about the length of the survey or time it takes to complete a questionnaire,[89] there is some evidence to suggest a longer survey could induce fatigue and reduce the quality of the data collected.[90,91] To minimize this possibility, a shorter questionnaire was chosen within the overall survey conducted. There are four established DASH indices, however, these all require a much longer FFQ.[92] Additionally, a long FFQ is difficult to administer and not feasible in a community nutrition setting. Secondly, this shorter 15-item FFQ was validated in elderly individuals with an average age of 70 years old,[85] which is the target population. Thirdly, the researchers concluded that the original short questionnaire was able to predict cardiovascular risk factors.[88] Since the research topic focuses on participants with hypertension and elevated cardiovascular risk factors, this survey was a good fit.

Using the 15-item FFQ and the previously established hPDI, a similar scoring system was adapted for data analysis. Positive scores were given to healthy plant groups, where higher frequency received a higher score, and reversed scoring used for unhealthy plant-based and animal foods. For example, the question, "How often do you eat vegetables (fresh, frozen or cooked)?" had the following scores: twice a day or more (4 points), once a day (3 points), a few times a week (2 points) and once a week or less (1 point). Conversely, the question, "How often do you eat red meat (beef, pork or game)?" was scored in reverse: three times a week or more often (1 point), twice a week (2 points), once a week (3 points), and a few times a month or less (4 points). Furthermore, other healthy dietary behaviors also received positive scores based on frequency (i.e. eating breakfast and avoiding excessive salt intake with hypertension). This is in line with the argument being presented that a healthy PBD is more than eliminating meat since it is possible for a person to have an unhealthy PBD. Sodium intake is especially relevant when it comes to hypertension. Finally, some questions were not able to be scored since they did not pertain to frequency such as the type of bread they consumed but provided additional information about their diet. Omitting these questions gave each question equal weight with a maximum of 4 points and a minimum of 1 point. Once the PBD scores were determined, quartiles were created for the first study where the highest quartile represented older adults on a more PBD and the lowest quartile represented a more average Western (meat-centered) diet. The third study used the healthy PBD scores as a continuous variable over the three time points.

Table 3.3 Summary of sections included in each questionnaire

Baseline questionnaire Week 0	**Intermediate questionnaire Week 9**	**24-week questionnaire Week 25**
• Demographics – age, ethnicity, race, marital status,	• Blood pressure measurement x3	• Blood pressure measurement x3

living status, education, income • Blood pressure measurement x3 • Physical health rating • Mental health rating • Medication adherence • Composite measure of Physical function • Food security • Perceived FV accessibility • Self-care activity levels • FFQ • HTN knowledge • Newest vital sign • Geriatric Depression Scale • PBD knowledge • PBD Willingness • Perceived barriers of PBD • Perceived benefits of PBD • Readiness to adopt a PBD • Height and weight of participants	• Physical health rating • Mental health rating • Self-Administered Comorbidity Questionnaire (SCQ) • Medication adherence • Composite measure of Physical function • Food security • FV accessibility • Groceries • Self-care activity levels • FFQ • HTN knowledge • Newest vital sign • Geriatric Depression Scale • Perceived barriers of PBD • Perceived benefits of PBD • Readiness to adopt a PBD • Meatless meals eaten • Height and weight of participants	• Physical health rating • Mental health rating • Self-Measured Blood Pressure Monitoring Practice • Produce delivery feedback • Mobile Device Proficiency (MDPQ-16) • Medication adherence • Composite measure of Physical function • Food security • FV accessibility • Groceries • Self-care activity levels • FFQ • HTN knowledge • Newest vital sign • Geriatric Depression Scale • Perceived barriers of PBD • Perceived benefits of PBD • Readiness to adopt a PBD • Frequency of meal sources • Importance of various issues when purchasing plant foods • Weight of participants

3.6 Evaluation and Analysis

3.6.1 Statistical analysis overview

All statistical analysis was performed using RStudio version 2024.12.1+563 and Statistical Package for the Social Sciences (SPSS) software version 29.0.2.0 (20). Both descriptive and inferential statistics were used. First, multiple imputations were performed to address missing values in all 3 studies. This was followed by an appropriate model analysis.

3.6.2 Analysis of Aim 1

Aim 1: Examine the psychosocial factors and demographic characteristics associated with a healthy plant-based diet (PBD) consumption among hypertensive older adults (≥60 y) and to identify factors that potentially influence the likelihood of adopting a plant-based dietary pattern in the future.

To evaluate the characteristics of older adults who consume a more PBD, their computed PBD scores were used as the dependent variable. The final PBD scores based on the hPDI were divided into quartiles where the top 25% consumed a more PBD and the bottom 25% represented a more meat-centered and unhealthy PBD diet. Several characteristics associated with PBDs previously were identified through a literature review. For example, differences in gender based on vegetarian diets have been seen.[63,93–95] Women are twice as likely as men to be vegetarian or vegan in Western cultures and men reported having a more positive attitude associated with meat consumption.[95] Additionally, compared to meat-eaters, vegetarians tend to be more educated.[63,93,94] However, Allès et al [93] reported that in their sample in France, vegans were more likely to be male and less educated. Vegetarians also tend to be younger,[63,93,94] and characteristics that improved adherence to healthful dietary patterns in older adults included younger age within the elderly population, living with company rather than alone, a higher education level, and more physical activity.[33] Therefore, even though this was a cohort of older adults, they were categorized by age (youngest-old: 65 - 74 y, middle-old: 75 - 84 y, oldest old: ≥85 y). Some studies showed that vegetarianism is associated with higher socioeconomic status.[93] One study showed an association between lower socioeconomic status with decreased consumption of a healthful PBD.[96] Low- and middle-income individuals were shown to consume more processed meats and less fish compared to individuals with a higher socio-economic bracket.[97] Income was

collected, however, 13.7% (n=29) of the participants preferred not to respond or did not know their income so this variable was omitted from analysis. Instead, education was used as a proxy variable, a commonly used practice due to the strong correlation between income and education. Finally, one study found that vegetarianism is stereotypically associated with White racial backgrounds in the US.[98] However, the British Broadcasting Corporation in 2020 reported that a higher percentage of Blacks (8%) were vegetarian, or vegan compared to the national average of 3% according to a Pew Research Center survey.

A cumulative logit model (CLM) was used to assess the relationship between the ordinal response variable, PBD scores divided into quartiles, and the explanatory variables using baseline data.

3.6.3 Analysis of Aim 2

Aim 2: To assess the effect of the DASH-Plus intervention on participants' readiness to consume a plant-based diet (PBD) and identify key socioeconomic and psychosocial factors including perceived barriers and benefits that predict readiness levels, using longitudinal data collected at three-time points.

For aim 2, older adults' readiness (precontemplation, contemplation, preparation, action/maintenance) to consume a PBD was the primary outcome and evaluated as an ordinal variable. Additionally, perceived benefits and perceived barriers of PBD were assessed as part of decisional balance. It was hypothesized that these two variables would be key determinants and that increasing perceived benefits and decreasing perceived barriers would increase an individual's readiness to consume a PBD through the DASH-Plus intervention. Other variables associated with PBD readiness were also examined to determine the final model.

3.6.4 Analysis of Aim 3

Aim 3: To evaluate the efficacy of the DASH-Plus program in promoting a plant-based diet (PBD) consumption and identify key predictors influencing adoption outcomes in older adults (≥60 years) with hypertension, utilizing longitudinal data from three time points.

To assess aim 3, the PBD scores for all three time points based on the hPBD were used as the primary outcome. A linear mixed-effects model (LMM) was used to evaluate the continuous response variable to capture as much information and nuance as possible. Previously identified variables that were significantly associated with PBD consumption were used and assessed during model analysis.

Chapter 4: Examining plant-based dietary adoption among hypertensive older adults: characterizing psychosocial factors

4.1 ABSTRACT

Objective: Examine the psychosocial factors and demographic characteristics associated with a healthy plant-based diet (PBD) consumption among hypertensive older adults (≥60 y) and to identify factors that potentially influence the likelihood of adopting a plant-based dietary pattern in the future.

Design: Cross-sectional analysis of baseline data from a community-based hypertension project.

Participants: Hypertensive, community-dwelling older adults.

Variables Measured: The primary outcome was PBD consumption among participating older adults, measured using a short, validated 15-item questionnaire based on the healthful plant-based diet index (hPDI). Perceived barriers and benefits related to PBDs, readiness to consume a plant-based diet, and sociodemographic information were also collected using structured questionnaires.

Analysis: A total of 207 participants were included in the final analytic sample. Descriptive statistics were used to summarize sample characteristics and study variables. Ordinal logistic regression analysis was performed to obtain odds ratios (OR).

Results: Compared to older adults living with roommates (OR = 0.17, 95% CI 0.05-0.60, p = 0.006), those living with family members showed a significantly higher likelihood of consuming a healthy PBD. Participants' stages of change (readiness) for a PBD were significantly associated with healthy PBD consumption. Compared to those in earlier stages, individuals at the action/maintenance stages (OR = 2.76; 95% CI 1.24-6.02, p = 0.01) reported significantly higher

PBD consumption. Findings of this study also showed that older individuals more likely to consume a healthy PBD were male (OR = 2.60; 95% CI 1.07-6.32), had fewer perceived barriers (OR = 0.34; 95% CI 0.19-0.61, p <0.001), maintained better hypertensive, self-care practices (medication adherence, low-salt diet, physical activity, and smoking) (OR = 1.25; 95% CI 1.14-1.37, p <0.001), and had fewer chronic diseases overall (OR = 0.85; 95% CI 0.76-0.95, p = 0.004).

Conclusions and Implications: Living arrangements, especially residing with family members (spouse or children), lower perceived barriers, and better self-care practices were significantly associated with higher consumption of healthy plant-based foods. Readiness for a PBD may predict actual dietary behavior while implying that greater readiness corresponds with a higher likelihood of PBD adoption. Higher healthy PBD consumption was also associated with a lower number of chronic diseases. Targeting perceived barriers and enhancing self-care strategies could potentially facilitate the adoption of healthy plant-based dietary choices among hypertensive older adults. Further research is warranted to better understand the variables affecting plant-based dietary patterns in this population and their impact on health outcomes.

4.2 Introduction

Plant-based diets (PBDs) have been proposed as a sustainable solution to some of the most prominent challenges currently faced by society: the burden of noncommunicable, chronic degenerative diseases, climate change, and potential economic stressors.[99–103,67,104] While the term plant-based diet encompasses a diverse array of definitions and dietary patterns, in commonality they all emphasize plant-based foods such as fruits, vegetables, legumes, nuts, and seeds while reducing or eliminating animal-based products like meats, dairy, and eggs. Lacking

consensus on a single definition, dietary patterns such as the Dietary Approaches to Stop Hypertension (DASH) diet, the Mediterranean diet, and the more newly explored Nordic diet have been included under the broad PBD category.[58,62,105] This paper will use the broader definition of a PBD that includes the DASH diet and other similar dietary patterns mentioned above rather than a more exclusive definition such as vegan.

Among chronic conditions, evidence suggesting the benefits of healthy PBDs, particularly against cardiovascular morbidity and mortality appear robust.[60,66,106,107] Arterial hypertension is a major risk factor for cardiovascular diseases such as heart failure, coronary artery disease, stroke and other comorbidities including end-stage renal disease. It not only represents a significant risk factor for cardiovascular complications but also threatens cognitive functionality and autonomy with advancing age. Prevalence of this condition is on the rise globally with the aging population.[2] It has been estimated by the National Health and Nutrition Examination Survey (NHANES) that around two-thirds of adults 65 years old or older have hypertension,[4] and recently published data from the US Centers for Disease Control and Prevention's National Center for Health Statistics reported that during August 2021–August 2023, the prevalence of hypertension was 71.6% for adults 60 and older.[5] Additionally, this is one of the fastest-growing demographics. By 2060, nearly 1 in 4 people are projected to be aged ≥65 years.[6] With increased life expectancy, those aged 80 years old will also have tripled by 2050 to 382 million from 2013.[7] As the population continues to age, the incidence of chronic diseases is expected to increase proportionately as well.

Over the last several decades, more research studies examining the positive effects of PBDs on a range of health issues in addition to cardiovascular diseases have been published including chronic kidney disease, type II diabetes, cognitive decline, chronic musculoskeletal

pain and function, and certain cancers.[108–113] Given these potential health benefits, studies involving PBDs in older adults (age ≥60) are important considering that this is a vulnerable population carrying most of the disease burden. Almost 95% of older adults have at least one chronic condition, and close to 80% have two or more.[3] To intervene in a safe and effective manner using healthy PBDs, a greater understanding of their perspective including their perceived barriers, facilitators, and readiness in terms of PBDs is a necessary step to improve their dietary pattern as well as chronic disease prevention and management.

Previously, a 2017 study investigating the prevalence of veganism and vegetarianism for health reasons in the US found that individuals who adopted these dietary patterns were more likely to be relatively young (30-65 years old), female, non-Hispanic, from the Western region, at least high school educated, chronically ill, and physically active. Another study analyzing the socioeconomic differences associated with PBDs reported that lower socioeconomic status with a poverty income ratio ≤130% was associated with a decreased consumption of a healthful PBD. This study also found that both their plant-based diet index (PDI) model and the healthful plant-based diet index (hPDI) model, a validated index that categorizes healthy plant-based foods (whole grains, fruits, vegetables, nuts, legumes, vegetable oils, tea and coffee) separately from unhealthy plant-based foods (fruit juice, refined grains, potatoes, sugar sweetened beverages, sweets and desserts) [66] showed an association between age, race/ethnicity, education level, marital status, and poverty income ratio ≤130%.[96] These two studies reported the characteristics associated with PBDs in the general population, but did not fully investigate the attributes associated with older individuals, especially those who have a chronic condition. More studies regarding PBDs in the older adult population are starting to emerge, but further studies are warranted.

The objective of this study was to examine the demographic information, psychosocial variables, and other associated characteristics of hypertensive, community-dwelling older adults (≥60 y) who consume a healthy plant-based dietary pattern. By identifying these key factors, the findings aim to inform potential strategies, future research, and other public health initiatives using PBDs to address this pressing issue in this population.

4.3 Methods

4.3.1 Study Design and Setting

The present study was conducted as a substudy under the Dietary Approaches to Stop Hypertension-Plus (DASH-Plus) project, a community-based hypertension project aimed at helping community-dwelling, older adults manage hypertension. Guided by community-based participatory research in partnership with the University of Maryland Extension system, the DASH-Plus program was developed. As the name suggests, the DASH-Plus program is a series of eight educational modules that integrate the DASH diet with physical activity and hypertension self-care skills to help older adults who have hypertension manage their condition. A detailed description of the DASH-Plus program is provided elsewhere.[114]

The present study used the data collected at baseline. Written informed consent was obtained from all participants, and the project was approved by the University of Maryland, College Park's Institutional Review Board.

4.3.2 Sampling

We contacted several local senior centers to participate in the study. After each site agreed to join, recruitment flyers were sent to the study sites that advertised the details of the

study. The directors and other staff members also actively participated in recruiting potential study participants for the program. The inclusion criteria for participants were: (1) ≥60 years of age, (2) attends community site for seniors regularly (at least three times per week), and (3) has systolic blood pressure (SBP) of 140–170 mm Hg and/or diastolic blood pressure (DBP) of 80–100 mm Hg or is taking anti-hypertensive medication(s). The following individuals were exceptions to the study: (1) having an acute and/or terminal condition such as terminal cancer, renal disease, and/or high alcohol consumption (>14 alcoholic drinks per week), (2) having a psychiatric diagnosis precluding participation, such as cognitive impairment as measured by the 6-item Mini-Mental State Exam, and (3) being underweight (BMI 18.5 kg/m^2) or class 3 obese (BMI 45.0 kg/m^2).

Trained research staff conducted eligibility screenings at each study site on scheduled dates. Potential participants underwent cognitive impairment screening using the Mini-Mental State Examination and hypertension assessment. Once a participant qualified by passing the screening process, upon enrollment a trained data interviewer conducted the rest of the survey in a standardized process. A total of n=212 participants were recruited at baseline.

4.3.3 Measures

Baseline data was collected through a structured questionnaire that included sociodemographic characteristics such as age, gender, ethnicity, race, marital status, education level, annual household income, and self-perceived general health status (physical and mental). In addition, the following measures were also collected.

Plant-based diet score

A PBD score was computed to evaluate the characteristics of older adults who consumed a healthy PBD. Using a validated 15-item food frequency questionnaire (FFQ) that was

specifically tested for this age group (sample population was 70-year-olds) [85] and by adapting an established healthful plant-based diet index (hPDI),[66] a PBD score was determined. Positive scores were given to healthy plant foods based on the hPDI, where higher frequency of consumption received a higher score and reversed scoring was used for unhealthy plant-based and animal-based foods. For example, the question, "How often do you eat vegetables (fresh, frozen or cooked)?" had the following scores: twice a day or more (4 points), once a day (3 points), a few times a week (2 points) and once a week or less (1 point). Conversely, the question, "How often do you eat red meat (beef, pork or game)?" was scored in reverse: three times a week or more often (1 point), twice a week (2 points), once a week (3 points), and a few times a month or less (4 points). In the original hPDI, meats and seafood or fish were two distinct categories so the red meat (beef, pork, or game) and white meat (poultry e.g. chicken) items from the questionnaire were combined and given 4 points for the lowest quartile frequencies and 1 point for the highest quartile frequencies. Fish or shellfish was scored separately from the meat category.

Furthermore, other healthy dietary behaviors also received positive scores based on frequency (i.e. eating breakfast [115–118] and avoiding salty foods with hypertension [119,120]). This is in line with the argument that a healthy PBD is more than reducing or eliminating meat since it is possible for a person to consume an unhealthy PBD.[66] The total scores were then averaged by the number of response items per participant to account for missing values. Questions that did not pertain to frequency such as the type of bread they consumed were not scored but provided additional information regarding their diet. Omitting these items gave each question equal weight with a maximum of 4 points and a minimum of 1 point. Finally, the average scores were separated into quartiles given the 4 response choices per item in the FFQ and relatively small

sample size. The top quartile with the highest PBD scores indicated a dietary pattern consisting of higher amounts of healthful plant-based foods while the bottom quartile with the lowest PBD scores represented a more meat-centered and less healthy plant-based dietary pattern based on the hPDI. This PBD score served as the primary outcome and was used to identify potential psychosocial factors and other characteristics associated with healthy PBD consumption.

Psychosocial factors

Perceived barriers to consuming a PBD were assessed using a list of 10 items compiled from earlier studies that included a significant proportion of the older adult population in their sample.[59,77] A 5-point Likert scale (strongly agree to strongly disagree) was used with a score range from 1 to 5. For example, the perceived barrier, "I don't want to change my eating habit or routine" was measured from strongly agree to strongly disagree in the same manner used previously and the top nine perceived barriers from that study were included in the present study.[59]Additionally, other papers reported that the enjoyment of meat was one of the main barriers, so this was included as the tenth perceived barrier to adopting a PBD.[77,78] (Cronbach's alpha = 0.65). A summative PBD barriers score was then averaged by the number of items answered by each participant to account for missing values. Higher scores were indicative of higher perceived barriers.

Perceived benefits to consuming a PBD for older adults were measured using a list of ten items gathered by conducting a literature review using a 5-point Likert scale (strongly agree to strongly disagree).[59,78,79] For instance, perceived benefits such as, "Decrease my saturated fat intake" and "Improve my digestion" were included. A score range of 1 to 5 points was assigned to each response where higher scores indicated more perceived benefits for consuming a PBD

(Cronbach's alpha = 0.88). These scores were then totaled and averaged by the number of items answered by each participant to account for missing items.

Participants' readiness to consume a PBD was determined using one question with choices that corresponded to the five stages of change of the transtheoretical model. This approach has been used previously.[80–83] The responses were categorized as: precontemplation stage ("I am not thinking about eating a PBD"), contemplation stage ("I am thinking about eating more PBD…planning to start within 6 months"), preparation stage ("I am definitely planning to eat a more PBD in the next month)," action stage ("I am trying to eat a more PBD now"), and maintenance stage ("I am already eating a PBD"). A score range of 1 to 5 was used where higher scores suggested more readiness to consume a PBD.

PBD knowledge was assessed by adapting a questionnaire from a study that surveyed medical providers (11 items) using a 3-point Likert scale (agree, not sure, disagree).[84] Due to the lack of a single definition of PBDs, ambiguous and controversial questions were omitted from the scoring. For example, "Dairy is encouraged in a PBD" and "Fish is a necessary part of a healthful diet" were excluded from the PBD knowledge scores as the answers to these questions depends on the definition of a PBD being used (DASH diet, Mediterranean diet, lacto-vegetarian diet, vegan etc.). A score of 1 was used for correct answers and 0 for not sure and incorrect answers (Cronbach's alpha = 0.57). The total scores of PBD knowledge scores were then averaged by the number of items answered by participants to account for missing values.

Hypertensive self-care was assessed using the self-care activity level effects (H-Scale) survey.[121] It consisted of four components: medication adherence, low-salt diet, physical activity, and smoking. Participants were asked, "How many of the past 7 days did you (insert activity): from 0-7 days. For example, "Take your blood pressure pills?" and "Do at least 30 minutes total

of physical activity?" were activities listed in the questionnaire. Scores ranged from 0 to 7 and items that represented non-hypertensive self-care activities such as "Salt your food at the table," were reverse scored so that higher scores represented more self-care behaviors. Each of the total scores in the 4 sections was then averaged by the number of items answered by the participant per section to account for missingness. A final composite score of all 4 sections was used to represent the individual's level of self-care.

4.3.4 Statistical Analysis

Statistical analysis was performed using RStudio version 2024.12.1+563 and Statistical Package for the Social Sciences (SPSS) software version 29.0.2.0 (20). Both descriptive and inferential statistics were used to assess the relationship between the ordinal response variable, PBD scores divided into quartiles, and the explanatory variables. Possible independent predictors associated with PBDs and the hypertensive, older adult population were identified through a literature review. Sociodemographic factors such as sex (female, male), age categories (youngest-old: 65 - 74 y, middle-old: 75 - 84 y, oldest old: ≥85 y), race (African American/ Black, Asian, Caucasian, Other), education (less than high school, high school/GED, post high school education through college, post-graduate studies including graduate/professional degrees), and living arrangement (lives alone, lives with family - spouse and/or children, lives with others) were considered. Hypertensive self-care consisting of medication usage, low-salt diet, physical activity and smoking status was assessed. In addition, perceptions and beliefs such as perceived barriers, perceived benefits, and readiness to adopt a PBD as well as PBD knowledge were also included as potential associated factors. Lastly, measured health traits such as the number of self-reported chronic medical conditions/diseases, average SBP, average DBP, BP controlled (<130/80 mmHg) versus uncontrolled (≥130/80 mmHg) according to the American Heart

Association,[16,46] number of anti-hypertensive medications, and body mass index (BMI) were investigated as other possible independent variables. Income was collected, however, 13.7% (n=29) of the participants preferred not to respond or did not know their income so this variable was omitted. Education was used as a proxy variable, a commonly used practice due to the strong correlation between income and education.

To address missing values, imputation was considered if less than 20% of the individual variable was missing using the multiple imputation by chained equations (MICE) method. Once missing values were imputed and reviewed, the 16 potential predictors of a plant-based dietary pattern in hypertensive, older adults were first analyzed using univariate ordinal logistic regression. Only significant variables ($p < 0.05$) were included in the univariate cumulative logit model. This was followed by backward elimination multivariate ordinal logistic regression analysis. Five significant variables were identified this way: living arrangement, number of medical conditions, hypertensive self-care, readiness to adopt a PBD, and perceived PBD barriers. A backward stepwise regression analysis starting with all 16 variables was further conducted to comprehensively assess their joint predictive ability and the least statistically significant variable ($p \geq 0.05$) was removed one at a time. This model yielded 8 variables total, the initial 5 variables from the univariate analysis as well as sex, average SBP, and uncontrolled BP (<130/80 mmHg) versus controlled BP (≥130/80 mmHg).

Final model selection occurred through Akaike information criterion (AIC) and Bayesian information criterion (BIC). With each iteration, a model where the AIC value decreased by 2 units was considered a statistically significant improvement [122] and a decrease in BIC value between 5 and 10 units was considered strong.[123] A model with the smallest absolute AIC and BIC values was considered a better model.[124] Multicollinearity was tested using variance

inflation factor (VIF) and generalized variance inflation factor (GVIF). No significant multicollinearity was found among the variables (VIF/GVIF < 2). The proportional odds assumption was assessed through the Brant test; the results showed that the parallel regression assumption held. Finally, the goodness of fit for the final model was examined through the Lipsitz test, the Pulkstenis-Robinson chi-squared test, the Pulkstenis-Robinson deviance test, the Hosmer-Lemeshow test, and the Nagelkerke *R* squared for ordinal regression.

4.4 Results

4.4.1 Socio-demographic characteristics of participants

Of the 212 total number of participants enrolled in the study, the average age was 74 ± 7.5 years old with slightly over half (51.9%) of the participants in the youngest-old (64 - 74 y) category. A large majority were female (88.7%), non-Hispanic (92.9%), and over half the individuals were Caucasian (57%). About 21% had a high school diploma/GED and 41% had an education level ranging from post-high school training through a 4-year college diploma. Half of the participants lived by themselves (50%), while many lived with family members such as a spouse/partner and/or children (42%). Most participants were prescribed one or more anti-hypertensive medication(s) (96.2%) and took an average of 1.7 ± 0.8 (median: 2; mode:1) anti-hypertensive medications. The average measured SBP was 137 ± 20 mmHg, the average DBP was 79 ± 11 mmHg, where 31.9% had their blood pressure under control (<130/80 mmHg), and the average number of self-reported medical conditions was 6 ± 2.6. The mean BMI was 31.0 ± 6.4 kg/m^2, with 48.1% classified as obese.

Table 4.1. Baseline demographics (n =212)

Variables	mean ±SD	n (%)
Age	74 ± 7.5	211 (99.1)
64-74 y		110 (51.9)
75-84 y		81 (38.2)
≥85 y		19 (9.0)
Sex		
Female		188 (88.7)
Male		24 (11.3)
Ethnicity		
Non-Hispanic/ Non-Latin American		197 (92.9)
Hispanic/ Latin American		11 (5.2)
Prefer not to answer		1 (0.5)
Race		
Caucasian		121 (57.1)
Black or African American		70 (33.0)
Asian		10 (4.7)
Other		9 (4.2)
Prefer not to answer		1 (0.5)
Living arrangement		
Alone		106 (50.0)
Family (spouse/partner and/or children)		89 (42.0)
Other (i.e. Roommate)		17 (8.0)
Education		
Less than high school		33 (15.6)
High school graduate/ GED		45 (21.23)
Post-high school training through college		87 (41.0)
Post-college through graduate/ professional degrees		47 (22.2)
Taking antihypertensive medications		
Yes		204 (96.2)
No		8(3.8)
Average number of anti-hypertensive medications (range: 0 - 4)	1.7 ± 0.8	
Blood pressure		
Average SBP (mm Hg)	137 ± 20	211 (99.5)
Average DBP (mm Hg)	79 ± 11	210 (99.1)
Controlled (<130/80 mmHg)		56 (31.9)
Uncontrolled (≥130/80 mmHg)		126 (68.1)
Number of medical conditions (range: 1 - 16)	6 ± 2.6	
Anthropometric measurements		
BMI (kg/m^2)	31.0 ± 6.4	
Healthy weight (18.5 and 24.9 kg/m^2)		30 (14.2%)

Overweight (25 and 29.9 kg/m^2)	76 (35.8%)
Obese (≥30 kg/m)	102 (48.1%)

*Gender included 1 person who identified as non-binary/third gender

4.4.2 Knowledge, perceived barriers, benefits, and readiness related to PBD consumption

The average scores for PBD-related knowledge, perceived barriers, benefits, and readiness are summarized in Table 4.2. The average PBD knowledge score was 0.623. Participants demonstrated high awareness of certain aspects, correctly identifying that dark green leafy vegetables are high in iron (94.3% correct) and nuts are high in protein (93.4% correct). However, knowledge gaps were evident regarding vitamin B12 monitoring in a PBD (30.2% correct) and plant sources of omega-3 fatty acids (29.2% correct). Regarding protein knowledge, 82.5% correctly disagreed with the statement that animal proteins are the only quality protein sources, yet only 43.4% correctly disagreed with the statement, "You cannot get enough protein on a PBD."

Of the top ten barriers measured, the largest perceived barrier for this population was that they needed more information about PBD (85.4% agreed) and not having enough plant-based choices when eating out (44.4% agreed) was ranked second. In terms of benefits, 89.6% agreed that increased fiber intake was the most important benefit of PBDs for older adults followed by the agreement (86.7%) that PBDs helped them stay healthy. The stages of change were surveyed to determine readiness to consume a PBD. A quarter of the participants were in the precontemplation stage, 20.3% were in the contemplation stage, 23.6% were in the preparation stage, 25% were in the action stage, and only 3.8% were in the maintenance phase. The latter two stages were combined for analysis due the small sample size of the maintenance phase.

Table 4.2 Mean scores of psychosocial factors and knowledge related to PBD

	Average ± SD or n(%)
PBD knowledge (11 items, range 0 - 1)	0.62 ± 0.18
Perceived barriers (10 items, score range: 1- 5)	2.89 ± 0.53
Perceived benefit (10 items, score range: 1- 5)	4.01 ± 0.50
Readiness to adopt PBD	
Precontemplation	53 (25.0%)
Contemplation	43 (20.3%)
Preparation	50 (23.6%)
Action	53 (25.0%)
Maintenance	9 (3.8%)

4.4.3 Predictors of plant-based dietary patterns in hypertensive, older adults

Based on the selection process detailed in the methods section, the final ordinal logistic regression included the following 8 variables: (1) living arrangement, (2) sex, (3) PBD readiness, (4) BP controlled (<130/80 mmHg) vs. uncontrolled (≥130/80 mmHg), (5) average SBP, (6) number of medical conditions/diseases, (7) hypertension self-care, and (8) PBD barriers. With the exception of BP controlled vs. uncontrolled, all other variables were statistically significant (p <0.05) shown in Table 4.3. This non-significant variable was still included in the final model because it helped explain the relationship between BP, an important variable in this cohort and the dependent variable. The AIC also increased slightly, although not to a significant degree when the variable was removed.

First, living arrangement was a key variable associated with consumption of a healthy PBD in hypertensive, older adults. Older individuals living with family members were more likely to adopt a healthy PBD compared to those living with a non-related roommate (OR = 0.17; 95% CI 0.05-0.60, p =0.006). The second variable in the present model was sex. Older males were 2.60 (95% CI 1.07-6.32) times more likely than older females to consume a more PBD (p =

0.035). Next, the average SBP was a significant variable (p =0.010) when assessing the consumption of a healthy PBD, but the OR (1.02; 95% CI 1.01-1.04) was not meaningful. When analyzing differences in plant-based dietary patterns between older adults who had their BP under control, defined by the American Heart Association as <130/80 mmHg, and those whose BPs were uncontrolled (≥130/80 mmHg), the results did not reach statistical significance (p = 0.074). The number of chronic conditions (p =0.004) was also significantly associated with a healthy PBD. Older individuals whose dietary pattern included more healthful plant-based foods had 15% fewer chronic diseases (OR = 0.85; 95% CI 0.76-0.95). The sixth variable in the model was hypertensive self-care (p <0.001). Individuals with higher levels of hypertensive self-care activity were 1.25 (95% CI 1.14-1.37) times more likely to consume a PBD. Lastly, four psychosocial factors were analyzed regarding PBD consumption: PBD barriers, PBD benefits, PBD readiness and PBD knowledge. Of these four variables, PBD perceived barriers (p <0.001) and readiness were included in the final ordinal regression model. Those with higher perceived barriers to consuming a PBD were 66% less likely to adopt this dietary pattern. Finally, PBD readiness was measured using the five stages of change. The action/maintenance phase (p = 0.01) was statistically significant compared to the precontemplation stage in relation to a healthy PBD. Older individuals who indicated that they were currently trying to consume a PBD and those who were already eating a PBD (maintenance phase) were 2.73 (95% CI 1.24 - 6.02) times more likely to consume a healthy PBD.

The following 8 variables were considered in the initial model, but excluded from the final model: age categories, race, education, BMI, number of anti-hypertensive medications, PBD perceived benefits, PBD knowledge, and average DBP. These factors did not contribute

significantly to the outcome variable and did not improve the model based on the AIC and BIC values.

Table 4.3 Predictors of plant-based dietary patterns in hypertensive, older adults

Predictors	Regression coefficient	Standard error	Odds ratio of adopting a PBD	*P* value
1. Living arrangement				
Family			Reference	
Alone	-0.036	0.282	0.90 (0.55 - 1.68)	0.90
Others	-1.796	0.652	0.17 (0.05 - 0.60)	0.006**
2. Sex				
Female			Reference	
Male	0.955	0.450	2.60 (1.07 - 6.32)	0.035*
3. Blood pressure				
Uncontrolled			Reference	
Controlled	0.719	0.400	2.05 (0.93 - 4.52)	0.074
4. Average SBP	0.024	0.009	1.02 (1.01 - 1.04)	0.010*
5. Number of medical conditions	-0.161	0.055	0.85 (0.76 - 0.95)	0.004**
6. Self-care score	0.226	0.047	1.25 (1.14 - 1.37)	<0.001***
7. PBD barriers	-1.094	0.300	0.34 (0.19 - 0.61)	<0.001***
8. PBD readiness (stages of change)				
Precontemplation			Reference	
Contemplation	-0.305	0.410	0.74 (0.33 - 1.66)	0.46
Preparation	-0.163	0.389	0.85 (0.39 - 1.83)	0.68

Action/Maintenance	1.006	0.400	2.73 (1.24 - 6.02)	0.01*

*Statistically significant *p* value <0.05
**Statistically significant *p* value <0.01
***Statistically significant *p* value <0.001

4.4.4 Ordinal logistic regression models

The final model (AIC: 509.29; BIC: 555.95) was a significantly better fit compared to the null model (AIC: 578.8147; BIC: 588.8128; X^2 =91.53, *p* <0.001). The Lipsitz test (*p* = 0.56), the Pulkstenis-Robinson chi-squared test (*p* = 0.92), the Pulkstenis-Robinson deviance test (*p* = 0.88), and the Hosmer-Lemeshow test for ordinal regression (*p* = 0.66) were also used to test model goodness of fit. All were non-significant indicating a good model fit. Finally, Nagelkerke's *R* = 0.357 suggested that the ordinal logistic regression model explained 35.7% of the variance in the outcome variable using the existing response variables, and the remaining were accounted for by possible error terms and other factors.

Table 4.4 Model Comparison

Model	**AIC**	**BIC**	**Pr(Chi)**
Null model	578.81	588.81	
Final model (8 variables)	509.29	555.95	<0.001

Table 4.5 Goodness of fit test for ordinal logistic models

Test	**Likelihood Ratio statistic/ Chi square**	**Degree of freedom**	***P*-value**
Lipsitz test	7.75	9	0.56
Pulkstenis-Robinson chi-squared test	88.98	109	0.92
Pulkstenis-Robinson deviance test	91.84	109	0.88
Hosmer-Lemeshow test (ordinal version)	8.55	11	0.66

Table 4.6 Model Summary

Nagelkerke *R* squared	Cox & Snell *R* squared	Mcfadden *R* squared
0.357	0.381	0.160

4.5 Discussion

In this cross-sectional analysis of predictors that characterized hypertensive, community-dwelling, older adults (≥60 y), several key factors influenced the consumption of a healthy PBD. First, this study found that living arrangement was an important explanatory variable which is in line with previous findings.[125–128] However, comparing participants who lived with family members to those living alone was not statistically significant, which is a deviation from earlier studies. Numerous studies have reported that older people living by themselves tended to have lower diet quality overall in relation to those living with family members. Specifically, older adults who lived alone tended to consume a lower variety of foods,[126–128] less fruits,[125,127,128] vegetables,[126,128] and fish.[127]

Additionally, due to the limited sample size, the participants in the present study who lived with spouses/partners were not separated from those who lived with children but rather categorized into one group under family. Previously, however, differences between these two groups have been seen. The most consistent finding over several decades including the NHANES I and III 1988-1994 studies showed that older adults living with a spouse/partner only, had the most beneficial effects in terms of diet quality.[125,127–130] Those who lived with a spouse/partner were less likely to skip breakfast and have more regular eating times.[125] Interestingly, the NHANES III study mentioned that although it did not reach significance, Mexican-American women aged ≥65 y consistently had poorer diets when living with a spouse/partner only.[128] These findings suggest that there may be a cultural aspect associated with living arrangements and dietary patterns that needs to be investigated further.

Living arrangements can also impact psychological and mental health factors that may shape dietary choices and intake. Not all older people who live alone are isolated, but most who

are isolated live alone.[131] Research suggests that the risk of social isolation and loneliness are higher in those who live alone, although it is possible to feel lonely in a marriage, friendship, family, or congregation.[131,132] Moreover, it has been found that loneliness is a significant predictor of malnutrition in the elderly. Older adults who lived alone consumed fewer meals per day and had significantly lower intake of fruits and vegetables in their diet compared to those who lived with family.[133] Finally, social isolation and loneliness have been associated with the development of depression and for older individuals, nutritional deficits and depression have also been connected.[126] Older adults who lived alone were more likely to be depressed than when living with a spouse/partner or children.[125] Participants in a recent study reported feeling less lonely when living with a spouse/partner in relation to those living with children only and this was mediated by eating irregularity.[130] These additional factors may help explain the findings that older persons who lived with family had better dietary habits that included more plant-based foods than those who lived by themselves.

In addition to the living arrangements explored above, the category of living with others was a significant finding in this study. Compared to those living alone and with family, older adults living with a non-related roommate (others) were less likely to consume a PBD. One possible explanation may be due to financial reasons. As mentioned earlier, although there was missing income data in the present study, of those collected a higher percentage of older adults living with others reported an income of <$20,000 (33.3%), compared to individuals living with family (16.5%) and alone (27.4%). Similarly, using education as a proxy for income, a higher percentage of older adults living with family (19.8%) and living alone (26.5%) had a post-baccalaureate to graduate/professional degree compared to those living with others (6.7%). Socioeconomic status has been shown to be associated with living arrangements, where

participants who lived alone or with their children had a lower monthly income and were less satisfied with their economic condition than participants who lived with a spouse/partner only.[125,127,129] In a similar manner, older adults who lived with non-family roommates may have done so out of economic concerns.

Alternatively, those who marked that they lived with others may also live in an assisted living facility suggesting poorer health. Older individuals who lived with others had lower self-care scores than those who lived with family and those who lived alone. Older adults who lived with others also reported lower overall mean physical health and mental health scores compared to individuals who lived with family and those who lived alone. However, those who lived with others did not report more average medical conditions than the other two groups. These results support the NHANES III findings that simply living with someone does not improve eating behaviors, but rather who they live with should be strongly considered,[128] especially those living with a non-related roommate(s).

Consistent with previous findings, sex differences in our study was significant when analyzing the association with PBD consumption in older adults. Vegetarian diet differences between genders have been commonly observed.[63,93–95] Contrary to previous findings, however, our study showed that older males had higher consumption of plant-based foods compared to females. Earlier studies found that women are twice as likely than men to be vegetarian or vegan in Western cultures and men reported having a more positive attitude associated with meat consumption.[95] An alternate 2017 French study found that vegans were more likely to be men and less educated.[93] Additionally, when living arrangement was stratified by sex, many studies indicated that older men living alone generally consumed more unhealthy food products than older women.[127–130] The NHANES I study found that older males living alone with lower income

had the worst dietary outcomes and that older females had better dietary intake regardless of income.[129] Unfortunately, the following NHANES III study analyzing living arrangements in older adults was not able to include income data due to missingness.[128] A more recent 2024 Chinese study, however, reported that females living alone experienced more negative impacts on their eating habits than men. This study mentioned that Asian studies often single out older individuals who lived alone as having more serious mental health problems, but they commented that western studies contradicted their findings.[125] These various findings also suggest a possible cultural aspect that can affect dietary patterns in conjunction with living arrangement.

Another finding was that the average SBP was associated with the consumption of a healthy PBD, but the odds ratio was not meaningful. These results are different from numerous previous studies that have shown that people with lower BP tend to consume a more healthful PBD.[60,104,106,134–138] The present study's results may be due to the fact that the study was conducted on a cohort of hypertensive individuals only, while the other studies involved a wider range of BPs including participants with normal BPs. A related variable, although it did not reach significance was the differences in plant-based dietary patterns between older adults who had their BP under control, defined by the American Heart Association as <130/80 mmHg versus uncontrolled (≥130/80 mmHg).[4,139] It should be noted these cutoff points for controlled and uncontrolled BP in the older adult population are controversial. The Systolic Blood Pressure Intervention Trial (SPRINT) Study found that for adults aged >50 y, compared to controlling SBP to <140 mm Hg targeting SBP to a goal of <120 mm Hg using medication and lifestyle modifications had better health outcomes. A more intensive management of SBP reduced cardiovascular events by 25 percent and reduced the overall risk of death by 27 percent.[19] However, depending on the organization, the recommended target BP may be different.

Congruent with previous study findings, older adults consuming a healthy PBD had fewer chronic diseases. Many studies have reported beneficial health effects that have helped prevent and manage noncommunicable, chronic conditions including hypertension.[67,112,140] Another finding from this study is that self-care (medication adherence, low-salt diet, physical activity, and smoking) was also significantly associated with the consumption of a healthy PBD in older adults. A low-salt diet has been strongly linked to better hypertension management and prevention and was included as part of a healthy PBD for this population.[85,88,119,120] One study found that older men who lived with a spouse/partner only reduced their intake of sodium in their diet.[130] Contrastingly, another study showed that older people living by themselves consumed less excessive salt and pickled foods in their diet.[125] This suggests that decreasing the intake of sodium may be influenced by multiple factors including living arrangements.

Perceived barriers were also significantly associated with PBD consumption in this population. The strongest perceived barrier for this population was that they needed more information about PBD and this was similar to a 2006 study that reported that the top barrier for older adults was unwillingness to alter eating habits and the second strongest barrier was lack of information about PBD.[59] The overlap and recent increase in rankings suggest that providing more information about this type of dietary pattern could be a helpful strategy to promote PBD in older adults. An alternate 2015 study that included a larger proportion of older adults reported that the enjoyment of eating meat was the greatest barrier to adopting a PBD followed by the belief that meat is a nutritionally necessary component for humans. Finally, opposite to the 2006 study, these researchers found that perceived barriers related to PBD decreased with older adults rather than increasing and mentioned that meat consumption tended to decrease with age,

particularly for women.[77] Both these papers suggest that addressing barriers to PBD is a key factor when helping older adults shift their dietary patterns toward more plant-based options.

Lastly, readiness was also found to be associated with PBD consumption in this population. Older adults in the action/maintenance stage were found to have increased intake of plant-based foods compared to the precontemplation stage. This is consistent with an earlier Australian study that included a higher proportion of older adults (24.2%) than the public based on the 2001 census (17.5%). In that study, it was reported that individuals in the action/maintenance stage had higher intake of plant-based foods such as fruit, vegetables, nuts, seeds, whole-meal bread, and cooked cereals than those in earlier stages. They did not find a difference on stages of change based on sex.[80]

Several variables were omitted from the final model in the present study including age, race, education, BMI, PBD perceived benefits, PBD knowledge, average DBP, and number of anti-hypertensive medications. Some of these findings do not align with previous studies. In an earlier 2017 study investigating the characteristics of Americans choosing vegetarian and vegan diets for health reasons, age, gender, race, education, and BMI were all statistically significant in their model.[94]

Another study analyzing the socioeconomic differences associated with PBDs also showed an association between age, race/ethnicity, education level, marital status, and poverty income ratio ≤130%. They reported that lower socioeconomic status with a poverty income ratio ≤130% was associated with a decreased consumption of a healthful PBD and that older age, higher education, being married or living with a partner, and alcohol consumption were less likely to be associated with a poverty income ratio ≤130%.[96] Low- and middle-income individuals were shown to consume more processed meats and less fish compared to individuals

with a higher socio-economic bracket.[97] As mentioned earlier, due to missing data in the present study although income levels of participants were collected, this data was removed from analysis due to missing values. Education was used as a proxy variable, but no significant differences were found among participants' level of education. Other studies have previously found that compared to meat-eaters, vegetarians tended to be more educated in general.[63,93,94] One 2017 study, however, had contradicting findings that vegans were more likely to be men and less educated.[93]

In terms of race, it was reported that vegetarianism is stereotypically associated with White racial backgrounds in the US.[98] However, the British Broadcasting Corporation found that in 2020 that a higher percentage of Blacks (8%) were vegetarian, or vegan compared to the national average of 3% according to a Pew Research Center survey and that Black Americans were almost three times as likely to be vegan or vegetarian compared to other racial groups.[141]

Having increased knowledge about PBD can help increase awareness, develop or improve skills, as well as explain why and how a change needs to be made. However, knowledge alone may not be sufficient to change behavior.[142] For example, other factors such as food insecurity and quality of the food supply have been shown to influence dietary choices.[143] The other variables in this model (i.e. living arrangements, readiness etc.) are also examples of factors besides knowledge that can affect an older person’s plant-based dietary choices.

Finally, higher PBD perceived benefits did not correspond to consumption of a PBD, which is similar to other findings. According to the Food Information Council’s Food and Health Surveys (2012–2022), a growing number of US consumers are aware of the benefits including health, environmental, and social sustainability, but the adoption of plant-rich dietary patterns

and practices remain low.[144] This suggests that PBD benefits may not be the best way to shift older adults' dietary patterns towards a more plant-based one.

To our knowledge, this is one of the first studies investigating the characteristics associated with PBD in community-dwelling, hypertensive, older adults. As such, the findings reported through this analysis should be carefully considered with certain limitations. First, the design of the study is cross-sectional and cannot show causation, only association due to its observational nature. Second, the sample size is modest (n=212) and most of the participants included in the study were female, so findings may be less generalizable to the entire older adult population and older males. Third, a short 15-item FFQ was used and did not include all of the components of healthy plant-based foods such as legumes, tea, and coffee from the hPDI. This method may not have been able to fully capture a person's healthy PBD compared to a longer FFQ with more items. However, this is a validated survey that tested diet quality in older adults with cardiovascular disease and may be helpful in providing a general sense of a person's diet quality, especially in a community nutrition setting where a long survey would not only be quite burdensome but also unfeasible.

4.6 Implications for Research and Practice

Considering the aging of the global population, the findings of this study provide several implications for future research, PBD interventions for older adults, and the prevention and management of chronic conditions in this population. Further exploration of the different factors affecting older adults' adoption of PBD is needed as they may differ significantly from other age groups and among different cultures. Importantly, an updated investigation into the living arrangements of older people and how it affects dietary choices including PBDs will be helpful

as this has been identified as a key variable. The study findings here also suggest that while PBD knowledge and PBD benefits should be included in interventions, focusing on identifying and lowering PBD barriers may be more useful in the adoption of PBD in this population. Finally, finding strategies that help older individuals feel ready to take action and maintain a plant-based dietary habit may be useful in helping to prevent and manage chronic diseases. Future research examining these topics will provide a better understanding of the psychosocial factors associated with an older person's dietary habits that may be more beneficial in terms of health outcomes.

Chapter 5: Assessing changes in readiness to consume a plant-based diet and its key determinants: findings from the DASH-Plus study

5.1 ABSTRACT

Objective: To assess the effect of the DASH-Plus intervention on participants' readiness to consume a plant-based diet (PBD) and identify key socioeconomic and psychosocial factors including perceived barriers and benefits that predict readiness levels, using longitudinal data collected at three-time points.

Design: Multi-site, 2-arm, quasi-experimental design. Recruitment May 26, 2022 to March 9, 2023; data collection through August 22, 2023.

Participants: Hypertensive, community-dwelling older adults (n = 212).

Variables Measured: Sociodemographic information and psychosocial factors related to plant-based diets (PBDs) including readiness (primary outcome), awareness, perceived benefits, perceived barriers, willingness to adopt a PBD, and other driving factors when choosing plant-based foods were collected at baseline, midpoint (9 weeks) and/or follow-up (24 weeks).

Analysis: An analytic sample of 176 participants was included. Repeated measures collected at three-time points (baseline, 9 weeks, and 24 weeks) were analyzed using a cumulative link mixed model (CLMM).

Results: The intervention group demonstrated significantly increased readiness to consume a PBD at 9 weeks ($p<0.001$), though this difference diminished by 24 weeks. The CLMM also revealed key determinants of readiness to consume a PBD among hypertensive older adults. Participants who had a post-baccalaureate degree were 3.59 (95% CI 1.43 - 9.01) times more

likely to increase PBD readiness compared to those with less than high school education. Participants with moderate (OR = 2.58; 95% CI 1.52-4.40) or high perceived benefits (OR = 3.74; 95% CI 2.15-6.52) were more likely to progress to higher stages of readiness. Conversely, moderate (OR = 0.34; 95% CI 0.2-0.58) and high perceived barriers (OR = 0.18; 95% CI 0.1-0.33) significantly reduced readiness to consume a PBD. Further, participants who ranked health and environmental concerns as moderately (health: OR = 7.87; 95% CI 1.63-37.9 and environmental: OR = 4.58; 95% CI 2.08-10.1, respectively) or highly important (health: OR = 10.84; 95% CI 2.39-49.2 and environmental: OR = 2.81; 95% CI 1.40-5.62, respectively) when purchasing or consuming plant-based foods showed an increased likelihood of PBD readiness.

Conclusions and Implications: While the DASH-Plus program effectively elevated PBD readiness in the short term, the diminishing effect at 24 weeks underscores the need for sustained engagement strategies. Implementing booster sessions may be beneficial to maintain and reinforce dietary behavior changes, ensuring lasting impact beyond the initial intervention period. Also, our findings demonstrate that readiness to consume a PBD among hypertensive older adults is significantly affected by education level, perceived benefits, and barriers (decisional balance) related to PBDs and individual values regarding health and environmental concerns.

5.2 Introduction

Plant-based diets (PBDs) encompass a spectrum of eating patterns, predominantly focused on foods derived from plants including fruits, vegetables, legumes, nuts, and seeds. While interpretations vary slightly, these diets generally minimize or exclude animal products. With these variations, some definitions consider the DASH diet and other similar dietary patterns such as the Mediterranean and Nordic diets as a PBD.[58,62,105] This broader definition will be used in this paper rather than a more restrictive one such as vegetarian or vegan.

PBDs have been found to improve the 4 domains of sustainability: nutrition and health, environment, economics, and society.[99–103,67,104] Focusing on the nutrition and health domain, healthy PBDs have been associated with the prevention and management of a wide range of noncommunicable, chronic conditions such as chronic kidney disease, type II diabetes, cognitive decline, chronic musculoskeletal pain and function, and certain cancers.[108–113] The evidence supporting the benefits of healthy PBDs against cardiovascular morbidities and mortalities is especially robust.[60,66,106,107] Among the comorbidities associated with cardiovascular disease, arterial hypertension is considered a major risk factor and prevalence of this condition is rising in the US and globally. In addition to being a significant risk factor for cardiovascular complications, it also affects individuals' cognitive functionality and autonomy with senescence.[2]

Older adults are a particularly vulnerable population, where almost 95% have at least one chronic condition, and close to 80% have two or more.[3] Furthermore, this is one of the fastest-growing demographics. It has been estimated that nearly 1 in 4 people are projected to be aged ≥65 years by 2060 [6] and people aged 80 years old will also triple by 2050.[7] With the aging population, chronic conditions will continue to rise including hypertension. The National Health

and Nutrition Examination Survey (NHANES) reported that around two-thirds of adults aged 65 years or older have hypertension [4] and more recently, the US Centers for Disease Control and Prevention's National Center for Health Statistics estimated that during August 2021–August 2023, the prevalence of hypertension was 71.6% for adults 60 and older.[5] Given these health statistics, people are increasingly turning towards modifiable lifestyle factors such as diet, nutritional behavior, and physical activity.

In terms of diet, healthy PBDs have been gaining popularity for their many benefits including health. Among PBDs, the DASH diet has been extensively studied and associated with lower chronic disease risk including hypertension.[32,145,146] This well-researched approach emphasizes a nutrient-rich combination of fruits, vegetables, whole grains, and low-fat dairy products, which are naturally low in sodium, saturated, and total fat content. The diet also contains other nutrients that may help lower blood pressure (BP) and decrease total cholesterol and low-density lipoprotein.[30] One study that assessed 22 nonpharmacologic interventions for older adults ranked the DASH diet as the most effective intervention in lowering BP for adults with prehypertension and hypertension (SBP: weighted mean difference, 6.97 mm Hg; 95% credible interval, 4.50–9.47 and DBP: weighted mean difference, 3.54 mm Hg; 95% credible interval, 1.80–5.28). Numerous other studies specifically mention the DASH diet as one of the most effective approaches to manage hypertension.[15,16,31]

Despite its efficacy, modifying one's diet can be challenging. Research demonstrates that dietary modifications are deeply influenced by individual perceptions and psychological readiness to change. This has been supported by both the health belief model (HBM) and the transtheoretical model (TTM). The HBM provides a theoretical framework for understanding this relationship, suggesting that a person's likelihood of adopting new dietary habits is shaped

by their personal beliefs and perceptions. Specifically, the model emphasizes how perceived benefits and perceived barriers play crucial roles in determining whether someone will adopt certain behaviors such as dietary habits.[71,72] Research has shown that perceived barriers is the single most influential factor predicting behavior change within the HBM framework.[73–75]

Few studies, however, have researched the perceptions of older individuals in relation to PBD choices. Previously, Lea and colleagues [59] investigated perceived barriers and benefits that included a higher proportion of older adults (24.2%) than in the public at the time based on the 2001 US census (17.5%), but this was conducted more than two decades ago. Recent examinations of this topic have been published in the last five years, but these also do not focus on the older adult population, especially individuals with chronic diseases including hypertension.[78,79,147] Assessing changes in perceived barriers and benefits in this population will be beneficial when trying to understand the current attitudes of older adults in order to help guide their dietary patterns, where the food landscape has changed significantly over the last several decades.[148]

Furthermore, the relationship between perceived barriers and benefits aligns closely with the TTM, particularly through decisional balance where individuals weigh the advantages and disadvantages of adopting the target behavior. The TTM theorizes that change in behavior occurs through five stages: (1) precontemplation (no intention to change behavior within the next 6 months); (2) contemplation (intends to take action in the next 6 months); (3) preparation (intends to take action within the next thirty days and has taken some behavioral steps in this direction); (4) action (has maintained action for less than 6 months); and (5) maintenance (has maintained behavior for >6 months). Research has shown that decisional balance is a key component of the

TTM, where the balance between the perceived benefits and barriers varies depending on the stage of change the individual is in.[149–151]

One study found that over half the consumers aged 20 years and older (58%) surveyed were in the precontemplation stage in terms of readiness to eat a PBD, where they were not thinking about it at all. About 14% were reported to be in the contemplation/preparation phase while 28% were in the action/maintenance phase. This study included a higher proportion of older adults than the public at the time (same numbers as mentioned above for perceived barriers and benefits). However, the paper included a wide range of ages (20 - 65+ y) and the authors found that age differences were not linear and difficult to interpret. The main reported difference for age groups was that participants in the precontemplation/preparation group were younger (47 ± 13 years) in comparison to the remaining other two groups (preparation and action/maintenance).[80] More recent studies regarding PBDs in the older adult population are starting to emerge, but further studies are warranted.

An individual's readiness level to consume a PBD serves as an important proxy measure to predict dietary behavior change and can be used to develop stage-specific, targeted interventions that effectively improve dietary patterns. Drawing from this theoretical foundation, our empirical study investigated whether a DASH-based hypertension management program (DASH-Plus) could influence the readiness of hypertensive older adults to adopt more plant-based dietary practices and whether key PBD related perceptions such as perceived barriers and benefits are important factors affecting the level of readiness.

The aim of this paper is to assess the effect of the DASH-Plus program on participants' readiness to consume a PBD and identify key socioeconomic and psychosocial variables such as participants' perceived barriers, and perceived benefits that predict readiness levels, using

repeated measures. The information gathered from the present study will allow for more effective strategies and interventions to promote a plant-based dietary pattern to help improve and maintain the health of the growing older adult population.

5.3 Methods

5.3.1 Study Design and Setting

The Dietary Approaches to Stop Hypertension-Plus (DASH-Plus), developed in partnership with the University of Maryland Extension (UME) system, is a community-based initiative to help hypertensive, community-dwelling, older adults manage their BP. The DASH-Plus expands beyond the traditional DASH dietary guidelines through three core components: (1) a series of eight comprehensive educational modules covering different DASH diet topics, physical activity, and hypertension self-care skills (8 weeks of education), (2) a produce delivery service to enhance produce accessibility, and (3) self-measured BP monitoring to promote regular BP tracking for 24 weeks. The entire intervention duration of the DASH-Plus program was 24 weeks. Using a quasi-experimental design, eight intervention senior centers and eight matching control sites were recruited throughout Maryland and participated in the study. Data was collected at three time points: baseline (week 0), intermediate (week 9), and final (week 24) at participating sites. The present study was conducted as a substudy under the DASH-Plus program with 212 enrolled participants. A longer, more in-depth description of the DASH-Plus study can be found elsewhere.[114] Written informed consent was obtained from all participants, and the project was approved by the University of Maryland, College Park's Institutional Review Board.

5.3.2 Sampling

The UME has maintained strong collaborative partnerships with aging service stakeholders throughout Maryland. UME educators leveraged their extensive experience working with community-dwelling older adults and local senior centers to identify and invite potential study sites. Given the lingering effects of COVID-19 during study implementation, a quasi-experimental design provided a feasible approach to site recruitment.

Participating senior centers received recruitment materials, including program description flyers and information about participant incentives. Additional recruitment occurred through the efforts of the directors and staff members involved with DASH-Plus, who spoke to the community members directly about the program. The inclusion criteria for participants were: (1) ≥60 years of age, (2) attends community site for seniors regularly (at least three times per week), and (3) has systolic blood pressure (SBP) of 140–170 mmHg and/or diastolic blood pressure (DBP) of 80–100 mmHg or is taking anti-hypertensive medication(s). The following individuals were exclusions to the study: (1) having an acute and/or terminal condition such as terminal cancer, renal disease, and/or high alcohol consumption (>14 alcoholic drinks per week), (2) having a psychiatric diagnosis precluding participation, such as cognitive impairment as measured by the 6-item Mini-Mental State Exam, and (3) being underweight (BMI 18.5 kg/m^2) or class 3 obese (BMI 45.0 kg/m^2).

To determine eligibility, trained research staff performed screenings at designated study sites. Potential participants were assessed for cognitive impairment using a 6-item Mini-Mental State Examination (MMSE) and screened for hypertension. Those who met the eligibility criteria proceeded with enrollment, after which a trained data interviewer administered the remainder of the survey.

5.3.3 Measures

A structured questionnaire was used to collect data at the three time points by trained research personnel. Baseline data included sociodemographic characteristics such as age, gender, ethnicity, race, living arrangement, education level, annual household income, and self-perceived general health status (physical and mental). The following measures were also collected.

Psychosocial factors

Readiness to consume a PBD was the primary outcome. It was measured using one question with responses that corresponded to the five stages of behavior change of the TTM. This approach has been used previously.[80–83] Participants' response options were rated with a score range of 1 to 4. Precontemplation: "I am not thinking about eating a PBD" (1 point); contemplation: "I am thinking about eating a more PBD…planning to start within 6 months" (2 points); preparation: "I am definitely planning to eat a more PBD in the next month" (3 points), action: "I am trying to eat a more PBD now" (4 points), and lastly, maintenance: "I am already eating a PBD" (4 points). The last two choices (representing the action and maintenance stages) were combined since participants could not reach the original definition of the maintenance stage (maintaining behavior change for >6 months) after intervention due to the study period (6 months total), except for individuals who were already eating a PBD prior to study enrollment. Higher scores indicated more readiness to consume a PBD.

Perceived barriers to consuming a PBD were assessed using a list of ten items determined from literature review using a 5-point Likert scale (strongly agree to strongly disagree).[59,77,78] Items such as "I don't want to eat strange or unusual foods," and "It would be too expensive to eat a plant-based diet" were included. A score range of 1 to 5 points were assigned to each response where higher scores indicated more perceived barriers to consuming a PBD

(Cronbach's alpha: baseline = 0.65; 9 weeks = 0.72; 24 weeks = 0.80). The total score was then averaged by the number of items answered by each subject to account for missing items at each time point. Individual averaged scores were then divided into tertiles, with the lowest third indicating lower perceived barriers and the highest third suggesting higher perceived barriers to consuming a PBD.

Perceived benefits to consuming a PBD were gather using a list of ten items gathered from a review of previous studies using a 5-point Likert scale (strongly agree to strongly disagree).[59,78,79] For example, benefits such as "Decrease my saturated fat intake," and "Improve my digestion" were included. A score range of 1 to 5 points were assigned to each response where higher scores indicated greater perceived benefits for consuming a PBD (Cronbach's alpha: baseline = 0.88; 9 weeks = 0.92; 24 weeks = 0.93). The individual summation of scores was then averaged by the number of items answered by the participant to account for missing items at each of the three time points. The averaged total scores were then divided into tertiles, with the lowest third indicating lower perceived benefits and the top third expressing higher perceived benefits to consuming a PBD.

Knowledge of PBDs was evaluated using a questionnaire (15 items) adapted from a previous study that surveyed medical providers at baseline.[84] Due to the variation in definition of PBD, ambiguous and controversial questions were omitted from the scoring (11 items included). For example, "Dairy is encouraged in a PBD" and "Fish is a necessary part of a healthful diet" were excluded from the PBD knowledge scores as the answers to these questions depends on the definition of a PBD being used (DASH diet, pescatarian, lacto-vegetarian diet, vegan etc.) (Cronbach's alpha: baseline = 0.57). PBD knowledge scores were then divided into tertiles

where the lowest tertile suggested less knowledge about PBDs and the highest tertile demonstrated higher knowledge about this topic.

Willingness to consume a PBD was evaluated by asking participants, "Would you be willing to follow a plant-based diet (limited to no animal products) for a week for health purposes? 3 weeks for health purposes? And for 6 months or longer for health purposes? Three response choices were provided: yes (3points), maybe (2 points), and no (1 point) (Cronbach's alpha: baseline only = 0.77). Higher total averaged scores suggested more willingness to consume a PBD for longer at the start of the study.

Finally, five motivations for purchasing and eating plant-based foods were assessed using a survey from the Yale Climate Change and the American Diet report. Health (1-item), environmental considerations (2-items), animal protections (1-item), taste (1-item), and cost (1-item) were assessed using a 5-point Likert scale (extremely important = 5, very important = 4, moderately important = 3, not too important = 2, and not at all important = 1). Participants were asked, "How important are each of the following to you personally, if at all, when you choose to purchase or eat plant-based foods (fruits, vegetables, meat/dairy alternatives)?"[152] The 2 items for environmental considerations were averaged for this study. The top 2 responses of the scale were grouped as high importance, the middle response was kept as moderately important, and the lower two choices were combined as low importance for data analysis.

Blood pressure measurements

Blood pressure was measured three times and then averaged at each time point. Participants were asked to sit with their backs supported by the chair, legs uncrossed, with their left arm at the level of their heart (right arm was used if needed) in a relaxed manner. A trained

research staff member then measured their BP using an automated blood pressure cuff with a minute rest period between measurements.

5.3.4 Statistical Analysis

Descriptive and inferential statistical analyses were performed using RStudio version 2024.12.1+563 and the Statistical Package for the Social Sciences (SPSS) software version 29.0.2.0 (20). First, multilevel imputation was performed to address missing values. Then a cumulative link mixed model (CLMM) was used to examine the effect of the DASH-Plus educational program on the ordinal dependent variable, readiness to consume a PBD at three different time points.

Missing Values and Multiple Imputation

Assuming that most missing values were missing at random (MAR) with participants being lost to follow-up, multilevel imputation was performed using multivariate imputation by chained equations (MICE). The R packages, mice (version 3.17.0) and miceadds (version 3.17.44) were used for this process. A three-level imputation was employed to properly account for the hierarchical structure of the study design.[153] The resulting imputation took into consideration that the longitudinal data was nested at three levels (e.g. repeated measures [Level 1], collected across participants [Level 2], and nested within different study sites, i.e. senior centers [Level 3]). All missing values were at level 1 so predictive mean matching was used for imputation. An interaction between the arm and time points was also included in the imputation model. Finally, following von Hippel's "multiple imputation, then deletion" (MID) method, all subjects were used for the imputation process with the outcome variable included. Under MID, however, participants with imputed outcomes are subsequently removed and excluded prior to

model analysis.[154] The seed was set at 1212 and 20 imputed datasets were created, each with 20 iterations.

After the imputation, convergence was visually assessed using plots and inspection of the predictor matrix, methods, and imputed values did not reveal any major issues. Imputed data was then analyzed using a CLMM (see below) and the results were pooled across all imputed datasets to obtain the final reported findings.

Analysis

A greater improvement in readiness to consume a PBD over time for the intervention group compared to the control group was hypothesized. Using CLMM, repeated measures of the ordinal outcome variable were assessed across the three time points (baseline, 9 weeks, and 24 weeks). The participants and study sites were treated as random effects. The following variables were considered in the initial model: arm and time point interaction, sex, education (less than high school, high school/GED, post high school education through college, post-graduate studies including graduate/professional degrees), living arrangement (lives alone, lives with family - spouse and/or children, lives with others), body mass index (BMI), systolic SBP, PBD perceived barriers, PBD perceived benefits, willingness to eat a PBD, and lastly how important health, taste, price, environmental considerations, and animal protections were when purchasing or consuming plant-based foods.

Backward stepwise selection was applied and the variable with the least significant p-value was eliminated to identify the variables for the final model. Models were assessed using the Akaike information criterion (AIC) and Bayesian information criterion (BIC). With each iteration, a model where the AIC value decreased by 2 units after removing a variable was considered a statistically significant improvement [122] and a decrease in BIC value between 5 and

10 units was considered strong.[123] The model with the smallest absolute AIC and BIC values was considered a better model.[124] Lastly, post hoc comparisons were assessed for readiness among the three time points and arm (intervention vs. control) using Tukey's Honest Significant Difference (HSD) test to determine the between-group and within-group differences. Multicollinearity was assessed using the available tools in R (vif and check_collinearity functions) as a guide since these are not specifically designed for CLMMs. Spearman's rank correlation coefficients among variables were also assessed to minimize multicollinearity. All correlations were weak to moderate ($\rho < 0.640$). The proportional odds assumption was tested using the nominal_test function. This method uses a simpler cumulative link model (CLM) with the same variables as the CLMM, but without random effects to test the proportional odds assumption. This showed a significant violation for the time point variable ($p < 0.001$) and the arm and time point interaction term ($p < 0.001$). All other variables were not significant. While not definitive, these results suggested that the proportional odds assumption was met for most variables as there is not a straightforward way to assess this currently.

Spearman's rank correlation was also used to specifically examine the relationship among perceived barriers, perceived benefits, and readiness for each of the three time points.

5.4 Results

5.4.1 Socio-demographic characteristics of participants

A total of 212 participants were enrolled into the study. The participant's average age was 74 ± 7.5 years old with slightly over half (51.9%) of the participants in the youngest-old (64 - 74 y) category. Most individuals were female (88.7%), non-Hispanic (92.9%), and over half were Caucasian (57%). Approximately 21% of older adults had a school diploma/GED and 41%

had an education level ranging from post-high school training through a 4-year college degree. About 50% of the participants lived by themselves, while many lived with family members such as a spouse and/or children (42%). A majority of participants were prescribed an anti-hypertensive medication (96.2%) and took an average of 1.7 ± 0.8 anti-hypertensive medications. The sample's average measured systolic SBP was 137 ± 20 mmHg, and the average diastolic DBP was 79 ± 11 mmHg. The average number of self-reported medical conditions was 6 ± 2.6, the mean BMI was 31.0 ± 6.4 kg/m^2, and 48.1% of the participants were categorized as obese. The characteristics of the participants have also been divided by the arm (intervention vs. control) in Table 5.1.

Table 5.1 Sociodemographic characteristics of study participants (n =212)

Variables	**Control (n = 90)**	**Intervention (n = 122)**	**Total (N = 212)**
Age (years), mean (SD)	74.5 ± 0.9	73.6 ±0.7	74 ± 7.5
Youngest-old (64-74 y), n (%)	43 (47.8)	67 (54.9)	110 (51.9)
Middle-old (75-84 y), n (%)	37 (41.1)	44 (36.1)	81 (38.2)
Oldest-old (≥85 y), n (%)	10 (11.1)	9 (7.4)	19 (9.0)
Sex, n (%)			
Female	79 (87.8)	109 (89.3)	188 (88.7)
Male	11 (12.2)	13 (10.7)	24 (11.3)
Ethnicity, n (%)			
Non-Hispanic/ Non-Latin American	88 (97.8)	109 (89.3)	197 (92.9)
Hispanic/ Latin American	1 (1.1)	10 (8.2)	11 (5.2)
Race, n (%)			
Caucasian	39 (43.3)	82 (67.2)	121 (57.1)
Black or African American	41 (45.6)	28 (23.0)	70 (33.0)
Asian	4 (4.4)	6 (4.9)	10 (4.7)
Other	6 (6.7)	3 (2.5)	9 (4.2)
Living arrangement, n (%)			
Alone	50 (55.6)	56 (45.9)	106 (50.0)
Family (spouse/partner and/or children)	34 (37.8)	57 (45.7)	89 (42.0)
Other (i.e. roommate)	6 (6.7)	9 (7.4)	17 (8.0)
Education, n (%)			
Less than high school	18 (20%)	15 (12.3)	33 (15.6)
High school graduate/ GED	17 (18.9)	28 (23.0)	45 (21.23)

Post high school training through college	31 (34.4)	56 (45.9)	87 (41.0)
Post college through graduate/professional degrees	24 (26.7)	23 (18.9)	47 (22.2)
Taking antihypertensive medications, n (%)			
Yes	88 (97.8)	116 (95.1)	204 (96.2)
No	2 (2.2)	6 (4.9)	8(3.8)
Average number of anti-hypertensive medications	1.7 ±0.1	1.7 ± 0.3	2 ± 0.8
Blood pressure			
Average SBP (mm Hg)	136.9 ± 18.7	137.3 ± 21.0	137.1 ± 20.0
Average DBP (mm Hg)	76.5 ± 10.3	80.2 ± 11.4	78.6 ± 11.1
Number of medical conditions	5.7 ± 0.3	5.81 ± 0.2	6 ± 2.6
Anthropometric measurements			
BMI (kg/m^2)	31.4 ± 0.8	30.4 ± 0.6	31.0 ± 6.4
Healthy weight (18.5 and 24.9 kg/m^2)	14 (15.6)	16 (13.1)	30 (14.2%)
Overweight (25 and 29.9 kg/m^2)	28 (31.1)	48 (39.3)	76 (35.8%)
Obese (≥30 kg/m)	48 (53.3)	54 (44.3)	102 (48.1%)

5.4.2 Correlations among perceived barriers, perceived benefits, and readiness to consume a PBD

Based on the core concept of decisional balance within the TTM, it was hypothesized that as perceived barriers decreased and perceived benefits increased, the participants' readiness would increase for the intervention group. Correlation analysis among perceived barriers, perceived benefits, and readiness at each of the three-time points was conducted prior to CLMM analysis to provide preliminary insights into the relationships between these key psychosocial factors. Understanding these associations helped inform the interpretation of the subsequent mixed model. Correlations for the control group were moderate to strong and remained relatively similar among the time points between perceived barriers and readiness to consume a PBD: baseline (-0.47; $p < 0.001$), 9 weeks (-.43; $p < 0.001$), and 24 weeks (-0.53; $p < 0.001$). In the intervention group, the correlations between perceived barriers and readiness started out weak

and non-significant but increased to become relatively strong and significant: baseline (-0.16; p =0.09), 9 weeks (-0.29; p =0.002), and 24 weeks (-0.52; p <0.001). In the control group, the correlation between perceived benefits and readiness to consume a PBD also did not show a clear trend among the three time points: baseline (0.33; p =0.003), 9 weeks (0.40; p <0.001), and 24 weeks (0.29; p =0.019). Comparatively, the correlation between these two variables showed a positive trend from weak to moderately strong for the three time points in the intervention group: baseline (0.18; p =0.091), 9 weeks (0.33; p <0.001), and 24 weeks (0.48; p <0.001).

Overall, the findings suggested that the negative correlation between perceived barriers and readiness to consume a plant-based diet strengthened over time for the intervention group, but not for the control group. This indicated that as the perceived barriers to consuming a PBD decreased over the three time points, the readiness to consume a PBD increased, and the relationship strengthened with the DASH-Plus intervention. Additionally, the positive correlation between perceived benefits and readiness to consume a PBD also increased for the intervention group. This suggested that as the perceived benefits to consume a PBD increased the readiness to consume a PBD also increased, and this relationship was strengthened with the intervention. This type of change was not observed for the control group. These changes are presented in Table 5.2 along with the changes in perceived barriers (low, moderate, high) and perceived benefits (low, moderate, high) for each group and time points.

Table 5.2 Changes in readiness, perceived barriers and benefits and Spearman's rank correlations

	Control, n (%)			**Intervention, n (%)**		
	Baseline	**9 weeks**	**24 weeks**	**Baseline**	**9 weeks**	**24 weeks**
Readiness						
Precontemplation	29 (32.2)	28 (36.1)	22 (34.3)	24 (19.7)	16 (14.4)	18 (18.2)
Contemplation	15 (16.7)	21 (27.3)	10 (15.6)	28 (23.0)	13 (11.7)	13 (13.1)

Preparation	23 (25.6)	5 (5.6)	7 (10.9)	27 (22.1)	8 (7.2)	4 (3.3)
Action/ maintenance	23 (25.5)	23 (25.6)	24 (31.3)	38 (31.1)	74 (66.7)	64 (52.5)
Perceived barriers						
low	25 (30.9)	35 (43.2)	29 (35.8)	37 (33.0)	72 (64.3)	57 (50.9)
moderate	24 (29.6)	23 (28.4)	16 (19.8)	41 (36.6)	16 (14.3)	22 (19.6)
high	32 (39.5)	19 (23.5)	19 (23.5)	34 (30.4)	24 (21.4)	20 (17.9)
Perceived barriers & readiness	-.47 (p <0.001)	-.43 (p <0.001)	-.53 (p <0.001)	-.16 (p =0.091)	-.29 (p =0.002)	-.52 (p <0.001)
Perceived benefits						
low	38 (46.9)	27 (33.3)	27 (33.3)	35 (31.3)	29 (25.9)	27 (24.1)
moderate	26 (32.1)	27 (33.3)	15 (18.5)	32 (28.6)	28 (25.0)	35 (31.3)
high	17 (21.0)	23 (28.4)	22 (27.2)	44 (39.3)	55 (49.1)	37 (88.4)
Perceived benefits & readiness	0.33 (p =0.003)	0.40 (p <0.001)	0.29 (p =0.019)	.18 (p =0.091)	.33 (p <0.001)	.48 (p <0.001)

5.4.3 Key determinants affecting readiness to consume a PBD

The final model was adjusted for the following variables based on the analytical process described in the methods section: arm and time point interaction term, education, average SBP, PBD barriers, PBD benefits, and the importance of health and environmental considerations when purchasing or consuming plant-based foods. The subjects and study sites were also included as random effects in the models.

Compared to participants with less than a high school education, older individuals who had a post-baccalaureate education through a graduate/professional degree were 3.59 (95% CI 1.43 - 9.01) times more likely to increase their readiness to consume a PBD. Participants who had a moderate (OR = 0.34; 95% CI 0.2-0.58) and high number of perceived barriers (OR = 0.18; 95% CI 0.1-0.33) were less likely to increase their readiness to consume a PBD than those with a low number of perceived barriers. Inversely, compared to older adults with a low number

of perceived benefits, those with a moderate (OR = 2.58; 95% CI 1.52-4.40) or high number of perceived benefits (OR = 3.74; 95% CI 2.15-6.52) were more likely to progress to a higher stage of readiness. Participants who ranked health as not too important when purchasing or consuming plant-based foods were less likely to increase their readiness compared to those who indicated a moderate (OR = 7.87; 95% CI 1.63-37.9) or high level of importance (OR = 10.84; 95% CI 2.39-49.2). Lastly, those who ranked environmental concerns as moderately (OR = 4.58; 95% CI 2.08-10.1) or very important (OR = 2.81; 95% CI 1.40-5.62) when purchasing or consuming plant-based foods were more likely to increase their readiness to consume a PBD compared to those who ranked that this issue as not too important.

Table 5.3 Predictors of readiness to consume a PBD in hypertensive, older adults

Predictors	**Regression coefficient**	**Standard error**	**Odds ratio of adopting a PBD**	**P value**
1. Arm				
Control			Reference	
Intervention	0.348	0.396	1.42 (0.65 - 3.08)	0.38
2. Time points				
Baseline			Reference	
9 weeks	-0.615	0.336	0.54 (0.28 - 1.04)	0.07
24 weeks	0.109	0.366	1.11 (0.54 - 2.28)	0.77
3. Education				
Less than high school			Reference	
High school/GED	0.256	0.426	1.29 (0.56 - 2.98)	0.54

Post high school training through college	0.392	0.395	1.48 (0.68 - 3.21)	0.32
Post college through graduate/ professional degree	1.28	0.469	3.59 (1.43 - 9.01)	0.006**
4. Average SBP	0.014	0.006	1.01 (1.00 - 1.03)	0.03*
5. PBD barriers				
Low			Reference	
Moderate	-1.07	0.270	0.34 (0.2 - 0.58)	<0.001***
High	-1.69	0.296	0.18 (0.10 - 0.33)	<0.001***
6. PBD benefits				
Low			Reference	
Moderate	0.950	0.271	2.58 (1.52 - 4.40)	<0.001***
High	1.320	0.283	3.74 (2.15 - 6.52)	<0.001***
7. Importance of Health				
Low			Reference	
Moderate	2.06	0.803	7.87 (1.63 - 37.9)	0.01*
High	2.38	0.772	10.84 (2.39 - 49.2)	0.002**
8. Importance of Environment				
Low			Reference	
Moderate	1.52	0.404	4.58 (2.08 - 10.1)	<0.001***
High	1.03	0.354	2.81 (1.40 - 5.62)	0.004**
9. Arm X timepoint				
Baseline	Reference			

9 weeks	1.77	0.463	5.87 (2.37 - 14.6)	<0.001***
24 weeks	0.755	0.483	2.13 (0.83 - 5.48)	0.12

*Statistically significant p value <0.05
**Statistically significant p value <0.01
***Statistically significant p value <0.001

5.4.4 Changes in Readiness to consume a PBD at baseline, 9 and 24 weeks

The CLMM showed a statistically significant difference for the arm and time point interaction term (p <0.001) for readiness to consume a PBD. Tukey's Honest Significant Difference (HSD) test was performed to assess these arm and time point differences. For the intervention group, the readiness level after the intervention (week 9) was significantly higher compared to the baseline readiness scores (p = 0.004). The readiness scores between baseline and at 24 weeks were not significant and the readiness scores between week 9 and week 24 were also not significant. This suggested that readiness increased after the intervention at week 9 but decreased when measured at week 24. In the control arm, there were no significant within-group differences observed among the three time points for readiness to consume a PBD.

For between-group differences, the pairwise comparisons showed a significant between-group difference that was observed at week 9 (p <0.001). No significant differences between the intervention and control groups were seen at baseline nor at week 24.

Table 5.4 Pairwise contrasts among time points for intervention and control groups

Contrast	estimate	SE	z.ratio	P values
Control (within-group differences)				
Baseline - 9 weeks	0.615	0.336	1.831	NS
9 weeks - 24 weeks	-0.723	0.375	-1.929	NS
Baseline - 24 weeks	-0.108	0.366	-0.297	NS
Intervention (within group differences)				
Baseline - 9 weeks	-1.156	0.319	-3.620	0.004**

9 weeks - 24 weeks	0.292	0.339	0.860	NS
Baseline - 24 weeks	-0.864	0.320	-2.702	0.07
Between group differences				
Baseline	-0.348	0.396	-0.877	NS
9 weeks	-2.118	0.444	-4.771	<0.001***
24 weeks	-1.103	0.458	-2.408	NS

*Statistically significant p value <0.05
**Statistically significant p value <0.01
***Statistically significant p value <0.001

5.4.5 Cumulative link mixed models (CLMMs)

Compared to the null model (AIC:1292.66; BIC:1309.851), the final model (AIC:1148.53; BIC:1243.063, $X^2 = 180.14$, $p < 0.001$) was a significantly better fit. The effects of the random variables were also tested and there was a significant difference between the final model with the random effects and the same model without the random effects (AIC:1166.8; BIC:1252.696, $X^2 = 22.23$, $p < 0.001$). The Nagelkerke's R = 0.437 suggested that the CLMM explained 43.7% of the variance in the outcome variable using the existing fixed and random effects, the remaining were accounted for by possible error terms and other factors.

Table 5.5 Model Summary

	Nagelkerke R squared	Cox & Snell R squared	Mcfadden R squared
Without random effects	0.311	0.282	0.140
With random effects	0.437	0.403	0.202

5.5 Discussion

This study examined changes in readiness to consume a PBD among hypertensive older adults following the DASH-Plus intervention. Utilizing a CLMM, we analyzed longitudinal shifts in readiness and identified key determinants influencing the transition of PBD readiness. The intervention group demonstrated a significant increase in readiness to adopt a PBD at 9 weeks ($p < 0.001$) compared to the control group, though this between-group difference diminished by 24 weeks. Prior research has shown that individuals in the action/maintenance stage exhibit a higher intake of plant-based foods, including fruits, vegetables, nuts, seeds, whole-meal bread, and cooked cereals.[80] Given readiness to consume a PBD serves as a proxy indicator for potential dietary behavior change, the significant increase in readiness at 9 weeks in the present study suggests a promising pathway to improved plant-based dietary patterns among the participants. While the intervention's effect was not sustained at 24 weeks, a positive trend also emerged, with the proportion of intervention participants in the action and maintenance stages increasing from 31.1% at baseline to 52.5% at 24 weeks. These findings underscore the importance of periodic follow-up sessions to maintain readiness. Implementing structured check-ins may be crucial in helping individuals sustain their initial progress and continue advancing toward a more plant-based dietary pattern.

In the present study, several key determinants affecting readiness to consume PBD were also identified. One of the key determinants of readiness to consume a PBD was perceived barriers, and it is important to further specify which aspects were perceived as barriers. At baseline, the strongest perceived barrier for this population was that they needed more information about PBDs (85.4% agreed). In 2022, it was reported that more than three times as many older consumers followed a plant-rich dietary pattern compared to 2019 (9.0% vs. 17.3%,

$X^2[1, N = 1312] = 20.307, p < 0.001)$.[144] Despite this rise in popularity of PBDs, 34% of participants in the present study were not aware of the term 'PBD.' This also indicates that older adults need more information about this type of diet. Not having enough plant-based choices when eating out (44.4% agreed) was ranked as the second highest barrier, and thirdly, 33.9% participants agreed that meat is too enjoyable to limit for a PBD. The latter sentiment regarding meat remains a challenge in the older adult population like in the general public when trying to consume a more PBD.[77,78,155,156]

Previously, the strongest barrier for this age group was unwillingness to alter their eating habits and lack of information about PBD was ranked second.[59] In the present study, unwillingness to alter their eating habits was ranked as the fifth largest barrier (26.5% agreed). This suggests that older adults may now be more willing to change their dietary habits and that their interest in learning about this type of dietary pattern has grown. Other studies have also mentioned that lack of knowledge including how to prepare plant-based proteins was a barrier to adopting a PBD.[79,156] Considering that perceived barriers has been shown to be the single strongest factor predicting behavior change within the HBM framework,[73–75] more studies examining perceived barriers to consuming a PBD are warranted in this population. These findings are relevant to public health professionals and highlight that a DASH diet educational program may be an effective strategy to increase readiness to consume a PBD by using perceived barriers as mediators.

Another key finding associated with PBD consumption readiness was perceived benefits. The most important benefit of PBDs for older adults at baseline was increased fiber intake (89.6% agreed). Secondly, 86.7% agreed that PBDs help them stay healthy while decreased saturated fats was ranked as the third strongest benefit of consuming PBDs by 85.9% of

participants. Previously, it was also found that increased fiber intake was ranked first (83% agreed) and decreased saturated fats (75% agreed) was ranked second in terms of PBD benefits. In addition, it was previously reported that with advancing age, the agreement that fiber intake was a benefit of eating a PBD increased and that there was a significant difference between the age groups ($p < 0.001$).[59] The results from the present study are consistent with these earlier findings. This suggests that increased fiber intake in particular and the health implications of fiber should be emphasized when discussing the benefits to PBDs with this population. Staying healthy in general by preventing chronic diseases and decreasing saturated fats should also be mentioned as additional benefits of consuming a PBD when encouraging this type of dietary pattern. Increasing the perceived benefits of older adults in this way will also help them increase their readiness to consume a PBD and facilitate dietary behavior changes towards a more plant-based dietary pattern.

In terms of motivations that affected readiness to consume a PBD, health and environmental considerations were significant factors. It was found that general health improvement (35% of people) and a desire to follow the dietary guidelines of Americans (16%) were common reasons for adopting a new diet.[99] Health benefits were usually ranked higher than environmental reasons or animal welfare for making dietary changes.[59,78,152] In a survey conducted by Yale in 2019, nine in ten Americans surveyed said that health was moderately important when purchasing or consuming plant-based foods.[152] Similar findings were seen in the present study, where 93.3% of older adults said that their health was at least moderately important when they chose to purchase or eat plant-based foods (fruit, vegetables, meat/dairy alternatives).

Additionally, in our study around 73.9% of older adults said how food companies affect the environment and 71.5% said that reducing global warming was at least moderately important when choosing to purchase or eat plant-based foods. These findings were slightly higher than the Yale report of the public that showed consumers' motivations to purchase or eat plant-based foods depending on how food companies affect the environment (71%) and helped to reduce global warming (64%).[152] One study also found that taste and cost were factors that affected the readiness of consumers to adopt an environmentally sustainable diet,[81] however, these variables and animal protections were not significant in the present study. Alternative motivations should be considered and further explored when assessing readiness to consume a PBD in this population.

Willingness is a related concept to readiness to consume a PBD. In the present study, almost 70% of participants were willing to eat a PBD for a week for health purposes, 46.2% were willing to eat a PBD for 3 months for health purposes, and 18.6% were willing to eat a PBD for 6 months or more. These results indicate that a large percentage of older adults are open to trying a plant-based dietary pattern and willing to modify their dietary choices for health purposes.

In a study that examined willingness to transition to a more PBD found that individuals with high levels of education, females, and younger participants (millennial and gen Z cohorts) had high willingness to adopt a more PBD and were amenable to dietary habit changes. They reported that older adults (baby boomer cohort), men, and those with low to intermediate levels of education were more reluctant to make dietary changes. Additionally, they reported that older people were particularly receptive to recommendations from their doctors and did not consider lower prices for plant-based foods as important as the other cohorts.[75] Similar to that study, we

found that those with the highest level of education had increased readiness to eat a PBD and the price of plant-based products did not have a significant association with readiness to consume a PBD for older individuals. Willingness to consume a PBD for health purposes, however, was not a significant predictor in the present study. It should be noted that only willingness to consume a PBD for health purposes was explored and other reasons will need to be further investigated for associations with readiness to consume a PBD.

When designing interventions, considering the stage of change an individual is at may be more helpful. For example, raising awareness of the benefits of PBDs and the need for change for those in the precontemplation stage may be conducive to changes in readiness to consume a PBD. However, those in the contemplation and preparation stages may benefit more from practical information that can be applied including the preparation of healthier nutrient-dense foods compared to high calorie, low-nutrient foods.[80] Based on the results of the present study, to maintain the changes in readiness to consume a PBD, periodic sessions to check in will be beneficial to facilitate the ongoing behavior change processes. Considering the significant relationship among the three constructs, perceived barriers, perceived benefits, and readiness in terms of PBDs, including all three in a targeted way through a DASH diet-focused educational intervention could be an effective strategy for older adults when changing their dietary patterns to one that is more plant-based.

There are several limitations to the present study. An over-representation of females in the study may limit the generalizability of the findings. It should be noted, however, that sex ratios shift significantly after the age of 65. It has been reported that the sex ratio is less than 0.98 between the ages of 65 and 79 and that at ≥80 y there are 65 or fewer males for every 100 females in most places globally.[9] Further, readiness to consume a PBD in this study was not

significantly associated with sex differences and would have been adjusted for this variable otherwise.

Another limitation of the study is that although the TTM is a widely used theoretical model in general, some issues have been raised. It has been criticized for its stepwise process in behavior change with arbitrary time periods for each stage.[157] One study examined the time period for a significant change in mean food consumptions for participants to set the boundary between stages and this is a possible way to strengthen the application of the theory in practice.[82] This was not possible in the present study due to the shorter study period (24 weeks), but can be explored in future studies. Additionally, the last two stages were combined in the present study also due to the shorter time frame, so differences in these two phases were not examined and will need further investigation.

Finally, the theory has been challenged for its simplicity and inability to explain more complex behavior changes that deviate from the outlined process. For example, it has been mentioned that some people may skip a stage or relapse to an earlier one. In response, one of the original authors of the TTM has explained that the intent of the model is not to have a set of rigidly established stages, but to help better understand the process of behavior change and provide a means to influence the process.[82,158]

A strength of the study is that in addition to readiness, the constructs of perceived barriers and perceived benefits have been included to show decisional balance. Integrating the three constructs together in one study helps to better understand the behavior changes of consuming a PBD and using all three constructs in an intervention may be more effective than readiness alone. It has been shown that increasing an individual's perceived benefits and decreasing their perceived barriers will help them progress toward the action and maintenance stages.[149] This can

be used as one strategy to encourage more readiness in terms of shifting dietary patterns since this is a key construct in behavior modification.[159]

5.6 Conclusion and future implications

In conclusion, the DASH-Plus intervention may be an effective method to change older adults' readiness to consume a PBD through key mediators, perceived barriers and perceived benefits. However, to facilitate sustained dietary behavior changes using stages of readiness, additional booster sessions may be necessary. Future studies that include these extra supportive measures will be needed to fully investigate the lasting effects of these types of interventions. Understanding this population's decisional balance with perceived barriers, perceived benefits, and readiness in terms of PBDs will help facilitate dietary modifications towards this type of dietary pattern to help preserve their health and other sustainability domains.

Chapter 6: Effect of the DASH-Plus program: dietary modifications in hypertensive older adults towards a plant-based dietary pattern

6.1 ABSTRACT

Objective: To evaluate the efficacy of the DASH-Plus program in promoting a plant-based diet (PBD) consumption and identify key predictors influencing adoption outcomes in older adults (≥60 years) with hypertension, utilizing longitudinal data from three time points.

Design: Multi-site, 2-arm, quasi-experimental design. Recruitment May 26, 2022 to March 9, 2023; data collection through August 22, 2023.

Participants: Hypertensive, community-dwelling older adults (n = 212).

Variables Measured: Plant-based diet (PBD) consumption was measured using a short, validated 15-item questionnaire based on the healthful plant-based diet index (hPDI). Sociodemographic information, and psychosocial-related factors associated with PBDs including perceived barriers and benefits, readiness to consume a PBD, and PBD knowledge were also collected using structured questionnaires.

Analysis: A total of 179 participants were included in the analytic sample. Repeated measures collected at three time points (baseline, 9 weeks and 24 weeks) were analyzed using a linear mixed-effects model (LMM).

Results: Participants reporting fewer PBD barriers ($p < 0.001$), fewer medical conditions ($p=0.04$), and better hypertensive self-care practices consumed significantly more plant-based foods. Also, education significantly influenced PBD consumption, with participants holding graduate/professional degrees showing higher intake compared to those with less than high

school education. Adjusting for these predictors, while the implementation of the DASH-Plus program produced a significant increase in PBD consumption at week 9 (p <0.001), these effects were not sustained at week 24.

Conclusions: The DASH-Plus program effectively modified dietary patterns toward PBD consumption in the short term, though effectiveness varied across time points as evidenced by the arm and time interaction. The findings also highlight the importance of educational attainment, addressing perceived barriers, accommodating medical conditions, and providing sustained support throughout the dietary change process. Further research is needed to explore strategies for maintaining these changes over the long term. Future interventions could be improved by increasing the duration of the intervention, adding booster sessions, and other lasting supportive measures. Even with the current limitations, the intervention may still provide a practical and safe strategy to transition older adults towards a healthy plant-based dietary pattern and improve sustainability domains.

6.2 Introduction

Plant-based diets (PBDs) have been increasingly recognized as an integral part of the sustainability discussion affecting all 4 domains of sustainability: nutrition and health, environment, economics, and society. This type of dietary pattern can help prevent noncommunicable, chronic diseases, improve climate change by reducing greenhouse gas emissions, and reduce economic stressors.[99–103,67,104] Under the nutrition and health domain, research has shown that healthy PBDs are associated with the prevention and management of a variety of noncommunicable, chronic diseases including type II diabetes, chronic kidney disease, cognitive decline, chronic musculoskeletal pain and function, and some cancers.[108–113] In particular, there is substantial evidence supporting the cardioprotective benefits of healthy PBDs against morbidities such as myocardial infarction, coronary artery disease, and mortalities.[60,66,106,107] For cardiovascular diseases, arterial hypertension is a significant risk factor that has become increasingly prevalent in the US and globally. Furthermore, it can also affect individuals' cognitive functionality, independence, and autonomy with senescence.[2]

With advancing age, our bodies experience a wide range of physiological changes both internally and externally. A decline in cellular function and pathogenesis of aging greatly increases the risk for various chronic diseases making the older adult population especially vulnerable.[160] Almost 95% of older adults have at least one chronic condition, and close to 80% have two or more.[3] Additionally, it has been projected that approximately 1 in 4 people will be aged 65 years or older by 2060 [6] and people aged 80 years old will also triple by 2050, making it one of the fastest-growing demographics.[7] As the population continues to age, conditions such as hypertension will also rise. The National Health and Nutrition Examination Survey (NHANES) reported that around two-thirds of older adults (≥65 years) have hypertension [4] and more

recently, the US Centers for Disease Control and Prevention's National Center for Health Statistics estimated that between August 2021 and August 2023, the prevalence of hypertension was 71.6% for older adults (≥60 years).[5] With increased life expectancy, a compression of morbidity is desirable. To help prevent and manage chronic conditions, a nonpharmacologic intervention using modifiable lifestyle factors such as diet, nutritional behavior, and physical activity should be the first line of defense.

Focusing on diet, healthy PBDs have been gaining traction for their numerous health benefits. The term 'plant-based diet,' however, lacks a single definition and includes a diverse array of dietary patterns. Sometimes PBDs have been used as a synonym for vegetarian or vegan, but others have used a more inclusive definition placing the Dietary Approaches to Stop Hypertension (DASH) diet, the Mediterranean diet, and the more newly explored Nordic diet under the PBD umbrella. These diets all emphasize the inclusion of plant-based foods such as fruits, vegetables, legumes, nuts, and seeds while reducing or eliminating animal-based products like meats, dairy, and eggs.[58,62,105]This paper will use the broader definition of a PBD that includes the DASH diet and other similar dietary patterns rather than a more exclusive definition such as vegetarian or vegan.

It is important to note that not all PBDs are created equal. A difference in various health outcomes was reported between healthful PBDs and unhealthful PBDs. Healthful PBDs have been associated with reduced chronic diseases including cardiovascular complications while unhealthful PBDs have shown to have the opposite effect.[60,66,112] It has become evident that meat elimination is not synonymous with a beneficial, high-quality diet, and therefore transitioning to a PBD requires careful consideration, especially in a population like older adults.

Of the PBDs, the DASH diet has been extensively studied for more than two decades and has been associated with decreased chronic disease risk including hypertension.[32,145,146] Among 22 nonpharmacologic interventions assessed by the American Heart Association for older adults, the DASH diet ranked as the most effective intervention in reducing blood pressure (BP) for individuals with prehypertension and hypertension (Systolic BP: weighted mean difference, 6.97 mm Hg; 95% credible interval, 4.50–9.47 and Diastolic BP: weighted mean difference, 3.54 mm Hg; 95% credible interval, 1.80–5.28). Following the DASH diet, ranking from most to least effective measures were aerobic exercise, isometric training, low-sodium, and high-potassium salt, and then comprehensive lifestyle modifications.[30]

The DASH diet encourages plant-based foods with a specific number of servings: 4 - 5 servings of fruits per diem, 4 -5 servings of vegetables per diem, 6 - 8 servings of whole grains per diem, and 4 to 5 servings a week of nuts, seeds, or dry beans and peas. It does not completely exclude animal-based products and recommends 2 to 3 servings a day of low-fat or fat free dairy products and two 3-oz servings or less of lean protein such as poultry or fish.[70] The diet is also naturally low in sodium, saturated, and total fat content. It contains other nutrients that may help lower BP and decrease total cholesterol and low-density lipoprotein (LDL) as well.[30] Several other studies specifically mention the DASH diet as one of the most effective approaches to manage hypertension.[15,16,31]

The systematic review and meta-analysis of non-pharmacological interventions for hypertensive older adults in one study determined that self-management education to be the most effective at lowering both systolic BP and diastolic BP. Older adults were likely to benefit from personalized repeated group education and individual counseling that addressed personal needs and preferences rather than one-time interventions. It was reported that these types of approaches

helped them significantly increase their adherence to lifestyle changes. A shorter, six-week educational intervention was also shown to be effective at significantly reducing BP.[31]

The aim of this paper is to evaluate the efficacy of the DASH-Plus, a comprehensive DASH diet-focused educational program in promoting the PBD consumption of hypertensive older adults and identify key predictors influencing adoption outcomes. The participants' healthy PBD consumption was measured as the primary outcome. The information gathered from the present study will demonstrate the implementation of a DASH diet educational intervention as a potential strategy to facilitate a more plant-based dietary pattern to help improve the health of the growing older adult population.

6.3 Methods

6.3.1 Study Design and Setting

The Dietary Approaches to Stop Hypertension-Plus (DASH-Plus) is a community nutrition initiative aimed at improving hypertension management in older adults through lifestyle changes. Partnered with the University of Maryland Extension (UME) system, an evidence-based program comprised of three core components was developed: (1) eight weekly educational modules covering different DASH diet topics, physical activity, and hypertension self-care skills, (2) a weekly delivery of fresh produce to facilitate fruits and vegetable accessibility, and (3) self-measured BP monitoring to encourage BP tracking. The duration of the intervention and study period was 24 weeks. A more in-depth description of the DASH-Plus study can be found elsewhere.[114] Briefly, the DASH-Plus study used a quasi-experimental design to analyze eight intervention sites with eight corresponding control sites. Each research site (i.e. senior center)

was recruited by an experienced Extension educator in their respective county. Data collection occurred at three time points: baseline (week 0), intermediate (week 9), and final (week 24) at participating sites. The present study was conducted as a substudy under the DASH-Plus program. Written informed consent was obtained from all participants, and the project was approved by the University of Maryland, College Park's Institutional Review Board.

6.3.2 Sampling

Using the UME's vast network of collaborative partnerships with aging service stakeholders throughout Maryland, select local sites from each county were invited to offer the DASH-Plus program as part of the research study. The quasi-experimental design provided a pragmatic solution to site recruitment, given the constraints imposed by the continuing effects of COVID-19 during the study's implementation phase.

Participating study sites received supplementary materials to help with recruitment such as flyers. Referrals from directors and staff involved with DASH-Plus contributed to additional recruitment. The inclusion criteria for participants were: (1) ≥60 years of age, (2) attends community site for seniors regularly (at least three times per week), and (3) has systolic blood pressure (SBP) of 140–170 mm Hg and/or diastolic blood pressures (DBP) of 80–100 mmHg or is taking anti-hypertensive medication(s). The following individuals were exceptions to the study: (1) having an acute and/or terminal condition such as terminal cancer, renal disease, and/or high alcohol consumption (>14 alcoholic drinks per week), (2) having a psychiatric diagnosis precluding participation, such as cognitive impairment as measured by the 6-item Mini-Mental State Exam, and (3) being underweight (BMI 18.5 kg/m^2) or class 3 obese (BMI 45.0 kg/m^2).

Prior to enrollment, participants first underwent a screening process. A 6-item Mini-Mental State Examination (MMSE) was used to check for cognitive impairment and BP was measured three times. Individuals who met the inclusion criteria and passed the initial screening process were enrolled into the study. A trained staff member then conducted the rest of the survey in a standardized process.

6.3.3 Measures

At each of the three time points, trained research personnel used a structured questionnaire to collect data. Baseline data included sociodemographic characteristics such as age, gender, ethnicity, race, living arrangement, education level, annual household income, and self-perceived general health status (physical and mental). The following measures were also collected.

Plant-based diet score

Participants' PBD consumption was assessed using a validated 15-item food frequency questionnaire (FFQ) that was specifically tested for this age group (sample population was 70-year olds).[85] Their PBD consumption was then quantified using a validated healthful plant-based diet index (hPDI) designed to measure the amount of overall plant foods in the diet.[66] Based on the hPDI, higher frequency of consumption for healthy plant-based foods received a higher score and reversed scoring was used for less healthy plant-based and animal-based products. For example, the question, "How often do you eat fruits (fresh, frozen or cooked)?" had the following scores: twice a day or more (4 points), once a day (3 points), a few times a week (2 points) and once a week or less (1 point). Conversely, the question, "How often do you eat red meat (beef, pork or game)?" was scored in reverse: three times a week or more often (1 point), twice a week (2 points), once a week (3 points), and a few times a month or less (4 points). The

original hPDI distinguished meats from seafood or fish into two distinct categories. Similarly, in the present study red meat (beef, pork, or game) and white meat (poultry e.g. chicken) items were combined under the category of meats and given 4 points for the lowest quartile frequencies and 1 point for the highest quartile frequencies. The fish or shellfish category was scored separately from the meat category.

The FFQ included items about other dietary habits such as regularity of meals and salt intake. These behaviors were also graded such that dietary behaviors considered healthy in general (i.e. eating breakfast [115–118] and avoiding salty foods with hypertension [119,120]) received positive scores based on frequency. As mentioned above, this is in line with the argument that when transitioning to a more PBD, it is important to differentiate a healthy PBD from an unhealthy one, and that a healthy PBD is more than reducing or eliminating meat.[66] The summation of individual scores were then averaged by the number of items with a response to account for missingness for each time point. Questions that did not measure the frequency of intake such as the type of bread they consumed were not scored but provided additional information about their diet. Omitting these questions gave each included item equal weight with a range of 1 to 4 points (12 items included).

Hypertensive self-care

Hypertensive self-care was assessed using the self-care activity level effects (H-Scale) survey.[121] It consisted of four activities: medication adherence (3 items), low-salt diet (9 items), physical activity (2 items), and smoking (2 items, one asking smoking status yes/no). Participants were asked, “How many of the past 7 days did you (insert activity): from 0-7 days, except for the smoking status question. For example, “Take your blood pressure pills?”, “Salt your food at the table?” and “Do at least 30 minutes total of physical activity?” were activities listed in the

questionnaire. Harmful activities such as the number of days smoking were reverse scored so that higher scores represented more self-care behaviors. Each of the 4 sections resulted in a score that was averaged by the number of items answered per section. A final composite score was totaled to represent the individual's amount of self-care with a score range from 0 - 105.

Psychosocial factors

Readiness to consume a PBD was measured using one item with response options that corresponded to the five stages of behavior change of the TTM. This approach has been used previously.[80–83]Participants' were classified in the following way: Precontemplation ("I am not thinking about eating a PBD"); contemplation ("I am thinking about eating a more PBD…planning to start within 6 months"); preparation ("I am definitely planning to eat a more PBD in the next month"), and action ("I am trying to eat a more PBD now")/ maintenance ("I am already eating a PBD"). The last two choices (action and maintenance stages) were combined since participants could not reach the original definition of the maintenance stage (maintaining behavior change for >6 months) after intervention due to the study period (6 months total), except for individuals who were already eating a PBD prior to study enrollment. Higher scores indicated more readiness to consume a PBD with a score range from 0 to 4.

Perceived barriers to consuming a PBD were assessed using a list of ten items determined from previous studies using a 5-point Likert scale (strongly agree to strongly disagree).[77,78] Items such as, "Someone else decides on most of the food I eat" and "Eating meat is too enjoyable to limit for a plant-based diet" were included. A score range of 1 to 5 points were assigned to each option, where higher scores indicated a greater number of perceived barriers to consuming a PBD (Cronbach's alpha: baseline = 0.65; 9 weeks = 0.72; 24 weeks = 0.80). The total score was then averaged by the number of items answered by each participant to account for missingness.

Perceived benefits to consuming a PBD were compiled using a list of ten items formulated from a literature review using a 5-point Likert scale (strongly agree to strongly disagree).[59,78,79] For example, benefits such as, “Prevent disease in general (e.g. heart disease, cancer)” and “Control my weight” were included. A score range of 1 to 5 points was assigned to each response where higher scores indicated more perceived benefits of consuming a PBD (Cronbach’s alpha: baseline = 0.88; 9 weeks = 0.92; 24 weeks = 0.93). The individual total scores were then averaged by the number of items with a response to account for missing items at all three time points.

Knowledge of PBD was measured using a questionnaire (15 items) adapted from a previous study that surveyed medical providers at baseline.[84] Due to the various definitions of PBD used, ambiguous and controversial items were omitted. For example, “Dairy is encouraged in a PBD” and “Fish is a necessary part of a healthful diet” were excluded from the PBD knowledge scores (11 items included) as the answers to these questions depended on the definition of a PBD being used (DASH diet, pescatarian, flexitarian, vegan etc.) (Cronbach’s alpha: baseline = 0.57).

6.3.4 Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software version 29.0.2.0 (20) and RStudio version 2024.12.1+563. Both descriptive and inferential statistics were performed. First, missing values were addressed using multilevel imputation. This was followed by model analysis using a linear mixed-effects model (LMM) to examine the effect of the DASH-Plus educational program on the continuous dependent variable, healthy PBD consumption at three different time points and identify determinants affecting PBD consumption.

Missing Values and Multiple Imputation

Considering that missing values were missing at random (MAR) with participants being lost to follow-up, multilevel imputation was performed using multivariate imputation by chained equations (MICE). The mice (version 3.17.0) and miceadds (version 3.17.44) packages in R were used to impute missing values. To account for the hierarchical structure of the study design, a three-level imputation with predictive mean matching was used for the missing data.[153] he resulting imputation took into consideration that the longitudinal data was nested at three levels (e.g. repeated measures [Level 1], collected across participants [Level 2], and nested within different study sites, i.e. senior centers [Level 3]). All missing values were at level 1. An interaction between the arm and time points was also included in the imputation model. Finally, von Hippel's "multiple imputation, then deletion" (MID) method was applied where all subjects were used for the imputation process with the outcome variable included. Under MID, however, participants with imputed outcomes are subsequently removed and excluded prior to model analysis.[154] The seed was set at 1212 and 20 imputed datasets were created, each with 20 iterations.

Once imputation was completed, convergence was visually examined using plots and inspection of the predictor matrix, methods, and imputed values did not reveal any major issues. A LMM was selected for model analysis given the continuous outcome variable, healthy PBD scores (see below) and the final results were pooled across all imputed datasets.

Analysis

A greater improvement in PBD consumption over time for the intervention group compared to the control group was hypothesized. Using LMM, repeated measures of the PBD consumption were assessed across the three time points (baseline, 9 weeks, and 24 weeks). The

participants and study sites were treated as random effects and the following variables were considered in the initial model: arm, time points, arm and time point interaction, sex, education (less than high school, high school/GED, post high school education through college, post-graduate studies including graduate/professional degrees), age category (youngest-old, middle-old, and oldest-old), living arrangement (lives alone, lives with family - spouse and/or children, lives with others), body mass index (BMI), PBD perceived barriers, PBD perceived benefits, PBD knowledge, readiness to consume a PBD, number of antihypertensive medications, hypertensive self-care, and lastly number of medical conditions.

Backward stepwise elimination was applied and the variable with the least significant p-value was iteratively removed while assessing the Akaike information criterion (AIC) and Bayesian information criterion (BIC) for model improvement and fit. With each iteration, a model where the AIC value decreased by 2 units after removing a variable was considered a statistically significant improvement [122] and a decrease in BIC value between 5 and 10 units was considered strong.[123] The model with the smallest absolute AIC and BIC values was considered a better model.[124] Once the most parsimonious yet effective model was reached, post hoc comparisons of estimated marginal means (adjusted means) were examined for PBD consumption among the three time points and arm (intervention vs. control) using Tukey's Honest Significant Difference (HSD) test to determine the between- and within-group differences.

Multicollinearity was tested using variance inflation factor (VIF). No significant (high) multicollinearity was detected among the variables (VIF < 2), except for the time point and the time point and arm interaction term which showed a moderate amount of multicollinearity. The linearity, normality of residuals and random effects, and homoscedasticity were assessed with

visual plots and were reasonably assumed to be met. Finally, the model predicted lines resembled observed data.

6.4 Results

6.4.1 Socio-demographic characteristics of participants

A total n=212 participants were enrolled into the study. The average age of participants was 74 ± 7.5 years old with marginally over half (51.9%) of the participants categorized as youngest-old (64 - 74 y). A majority of the individuals were female (88.7%), non-Hispanic (92.9%), and over half were Caucasian (57%). Almost a quarter of the older adults (21%) had a high school diploma/GED, and a large proportion (41%) had an education level ranging from post-high school training through a 4-year college degree. About 50% of the participants lived by themselves, while many lived with family members such as a spouse and/or children (42%). Most of the participants (96.2%) were prescribed an anti-hypertensive medication and took an average of 1.7 ± 0.8 anti-hypertensive medications. The average measured SBP was 137 ± 20 mmHg, and the average DBP was 79 ± 11 mmHg. The average number of self-reported medical conditions was 6 ± 2.6, the mean BMI was 31.0 ± 6.4 kg/m^2, and close to half of the participants (48.1%) were categorized as obese. The baseline characteristics of the participants have also been divided by the arm (intervention vs. control) in Table 6.1.

Table 6.1 Sociodemographic characteristics of study participants (n =212)

Variables	**Control (n = 90)**	**Intervention (n = 122)**	**Total (N = 212)**
Age (years), mean (SD)	74.5 ± 0.9	73.6 ±0.7	74 ± 7.5
Youngest-old (64-74 y), n (%)	43 (47.8)	67 (54.9)	110 (51.9)
Middle-old (75-84 y), n (%)	37 (41.1)	44 (36.1)	81 (38.2)

Oldest-old (≥85 y), n (%)	10 (11.1)	9 (7.4)	19 (9.0)
Sex, n (%)			
Female	79 (87.8)	109 (89.3)	188 (88.7)
Male	11 (12.2)	13 (10.7)	24 (11.3)
Ethnicity, n (%)			
Non-Hispanic/ Non-Latin American	88 (97.8)	109 (89.3)	197 (92.9)
Hispanic/ Latin American	1 (1.1)	10 (8.2)	11 (5.2)
Race, n (%)			
Caucasian	39 (43.3)	82 (67.2)	121 (57.1)
Black or African American	41 (45.6)	28 (23.0)	70 (33.0)
Asian	4 (4.4)	6 (4.9)	10 (4.7)
Other	6 (6.7)	3 (2.5)	9 (4.2)
Living arrangement, n (%)			
Alone	50 (55.6)	56 (45.9)	106 (50.0)
Family (spouse/partner and/or children)	34 (37.8)	57 (45.7)	89 (42.0)
Other (i.e. roommate)	6 (6.7)	9 (7.4)	17 (8.0)
Education, n (%)			
Less than high school	18 (20%)	15 (12.3)	33 (15.6)
High school graduate/ GED	17 (18.9)	28 (23.0)	45 (21.23)
Post high school training through college	31 (34.4)	56 (45.9)	87 (41.0)
Post college through graduate/professional degrees	24 (26.7)	23 (18.9)	47 (22.2)
Taking antihypertensive medications, n (%)	88 (97.8)	116 (95.1)	204 (96.2)
Yes	2 (2.2)	6 (4.9)	8(3.8)
No			
Average number of anti-hypertensive medications	1.7 ±0.1	1.7 ± 0.3	2 ± 0.8
Blood pressure			
Average SBP (mm Hg)	136.9 ± 8.7	137.3 ± 21.0	137.1 ± 20.0
Average DBP (mm Hg)	76.5 ± 10.3	80.2 ± 11.4	78.6 ± 11.1
Number of medical conditions	5.7 ± 0.3	5.81 ± 0.2	6 ± 2.6
Anthropometric measurements			
BMI (kg/m^2)	31.4 ± 0.8	30.4 ± 0.6	31.0 ± 6.4
Healthy weight (18.5 and 24.9 kg/m^2)	14 (15.6)	16 (13.1)	30 (14.2%)
Overweight (25 and 29.9 kg/m^2)	28 (31.1)	48 (39.3)	76 (35.8%)
Obese (≥30 kg/m)	48 (53.3)	54 (44.3)	102 (48.1%)
PBD consumption scores (range: 2 - 3.91)			
Baseline	3.00 ± 0.33	3.03 ± 0.31	3.01 ± 0.32
9 weeks	3.04 ± 0.32	3.18 ± 0.27	3.12 ± 0.30
24 weeks	3.02 ± 0.35	3.14 ± 0.30	3.09 ± 0.33

6.4.2 Correlation matrix of fixed effects

The relationships among the estimated coefficients of fixed effects were examined and the correlations are shown below in Table 6.2 These results showed a fairly weak relationship among the uncertainty in the estimated effects of predictors and support low collinearity among the variables and that the estimates are relatively independent.

Table 6.2 Correlation matrix of estimated coefficients of fixed effects

Variables	Int	1	2	3	4	5	6	7	8	9	10	11
1. Arm, 0	-0.226	1										
2. 9 weeks	-0.176	0.281	1									
3. 24 weeks	-0.189	0.266	0.463	1								
4. Edu2	-0.193	-0.093	-0.002	-0.003	1							
5. Edu3	-0.273	-0.115	0.013	0.016	0.647	1						
6. Edu4	-0.282	0.062	0.025	0.020	0.569	0.666	1					
7. Barriers	-0.574	0.032	0.148	0.142	-0.002	0.093	0.146	1				
8. Med Conds	-0.275	0.014	-0.009	-0.001	-0.049	-0.122	-0.025	-0.013	1			
9. Selfcare	-0.699	0.041	-0.005	0.024	-0.052	-0.003	-0.042	-0.084	-0.003	1		
10. Arm* 9weeks	0.145	-0.370	-0.739	-0.333	0.010	0.007	0.014	0.540	0.005	-0.144	1	
11. Arm* 24weeks	0.143	-0.351	-0.330	-0.750	0.002	0.005	0.012	0.055	-0.006	-0.140	0.476	1

(1) Arm: 0 = Control (reference), 1 = Intervention; (2) Time points: 1 = baseline (reference), 2 = 9 weeks, 3 = 24 weeks, (3) Education: 1 = less than high school (reference), 2 = High school graduate/GED, 3 = post high school training through bachelor's degree, 4 = post baccalaureate through graduate/ professional degrees (7) perceived barrier of PBD scores (8) number of self-reported medical conditions (9) hypertensive selfcare (1) Arm and time point interaction: 1 = baseline (reference), 2 = 9 weeks, 3 = 24 weeks

6.4.3 Predictors of PBD consumption

Using a LMM, PBD consumption was included as the dependent variable. The model incorporated a set of fixed-effects that included the study arm (control vs. intervention), time points, education, PBD perceived barriers, number of medical conditions, self-care, and the

interaction between the arm and time points. By including an interaction term between the study arm and time points, we examined how the intervention's effect might vary across different time points. To account for potential clustering and individual variability, we included each subject and study sites (i.e. senior centers/ living) as random effects. This approach allowed for a nuanced understanding of how various factors might influence PBD consumption over time while controlling for potential sources of variation within the study sample. The final model specification was as follows: Arm + Time point + Arm * Time point + Education + PBD perceived barriers + Number of medical conditions + Selfcare + (1|StudySite.I) + (1|SubjectSID).

All variables were significant except for the individual arm and time point variables as shown in Table 6.3. There was a significant main effect of education levels associated with PBD consumption. Compared to older adults with less than a high school education, older individuals who had a post-baccalaureate education through a graduate/professional degree were significantly more likely to increase their PBD consumption (p =0.001). There was also a significant main effect between perceived PBD barriers (p <0.001), number of medical conditions (p =0.04), self-care, and the outcome. Participants who reported less PBD barriers, a lower number of self-reported medical conditions, and higher hypertensive self-care practices consumed significantly more plant-based foods. Lastly, the arm and time point interaction (p = 0.04) showed a significant main effect indicating that the intervention's effect on PBD consumption varied across different time points and was investigated further below.

Table 6.3 Predictors of PBD consumption in hypertensive, older adults

Predictors	Fixed - effect Estimate	Confidence intervals	Standard error	Statistic	*P* value
Intercept	2.83	[2.58, 3.08]	0.13	22.28	<0.001***
1. Arm					
Control		Reference			
Intervention	0.031	[-0.064, 0.125]	0.048	0.63	0.53
2. Time points					
Baseline		Reference			
9 weeks	0.024	[-0.031, 0.080]	0.028	0.88	0.38
24 weeks	0.014	[-0.045, 0.073]	0.030	0.47	0.63
3. Education					
Less than high school		Reference			
High school/GED	0.042	[-0.069, 0.153]	0.056	0.74	0.46
Post high school through college	0.076	[-0.027, 0.178]	0.052	1.44	0.15
Post college through graduate	0.192	[0.076, 0.308]	0.059	3.25	0.001**
4. PBD barriers	-0.077	[-0.119, -0.035]	0.021	-3.61	<0.001***
5. Medical conditions	-0.014	[-0.027, -0.001]	0.007	-2.11	0.04*
6. Selfcare	0.018	[0.010, 0.025]	0.004	4.61	<0.001***
7. Arm X timepoint					
Baseline		Reference			
9 weeks	0.077	[0.005, 0.150]	0.037	2.10	0.04*
24 weeks	0.045	[-0.032, 0.121]	0.039	1.15	0.25

*Statistically significant *p* value <0.05
**Statistically significant *p* value <0.01
***Statistically significant *p* value <0.001

6.4.4 Changes in PBD consumption

Tukey's Honest Significant Difference (HSD) test was performed to assess the time point and arm interaction differences for within-group and between-group differences for PBD consumption. The PBD consumption for the intervention group was significantly higher at week 9 compared to the baseline (p <0.001). No significant differences in PBD consumption were seen between baseline and at 24 weeks nor between week 9 and week 24 in the intervention group. This suggested that PBD consumption increased after the intervention at week 9, but decreased when measured at week 24 shown in Table 6.1. In the control group, there were no significant within-group differences observed among the three time points for PBD consumption. There were also no significant between-group differences between the intervention and control arm among the three time points also shown in Table 6.4

Table 6.4 Pairwise contrasts for PBD scores (consumption among time points for intervention and control groups

Contrast	**estimate**	**SE**	**df**	**t.ratio**	***P* values**
Control (within-group differences)					
Baseline - 9 weeks	-0.025	0.028	352.9	-0.877	NS
9 weeks - 24 weeks	0.011	0.030	357.4	0.348	NS
Baseline - 24 weeks	-0.014	0.030	359.0	-0.475	NS
Intervention (within group differences)					
Baseline - 9 weeks	-0.102	0.025	379.4	-4.105	<0.001***
9 weeks - 24 weeks	0.043	0.024	350.6	1.779	NS

Baseline - 24 weeks	-0.059	0.026	377.3	-2.284	NS
Between group differences: control and intervention comparisons					
Baseline	-0.031	0.049	16.8	-0.628	NS
9 weeks	-0.108	0.491	17.6	-2.201	NS
24 weeks	-0.075	0.051	20.2	-1.485	NS

*Statistically significant *p* value <0.05
**Statistically significant *p* value <0.01
***Statistically significant *p* value <0.001

6.4.5 Linear mixed-effects model (LMM) comparisons

The final model (Table 6.5) was a significantly better fit (AIC: 44.90; BIC: 109.44) compared to the null model (AIC: 59.34; BIC: 76.55, $\chi^2 = 100.88$, $p < 0.001$). The BIC value for the null model is lower but considering that the objective is to determine the effect of intervention on PBD consumption, the AIC value was followed. The effects of the random variable were tested as well and there was a significant difference between the final model (with the random effect) and the same model without the random effect (AIC: 130.23; BIC: 186.16, $\chi^2 = 158.67$, $p < 0.001$). The marginal R-squared (R^2m) showed that 19.6% of the variance in the outcome variable is explained by the fixed effects alone and the conditional R-squared (R^2c) showed that 67.6% of the variance seen is explained by using the existing fixed and random effects, the remaining were accounted for by possible error terms and other factors.

Table 6.5 Model Comparisons and Summary

	AIC	BIC	χ^2	*P* value
Final LMM	44.90	109.44		
Null LMM	59.34	76.55	100.88	<0.001

Without random effects (LM)	130.23	186.16	158.67	<0.001

Model Summary

	Marginal R-squared (R^2m)	Conditional R-squared (R^2c)
Final LMM	0.196	0.675

6.5 Discussion

This study investigated the potential use of a community-level intervention, the DASH-Plus program in facilitating dietary changes in community-dwelling, hypertensive older adults towards a more PBD and examined key predictors affecting PBD consumption. Participants with higher education levels (p <0.001), fewer plant-based diet barriers (p <0.001), fewer medical conditions (p = 0.004), and better hypertensive self-care practices consumed significantly more plant-based foods. Using a LMM, adjusting for significant predictors associated with PBD consumption including education level, perceived barriers for PBDs, number of medical conditions and hypertensive self-care, a significant increase in PBD consumption at week 9 (p <0.001) was observed, although these effects were not sustained at week 24. These findings suggest that the intervention has the potential to influence dietary behavior in the short term and further research is needed to explore strategies for long-term efficacy. Future interventions could be improved by increasing the duration of the educational portion of the intervention, adding booster sessions periodically, and other supportive measures.

While the key predictors in the final model showed relatively small effects, as indicated by the fixed effect estimates, the model explained a moderate proportion of variance (19.6%) in PBD consumption, offering valuable insight into the outcome. Moreover, the substantial

conditional R-squared (67.6%) highlights the importance of accounting for individual and site-level variability to fully understand patterns of PBD consumption in future studies. In recent years there has been a growing interest in PBDs. Adherence to PBDs increased from 4.0% to 11.8% ($X^2[1, N = 2060] = 43.624$, $p < 0.001$) from 2019 to 2022 in surveyed respondents (18 - 80 y), and adherence to the DASH diet in consumers (18 - 80 y) was 1.9% on average between 2019 and 2021, but increased to 5.5% in 2022.[144] With the rising popularity, it has become increasing important to explore safe and effective ways to transition to a healthy PBD, especially in older adults. One author writes, "Once it is clear 'what' needs to be done, the issue of 'how' change may occur is another matter" when discussing behavior changes to improve nutritional quality and health outcomes.[143]

As mentioned previously, it is important to note that not all PBDs are created equal in terms of environmental and health effects. There are healthful and unhealthful plant foods associated with coronary heart disease. Whole grains, fruits, vegetables, nuts, legumes, vegetable oil, tea, and coffee have been identified as healthful plant foods. In contrast, fruit juices, refined grains, potatoes, sugar-sweetened beverages, sweets, and desserts are considered unhealthful plant foods.[66] It has been shown that a diet consisting of primarily unhealthful plant foods could put an individual at greater risk of cardiovascular disease compared to an average omnivorous diet.[107] Additionally, one study concluded when analyzing data from 1999 to 2020, among individuals who consumed a PBD, ultra-processed foods provided most of their energy intake.[161] Although not all ultra-processed foods are of low diet quality,[162] consuming large amounts of ultra-processed foods has been associated with numerous adverse health outcomes.[163,164] When designing interventions to help transition older adults to a more PBD, it will be crucial to ensure that nutrition quality does not diminish.

The rise in popularity of PBDs has also been seen in older adults. In 2022, it was reported that more than three times as many older consumers followed a plant-rich dietary pattern compared to 2019 (9.0% vs. 17.3%, $X^2[1, N = 1312] = 20.307$, $p < 0.001$).[144] In the present study, baseline data showed that most of the participants identified as omnivores (84.4%) with no dietary restrictions, except for food allergies. About 8% of the participants identified as flexitarians, where they mostly consumed plant-based foods, but occasionally ate meat. A small percentage (2.8%) indicated that they were vegetarian. Four participants (1.9%) were pescatarian, and 5 individuals (2.4%) chose 'other.' For example, meat was included in their diet, but red meat was excluded. The distribution of dietary habits in surveyed respondents were similar to those found in a study that examined meat consumption in older consumers. The researchers reported a majority of older adults were meat-eaters, with only 1.1% of the study sample self-identifying as a pescatarian and, 0.5% ovo- and/or lacto-vegetarian, and 0.1% vegan.[165] However, transitioning to a PBD in a safe and effective manner, especially in the older adult population needs more careful consideration and the findings in the present study have shown that the DASH-Plus program helped increase PBD consumption in the intervention group and offers a good starting point to address this issue.

In terms of efficacy and safety, PBDs have been gaining broad support in recent years for many different benefits including health. Research has shown the significant association between foods consumed and health outcomes including non-communicable diseases [108–113] and especially with cardiovascular conditions, the current leading cause of mortality.[60,66,106,107] This recognition is seen in different movements such as the Food is/ as Medicine [166] as well as in many professional and medical organizations. For example, the American Heart Association has encouraged PBDs by stating that adherence to diets such as the Mediterranean, DASH,

pescetarian, and vegetarian would support optimal cardiovascular health.[167] The Academy of Nutrition and Dietetics released a position statement in 2025 saying that vegetarian and vegan dietary patterns can be nutritionally adequate providing health benefits including cardiometabolic disease, but that it needs to be planned appropriately.[168] Among PBD, the DASH diet incorporates a variety of plant-based foods. Fruit and vegetable intake during the later life stage in older adulthood has been associated with a decreased risk of chronic diseases, protects against hypertension, and supports cardiovascular health.[169,170] Despite these benefits, it has been found that less than half the older adults consume the recommended five servings of fruits and vegetables. Most include at least one serving of fruit and vegetables a day. It has been estimated that 21 to 37% of older men and 29 to 45% of older women (≥ 65 y) reach the recommended servings per day. Within the older adult population, differences among age groups have been reported. Seniors aged 75 and older were more likely to consume fruit compared to older adults 65 - 74 y tended to have more vegetable intake. It is especially important for older individuals to be aware of their fruit and vegetable intake because they likely consume smaller quantities of food in general and this may lead to vitamin and mineral deficiencies.[169] The present study did not find a difference in healthy PBD consumption based on age categories. Regardless, following the DASH diet can be used as a guide for older adults to encourage more fruits and vegetables consumption.

Protein is another nutrient that needs to be considered when transitioning to a PBD, especially for older adults. Although controversial, it has been argued that older adults should increase their protein intake to 1.2g of protein/ kg/ day, which is above the current recommendation of 0.8g/kg/day.[34,40] This is a concern that has been raised with certain PBDs such as vegetarianism and veganism.[171,172] Despite these concerns, there is some evidence to

suggest that older adults' average meat consumption may be above the recommended amount in a healthy diet.[165] These findings are similar to the meat consumption pattern in the rest of the population.[82,173] The DASH diet does not advocate a complete elimination of animal-based products including meat, but it does encourage lean meats, poultry, and fish and recommends six 1-ounce servings or fewer.[70] This may be a more appropriate strategy to use with this population and offer a more balanced approach. These characteristics of the DASH diet make it a more practical, safer, and effective guideline for this population. Additionally, given the rising health statistics that most seniors have hypertension, which is a major risk factor to multiple adverse health outcomes [2] using the DASH diet will help address this pressing issue as well. A description of the BP findings of the DASH-Plus program can be found elsewhere.

The results of this study should be carefully interpreted with the following limitations. First, as mentioned, the PBD consumption was determined using self-reported dietary behaviors and these are often subject to recall and social desirability bias. Due to this the actual consumption of plant-based foods may have been over- or underestimated. Secondly, the survey does not list some of the plant-based foods in the healthful PDI such as whole grains, tea, and coffee. However, in a community nutrition setting, a long extensive survey may not be feasible and burdensome to this population. The chosen validated survey provides a general overview of a person's diet and was specifically tested for older individuals with cardiovascular diseases. Finally, the ratio of females to males in the study was largely skewed. A large majority of participants were female and although it has been shown that sex ratios shift significantly for older adults,[9] results may not be generalizable to the whole older adult population and for males.

6.6 Conclusion and future implications

While the intervention demonstrated a modest effect on PBD scores, the DASH-Plus still offers an initial safe and effective method to help older adults transition to a more PBD. Furthermore, the educational interventions are relatively low-cost and easy to implement, making it a feasible option for widespread use. Additional research is needed to optimize the intervention and explore its long-term effects. In the meantime, this intervention represents a promising step towards improving dietary habits and sustainability in this vulnerable population.

Chapter 7: Discussion

7.1 Summary of findings

Starting with the cross-sectional analysis of baseline data collected, the psychosocial factors and demographic characteristics associated with a healthy PBD consumption among hypertensive older adults (≥60 y) were examined and related factors that potentially influence the likelihood of adopting a plant-based dietary pattern were identified. Several predictors were found to be significantly associated with PBD consumption in this population. Older adults who lived with family members (spouse/partner and/or children) showed a significantly higher likelihood of consuming a healthy PBD compared to older adults living with non-related roommates (others). This finding was not discussed extensively in earlier studies. One possible reason may be due to financial hardship. It has been shown that SES is associated with living arrangements, where participants who lived alone or with their children had a lower monthly income and were less satisfied with their economic condition than participants who lived with a spouse/partner only.[125,127,129] In a similar manner, older adults may live with non-family roommates out of financial concerns. Additionally, this group may live in an assisted living type of facility with others because they need more care for various health conditions, which could explain both their lower plant-based food intake and living arrangement. Certain health conditions may prevent older adults from consuming plant-based foods such as nuts due to swallowing difficulties or dental issues and if they are physically unable to cook for themselves or have reduced appetites due to feeling unwell, it could also potentially decrease their intake of

healthy plant-based foods. The relationship between these living arrangements and dietary patterns warrants further investigation to determine the relevant associations.

Previous findings showed that living arrangement was an important factor associated with dietary habits of older adults in general. Most of the research showed that older individuals who lived alone were less likely to have healthier dietary practices, they consumed a lower variety of foods,[126,127,129] less fruits,[125,127,129] vegetables,[126,129] and fish.[127] These studies, however, are dated and were conducted several decades prior and should be updated. Living arrangements were also linked to other factors such as social isolation and loneliness that can contribute to the development of depression, although not in all cases. Furthermore, depression was shown to be associated with nutritional deficits.[126] Older adults living with a spouse/partner or children were less likely to be depressed than when those who live by themselves.[125] These results support earlier findings that simply living with someone does not improve eating behaviors, but rather who they live with is an important consideration,[128] especially those living with a non-related roommate(s).

Older adults' consumption of healthy plant-based foods was also associated with their readiness to consume a PBD. Compared to those in earlier stages, individuals at the action and maintenance stages reported significantly higher PBD consumption. Finally, older individuals more likely to consume a healthy PBD were male, had fewer perceived barriers, maintained better hypertensive, self-care practices (medication adherence, low-salt diet, physical activity, and smoking) and had fewer chronic diseases overall. The gender findings in the present study were inconsistent with previous studies that reported that females were more likely to consume a healthy PBD compared to males. It should be noted that only about 11% of our sample were males so it may not reflect the broader population-level trend. It is also possible that males in our

sample were living with partners/spouses who prepared healthier plant-based meals for them, and this may indirectly explain the findings in this study.

Many of these characteristics were held when examining readiness to consume a PBD and the reported consumption of PBD. First, perceived barriers were found to be a significant predictor in all three studies. It was found to be associated with both readiness as a mediator and directly with reported PBD consumption under the DASH-Plus intervention. This is unsurprising as the perceived barrier construct has been found to be the single strongest predictor in the HBM in terms of behavior change.[73–75] This finding provides an important insight, when designing future interventions for dietary behavior change. To facilitate a plant-based dietary pattern, a focus on decreasing barriers will be an effective strategy. For older adults, the main perceived barriers that should be addressed were needing more information about this type of dietary pattern, followed by not having enough plant-based choices when eating out, and the perceived barrier that meat is too enjoyable to limit for a PBD. Future interventions should offer strategies to help lower these barriers.

Perceived benefits of PBD such as increased fiber intake, helping older adults stay healthy, and decreasing saturated fats should also be included. For readiness to consume a PBD, perceived benefit was still a key determinant in addition to perceived barrier through decisional balance. This finding suggested that as participants considered the advantages and disadvantages of consuming a PBD, their readiness changed. Specifically, as their perceived barriers decreased and their perceived benefits to consuming a PBD increased through the DASH-Plus program. An increase in the correlation between the two variables with readiness was observed for the intervention group, but not for the control group through the three time points. Furthermore, an initial difference between the intervention and control group was seen at 9 weeks. Including all

three variables when encouraging a more PBD in older adults will likely be an effective approach as readiness is a known mediator for behavior change.[159]

Finally, individual motivations such as the importance of health and environmental considerations such as global warming when purchasing or consuming plant-based foods were also associated with readiness to consume a PBD. Compared to participants who ranked health as not too important when purchasing or consuming plant-based foods, those who indicated a moderate or high level of importance were more likely to increase their readiness. Older adults who ranked environmental concerns as moderately or very important when purchasing or consuming plant-based foods were also more likely to increase their readiness to consume a PBD compared to those who ranked that this issue as not too important. This is in line with previous findings that have shown that many people often change dietary habits for health reasons and that health reasons are usually ranked higher than environmental reasons or animal welfare.[59,78,99,152] These types of motivations also need further investigation to understand the driving factors behind behavior change, especially in this population in order to tailor interventions more effectively.

The reported consumption of PBD helped examine the change in dietary behaviors more directly. It was hypothesized that the DASH-Plus intervention would increase PBD consumption in intervention participants over the three time points. This effect was seen at 9 weeks for the intervention group but was not sustained at 24 weeks in a similar manner to readiness. To maintain dietary behavior changes, the intervention may need more long-term strategies such as additional booster sessions and other supportive measures. Future research will be needed to investigate the effects of these additions. It was also found that participants reporting fewer PBD barriers, fewer medical conditions, and better hypertensive self-care practices consumed

significantly more plant-based foods. Also, education significantly influenced PBD consumption, with participants holding graduate/professional degrees showing higher intake compared to those with less than high school education.

7.2 Implications

There has been a growing interest in PBDs for their health and other sustainability benefits. With the rise in popularity, when considering a more plant-based dietary pattern it is important to make dietary changes in an appropriate manner. For the older adult population, there are important nutritional considerations in order to provide a safe and effective intervention. Behavior change in general can also be challenging including dietary behavior changes to consume more plant-based foods. Understanding their underlying perceptions, beliefs, and attitude will help tailor interventions to address their specific needs and challenges. For example, targeting perceived barriers found through this research and enhancing self-care strategies could potentially facilitate the adoption of healthy plant-based dietary choices among hypertensive older adults.

Additionally, when using readiness to change PBD consumption in an intervention, one focus should be to decrease perceived barriers and increase perceived benefits that affect older adults most. Providing more information about PBDs and the currently available PBD choices when eating out should be included as well. The enjoyment of meat was also a highly ranked barrier. To address this barrier, more studies regarding meat consumption in this population is needed. Simultaneously, discussing the benefits of PBD such as increasing fiber intake, staying healthy, and decreasing saturated fats should also be highlighted. The findings of this study suggest that including all three aspects into one study may be a way to increase effectiveness.

Another implication is that the DASH-Plus provided significant short term benefits in readiness to consume a PBD and in reported consumption of PBDs offering a promising strategy to modify older adults' dietary choices. The DASH diet offers a structured dietary guidance that has been rigorously tested for over two decades. To have lasting impact, however, future interventions should include more long-term supportive measures. Adding booster sessions, increasing exposure to educational materials, increasing the frequency of sessions should all be investigated further. These implications can be used to inform potential strategies, future research, and other public health initiatives using PBDs to address chronic disease prevention and management in the aging population. Using PBDs to improve health outcomes will help improve other sustainability domains well.

7.2.1 Limitations

While the enclosed findings offer positive implications for improving older adult health through lifestyle changes, it's important to consider the following limitations. The sample size in the study was modest and skewed towards female participants. While the target of 120 intervention participants was reached, only 90 participants were recruited in the control cohort and both decreased further at later time points. This may have reduced the statistical power and the external validity. As a result it may not be applicable to the general older adult population or to older males.

As previously mentioned, the study design was also changed from cluster randomization to a quasi-experimental design due the prolonged effects of COVID-19 during the implementation stage. This may have increased selection bias, reduced internal and external validity as well. The sample may not be representative of the population being examined.

Finally, when measuring the consumption of plant-based foods, this was captured using a FFQ. First, these were self-reported measures and may not accurately reflect the actual consumption in an individual's diet. They may also have been subject to social desirability bias and recall bias. Additionally, although the FFQ used was able to provide a general depiction of a person's diet, it was relatively short and may also not have been able to measure the true dietary consumptions as a longer FFQ or alternative methods. The questionnaire also did not contain all of the components of a healthy PBD. It was missing whole grains, tea, and coffee that are a part of the hPDI.

7.2.2 Strengths of the studies

There are also several strengths supporting the current findings. Psychosocial variables with a strong theoretical background were applied to better understand the characteristics of older adults who consume a more PBD. Few studies have examined the perceptions, attitudes, and readiness in older adults, so these findings provide an additional consideration that helps personalize interventions towards this population. The studies also incorporated scales that were previously used so that the results were directly comparable to previous measures. This provides continuity and helps detect changes over time. For example, the perceived barriers and benefits in this present study were able to be compared to the past study to discern what is currently relevant.

Another strength of the study is the multiple imputation used for handling missing data. This is especially useful with a repeated measures longitudinal study. In this type of study, missing data is common and can reduce the statistical power especially when using complete case analysis. It is a useful method when there is missing data in covariates rather than only in the outcome variable.[174] The imputation process is also enhanced when using the "multiple

imputation, then deletion" method. Including the outcome variable in the imputation process improves accuracy as it preserves the relationship among the variables and removing the imputed outcomes reflects the actual data collected.

Finally, there is strong potential for program sustainability through the vast Extension network. The educational portion is low-cost with few necessary equipment (e.g. an overhead projector may be needed to share power point slides). The DASH diet is a safe and effective diet that will help address the rising prevalence of hypertension in this population as well as prevent and manage other chronic conditions.

7.2.3 Consideration for future research

The findings of this study offer some considerations for future research. Previous findings and the present study both support the importance of older adults' living arrangements when examining dietary habits including PBDs. There are some studies that have examined this topic recently,[175,176] but further studies are warranted. Future studies should also explore older adults who live with non-related roommates. Examinations of motivations associated with PBD consumption in older adults specifically such as health, climate change, animal welfare, and taste among others will help further guide intervention strategies when modifying diets towards a more plant-based one.

Additionally, interventions that include and examine measures for long term changes are also needed. Future interventions that include continual support such as booster sessions, increasing the duration of the educational portion of the intervention or the frequency can also be explored to find the best approach. Further testing of the perceived benefits and barriers will be informative as well as more investigations into the psychosocial factors in this population in general.

Lastly, the DASH-Plus program was conducted in English, assuming participant comprehension in this format. However, as population diversity increases, so does the need for culturally adapted interventions. To broaden the program's reach, future research should explore the DASH-Plus program and similar interventions across diverse cultural contexts.

7.3 Conclusions

The escalating burden of chronic diseases, particularly cardiovascular disease and major risk factors like hypertension, coupled with a rapidly aging population, underscores the critical need for effective dietary interventions like PBDs. The investigations and findings presented, building upon the established DASH-Plus program—a dietary approach emphasizing fruits, vegetables, and whole grains while limiting sodium and saturated fats—offer practical and safe strategies to facilitate the transition towards a PBD in older adults. Specifically, this research also highlights the importance of tailored educational interventions that address the unique dietary needs and preferences of older adults, as well as the necessity of longer-term strategies such as booster sessions to promote lasting adherence to PBDs. Future studies should focus on developing culturally adapted PBD interventions, evaluating their long-term effectiveness in diverse populations of older adults, and assessing their cost-effectiveness in real-world settings. Promoting PBDs in older adults can significantly improve their cardiovascular health, reduce the risk of chronic disease complications, and enhance cognitive function. This, in turn, can alleviate the burden on the already overstrained healthcare system by reducing hospitalizations and medication use. Furthermore, PBDs contribute to broader sustainability efforts by reducing greenhouse gas emissions and minimizing water consumption associated with animal agriculture.

Appendices

1. Baseline DASH-Plus questionnaire

SID number: _____

Study Site_____
County_____

Intervention or Control

Questionnaire
(Baseline)

Effects of an Integrated System Approach on Hypertension Management in Community-Dwelling Older Adults

INTRODUCTION

My name is (NAME OF INTERVIEWER) and I am from (NAME OF AGENCY). We are doing an important project with Maryland senior centers and several community sites in collaboration with the University of Maryland College Park. The goal of the project is to find out how an effective hypertension management program will help older adults manage their blood pressure. During this interview, I will be asking you questions about your health and living situation. Please remember that all the information you provide me is confidential. Do you have any questions at this time?

A. Screener

A1. Date & Time:_____yy_____mm_____dd_____time (AM/PM)

A2. Interviewer name: _____

A3. Respondent's Name :_____

A4. Respondent' address:_____

_____

A5. Telephone number: (_____)_____

A6. Email: _____

A7. Hypertension measurement

a. 1st systolic BP: _____ 1st diastolic BP: _____

b. 2nd systolic BP: _____ 2nd diastolic BP: _____

c. 3rd systolic BP: _____ 3rd diastolic BP: _____

A8. Are you taking antihypertensive medication? □1. Yes □2. No

A8-1. Does the interviewee take antihypertensive medication?

1 Yes (ELIGIBLE. GO TO B1, next section.) 2 No (next question. GO TO A8.2)

A8.2. Is the mean systolic BP ≥ 140 or mean diastolic BP ≥ 90?

1 Yes (ELIGIBLE. GO TO B1, next section) 2 No (NOT eligible for the study)

If an interviewee is NOT eligible for the study, please stop here.

B. 6-Item Screener (Callahan et al. 2Mini-Mentalental State Exam (MMSE)

Now, I am going to name 3 objects. Please wait until I say all 3 words; then repeat them. Remember what they are because I am going to ask you to name them again in a few minutes. Please repeat these words for me.

(Interviewer may repeat names 3 times if necessary but repletion not scored)

B1. Did the patient correctly repeat all 3 words?	Yes	No
	Incorrect	**correct**
B2. What year is this? ( )	0	1
B3. What month is this? ( )	0	1
B4. What is the day of the week? ( )	0	1
What were the 3 objects I asked you to remember		
B5. Word 1	0	1
B6. Word 2	0	1
B7. Word 3	0	1
Total score ( )		

*__INTERVIEWER__: If the score of a respondent is ≤3, or if an interviewer is not able to proceed the interview because of communication issue, please notify it to a project coordinator and write down a brief note on the questionnaire.

*****If participant qualifies - OBTAIN CONSENT BEFORE CONTINUING*****

C. Demographics

C1**. Gender:** 1) Male 2) Female __ 3) Non-binary/third gender__4) Prefer not to say __

C2**. Date of birth**: ____/____/19____

C3. **How do you describe your ethnicity**? 1) Hispanic/Latino 2) Non-Hispanic

C4**. How do you describe your race?**

1) Black or African American
2) White
3) Asian
4) Native Hawaiian or Pacific Islander
5) American Indian or Alaska Native
6) Some other race

C5. **What is your current marital status?**

1) Married
2) Not married, living with partner
3) Separated
4) Divorced
5) Widowed
6) Never married

C6. **Current living status?**

1) Lives by myself
2) Lives with my spouse
3) Lives with children
4) Lives with others

C7. **Education completed**

1) K-12th grade
2) High school graduate, GED
3) Post-high school education/training
4) 2-year college degree
5) 4-year college degree
6) Post-graduate study
7) Graduate or professional degree(s)
8) None

C8. Please **list your current medical conditions**:_____

_____

_____

C9. **What kind of health insurance coverage do you have?** (**Check all that apply**)

1) None
2) Medicaid
3) Medicare
4) Private insurance paid by me only
5) Private insurance paid by my employer only
6) Private insurance paid by my employer and me
7) Military insurance (TRICARE or VA)
8) Others: _____

C10. **What is the annual household income including salary, interest, and supplementary income?**

1) Less than $10,000
2) $10,000-19,999
3) $20,000 – $29,999
4) $30,000 - $49,999
5) $50,000 - $74,999
6) $75,000 - $99,999
7) $100,000 to $ 149,999
8) $150,000 or more

C11. Please tell me the **list of antihypertensive medications (Type, dose, frequency)**. (If a participant doesn't know what medication he or she is taking, please ask them whether it is ok to call them later to ask about this information. ☐ **Check box if ok to call later**

_____

_____

_____

_____

C12. **How long have you known about your hypertension? _____years _____months**

C13. **Please rate your physical health**

1) Excellent 2) Very Good 3) Good 4) Fair 5) Poor

C14. **Please rate your mental health**

1) Excellent 2) Very Good 3) Good 4) Fair 5) Poor

D. MEDICATION ADHERENCE (Morisky et al. 2008)

Now, I am going to ask about your hypertension medication-taking practice.

Questions	Answers
D1. Do you sometimes forget to take your high blood pressure pills?	1) Yes 2) No
D2. Over the past 2 weeks, were there any days when you did not take your high blood pressure medicine?	1) Yes 2) No
D3. Have you ever cut back or stopped taking your medication without telling your doctor because you felt worse when you took it?	1) Yes 2) No
D4. When you travel or leave home, do you sometimes forget to bring along your medications?	1) Yes 2) No
D5. Did you take your high blood pressure medicine yesterday?	1) Yes 2) No
D6. When you feel like your blood pressure is under control, do you sometimes stop taking your medicine?	1) Yes 2) No
D7. Do you ever feel hassled about sticking to your blood pressure treatment plan?	1) Yes 2) No
D8. How often do you have difficulty remembering to take all your blood pressure medication?	1) Never/rarely 2) Once in a while 3) Sometimes 4) Usually 5) All the time

E. Composite measure of PHYSICAL FUNCTION

Now, I would like to ask about your physical function to understand whether you experienced any difficulty or needed help to do daily activities or chores **in the past month.**

	No help with no difficulty	**Difficulty**	**Help needed**
During the past month, did you need help with…			
E1. Bathing?			
E2. Personal grooming?			
E3. Dressing			
E4. Feeding?			
E5. Getting from a bed to a chair			
E6. Using the toilet?			
E7. Walking across a small room?			
E8. During the past month, did you get to places out of walking distance?			
E9. During the past month, did you go shopping for groceries?			
E10. During the past month, did you prepare your own meals?			
E11. During the past month, did you do your own housework?			

	Yes	No	
E12. During the past month, have you as a result of physical health accomplished less than you would like?			
E13. During the past month, were you as a result of your physical health limited in the kind of work or other activities?			
E14. During the past month, have you had any problems with your work or other regular daily activities as a result of your physical health?			
	Yes, a lot	**Yes, a little**	**Not at all**
E15. Does your health now limit you in moderate activities?			
E16. Does your health now limit you from climbing several flights of stairs?			

Now, I would like to know whether you have any trouble getting food.

F. Food security (2-item)

F1. **Within the past 12 months**, we worried whether our food would run out before we got money to buy more.

- □1 Often true
- □2 Sometimes true
- □3 Never true
- □4 Don't know or Refused

F2. **Within the past 12 months**, the food we bought just didn't last and we didn't have money to get more.

- □1 Often true
- □2 Sometimes true
- □3 Never true
- □4 Don't know or Refused

G. Perceived FV accessibility

G1. How easy or difficult is it for you to get fresh produce (fruits and vegetables)?

1) Very difficult 2) Somewhat difficult 3) Somewhat easy 4) Very easy

Thinking about where you go to buy most of your groceries, please tell us how far you travel and how long it takes:

G2. For groceries, I travel about (_____) miles and it usually takes about (_____) minutes

G3. What is the most typical way you travel to the store for your groceries?

1) I drive my own car
2) I ride with a friend and family member
3) I take the bus
4) I take a taxi
5) I walk or ride my bicycle
6) Other

G4. Do you own a car? 1) Yes 2) No

Think about your neighborhood as the area within a 20 min walk or about a mile from your home and answer the following questions.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
G5. It is easy to buy fresh fruits and vegetables in my neighborhood					
G6. There is a large selection of fresh fruits and vegetables in my neighborhood					
G7. The fresh fruits and vegetables in my neighborhood are high quality					

H. Self-care activity level effects (H-Scale)

Medication Usage	How many of the past 7 days did you: from 0-7 days		
H1	Take your blood pressure pills?	days	
H2	Take your blood pressure pills at the same time every day?	days	
H3	Take the recommended number of blood pressure pills?	days	
Low-salt Diet	How many of the past 7 days did you…from 0-7days		
H4	Follow a healthy eating plan as prescribed by a physician?	days	
H5	Eat potato chips, salted nuts, or salted popcorn?	days	
H6	Eat smoked meats or smoked fish?	days	
H7	Eat salted vegetables	days	
H8	Eat ≥5 servings of fruits and vegetables?	days	
H9	Eat store-bought or packaged bakery goods?	days	
H10	Salt your food at the table?	days	
H11	Add salt to food when you're cooking?	days	
H12	Avoid eating fatty foods?	days	
Physical Activity	How many of the past 7 days did you…from 0-7days		
H13	Do at least 30 minutes total of physical activity?	days	
H14	Do a specific exercise activity (such as swimming, walking, or biking) other than what you do around the house or as part of your work?	days	
Smoking			
H15	**Are you currently smoking?**	**Yes**	**No**
H16	If yes, how many of the past 7 days did you smoke…from 0-7 days	days	

I. 15-item FFQ

You are doing a great job! Now, I am going to ask about your diet. For example, how often you eat each food group.

I1. How often do you eat vegetables (fresh, frozen, or cooked)?

1) Twice a day or more often
2) Once a day
3) A few times a week
4) Once a week or less

I2. How often do you eat fruit and/or berries (fresh, frozen, preserved, juice, etc.)?

1) Twice a day or more often
2) Once a day
3) A few times a week
4) Once a week or less

I3. How often do you eat nuts (almonds, peanuts, hazelnuts, pistachio nuts, pine nuts, walnuts, cashews)?

1) Twice a day or more often
2) Once a day
3) A few times a week
4) Once a week or less

I4. How often do you eat fish or shellfish?

1) Three times a week or more often
2) Twice a week
3) Once a week
4) A few times a month or less

I5. How often do you eat red meat (beef, pork, or game)?

1) Three times a week or more often
2) Twice a week
3) Once a week
4) A few times a month or less

I6. How often do you eat white meat (poultry e.g. chicken)?

1) Three times a week or more
2) Twice a week
3) Once a week
4) A few times a month or less

I7. How often do you eat buns/cakes, chocolate/sweets, crisps, or soda/juice?

1) Twice a day or more often
2) Once a day
3) A few times a week
4) Once a week or less

I8. How often do you eat breakfast?

1) Every day
2) Almost every day
3) A few times a week
4) Once a week or less

I9. How many slices/pieces of bread do you eat per day in total?

1) I don't eat bread

Number of slices/pieces _____

I10. What type(s) of bread do you eat?

1) White bread
2) Whole wheat bread (labeled as high-fiber, low fat, and low sugar)
3) Crispbread
4) Other, please specify

I11.How often do you drink/eat milk, sour milk, and/or yogurt?

1) Twice a day or more often
2) Once a day
3) A few times a week
4) Once a week or less

I12.What type of milk, sour milk, and/or yogurt do you usually drink/eat?

1) Whole / full fat (3%)
2) Semi-skimmed / reduced fat (1.5%)
3) Skimmed / low fat (0.5%) or non-fat (0.1%)

I13. What kind of spread do you usually use on sandwiches?
Select *one* option, the one you usually use.

1) Butter
2) Spread containing 75% fat
3) Margarine
4) Spread made with seed and plant oils containing 70% fat
5) Low-fat margarine containing 30-40% fat
6) Margarine with plant sterols
7) I don't use spread on sandwiches
8) I don't know

I14. What kind of fat do you usually use for cooking at home?
Select *one* option - the one you usually use.

1) Butter
2) Margarine containing 60-80% fat
3) Cooking margarine
4) Margarine made with seed and plant oils
5) Liquid margarine
6) Vegetable oil, e.g. rapeseed oil, olive oil, corn oil, sunflower oil
7) I don't use fat in cooking
8) I don't know

I15. Do you usually add salt to your food?

1) No
2) Yes, sometimes
3) Yes, often
4) Yes, I always add salt before I taste the food

I16. Do you consciously avoid salty foods?

1) No
2) Yes

I17. Have you followed any diet during the past year?

1) No
2) Yes

I18. If yes, which one (s)?

	All the time	In periods	Currently
LCHF (low carbohydrate, high fat) or The Atkins Diet			
The GI diet			
Weight Watchers			
The Mediterranean Diet			
Low-calorie meal replacement powders/bars			
Other**,** state which one:			

J. HELM KNOWLEDGE Scale

Mark your answers to the following questions.

	True	**False**	**Uncertain**
J1. A blood pressure reading of 140 over 90 or higher is considered high blood pressure.			
J2. High blood pressure is especially dangerous because it often has no warning signs or symptoms.			
J3. High blood pressure can cause heart failure.			
J4. Once high blood pressure develops, it usually lasts a lifetime.			
J5. High blood pressure can cause kidney disease.			
J6. A person who has high blood pressure should eat more fruits and vegetables.			
J7. Exercise can lower a person's blood pressure.			
J8. Most of the salt Americans eat is added with a salt shaker.			

K. Newest Vital Sign

Now, I am going to show you an ice cream label. Please check this nutrition label and answer the questions. (Please give the nutrition label on the last page to a participant)

K1. If you eat the entire container, how many calories will you eat? **Answer:** _____

K2. If you are allowed to eat 60 grams of carbohydrates as a snack, how much ice cream could you have? **Answer**: _____

K3. Your doctor advises you to reduce the amount of saturated fat in your diet. You usually have 42 g of saturated fat each day, which includes one serving of ice cream. If you stop eating ice cream, how many grams of saturated fat would you be consuming each day?
Answer: _____

K4. If you usually eat 2,500 calories in a day, what percentage of your daily value of calories will you be eating if you eat one serving? **Answer:** _____

K5. Pretend that you are allergic to the following substances: penicillin, peanuts, latex gloves, and bee stings. Is it safe for you to eat this ice cream? **Yes** _____ **No** _____

K6. (Ask only if the patient responds 'no' to question K5). Why not?
Answer: _____

L. GDS-5/15: Weeks et al. 2003

Over the last 2 weeks, how often have you been bothered by any of the following problems?

	No	**Yes**
L1. Are you satisfied with your life?	**1**	0
L2. Do you often get bored?	☐ 0	☐ 1
L3. Do you often feel helpless?	0	1
L4. Do you prefer to stay home rather than going out and doing new things?	☐ 0	☐ 1
L5. Do you feel pretty worthless the way you are now?	0	1
Score GDS- 5	_____	
A score of 2 or more on GDS-5? Please continue with the remaining 10 questions:		
L6. Have you dropped many of your activities and interests?	☐ 0	☐ 1
L7. Do you feel that your life is empty?	☐ 0	☐ 1
L8. Are you in good spirits most of the time?	☐ **1**	☐ 0
L9. Are you afraid that something bad is going to happen to you?	☐ 0	☐ 1

	No	Yes
L10. Do you feel happy most of the time?	□ **1**	□ 0
L11. Do you feel you have more problems with memory than most?	0	1
L12. Do you think it is wonderful to be alive now?	□ **1**	□ 0
L13. Do you feel full of energy?	**1**	0
L14. Do you feel your situation is hopeless?	□ 0	□ 1
L15. Do you think that most people are better off than you are?	□ 0	□ 1
Score GDS-15 =	_____	

Now, we are almost getting there!

M. Plant-based diet questions

I will now ask you questions about plant-based diets. First, we will go over the definition of a plant-based diet. There may be other definitions you may have heard of, but please use the following definition to answer the questions.

Definition of a plant-based diet: An eating pattern dominated by fresh or minimally processed plant foods and decreased consumption of meat, eggs, and dairy products. Compared to meat-centered diets, it involves increased consumption of a variety of grains (including whole grains), fruits, vegetables, legumes, nuts, and seeds. This does not necessarily mean a vegetarian diet (Lea, 2006).

M1. Which statement best describes your dietary practices:

1) No restrictions - eats meats, vegetables, fruits etc., except for food allergies (Omnivore)
2) Eats fish, but no other meats and eats all other foods, except for food allergies (Pescatarian)
3) Does not eat meat, but may eat dairy products and eggs (Vegetarian)
4) Does not eat meat, dairy, or eggs (Vegan)
5) Mostly eat plant-based, but occasionally consumes meat (Flexitarian)
6) Other _____

M2. Please indicate if you Agree, are Not sure, or Disagree with the following statements:

	Agree	Not sure	Disagree
1. You cannot get enough protein on a plant-based diet.			
2. Processed foods are avoided in a plant-based diet.			
3. Dairy is encouraged in a plant-based diet.			
4. Animal foods are limited from a plant-based diet.			
5. Oil is encouraged in a plant-based diet.			

	Agree	Not sure	Disagree
6. Complex carbohydrates are discouraged in a plant-based diet.			
7. Nuts are high in protein.			
8. Dark green leafy vegetables are high in iron.			
9. Vitamin B12 is a nutrient that must be monitored closely in a plant-based diet.			
10. The best source of calcium is milk.			
11. Omega-3 fatty acids cannot be obtained from plant-based foods.			
12. A plant-based diet can prevent and treat many chronic diseases such as hypertension, type 2 diabetes, and some cancer.			
13. Animal proteins are the only quality protein sources.			
14. A plant-based diet is a safe and health-promoting diet.			
15. Fish is a necessary part of a healthful diet.			

M3. Have you heard of a plant-based diet before today?

1) Yes 2) No

M4. Please answer the following questions:

	Yes	No	Maybe
Would you be willing to follow a plant-based diet (limited to no animal products) for a week for health purposes?			
Would you be willing to follow a plant-based diet (limited to no animal products) for 3 weeks for health purposes?			
Would you be willing to follow a plant-based diet (limited to no animal products) for 6 months or longer for health purposes?			

M5. Thinking about what might prevent you from switching to a plant-based diet, please choose how much you agree or disagree with the following statements:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1. I don't want to change my eating habit or routine.					
2. I need more information about a plant-based diet.					
3. Someone else decides on most of the food I eat.					
4. I don't want to eat strange or unusual foods.					
5. There are not enough plant-based choices when I eat out.					
6. My family/partner won't eat a plant-based diet.					
7. I would get indigestion, bloating, gas or flatulence from plant-based foods.					
8. I think humans are meant to eat lots of meat.					

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
9. It would be too expensive to eat a plant-based diet.					
10. Eating meat is too enjoyable to limit for a plant-based diet.					

M6. Thinking about the benefits of a plant-based diet, please choose how much you agree or disagree with the following statements:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1. Eat more fiber					
2. Decrease my saturated fat intake					
3. Prevent disease in general (e.g. heart disease, cancer)					
4. Have lots of vitamins and minerals					
5. Eat a more 'natural' diet					
6. Stay healthy					
7. Control my weight					
8. Improve my digestion					
9. Eat a greater variety of foods					
10. Be fit					

M7. Choose the statement that best fits your preference.

1) I am not thinking about eating a plant-based diet.
2) I am thinking about eating a more plant-based diet ... planning to start within 6 months.
3) I am definitely planning to eat a more plant-based diet in the next month.
4) I am trying to eat a more plant-based diet now.
5) I am already eating a plant-based diet. (_____years _____months eating a plant-based diet)

Participants should **remove their shoes** for height and weight measurements.

C15. **Measured weight** _____lbs

C16. **Measured height** _____ ft _____inches or _____cm

THE END - THANK YOU FOR YOUR PARTICIPATION!

Nutrition Facts

Serving Size	½ cup
Servings per container	4

Amount per serving			
Calories	250	Fat Cal	120
			%DV
Total Fat	13g		20%
Sat Fat	9g		40%
Cholesterol	28mg		12%
Sodium	55mg		2%
Total Carbohydrate	30g		12%
Dietary Fiber	2g		
Sugars	23g		
Protein	4g		8%

*Percentage Daily Values (DV) are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Ingredients: Cream, Skim Milk, Liquid Sugar, Water, Egg Yolks, Brown Sugar, Milkfat, Peanut Oil, Sugar, Butter, Salt, Carrageenan, Vanilla Extract.

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