ABSTRACT

Title of Dissertation: DIET, FOOD SECURITY, SOCIAL RELATIONSHIPS AND DEPRESSIVE SYMPTOMS IN HOMEBOUND OLDER ADULTS IN THE UNITED STATES AND THEIR IMPACT ON HEALTHCARE UTILIZATION

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Background: Homebound older adults may be at an increased risk for malnutrition and social isolation, posing a potential threat to them aging in their communities and increasing healthcare cost. The Nutrition Service Program under Older Americans Act (OAANSP) was established to support older adults aging in place by delivering meals and providing nutrition-related services.

Aims: 1) Examine diet quality of home-delivered meal (HDM) recipients; 2) examine direct and indirect associations between social relationships, depressive symptoms, food insecurity (FI) and diet quality; and 3) examine direct and indirect associations between social relationships, FI, diet quality and hospitalization.

Methods: Data obtained from OAANSP Outcomes Evaluation study included: 1) client outcomes survey, 2) two 24-hour dietary recalls, and 3) Medicare healthcare utilization data. Dietary recalls examined diet quality by calculating 1) population-level mean HEI scores; and 2) usual vegetable and protein intakes. Diet quantity was compared to Dietary Guidelines for Americans 2010 (DGA), and structural equation modeling was used to examine direct and indirect relationships.

Results: HDM recipients and controls have high prevalence of FI, 22.4% and 16.5%, respectively. HDM recipients who did not receive a meal on day of dietary recall (no-meal recipients) had significantly poorer diet quality than HDM recipients who received a meal (meal recipients) that day and control group. Quality of overall diet for meal recipients, no-meal recipients and controls did not meet recommendations for several food groups/nutrients. Compared to DGA, HDM and complementary foods were low in whole grains, dairy, fiber, and surpassed upper limit of consumption for saturated fats, refined grains, sodium and added sugar. High FI was associated with greater depressive symptoms and lower usual vegetable intake in control group. Additionally, high FI was associated with lower usual protein intake in HDM

recipients and controls. Both groups were at high risk for protein insufficiency, which was associated with greater hospitalization in the control group.

Conclusions: HDM recipients and controls have high prevalence of FI, poor diet quality, and insufficient protein intake. Increasing funding for OAANSP can allow program expansion and improvement of HDM. Validated tools to examine social relationships and additional contributors to FI are needed.

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By

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Dedication

To my backbone, Mom and Dad, I am grateful for you every single day, and to my beloved sister and friend, Fadwa, I long to be reunited with all of you.

Acknowledgements

If it were up to me, this section would be many more pages. This is where I get to pour my heart, six years, in one page. "*It takes a village*" is how my friend, Kareshma, would often refer to getting through a PhD.

I'd like to start by thanking my committee members for their valuable input throughout this journey. I thank my advisor, Dr. Sahyoun who has agreed to take me on as a student during unsteady times of my PhD. She introduced me to a new population, older adults, which has grown and evolved over the past six years, to become a passion of mine. Dr.Sahyoun is very passionate about what she does and was extremely patient with me throughout this process. I learned a lot from her, and I am indeed thankful.

I'd like to also individually thank other committee members; Dr. Song, a fellow JHSPH alumni, who has always treated me as a soon-to-be colleague, with a great deal of kindness and respect. Dr. Jenkins, who showed much appreciated enthusiasm for my ideas, and was very responsive to my many questions on the dataset; Dr. Lemay, who had to deal with a lot of psychology ignorance initially, but very willingly engaged in stimulating conversations that offered a lot guidance. I thank you for making sure that the work I did was scientifically sound and respectable in the psychology field. Last, but by no stretch of the imagination least, is Dr. Hancock, the Superman behind this project. I took his SEM class, and quickly became interested in structural equation modeling, determined to explore that method as one of my statistical analysis techniques. He is a well-deserving distinguished teacher who generously gave many hours of his time to guide, explain and support me, very kindly and patiently. To all of you; I look forward to working with you on publishing my dissertation findings and collaborating further in the future.

I thank my small family; my mother, father and sister, they endured a lot. I can't thank them enough! I am here today because they believed in me, supported me in every way, and waited eagerly for me at the finish line.

A heartfelt thank you for my friend and colleague, Edwina Wambogo, for all the help and support that she has provided. I'd also like to thank Sara Kao, the Assistant Director of our Department, whose open-door policy, and unwavering assistance saved many PhD students to date, me included. I'd like to thank my colleagues Anna Vaudin and Olfat Sheikomar for their support and Dr.Ugahodora for adopting me as a Teaching Assistant for four plus years. As for *My Village*, endless thanks go to Kareshma Mohanty, my unwavering support and the single cheerleader on duty. Offering many hugs of support and love and reminding me to be kind to myself. Swetha Manohar, the voice of reason, wisdom, and everything sane. Offering tough love when needed, but providing the dark humor and subtle sarcasm that got me through "it", including her promise of a PhD trip to the Czech Republic. And a grateful thank you note for The Manohars, who cheered me on from a distance…and Connie Hoe, who I counted on for joy and laughter. Thanks to the many village members who provided support, forgave me for putting the PhD first on many of those social nights. And a special thank you to the most recent member of this village, Matt Ragan, who made this past year happier for me in many ways.

And, of course, the BAC, my solid circle of friends from home who had to listen to my voice messages and texts almost daily, for six years, with words like 'structural equation modeling' but still didn't give up on getting their friend back one day. This day may be near.

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List of acronyms

AAA	Area Agencies on Aging
ACL	Administration for Community Living
ASA-24	Automated Self-Administered 24-hour
CMS	Centers for Medicare and Medicaid services
CNPP	Center for Nutrition Policy and Promotion
DGA	Dietary Guidelines for Americans
DRI	Dietary Reference Intake
ED	Emergency Department
FI	Food insecurity
HDM	Home-delivered meals
HEI	Healthy Eating Index
HFSSM	Household Food Security Survey Module
HPA	Hypothalamic-pituitary adrenal
kcal	kilocalories
LSP	Local Service Providers
OAA	Older Americans Act
PHQ-2	2-item Patient Health Questionnaire
PUFA	Polyunsaturated fatty acids
MUFA	Monounsaturated fatty acids
NCI	National Cancer Institute
NSP	Nutrition Service Program
RMSEA	Root mean square error of approximation
SEM	Structural equation modeling
SFA	Saturated fatty acids
SoFAS	Solid fats, alcohols, and added sugars
SRMR	Standardized root mean square residual
SUA	State Units on Aging
UCLA	University of California, Los Angeles
USDA	United States Department of Agriculture

Chapter 1: Introduction

In 2011, the oldest of the Baby Boomer Generation turned 65 years old. Since then, that generation has been a major contributor to the changes seen in the country's population pyramid. Together with the increase in average life expectancy and continued advancements in medical research, the contribution of this age group to the population has reached an all-time high, and will only continue to increase, outnumbering children under 18 years by 2034. As of now, older adults represent almost 15% of the population, and are forecasted to constitute approximately 21% of the United States inhabitants by the year 2030 (1).

This growing older adult population is reflected in healthcare utilization and costs, which are forecasted to increase 5.5% per year (2). Older age is disproportionately responsible for 36% of healthcare cost (3), leading to research on ways to curtail spending. One way to do that is by assisting older adults to age in their environments and remain in their homes.

It is anticipated that the foreseen growth of the older population will be coupled with an increase in the homebound population. Homebound older adults are commonly older, sicker, have more functional limitations, and are at higher risk for malnutrition and social isolation (4, 5). This population has higher rates of hospitalization, emergency department visits and institutionalization. In fact, homebound older adults are among the top 5% utilizers of healthcare (6). Despite these vulnerabilities, homebound older adults are often an overlooked population (7).

Food and nutrition adequacy and social relationships are some of the modifiable risk factors that can support the health and well-being of older adults, helping them age-in-place. The burden on vulnerable homebound older adults is twofold; their homebound status and socioeconomic disadvantage, putting them at high risk for food insecurity (FI), poor diet quality

and social isolation (8, 9). Promoting a healthy and adequate diet and preventing social isolation may help decrease hospitalization and hospital stay, decrease readmission and delay or prevent institutionalization (10-13). In 1965, the Older Americans Act (OAA) was enacted to provide an array of home and community-based services for older adults in an effort to support a dignified aging process and decrease institutionalization (14). As part of this legislation, Title III-C: Nutrition Service Program (referred to as OAANSP thereafter) provides nutrition services for older homebound men and women (over 60 years old), targeting those with the greatest need for food assistance; minorities, lower socioeconomic status, those with limited English proficiency and rural residents (15).

The program serves meals in congregate settings (congregate meals) and delivers meals to home-bound older adults (home-delivered meals; HDM). Funding for the OAANSP has decreased from FY 2010 to FY 2019 (16). Limited published research on the impact of the program on the health of participants is partially to blame for the gaps in funding. The goal of this dissertation is to examine FI, diet quality, aspects of social relationships, and depressive symptoms in vulnerable homebound older adult participants and non-participants of the HDM program and how these factors could potentially contribute to healthcare utilization.

Chapter 2: Literature Review

2.1. Aging-in-place and homebound older adults

Individuals have a strong sense of connection to their homes, both the physical space and the neighborhood (17). Nearly 90% of the growing population of older men and women would rather age-in-place (18), and consider it to be an important element of their life satisfaction (19). Aging-in-place refers to "the ability to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level" (20, 21). The functional decline that sometimes accompanies the aging process can be a great threat to independence. Functional limitations are highly prevalent in homebound older adults, threatening their ability to age-in-place (22).

Medicare describes two criteria for considering a person homebound. The first criterion is if, as a result of illness or injury, the person needs the assistance of supportive devices (such as crutches, canes, wheelchairs, and walkers), the usage of special transportation, or the help of another individual in order to leave his/her home, or if there is a contraindication for leaving one's place of residence as a result of a medical condition. The second criterion is if the person has an inability to leave their home, and leaving it requires considerable and taxable effort (23).

The ability of homebound older adults to age in their communities may be further complicated by challenges that face this population, such as nutritional risk, social isolation and depression (9, 24, 25). However, policy makers have recognized the fiscal advantages of having older adults age in their communities and passed, in 1965, the Older Americans Act legislation by providing a range of home and community-based services, such as meals-on-wheels, in-home, transportation and legal services, elder abuse prevention and caregivers support for adults 60 years and older (26).

2.2. Older Americans Act: Title III-C Nutrition Service Program

The OAANSP was established in 1972 to support older adults to stay in their communities (27). It is administered by the Administration for Community Living's' (ACL) Administration on Aging (AoA), which is the federal body concerned with older adults. The goal of the AoA is to maintain and promote the dignity and independence of the older adult population, allowing them to age in place. The purpose of the OAANSP is to 1) decrease hunger and FI; 2) promote socialization; and 3) support the health and wellbeing of older adults by providing access to nutrition and other disease prevention and health promotion services to prevent or delay the onset of adverse health conditions (28).

2.2.1. Target population and meals provided

The OAANSP targets older individuals with the highest economic or social need, especially those living in rural or low income-settings, minorities and older adults at high risk of institutionalization and social isolation (29). Risk factors for institutionalization in older adults include advanced age, ethnic minorities, having lower socioeconomic status and older adults suffering from depression, chronic diseases and functional limitations (30, 31). The services of the OAANSP are not means tested, which means that the older person's income or resources do not determine their eligibility for services. However, the program recommends a monetary contribution and individuals will donate money according to their means but they cannot be denied any of these services if they choose not to offer such donations (14).

The OAANSP provides meals and a range of nutrition-related services such as nutrition education, screening, assessment, and counseling. The meals provided are either congregate meals (CM), which are offered at senior centers, community centers, schools, churches and adult day care centers, or home-delivered meals (HDM; commonly known as 'Meals on Wheels'),

which are delivered to homebound older adults (4). The OAANSP providers are required to offer at least one meal per day, five or more days every week (less frequency is allowed in rural areas). Meals provided should comply with the most recent Dietary Guidelines for Americans (DGA) and must provide at least of one-third of the Dietary Reference Intakes (DRIs) (32, 33). The DGA are evidence-based nutritional advice developed every five years by the Department of Health and Human Services and the US Department of Agriculture, which provides information and guidance on healthy eating patterns for Americans aged two years and older, and serves as the foundation for crucial nutrition policies and programs in the United States (34). The DRIs are a set of reference values developed by the Food and Nutrition Board of the Academy of Medicine (previously known as the Institute of Medicine) of the National Academies of Sciences, Engineering, and Medicine (also known as NASEM or the National Academies), which are used to plan and assess nutrient intakes of healthy people in the U.S. (35).

2.2.2. Organizational flow and the National Aging Network

The nutrition services are planned and administered under the authority of the State Units on Aging (SUA), which are state-level agencies located in each of the 50 states, the District of Columbia, Guam, Puerto Rico, American Samoa, the Mariana Islands, and the Virgin Islands. Together with the Area Agencies on Aging (AAA), SUA provide support to the OAANSP operations. The AAAs can be the direct providers of the OAANSP, or, more commonly, contract local service providers (LSP), which can be for profit or nonprofit or public providers. AAAs can also be private or non-profit agencies, and represent a specific geographic location (city, a single county, or a multi-county district). Together, these organizations and agencies make up the National Aging Network (**Figure 1**), which is one of the U.S.'s largest network of providers of community- and home-based services for older individuals and their caregivers (32, 36).

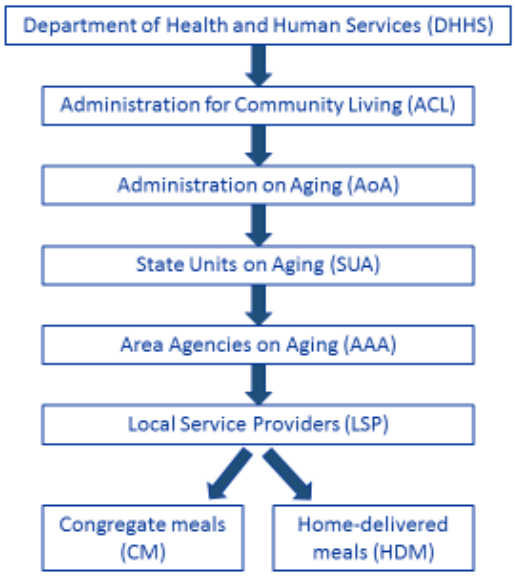


Figure 1. A simplified organizational flowchart of the Nutrition Service Program under the Older Americans Act depicting the National Aging Network.

2.2.3. Funding

The OAANSP is the largest OAA program providing meals and other nutrition services to older adults, representing 72% of Title III-OAA funding. State, local, and private funding sources supplement the federal OAA funds for these services. The annual funding of the OAA has declined over the 10-year period from 2.33 billion dollars in FY2010 to 2.09 billion dollars in FY2019 (unadjusted for inflation) (16). One of the major arguments for the deficient funding is the scarcity of evidence of the impact and effectiveness of the OAANSP on saving money in the long-term. The reauthorization of the OAANSP that occurred in 2006 congressionally mandated the conduct of an evidence-based evaluation study (37). This OAANSP Outcomes Evaluation Study (referred to as the Outcomes Evaluation Study thereafter) was only the second one conducted since the inception of the program. The study was intended to (1) assess the program's impacts on the nutrition, health and well-being, socialization, and FI of HDM and CM

recipients; (2) conduct a program cost analysis; and (3) evaluate the process of implementation at the state and local levels (38).

2.3. Nutrition of older adults

Malnutrition among older adults is an important risk factor for the loss of independence, hospitalization and institutionalization (39, 40), especially in homebound older adults (41). It encompasses the low or excess intake of nutrients, known as under- and over-nutrition, respectively (42). Older adults are at a higher risk of macro and/or micronutrient deficiency due to the decreased consumption, absorption and utilization of nutrients (43). While there is a normal overall decrease in energy requirements in older adults, this does not correspond to a decrease in the requirements of other nutrients. Satisfying the nutritional needs of the older population to maintain proper and adequate body functions then becomes a challenge and nutrient density of food becomes essential (42).

In addition to the natural decline in calorie needs, there are other various causes that result in lower dietary intake in older adults. These causes include physiological (e.g. anorexia), physical (e.g. physical disabilities), psychological (e.g. depression) and social factors (e.g. FI and isolation) (44). However, FI and social factors are among the potentially modifiable factors that put older adults at high risk of nutritional deficiencies and adverse health consequences, and thus, are the focus of the OAANSP.

2.3.1. Food insecurity

FI exists when "people do not have adequate physical, social or economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (45). Indeed, FI has been shown to negatively impact diet quality (46, 47). It is particularly problematic in the older vulnerable population and is significantly

associated with poorer health outcomes, depression, and limited activities of daily living (8). This is not surprising since older adults enrolling in the HDM programs are more likely to be women, living alone, financially disadvantaged, less educated and with more chronic diseases; many of the same risk factors for FI (48-50). Yet, the literature examining FI in homebound older adults is limited, and the existing literature often examined FI in specific subpopulations of homebound older adults (such as diabetics and recently discharged patients) (51, 52). The first Outcomes Evaluation Study conducted in 1993-1995; and much of the limited, subsequent literature showed that the provision of meals to this target older adult population improved FI in OAANSP participants (50, 53-56).

2.3.2. Diet quality

Poor diet quality is prevalent in homebound older adults (57), which in turn, has been shown to increase disability in the homebound population even further (58). In addition, malnourished older adults have an increased susceptibility to infections and non-infectious diseases (e.g. respiratory failure and cardiac arrest) highlighting the role of nutrition in morbidity, mortality and hospital costs (13). Although malnutrition may be an outcome of multiple factors, FI is one of the risk factors that inevitably leads to poor dietary intake.

To assess diet quality, the Healthy Eating Index (HEI) is a commonly used summary measure tool developed by the U.S. Department of Agriculture's (USDA) Center for Nutrition Policy and Promotion (CNPP) and the National Cancer Institute (NCI) in accordance with the DGA (59). The HEI is composed of adequacy components that individuals are encouraged to eat, and moderation components, that individuals are advised to consume less. In 2012, during the design of the second Outcomes Evaluation Study, HDMs were planned using the 2010 DGA, which are also the basis for the HEI-2010. In 2015, an update of the HEI was released. The HEI-

2010 and HEI-2015 are similar, except that, in the latter, dark green vegetables and legumes replaced greens and beans in the adequacy components group, and added sugars and saturated fats replaced the empty calories in the moderation component (60, 61). In our study, dietary intake of participants was assessed using the HEI-2010 and was compared to the HEI-2015.

Earlier studies of older adults on meal programs indicate that they are at higher nutritional risk, and that HDM programs did in fact, improve their nutritional intake (50, 53, 55, 62-64). However, in a literature review of the impact of HDM on diet and nutrition in OAANSP participants, most studies examined specific subpopulations (such as diabetic or hypertensive older adults) (56). Additionally, few studies examined foods that were consumed in addition to the HDMs (65). The ultimate goal of the OAANSP is to maintain and support community dwelling older adults. And while it is useful to evaluate the contribution of the HDM to recipients' diet, it is of equal importance to understand the food that HDM recipients select to complement their OAANSP meals (65). This includes what foods recipients consume in addition to the HDM on days when a meal is received (referred to as complementary foods thereafter), and what they consume on days when they do not receive HDMs (e.g. weekends). According to the second Outcomes Evaluation Study, 71% of HDM recipients received five meals or more (4). The 1993-1995 evaluation and the recent Outcomes Evaluation Study both showed that HDM provide more than one third of daily caloric requirements (4, 66). However, to our knowledge, the only study that specifically explored food other than that provided by the HDM, albeit dated, showed that individuals do not consume enough nutrients to supplement the meals received (67). Understanding how older adults complement the HDM would offer further leads into whether one meal is sufficient to support older adults in their consumption of a healthy overall diet.

2.3.3. Protein intake, health outcomes and aging-in-place

Several studies showed that low protein intake is associated with a loss of lean muscle mass, sarcopenia, and frailty (68-72) with subsequent negative impact on maintaining independence (73, 74). Ethnic minorities, people in residential care (compared to community-living) and those of lower socioeconomic status were shown to be significantly at risk of frailty (73), which is the same population at risk of FI. With homebound older adults being more frail (7), and at risk of FI, it is important to understand the relationship between FI and protein intake in this population.

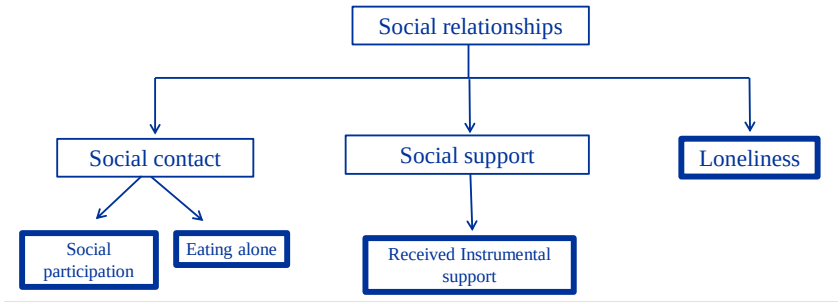
Most studies that examined protein intake in older adults included select populations (such as critically ill patients), and/or focused on outcomes such as sarcopenia, frailty, falls (68-80) rather than overall healthcare utilization. And while evidence suggests that homebound older adults receiving HDMs are almost three times more food insecure than the national average for older adults (4), have a poor diet quality (81), and have increased healthcare care utilization, the relationships between food insecurity, protein intake and hospitalization has not been previously explored in this population.

2.4. Social relationships in older adults

Social well-being is as important as physical well-being for older adults (82). In fact, health is defined as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (83). Close social ties and relationships that offer support have been proposed to have immunological benefits (84). Furthermore, the lack or deficiency of social relationships has been associated with increased hospitalization, institutionalization and healthcare cost (11, 12, 85). Studies showed that older adults place emphasis on their social relationships, identifying them as an important aspect of their aging experience (82, 86). In fact,

some of the most frequently used services that older individuals seek as they age, to assist them in living independently, are social services (such as homecare, social activities and personal calls from a network of older adults designed to prevent social isolation) and meal provision (87). A systematic review of the literature provided further evidence to support the positive impact of interventions that incorporate both social and nutrition aspects (88). Meals can also serve as an important social function for many, especially older adults (89-91). Therefore, social factors have gained importance as potentially modifiable risk factors for malnutrition in the older adult population. Yet, evidence suggests that more than 40% of older adults feel lonely and approximately one quarter are socially isolated (92).

However, there is a lack of consensus on the definition of social isolation, and the constructs subsumed within the concept of social isolation (93). Early attempts defined social isolation as the loss of social attachment and community ties (94). More recent research attempted to capture the quantity, quality and structure of the social networks that one has, and an appraisal of these social relationships (95). Social relationships can have different and independent relationships with food security and diet quality (96-99). Some constructs of social relationships may also influence each other, further complicating our understanding of their relationship with diet quality and health (100-102). In this dissertation, we will examine the relationships between some constructs of social relationships; social participation, eating alone and received instrumental social support; and the perceived construct, loneliness with FI, dietary quality and healthcare utilization (**Figure 2**).



[1]Bold constructs indicate those used in this dissertation.

Figure 2: Visual illustration of constructs of social relationships used in this study.

Social participation refers to a person's involvement in activities that provide opportunities for interactions with others in the society or community (103). Studies have found that membership in churches, sports, and hobby groups had a positive impact on all-cause mortality (104, 105). Studies also showed that having close friends and attending religious services was associated with better diet quality (106-108). In fact, social participation ranked second among enablers that facilitate healthy eating in older individuals while food access ranked first (109). Participation in social or religious activities promotes a positive psychological state and buffers stress, which are postulated to motivate health-promoting and health-protective behavior, including the consumption of healthy diets (110-112).

Commensality, the practice of eating together may also offer an opportunity/resource for social connectedness (89). Several social phenomena influence eating behavior when individuals eat with others, such as social facilitation, , eating more in the presence of others (113), social modeling; adapting food intake according to that of the eating companion (114); and impression management, modifying one's eating behavior to create a certain impression (115-117). Commensality is often examined as an individual construct in the nutrition literature. Evidence

from a recent meta-analysis of studies examining the social facilitation of eating showed that adults ate more food when they ate with friends compared to eating alone (118). There is also evidence to suggest that eating together is associated with greater diet diversity, lower nutritional risk and higher self-reported health (119-121), however eating together has not always been associated with healthier diets (122).

Social support is considered as the resources available (or perceived to be available) to a person by way of his/her social connections (89). According to the type of function it serves, social support can be classified into; informational (information during stressful times used for problem solving), emotional (feelings of care, empathy, and love), and instrumental (goods and services providing concrete assistance to the person in need). Studies have shown a positive relationship between social support and FI, diet quality and nutritional status in older adults (107, 123, 124), however, these studies often used tools that did not separate the different types of social support (instrumental, emotional and informational). Results from studies that did examine instrumental social support are controversial (125-127). Receiving instrumental social support can alleviate the burden of FI and improve diet quality, yet, it can also denote poorer health and functional limitations, which are associated with poor quality diets (128). And so, the relationship between receiving instrumental social support, FI and diet quality may warrant further exploration in homebound older adults who have higher FI and functional limitations than the general population.

The lack of social contact or social support can trigger feelings of loneliness (129). Loneliness refers to the negative experience of feeling socially isolated that arises as a result of a discrepancy between an individual's desired and actual social relations (130). Associations between loneliness and FI, diet quality and nutritional status have been shown in the literature

(97, 131, 132). However, feelings of loneliness do not always reflect the individual's social connectedness, or received social support (133-135), as they have separate pathways to nutrition (96, 131). Hypothalamic-pituitary adrenal (HPA) axis dysregulation, impaired immune function, sympathetic stimulation and poor health practices are some of the postulated mechanisms by which loneliness influences health (136, 137). These various mechanisms, which are a response to stress, are geared towards short-term survival and threat aversion, with an inhibitory effect on appetite (138). The anxiety and negative energy balance associated with FI can further stimulate the HPA axis, possibly accentuating the impact of loneliness on diet quality (139-141). However, the potentially moderating effect of FI on the relationship between loneliness and diet quality, to our knowledge, has not been previously explored in homebound older adults.

In addition to the potential direct influence that loneliness can have on diet quality (102), loneliness is an important risk factor for depression (142). This is particularly important given that depression is highly prevalent in homebound older adults (143-145), and is often associated with FI, greater nutritional risk, poor nutritional status and/or lower diet quality (16, 24, 34, 56, 57). The feelings of inadequacy and deficiency, motivational deficit, and/or the lack of self-efficacy associated with depression have been shown to influence the initiation and maintenance of health behavior, including healthy dietary practices (146-149). In addition to the psychological mechanisms, biological changes associated with depression may affect food intake, such as the autonomic and HPA axis dysregulation (150, 151). The sympathetic overstimulation and increased corticotrophin releasing hormone resulting from overactivation of the HPA axis reduces appetite in typical depression (152). The correlations observed between depression and nutritional risk, underscore the impact of mental health on nutrition in this population (24, 50, 63, 153). Lack of social support, loneliness and FI has also been associated with depression,

however, the nature and extent of these relations have been found to be inconsistent in the older adult population (154-161). Furthermore, depressed older adults are also more likely to eat alone (162), emphasizing the complexity of the relationships between these aspects of social relationships, FI, diet quality and depression. Therefore, it is important to examine these constructs simultaneously and to understand their association, considering the vulnerable population of homebound older adults on HDM programs (133, 134, 163-167).

Recognizing the importance of the social aspect of older adults' lives in promoting health and well-being, amendments were made to the OAA in 2006, adding the promotion of socialization of older individuals as a second goal of the OAANSP. Meals served in a communal space for CM recipients provide chances for socialization, such as interacting with staff and peers during mealtimes and participating in volunteer activities. However, homebound older adults who receive HDMs may not have as many opportunities for social connectedness and therefore recipients may be more socially deprived.

Although the OAANSP includes nutritional and social components, limited research has been done to examine the social aspect of the program. This is particularly challenging for the homebound population who tend to be sicker than the general population of older adults, are at higher risk of FI (168), and are more prone to physical limitations, loneliness, depression and social isolation (144, 169). Furthermore, available studies rarely examine multiple social constructs at the same time (153, 170). The single and brief, daily interaction that HDM recipients have with the person delivering their meals may be the only direct human interaction an older adult may have for the entire day (171). In fact, there is evidence to support the importance of social contact between the person delivering meals and the homebound individual in decreasing loneliness (153). However, Osteraas and colleagues failed to see an impact of

social contact on older adults who received a HDM daily compared to those who received meals once per week (as frozen meals) (172). While homebound older adults may be less able to participate in social activities as a result of their physical limitations, being homebound does not necessarily preclude them from being engaged in their communities (173). It does, however, underscore the importance of examining social relationships in this population.

2.4.1. Social constructs' research challenges

There are numerous social constructs that can represent social relationships, and psychologists encourage examining multiple social constructs at the same time (174-176). However, the heterogeneity of operational definitions and measurement tools of the constructs discussed above may have hindered our understanding of the true relationship between social relationships, nutrition and health (95, 177-179). Operationalizing some of these constructs in the older adult population can be a challenge because, for example, getting older does not necessarily mean being socially isolated (173, 180). There is variability in the course that social relationships take as one ages. It is hard to tell to what extent loneliness, for example, is reflective of an actual loss of social contact (133). People who are socially active and surrounded by an extensive social network may still feel isolated (133). Older individuals may also be satisfied with a smaller but closer group of people, so it seems essential to understand the degree to which older adults' perceptions reflect actual social situations (180).

In the literature, there is also much variability in the use of terminology referring to certain social concepts, rendering comparisons and interpretations problematic (174). This is especially true for the increasingly popular term, social support; which is generally, any aspect of social relationships that could promote health (181). For example, some studies use the term social support to refer to emotional and financial support, marital status, close friendships, and

religious service attendance with an overlap between some of the abovementioned constructs (107).

2.5. Healthcare utilization and costs in older adults

Homebound older adults have higher hospitalization and emergency department (ED) visits, compared to non-homebound (182), and are considered one of the high-cost populations, which means that they are disproportionately responsible for a greater share of the health care costs (183). Trends in using the ED by older adults have shown a gradual increase since the beginning of this century, exceeding what would be expected from the observed population growth, representing a quarter of all ED visits (184, 185). The proportion of older adults visiting the ED who are readmitted to the hospital has also risen (185). In fact, most short-stay hospital admissions (three days or less) of older adults start in the ED, the former representing a large portion of total hospital admissions in this population (186). Hospital care represents about 33% of healthcare expenditure, the largest proportion of healthcare utilization and older adults constitute approximately 40% of hospitalized individuals (187). Hospitalization of older adults is also associated with a higher risk for institutionalization (188). Regardless of the cause of ED visits or hospitalization, discharged older adults had difficulties restoring their previous independence, and hence threatening aging-in-place (189). Institutionalization and long-term care have also been shown to be a rapidly growing sector of healthcare cost (190). Therefore, a better understanding of homebound older adults can further our understanding of the needs of this vulnerable population to continue aging-in-place and delay or prevent hospitalization.

Older adults who are malnourished or at high nutritional risk have an increased risk of hospitalization (191), and those who are malnourished at the time of admission have shown an increase in the length of stay and hospitalization costs (10). Additionally, homebound older

adults have a greater risk of being malnourished if they had been previously hospitalized (25). FI was also found to be associated with greater hospitalization and ED visits in older adults (192, 193), but studies of the homebound population are lacking (8). The burden for homebound older adults is further complicated by their increased susceptibility to social isolation (194, 195). The co-existence of social isolation and homebound status increase the risk of all-cause mortality (196). Furthermore, social participation and perceived social support were inversely associated with duration of hospital stay and hospital readmission, respectively (12, 197, 198). Loneliness in older adults was also linked to more ED and outpatient visits (199-201), yet findings were inconsistent (99, 167, 196, 197, 202-205).

Ensuring food security, a healthier diet and better social relationships can help support older adults to stay in their communities and contribute to alleviating the burden on the healthcare system. A clear understanding of the possible direct and indirect pathways between the nutrition and the social components of the HDM program and how they might impact hospitalization in older adults is of interest.

2.6. Conceptual framework

The premise of the socioecological model is that an individual's behavior is influenced by their intrapersonal characteristics and the various contextual factors related to the environment in which they live (206, 207). The socioecological model identifies the intrapersonal, interpersonal, community, organizational, and policy levels as the "spheres" from which the different factors influencing an individual's behavior emerge. The National Academy of Medicine (previously known as the Institute of Medicine) defines the socioecological model as a health model that underscores the linkages and relationships between multiple factors (or determinants) that affect health. (208).

The socioecological model was first introduced by psychologist Lewin and Bronfenbrenner in the early and mid-20th century, as a model for health promotion (209-211). The socioecological model has been widely used in the field of public health to understand health behavior as an interaction between individual and external factors (**Figure 3**) (212-215). The framework is used to examine the relative contribution of the various layers of the model in complex health and nutrition challenges and to design interventions for multilayered problems such as childhood obesity (212, 215-218). It has also been used as a framework to explore determinants of food security and healthy eating among population of older adults in the US (109, 219).

Interventions that incorporate the socio-ecological perspective framework are geared towards creating change on various levels and often referred to as multilevel interventions (220). Single level interventions, on the other hand, are mostly focused on achieving intrapersonal change, and are more abundant in the literature (220). Examining this population through a socioecological lens and understanding the linkages between the different spheres could help contextualize the various constructs involved in the diet quality of vulnerable older adults. It may also offer guidance on potential points of intervention and ways to enhance the impact of existing interventions.

The conceptual framework within the socioecological model outlines the hypothesized relationships between the two modifiable risk factors discussed above; FI and social relationships and their association with diet quality **(Figure 3)**. The social relationship's constructs examined in this dissertation are the ones collected by the Outcomes Evaluation Survey and that are believed to be associated with health outcomes. These variables which include, eating alone, loneliness and depressive symptoms may directly affect quality of dietary intake and these in

turn may be affected by social participation and received instrumental social support. In addition, food insecurity has been shown to affect dietary quality directly and, potentially moderate the relationship between loneliness, depressive symptoms and dietary quality. One of the theories postulated by which loneliness and depression exert an impact on diet quality is the neuroendocrine pathway; by overstimulation of the HPA and sympathetic nervous system, which in turn depress appetite. The relationships between all of these social constructs and health outcomes are very complex and non-linear and are depicted in Figure 3.

In this dissertation, the relationships described above are examined separately for OAANSP participants and non-participants because those who are on the program are offered support services and opportunities for socialization, in addition to the meal. In fact, OAANSP can serve as an entry point to link HDM recipients to additional resources and services available to support them. It is thus plausible that older adults who participate in the HDM program have different social relationships, food security status and diet quality than those who do not participate in the program. The potential differences in these nutritional and social constructs between program participants and non-participants may also influence the relationships with health outcomes. Therefore, the focus of this dissertation is to examine the association between two potentially modifiable risk factors; FI and social relationships and their relationship to diet quality and healthcare utilization in HDM recipients and separately in the control group.

The specific aims of this study were to:

1. Examine the dietary quality of HDM recipients and their control.
2. Examine the direct and indirect association between social relationships (social participation, eating alone, instrumental social support, and loneliness), depressive symptoms, FI and diet quality in HDM recipients and non-recipients

3. Examine the direct and indirect associations between social relationships (social participation, eating alone, instrumental social support, and loneliness), depressive symptoms, FI, diet quality and healthcare service utilization, more specifically; hospital admission and ED visits.

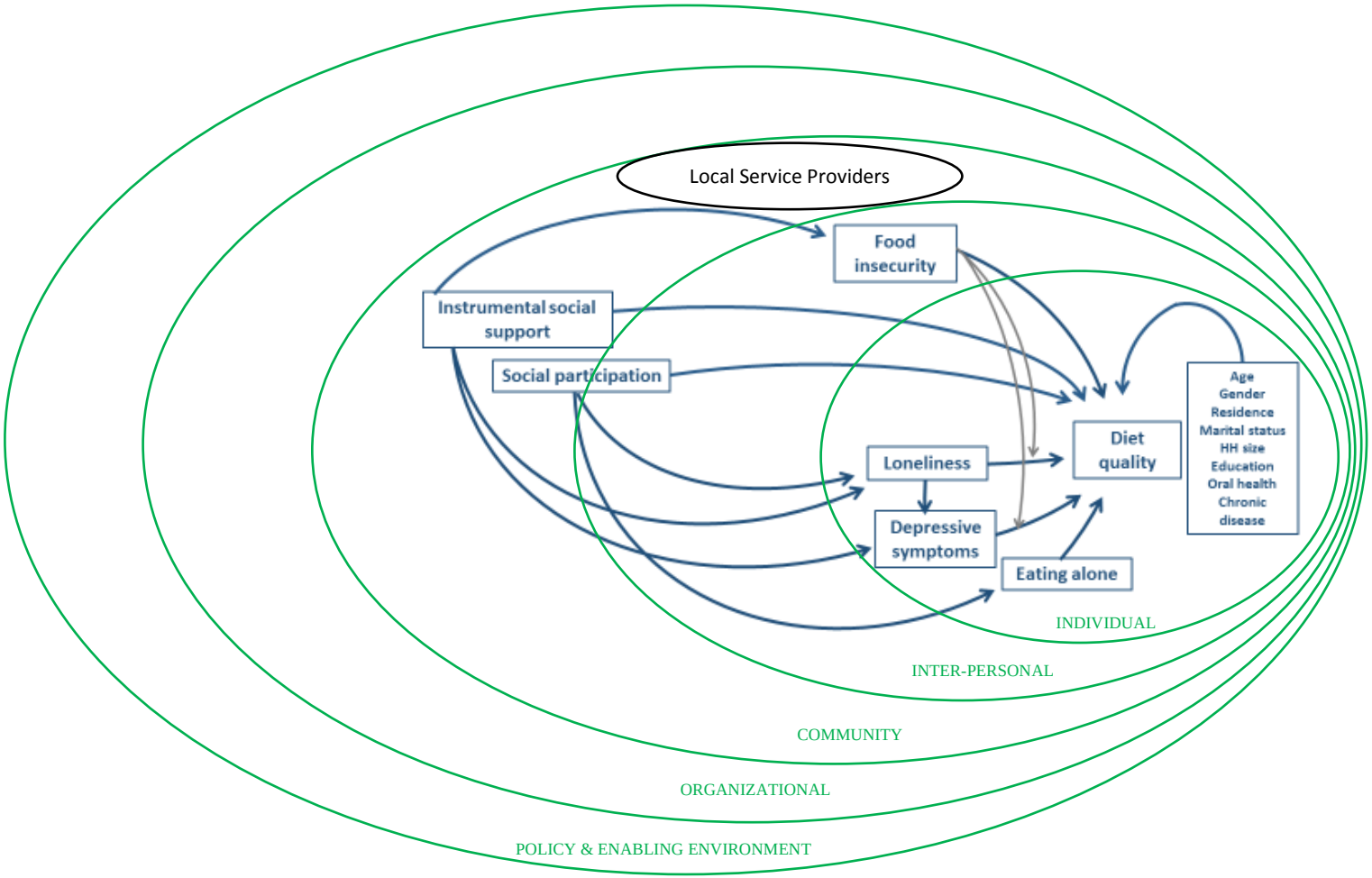


Figure 3: A multilevel conceptualization of the relationships explored between diet quality, food insecurity, instrumental social support, social participation, eating alone, loneliness, and depressive symptoms within the socioecological model, depicting the position of the local service providers (LSPs) of the HDM.

The blue arrows depict the hypothesized relationships between the studied variables, gray arrows show potential moderator effect and the green spheres represent the multiple levels of the socioecological model.

Chapter 3: Methods

3.1. Dataset and Study Population

The Outcomes Evaluation Study which was conducted from 2015 to 2017 collected data from two OAANSP populations; the CM and HDM recipients and controls, who had to be at least 67 years old in order to guarantee Medicare records for a minimum of one year (Medicare benefits begin at 65 years of age). The comparison group for the study was a matching group of non-participants (control group) that was chosen from the same geographic location as that of HDM recipients, using a list of the Centers for Medicare and Medicaid Services (CMS) beneficiaries. Individuals in the control group were then screened using a telephone interview from December 2015 to March 2016 according to the following exclusion criteria: (1) having joined either the HDM program in the year preceding the start of the Outcomes Evaluation Study; (2) having lived in a long-term care residential facility (nursing home, assisted living facility, group home) or a rehabilitation facility; or (3) did not have the same geographical location (zip code) as the recipient to whom they were matched. Only the data of HDM recipients and their controls were analyzed in this dissertation.

For every HDM recipient, 50 individuals were selected as potential controls using CMS data, and were ranked according to the strength of their match. Propensity scores were used to match controls to recipients based on some characteristics; age, sex, race and ethnicity, Medicare eligibility, whether the beneficiary was dually eligible for both Medicare and Medicaid (was used as a proxy for socioeconomic status), indicators for different cancers (breast, colon, prostate, lung, endometrial), number of chronic conditions (including cataract, chronic kidney disease, glaucoma, hip fracture, depression, stroke, diabetes, and asthma), Medicare service utilization indicators (inpatient and emergency department visits and skilled nursing facility and

home health visits) and total Part A and Part B Medicare expenditures (4). However, the control group for the HDM recipients were not matched based on homebound or mobility status.

3.2. Study Sampling Methods

The Outcomes Evaluation Study used a multistage cluster sampling design that is briefly discussed below (4). The different stages of the sampling procedure is provided in **Figure 4**.

i. Area Agencies on Aging (AAAs)

ii. Local service providers (LSPs) from a subsample of the sampled AAAs

iii. HDM distribution routes in the congregate meal (CM) site of the selected LSPs

iv. HDM recipients along the HDM route

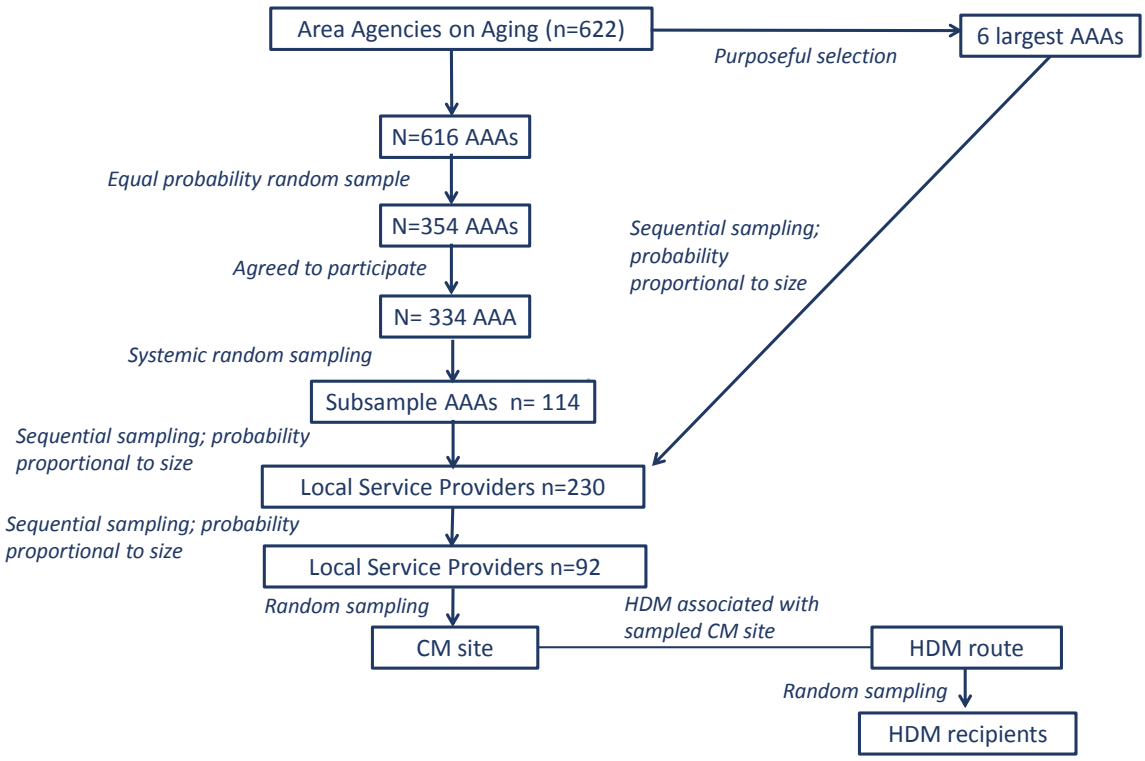


Figure 4: The sampling framework for the Outcomes Evaluation Study for home-delivered meal recipients.

Of the 622 existing AAAs, the largest six were purposefully selected, and the rest were chosen based on an equal-probability random sample. The six largest AAAs were the Chicago Department of Family and Support Services, the New York City Department for the Aging, the New Hampshire Bureau of Elderly and Adult Services, the Los Angeles County Community and Senior Services, the New Mexico Non-metro AAA, and the Greater Wisconsin Agency on Aging Resources, Inc. A subsample of 114 AAAs and the six largest AAAs were used to obtain a list of LSPs within each AAA. This list of 1,169 LSPs was used as the sampling frame to select 230 LSPs by means of sequential sampling with the probability of being chosen proportional to size. The size of the LSPs was calculated as the sum of both congregate and HDMs. Of these 230 LSPs, 92 LSPs were sampled using the same method. CM sites was randomly selected among the 92 LSPs' sites using probability proportional to size sampling. A list of HDM routes associated with the selected CM sites were used to represent the sampling frame to select the HDM route, and for each HDM route within a LSP, simple random sampling technique was used to select HDM recipients. (4). Oral consent from individuals who agreed to participate in the Outcomes Evaluation Study, and IRB approval was obtained by the contractor who administered the Outcomes Evaluation Study.

3.3. Data Collection Tools

The data collection tools used by the Outcomes Evaluation Study were a) Client Outcomes Survey, b) two 24-hour dietary recalls, and c) Medicare files. The Client Outcomes Survey and the two 24-hour dietary recalls were collected using computer-assisted personal interviews and were merged with the Medicare files for all of the study participants. These data collection tools are described below.

3.3.1. Client Outcomes Survey

The Client Outcomes Survey collected information on sociodemographic characteristics, food security, health insurance coverage, self-reported, physician diagnosed chronic diseases, depressive symptoms, loneliness, OAANSP participation history and types of services received (221). Survey questions were pre-tested by phone, and modifications were made as necessary. A small-scale pilot test was also conducted with 32 recipients to assess the operational aspects of the interviewing process (e.g. respondent burden). A skip logic allowed the survey to be administered to both HDM recipients and controls (4). Only variables that are pertinent to our study will be discussed below.

Food security

The six-item short form of the 18 questions in the U.S. Household Food Security Survey Module (HFSSM) was the tool used to assess household food security status (222, 223) (**Table 1**). The six-item short form was developed and validated by researchers at the National Center for Health Statistics (223). The raw score ranges from 0-6 and classifies households into three main categories of food security; high or marginal food security (raw score 0-1), low food security (raw score 2-4), and very low food security (raw score 5-6). The last two groups were combined to create a dichotomous variable, food secure and food insecure (low food security and very low food security). Food insecurity was also used as a continuous variable.

Table 1: The 6-item food security questionnaire (short-form) extracted from the Client Outcomes Survey

Questions	Response options	Code
Food security		
"*I'm going to read you several statements that people have made about their food situation*."		

Q1. "The food that I bought just didn't last, and I didn't have money to get more." Was that often, sometimes, or never true for your household in the last 30 days?	Often true Sometimes true Never true Don't know/refused	Often true/Sometimes true → 1 Never true → 0 Don't know/refused→99
Q2. "I couldn't afford to eat balanced meals." Was that often, sometimes, or never true for your household in the last 30 days?	Often true Sometimes true Never true Don't know/refused	Often true/Sometimes true → 1 Never true → 0 Don't know/refused→ 99
Q3. In the last 30 days, did anyone in your household ever cut the size of your meals or skip meals because there wasn't enough money for food?	Yes No (*Skip to Q5*) Don't know/refused (*Skip to Q5*)	Yes → 1 No → 0 Don't know/refused→ 99
Q4. In the last 30 days, how many days did this happen?	__ days (1-99) Don't know/refused	Any number of days→ 1 Don't know/refused→ 99
Q5. In the last 30 days, did you ever eat less than you felt you should because there wasn't enough money to buy food?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Q6. In the last 30 days, were you ever hungry but didn't eat because you couldn't afford enough food?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99 *Affirmative responses Q1-Q6 are summed → raw score

Social relationships' constructs of interest (social participation, eating alone, instrumental social support, and loneliness)

The social participation construct was measured by a single item (yes/no) inquiring about belonging to any religious or social groups, book clubs, special interest groups, or other organizations (**Table 2**). Eating alone (yes/no) was examined as a distinct construct. The participant's receipt of instrumental social support was evaluated by seven items as shown in Table 5. If participants answered affirmatively (yes) to any of the seven items, this was coded as receiving *any* instrumental social support, and answering negatively (no) to all of the items was coded as not receiving instrumental social support. The small number of participants who answered affirmatively to any of the instrumental social support items did not allow individual examination of the items.

Table 2: Questions extracted from the Client Outcomes Survey and the management of each one.

Questions	Response options	Code
Social participation		
Q1. Do you belong to any religious or social groups, book clubs, special interest groups, or other organizations?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Eating alone		
Q2. Do you eat alone most of the time?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Instrumental social support		
Q3. In the past 6 months, have you participated in an adult day care program?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Q4. In the past 6 months, have you received personal care services for help with dressing or bathing?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Q5. In the past 6 months, did a visiting nurse or therapist come to your home to provide physical, occupational, or speech therapy?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→99
Q6. In the past 6 months, have you received case management services in which a case manager set up in-home services for you such as homemaker or personal care services, or called to see how you are doing?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Q7. In the past 6 months, have you received free or discounted housing?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Q8. In the past 6 months, have you received homemaker or housekeeping services to help with light housework, preparing meals, or shopping?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99
Q9. In the past 6 months, have you received chore services to help with heavier housecleaning or yard work?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused→ 99 *Affirmative responses for Q3-Q9 are summed → raw score: If raw score >0; received instrumental response=1, otherwise =0
Loneliness		
Q10. How often do you feel that you lack companionship?	Hardly ever Some of the time	Hardly ever → 1 Some of the time → 2

	Often Don't know/refused	Often → 3 Don't know/refused→ 99
Q11. How often do you feel left out?	Hardly ever Some of the time Often Don't know/refused	Hardly ever → 1 Some of the time → 2 Often → 3 Don't know/refused→ 99
Q12. How often do you feel isolated from others?	Hardly ever Some of the time Often Don't know/refused	Hardly ever → 1 Some of the time → 2 Often → 3 Don't know/refused→ 99 *Responses Q10-Q12 are summed → raw score

Loneliness was assessed using an abbreviated version of the validated University of California, Los Angeles (UCLA) Loneliness Scale (224, 225). Scoring of the three items in this scale is shown in Table 2, and ranges from 1-9 such that higher scores denote greater feelings of loneliness.

Depressive symptoms

The short form of the Patient Health Questionnaire (PHQ-2) was used to screen for depression (226). The two items of this validated questionnaire inquired about the frequency of depressed mood and anhedonia over the past two weeks (**Table 3**). The PHQ-2 raw scores range from 0 to 6, with higher scores indicate more depressive symptoms (not at all=0, several days=1, more than half of the days=2, nearly every day=3). There is no agreed upon threshold for the PHQ-2 raw score, but researchers suggest that a cutoff of three or more balances specificity with sensitivity (227, 228).

Table 3: Patient Health Questionnaire (PHQ-2)

Questions	**Response options**	**Comments**
Q1. During the past 2 weeks how often have you been bothered by any of the following problems? Little	For each: Not at all Several days More than half of the days Nearly everyday	Not at all → 0 Several days → 1 More than half of the days → 2 Nearly every day → 3

interest or pleasure in doing things.	Don't know/refused	Don't know/refused→ 99
Q2. Over the past 2 weeks how often have you felt down, depressed or hopeless?	Not at all Several days More than half of the days Nearly everyday Don't know/refused	Not at all → 0 Several days → 1 More than half of the days → 2 Nearly every day → 3 Don't know/refused→ 99

Other sociodemographic and health-related covariates

The sociodemographic data extracted from the Client Outcomes Survey include age, sex, ethnicity, marital status, level of education, household size and residence. Coding of the variables is shown in **Table 4**.

Table 4: Sociodemographic questions extracted from the Client Outcomes Survey.

Question	Response options	Code
Demographics		
Q1. What is your date of birth?	_ _month/_ _day/_ _ _ _ year Don't know/refused	Age:_ _ years Don't know/refused → 99
Q2. Sex	Male Female	Male → 0 Female → 1
Q3. What is the highest grade or level of school you have completed or the highest degree you have received?	Never attended/kindergarten only 1st grade 2nd grade 3rd grade 4th grade 5th grade 6th grade 7th grade 8th grade 9th grade 10th grade 11th grade 12th grade, no diploma High school graduate GED or equivalent Some college, no degree ssociate degree; occupational, technical, or vocational program	Less than 12th → 1 High school graduate/GED or equivalent → 2 Some college or Associate degree, college graduate or above → 3 Don't know/refused → 99

	ssociate degree: academic program Bachelor's degree (e.g. BA, BS) laster's degree (e.g. MA, MS, MBA) rofessional school degree (e.g. MD, JD) Doctoral degree (e.g. PhD, EdD) Don't know/refused	
Q4. Please choose one or more races that you consider yourself to be:	American Indian or Alaska Native Asian African American or Black Native Hawaiian or other Pacific Islander White Other (Please specify: _ _ _ _ _) Don't know/refused	Non-Hispanic Black → 1 Non-Hispanic White → 2 Latin/Hispanic/Other → 3 Don't know/refused → 99
Q5. Are you Hispanic or of Latino origin?	Yes No Don't know/refused	
Q6. Including yourself, how many people live in your household? (I mean all people who usually stay in the household. Please do include people who are away, such as students, people on vacation, or traveling for business, or people who are in the hospital for a brief stay. Do not include people in institutions, in the military or people who are temporary visitors.)	_ _ number of people in household Don't know/refused	_ _ number of people in household Don't know/refused → 99
Q7. Are you	Married/living with a partner Widowed Divorced Separated Never married Don't know/refused	Married/living with a partner → 1 Widowed/Divorced/Separated /never married → 2 Don't know/refused → 99

Responses for 10 chronic diseases (**Table 5**) were summed to create a continuous variable, ranging from one to ten. Oral health was assessed using a single dichotomous question.

Table 5: Health-related questions extracted from the Client Outcomes Survey.

Question	Response options	Code
Chronic diseases		
Q1. *Has a doctor ever told you that you have:…"*		
i. Arthritis or rheumatism? ii. High BP or hypertension? iii. A heart attack, CHD, angina, CHF, or any other heart problems? iv. High cholesterol? v. DM or high BS? vi. Allergies, asthma, emphysema, chronic bronchitis, or other breathing and lung problems? vii. Cancer or malignant tumor, excluding minor skin cancers? viii. Stroke? ix. Osteoporosis? x. Kidney disease?	For each: Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused → 99 *Sum of affirmative responses
Oral health Q2. Do you currently have trouble eating due to the condition of your teeth, gums or another dental issue?	Yes No Don't know/refused	Yes → 1 No → 0 Don't know/refused → 99

3.3.2. The 24-hour Dietary Recall

Dietary intake data for the 24-hour dietary recalls of recipients and controls were collected and analyzed using the Automated Self-Administered 24-hour (ASA24®) Dietary Assessment Tool, version 2014, developed by the NCI, Bethesda, MD (229). The 24-hour dietary recall is a structured interview that is designed to collect detailed information about all the foods and beverages consumed by an individual in the past 24 hours (230). This public access web-based tool was developed to closely resemble the USDA's Automated Multiple Pass Method, which is a computerized interviewer-administered tool that is used as part of the National Health and Nutrition Examination Survey (231, 232). The recalls were collected through a computer-assisted in-person interview. The 24-hour dietary recall was not always collected on the day a recipient consumed a HDM, but this was indicated in the 24-hour dietary

recall data, and these HDM recipients were referred to as no-meal recipients in our analysis of their diet quality and quantity. For recipients who received a meal on the day of the 24-hour recall, food items that were part of the HDM were identified. For a subsample of HDM recipients, a second 24 hour-recall was collected on a non-consecutive day to allow for the estimation of the distributions of usual intake of some key macro and micronutrients. ASA24® adopts the nutrient values from the Food and Nutrient Database for Dietary Studies (version 4.1), and food group values from MyPyramid Equivalent Database (version 1.0), respectively (233, 234).

The Healthy Eating Index (HEI)

The HEI is a validated scoring metric that measures diet quality and how well the diet aligns with the Dietary Guidelines for Americans (DGA) that are published by the US Department of Health and Human Services and the US Department of Agriculture (235). This measure of diet quality is used to examine dietary patterns of populations and subpopulations, to examine the relationships between diet and health, and to evaluation community interventions (e.g. quality of food assistance packages and programs). HEI was originally developed by the USDA Center for Nutrition Policy and Promotion (CNPP) and the National Cancer Institute in 1995 and updated every five years based on the mandated update of the DGA (59, 236).

Table 6: The Healthy Eating Index- 2010 food components and scoring system.

HEI- 2010 components[1] (maximum points)	Standard for maximum points	Standard for minimum points
Adequacy (higher score indicates higher consumption)		

Total Fruit[2] (5)	≥ 0.8 cup equiv. / 1,000 kcal[10]	No Fruits
Whole Fruit[3] (5)	≥ 0.4 cup equiv. / 1,000 kcal	No Whole Fruits
Total Vegetables[4] (5)	≥ 1.1 cup equiv. / 1,000 kcal	No Vegetables
Greens and Beans[4] (5)	≥ 0.2 cup equiv. / 1,000 kcal	No dark-green vegetables, beans, or peas
Whole Grains (10)	≥ 1.5 ounce equiv. / 1,000 kcal	No Whole Grains
Dairy[5] (10)	≥ 1.3 cup equiv. / 1,000 kcal	No Dairy
Total Protein Foods[6] (5)	≥ 2.5 ounce equiv. / 1,000 kcal	No Protein Foods
Seafood and Plant Proteins[6,7] (5)	≥ 0.8 ounce equiv. / 1,000 kcal	No Seafood or Plant Proteins
Fatty acids ratio[8] [(MUFA + PUFA)/SFA]* (10)	≥2.5	≤1.2
Moderation (higher scores indicate lower consumption)		
Refined grains (10)	≤ 1.8 ounce equiv. / 1,000 kcal	≥ 4.3 ounce equiv. / 1,000 kcal
Sodium (10)	≤ 1.1 gram / 1,000 kcal	≥ 2.0 grams / 1,000 kcal
Empty Calories[9] (20)	≤ 19% of energy	≥ 50% of energy

[1] Intakes between the minimum and maximum standards are scored proportionately.

[2] Includes 100% fruit juice.

[3] Includes all forms except juice.

[4] Includes any beans and peas not counted as Total Protein Foods.

[5] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.

[6] Beans and peas are included here (and not with vegetables) when the Total Protein Foods standard is otherwise not met.

[7] Includes seafood, nuts, seeds, soy products (other than beverages) as well as beans and peas counted as Total Protein Foods.

[8] MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

[9] Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is > 13 grams/1,000 kcal.

[10] Equiv. = equivalent, kcal = kilocalories.

Scores are calculated according to the amounts consumed of each food component. The HEI-2010 classified foods into 13 groups, nine items (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) are categorized as adequacy components (i.e. higher scores indicating higher consumption), and three (refined grains, sodium, and empty calories) moderation components (i.e. lower scores indicate higher consumption) (**Table 6**) (236). Solid fats, alcohols, and added

sugars (SoFAAS) represent the empty calorie items. The HEI score is coded to reflect higher score of the adequacy components and a higher score of moderation components to indicate a lower intake (reverse coding). The fatty acid component is computed as the ratio of unsaturated fatty acids to saturated fatty acids and the empty calories component is presented as the percentage of energy. All of the other HEI components are calculated using a density basis of recommended serving size per 1000 kcal (236). Each component is scored on a scale from zero to X, where zero reflects no consumption of the food component and X represents the maximum score for consumption, which can be 5, 10, or 20, depending on the component (236) (Table 6). The maximum score is assigned based on the least restrictive recommendations. This means that these are the recommendations that are easiest to achieve (236, 237). Higher total HEI scores signify better dietary quality. (59).

During the Outcomes Evaluation Study design, the HDMs were planned using the DGA released in 2010 (60). The HEI-2010 were, therefore, used to evaluate dietary intake of study participants. The HEI-2015 were released after completion of the study **(Table 7)** (60). The HEI-2010 and HEI-2015 are similar, except that, in the latter, dark green vegetables and legumes replaced greens and beans in the adequacy components group, and added sugars and saturated fats replaced the empty calories component. Since the HEI-2015 is the current recommendation, the level of agreement between the HEI-2010 and HEI-2015 in classifying participants' diet quality was assessed.

Table 7: The HEI-2015 food components and scoring system.

HEI-2015 components[1] **(maximum points)**	**Standard for maximum points**	**Standard for minimum points**
Adequacy (higher score indicates higher consumption)		
Total Fruit[2] (5)	≥0.8 cup	No Fruits
Whole Fruit[3] (5)	≥0.4 cup	No Whole Fruits

Total Vegetables[4] (5)	≥0.4 cup	No Vegetables
Dark Green Vegetables or Legumes[4] (5)	≥0.2 cup	No Dark Green Vegetables or Legumes
Whole Grains (10)	≥1.5 oz	No Whole Grains
Dairy[5] (10)	≥1.3 cup	No Dairy
Total protein foods[6] (5)	≥2.5 oz	No Protein Foods
Seafood and Plant Proteins[6,7] (5)	≥0.8 oz	No Seafood or Plant Proteins
Fatty acids ratio [(MUFA + PUFA)/SFA] [8] (10)	≥2.5	≤1.2
Moderation (higher scores indicate lower consumption)		
Refined grains (10)	≤1.8 oz	≥4.3 oz
Sodium (10)	≤1.1 gram	≥2.0 grams
Added Sugars (10)	≤6.5% of energy	≥26% of energy
Saturated Fat (10)	≤8% of energy	≥16% of energy

1 Intakes between the minimum and maximum standards are scored proportionately.
2 Includes 100% fruit juice.
3 Includes all forms except juice.
4 Includes legumes (beans and peas).
5 Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.
6 Includes legumes (beans and peas).
7 Includes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas).
8 Ratio of poly- and monounsaturated fatty acids (PUFAs and MUFAs) to saturated fatty acids (SFAs).

MyPyramid Guidelines and Dietary Reference Intake (DRI)

The measures used to assess the diet of HDM recipients and controls were MyPyramid Guidelines and the Dietary Reference intakes of the DGA-2010. MyPyramid was released by the USDA CNPP in 2005 and was used until 2011, when it was replace by MyPlate. MyPyramid is a visual illustration which displays proportionality and variety in the five groups of foods and beverages that is designed to educate Americans on how to modify their diets to meet the nutritional goals set in the DGAs (238). It is also a reference for the recommended number of servings of some of the major food groups (vegetables, fruits, grains, and dairy) and the DRIs were used as a reference for important food components/items (protein, fiber, whole grains, refined grains, saturated fats, sodium and added sugar) as outlined in the DGA-2010 (**Table 8**) (239). The DRIs are a set of nutrient reference values developed by the Academy of Medicine that are used to plan and evaluate nutrient intakes of healthy individuals and provide the

scientific basis for the development of food guidelines (240). MyPyramid was used as. The mean dietary intake of major food groups consumed by study participants was calculated as a percentage of MyPyramid Guidelines, and mean intake of food components and nutrients was calculated as a percentage of the DRIs for men and women ages 50 years and older.

Table 8: MyPyramid guidelines and dietary reference intakes of food groups/items for individuals ≥ 50 years by sex, adapted from the 2010 DGAs.

Food groups/items	Dietary Guidelines for Americans	
	Males	Females
Total protein (g)	56	46
Dairy (cups)	3	3
Fruit (cups)	2	1.5
Vegetables (cups)	2.5	2
Grains (oz)	6	5
Whole grains (oz)	3	2.5
Fiber (g)	28	22
Saturated fat (% of kcal)	10	10
Refined grains (oz)	3	2.5
Sodium (mg)	1500	1500
Added sugar (% of kcal)	10	10

Usual protein and total vegetable intakes

The 24-hour dietary recalls were used to calculate usual total vegetable and protein intakes as indicators of diet quality. Usual dietary intake refers to the long-term mean daily intake of a nutrient or food. It is important to note that, due to the day-to-day variation in dietary intake of individuals, a single 24-hour recall does not necessarily capture usual dietary patterns (230). Usual intake was, therefore, calculated using the NCI methodology which requires a second non-consecutive 24-hour recall from at least a subsample of the population (241). More details about the NCI method can be found in the statistical analysis section below.

3.3.3. Medicare Files

Data on healthcare utilization of survey participants were obtained from the CMS files of those enrolled in the fee-for-service Medicare Part A and B (commonly known as Original Medicare; where Medicare is the primary service payer) Medicare claims of participants enrolled in managed care plans (e.g. Medicare Advantage) are not collected by CMS and, therefore, were unavailable for this study.

Healthcare utilization

Medicare files of participants were merged with the survey responses and 24-hour dietary recall information. Medicare claims data on healthcare utilization included hospital admission, ED visits that resulted in inpatient stay, outpatient ED visits and observational stays. Two variables; 1) number of hospital stays, and 2) number of ED visits and observational stays were summed to create a continuous variable that represents hospitalization.

3.4. Data Collection and Process

HDM Recipients

Primary data collection for the Outcome Evaluation Study took place between October 2015 and April 2016. A 'target' week was prescheduled for field interview administration, lasting for five days. From late October to early January, a random sample of HDM recipients was identified on the first day of the target week. Field staff conducted the Client Outcomes Survey and the 24-hour recall during the subsequent four days, by means of a computer-assisted in-person interview, which lasted approximately 75 minutes. HDM recipients were interviewed at home or at another convenient location. On a non-consecutive day, a second 24-hour dietary recall was collected from a subsample of the HDM recipients (n=123) (4).

Control Group

Outcomes Evaluation Study data collectors selected one or two controls for every HDM participant out of the potential 50 individuals identified. Field staff conducted computer-assisted personal interviews in the control's home. Interviews took place between the end of January 2016 to early April 2016 using the same tools and procedures as those used for interviewing HDM recipients.

3.5. Statistical analysis

Descriptive statistics were used to summarize study participants' socio-demographic and health-related characteristics. Differences in characteristics were analyzed for statistical significance using chi-square test for categorical data and independent sample t-test for continuous data. Prior to analyses, variables were examined for outliers and normality. All analyses were controlled for complex survey design, using the sample weights, cluster and strata to account for the unequal probabilities of selection, nonresponse, and non-coverage. The level of significance was set to $\alpha = .05$ and all tests were two-tailed. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC), R (version 3.5.0) and MPlus version 7.3 (Muthén & Muthén, Los Angeles, CA).

3.5.1. HEI

Radar plots were created to visualize individual HEI components contributing to the overall HEI score (242). The radar plots were created to examine 1) the density of HEI component scores of the HDM and that of complementing foods in meal recipients, and 2) the density of HEI component scores of meal recipients, no-meal recipients and the control group. The plots show the percentage of total points received by each HEI component, such that the HEI score increases (diet quality increases) as the plot moves from the center outwards (242).

3.5.2. Usual total vegetable and protein intakes

Researchers at the NCI created a statistical method to model usual dietary intakes of ubiquitously and/or episodically consumed foods and nutrients using 24-hour dietary recalls (243). The principle of the NCI method is that usual intake is equivalent to the probability of consumption on a given day multiplied by the average amount consumed that day. One important assumption that is made when calculating usual intakes is that the 24-hour dietary recall provides an unbiased estimate of dietary intake on a given day, however, because of random error from the variability in what people eat day-to-day, a single 24-hour recall is unable to provide estimates of usual intake. Therefore, this method requires that at least a subsample of the population have a second non-consecutive 24-hour recall (241). Initially, a transformation step is used to obtain data that are, approximately, symmetrically distributed. Secondly, the mean usual intake on the transformed scale is estimated (controlling for age and sex), along with the within- and between-person variance using a linear mixed-effects model. Finally, the within-person variance is eliminated, and results obtained are back-transformed to the original scale, resulting in the usual intake distribution. Maximum likelihood estimation was used to fit the model. Mean usual protein and vegetable intake (in grams and cups for usual protein and vegetable, respectively) were compared in HDM recipients and controls using simple linear regression to adjust for complex survey design.

3.4.3. Diet quantity

To compare dietary intake to MyPyramid guidelines and DRIs of the DGAs, male and female recipients' mean intakes of major food groups and nutrients (proteins, fruit, dairy, vegetables, fiber, grains, whole grains and refined grains, sodium, saturated fats and added sugar) were calculated using the two 24-hour recalls. For individuals who had two 24-hour dietary

recalls, an average intake reflecting both days was first calculated, before computing the average intake of the nutrient/food group for the HDM recipients and controls. For meal recipients, the contribution of the HDM and complementing food to the total daily intake were plotted on a bar graph as a percentage of the 2010 DGAs (239). A similar graph displayed the mean total intake for food groups/nutrient for meal recipients, no-meal recipients, and controls.

3.4.4. Food Security Scale: Rasch modeling

In addition to categorizing individuals by food security status, we examined the food security raw score as a continuous variable. To do so, we used the single-parameter logistic measurement model (Rasch model) to create an equal-interval scale that reflects the severity of the latent trait (in this case, FI). The Rasch model is a non-linear factor analysis method based on item response theory that specifies a nonlinear relation between a binary, ordinal, or categorical item (HFFSM items) response and the latent trait (FI) they are intended to measure. The latent trait estimates depend on both the participant's responses and the properties of the items. (244). Participant's severity parameter estimates are calculated as the maximum likelihood values given the item severity parameters (245), and can then be used as an equal-interval approximation continuous scale.

3.4.5. Structural Equation Modeling (SEM)

SEM was utilized to examine the direct and indirect relations illustrated in the hypothesized structural models. SEM can be viewed as a series of simultaneous regression equations, with several advantages over the traditional multivariate statistical analysis techniques by offering an assessment of goodness-of-fit for the hypothesized model to the sample data (how well the sample data fit the model), and allows theory testing (246). The model was estimated

separately for HDM recipients and controls. Path diagrams, the visual statistical depiction of the hypothesized relationships for aims 2 and 3 are shown in **Figure 5** and **6**, respectively.

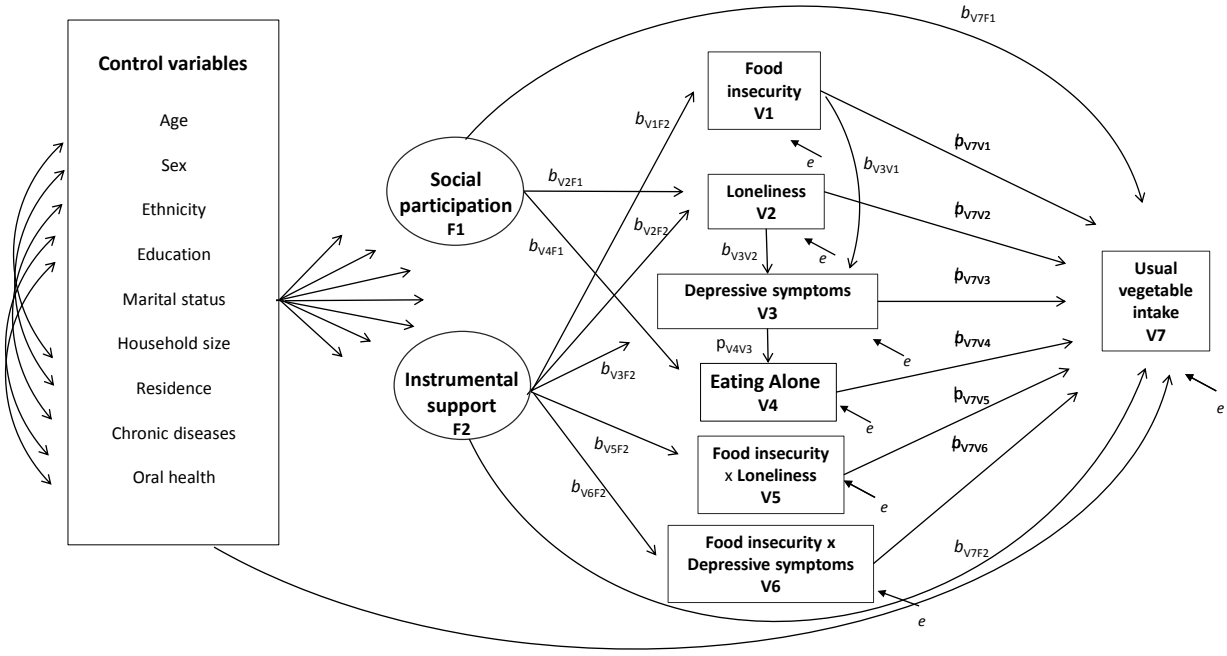


Figure 5: The measurement model for the hypothesized pathways (p) between diet quality, FI, loneliness, depressive symptoms, eating alone, instrumental social support and social participation. Latent constructs are shown in eclipses (F) and observed variables are represented by a square (V). Lines with arrows represent the path or direction of influence, double-headed arrows represent covariances. Residual variance or error terms of observed variables are labeled "e".

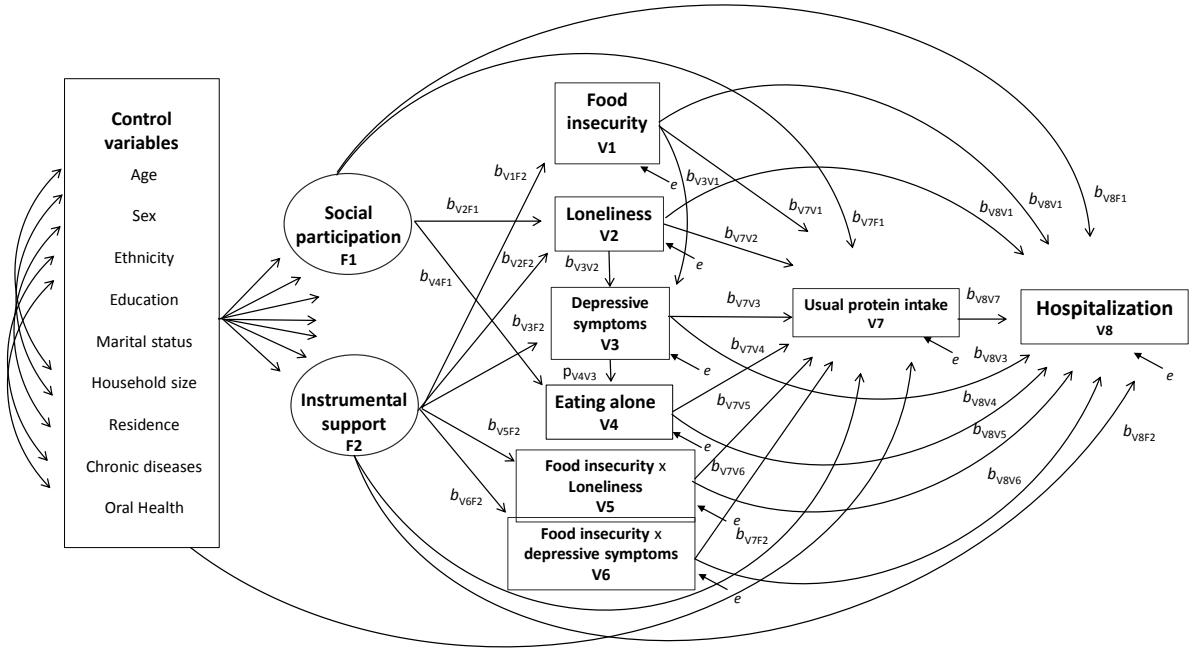


Figure 6: The measurement model for the hypothesized pathways (p) between diet quality, FI, loneliness, depressive symptoms, eating alone, instrumental social support and social participation. Latent constructs are shown in eclipses (F) and observed variables are represented by a square (V). Lines with arrows represent the path or direction of influence, double-headed arrows represent covariances. Residual variance or error terms of observed variables are labeled "e".

Conditional process modeling was undertaken to examine the mediation and moderation effects in the model. Conditional process modeling combines two important concepts: process modeling and moderation analysis. Process modeling analysis (also known as mediation analysis) is an attempt to specify and examine the causal mechanisms that resulted in a certain outcome, i.e., examining *how* the effect was produced (direct and indirect effects). Moderation analysis examines the conditional effect of a variable on an outcome, given the value of a third variable (247). The following steps were undertaken:

1) Complex survey data features (stratification, clustering, and sampling weights) were used to account for the multistage sampling design.

2) Two moderation terms (FI×loneliness and FI×depressive symptoms) were created to examine the conditional effect of loneliness and depression on diet quality, given FI.
3) To overcome the instability created as a result of the high correlation between these interaction terms and their first order predictors (FI, loneliness, and depressive symptoms), the latter were mean-centered.
4) To manage missing values for independent variables, constraining control variables was attempted (covariates held constant across groups), however model convergence issues appeared. We used another approach to handle the social participation and instrumental social support constructs as latent factors with zero error variance to manage missing observations.
5) Usual vegetable intake and age were rescaled (divided by 10) to facilitate convergence.
6) Although Weighted Least Squares estimation would be most appropriate for fitting the current models given the modeling of endogenous categorical variables, the software was unable to reach convergence likely due to the complex sample data. Instead, a maximum likelihood approach was used to estimate model fit and pathway coefficients to estimate the indirect, direct, and total effects in the multi-group analysis.
7) To examine the invariance of parameters across recipients and controls, estimates for model pathways for recipients and controls were compared and significant differences were established using the two-sample z statistic.
8) Age, sex, ethnicity, education, marital status, household size, residence, chronic diseases and oral health were included as potential confounders in the models.

The degree of correspondence between the hypothesized models and actual data (model evaluation) was assessed with goodness-of-fit indices. Goodness-of-fit indices reported are the

standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), and comparative fit index (CFI). Common cut-off criteria for these indices include a CFI >0.95 and a RMSEA <0.06. Parameter estimations (analogous to regression coefficients) were evaluated for recipients and controls, and the difference in estimates between recipients and controls were also established using Z score test statistic with significance set at $p<0.05$. The SEM was developed in MPlus version 7.3 (Muthén & Muthén, Los Angeles, CA).

3.6. Human Subjects Research

The study involved analysis of secondary data, and its activities did not present any potential hazard to recipients. In addition, the data files obtained from the Outcomes Evaluation Study did not contain any personally identifiable information.

Chapter 4: Results

A) Home-delivered Meal Recipients may be at risk of malnutrition without the meal program

Introduction

In 2011, the oldest of the baby boomer generation turned 65 years old. As of now, older adults represent almost 14% of the population, and are forecasted to constitute more than 20% of the United States inhabitants by the year 2030 (1). Homebound older adults represent 19.6% of the older adult population and are considered the fastest growing subpopulation, with more than a fourth of community-living older adults becoming homebound within a seven year period (248). This homebound population tends to be older, have poorer health, higher comorbidities, and so have a disproportionately greater share of healthcare utilization and cost compared to the total older adult population (182). Older adults, in general, are a population at a higher risk for malnutrition, which is an important risk factor for hospitalization and institutionalization (39, 40). Poor nutrition and homebound status share many of the same predictors, making homebound older adults an especially vulnerable subpopulation (5, 249).

To prevent or alleviate malnutrition, the Older Americans Act (OAA) of the Administration for Community Living provides nutrition services for many of these vulnerable populations to maintain and promote their dignity and independence (250). The Nutrition Service Program under the Older Americans Act (referred to as OAANSP thereafter) is considered the largest federal program for home-based nutrition services. One of the program's services is the home delivery of meals (referred to as home-delivered meals; HDM) to homebound older adults. This program typically provides five meals per week, delivered either daily on weekdays, or once a week, as frozen meals. The OAANSP is required to comply with the Dietary Guidelines

for Americans (DGA) and must provide at least one-third of the Dietary Reference Intakes (DRI) (250). The OAANSP targets economically disadvantaged populations, ethnic minorities, those with limited English proficiency, and those at risk for social isolation and institutionalization. These are many of the risk factors for malnutrition. Older adults enrolled in the HDM programs are more likely to be women, living alone, financially disadvantaged, less educated and with more chronic diseases; many of the same risk factors for poor nutrition (48-50, 251-254). Despite their vulnerability, little is known about the overall diet of this population.

Funding has not matched the increasing need for the program as the older adult population increases, (1, 255), giving way to waitlists for HDM programs nationwide (256). This gap in funding is arguably the result of limited evidence regarding the effectiveness of the OAANSP (255). In response to a congressional mandate for an evaluation of the program, the Administration for Community Living, of the Department of Health and Human Services, conducted an Outcomes Evaluation Study in 2015-2017. The primary focus of the Outcomes Evaluation study was to evaluate the impact of the OAANSP meals on client outcomes that would delay or circumvent institutionalization.

Much of the literature on the HDM population is limited to a specific group of recipients (e.g. hypertensive) or confined to certain geographic locations, making findings less generalizable (56, 257). Nevertheless, findings from these studies suggest that participation in HDM programs is associated with a more nutritionally adequate diet (56, 258). Less is known about the food consumed by recipients to complement those HDM, and the nature of the diet consumed by this population group on days when the meals are not provided. One study, albeit dated (1988), suggests that food used by HDM recipients to complement their meals did not provide the rest of their nutrient requirements, and in many instances provided less than a third

of the recommended dietary allowance (67). The objectives of the current study are to: 1) examine the overall diet quality of HDM recipients (compared to controls); 2) examine the quality and quantity of the foods consumed to complement HDM; 3) examine the quantity and quality of foods consumed on the day a HDM was not served.

Methods

Study design

This cross-sectional study uses secondary data from the Outcomes Evaluation Study, which was conducted nationally from 2015-2017. Details on recruitment, sampling technique, and exclusion criteria are described in details elsewhere (4). In summary, the Outcomes Evaluation Study used a multistage clustered sample design and respondents constituted a nationally representative sample of HDM recipients (n=504), and a matching control group (n=525). Recipients chosen for the study had to be at least 67 years old. Propensity scores were used to match controls to recipients based on age, gender, race and ethnicity, presence of chronic conditions, indicators for cancer, Medicare eligibility, and dual eligibility for Medicare and Medicaid (used as a proxy for socioeconomic status). However, the control group was not matched on homebound status.

Researchers in the Outcomes Evaluation study used computer-assisted personal interviews to collect data using: a) Client Outcomes Survey and b) two 24-hour dietary recalls. The Client Outcomes Survey collected information on demographic characteristics, food security status, health insurance coverage, self-reported health status, the presence of chronic conditions, depression, loneliness, HDM program participation history, and types of services received (221). The 24-hour dietary recalls of study participants were collected through an in-person interview and analyzed using the Automated Self-Administered 24-hour (ASA24®) Dietary Assessment

Tool (229). The first 24-hour recall was taken from the entire sample, and the second was taken from a randomly selected subsample (n=123). The 24-hour dietary recall was not always collected on the day the participant received a meal, but this was indicated in the 24-hour dietary recall data.

Respondents who did not have any dietary recall information (n=13) and those whose calculated energy intakes were ±3SD of the mean (n=11) were excluded from the study, with a final total sample of 1005 respondents. This sample was classified into three groups; HDM recipients who received a meal on the day of the 24-hour recall (meal recipients) (n=429); HDM recipients who did not receive a meal on the day of the 24-hour recall (no-meal recipients) (n=68); and the control group (n=508). Oral consent from individuals who agreed to participate in the Outcomes Evaluation Study, and IRB approval was obtained by Mathematica, the contractor who administered the Outcomes Evaluation Study.

Outcome variables

Diet quality assessment

To assess dietary quality, the two 24-hour dietary recalls of recipients were utilized to calculate the Healthy Eating Index (HEI). The USDA Healthy Eating Index-2010 (HEI-2010) is a validated tool to evaluate the diet quality in terms of its adherence to the 2010 Dietary Guidelines for Americans (235, 236) (**Table 9**). The HEI-2010 was used instead of the more recent HEI-2015 because the study was conducted before the release of the latter, and the HDM menus were designed to conform to the HEI-2010. The HEI-2010 consists of nine adequacy items (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) and three moderation items (refined grains, sodium, and empty calories) (236). Solid fats, alcohols, and added sugars (SoFAAS)

represent the empty calorie items. Higher scores for adequacy items indicate higher consumption while higher scores for moderation items denote lower consumption. The fatty acid component is computed as the ratio of unsaturated fatty acids to saturated fatty acids and the empty calories component is presented as the percentage of energy. All of the other HEI components are calculated using a density basis of recommended serving size per 1000 kcal (236). Each component is scored on a scale from zero to X, where zero reflects no consumption of the food component and X represents the maximum score for consumption, which can be 5, 10, or 20, depending on the component (236) (Table 4.1). The maximum score is assigned based on least restrictive recommendations. This means that these are the recommendations that are easiest to achieve given the variation in energy level (ranging from 1,000 to 3,200 kcal), sex and age (236, 237).

The total HEI score represents the sum of the component scores and ranges between 0 and 100 points (259). Scores of individual components are expressed as percentage of maximum possible score assigned for each component. The HEI-2015 is similar to the HEI-2010 except that, in the former, the greens and beans component was replaced with dark green vegetables and legumes, and the empty calories component was replaced with added sugars and saturated fats. The level of agreement between HEI-2010 and HEI-2015 in classifying respondents' diet quality was assessed.

Diet quantity assessment

The Outcomes Evaluation Study used the two 24-hour recalls to obtain nutrient values from the Food and Nutrient Database for Dietary Studies (version 4.1), and food group values from MyPyramid Equivalent Database (version 1.0) (233, 234). Major food groups (protein, vegetables, fruits, grains, and dairy) and food components (fiber, whole grains, refined grains,

saturated fats, sodium and added sugar) consumed were compared to MyPyramid guidelines and dietary reference intakes (DRI) as outlined in the DGA-2010 (**Table 10**) (239). The mean intake of major food groups and food components was calculated as a percentage of the DGAs for men and women 50 years and older.

Covariates

Food security

Household food security status was assessed using the validated six-item short form of the U.S. Household Food Security Survey Module (HFFSM) (222, 223). It identifies categories of food security status; high or marginal food security (score=0-1), low food insecurity (score=2-4), and very low food security (score=5-6). This scale will be analyzed as a dichotomous variable; food secure versus food insecure (combination of low food security and very low food security).

Sociodemographic and health-related characteristics

Age, sex, ethnicity, marital status, level of education, urban/rural residence and household size were extracted from the survey. Age was examined as a continuous variable. Ethnicity was categorized as non-Hispanic black, non-Hispanic white, and others. Educational attainment was used as a proxy for socioeconomic status and was classified as 1) less than 12^{th} grade; 2) high school graduate/GED or equivalent; 3) some college or associate degree, or college graduate or above. Marital status was coded as 1) married or living with a partner; and 2) separated, widowed, divorced, or never married. The Outcomes Evaluation Study research team used the respondents' area of residence and the US Census Bureau geographic boundaries to determine urban versus rural residence (260).

Physician-diagnosed, self-reported chronic diseases were grouped into two categories: 1) less than or equal to two chronic diseases, and 2) more than two chronic diseases. These chronic conditions include hypertension, coronary heart disease, diabetes mellitus, cancer, allergies and other breathing or lung problems, stroke, high cholesterol, anemia, osteoporosis, and kidney disease. Respondent's self-rated health was classified into three categories; 1) excellent/very good; 2) good; and 3) fair/poor. Respondent's appetite was grouped into three categories; 1) excellent; 2) good; and 3) fair/poor. Having dental problems was used as a dichotomous variable (Yes/No). The question examining respondents' mobility was classified into two categories; 1) able to walk, or 2) bedbound or chairbound/wheelchair bound (combining bed and chair bound). The number of meals consumed per day was classified as two meals or less per day, and three of more meals per day.

Statistical analysis

Means (for continuous data), frequencies and percentages (for categorical data) were calculated for descriptive statistics. Sociodemographic and health-related characteristics of respondents were compared using Chi square tests for categorical variables, and student's *t*-test for continuous variables. Analysis was adjusted for complex survey design. The significance level was set at $\alpha = 0.05$, and the Bonferroni method of adjustment was used to correct for multiple comparisons. The data were analyzed using SAS (version 9.4; SAS Institute Inc., Cary, NC).

Using the two 24-hour recalls, the mean total HEI scores were calculated using the population ratio method to provide population level means. Using this method, the means of each HEI component across individuals were calculated, then ratios of each dietary component to 1000 kcal were computed for the population. Each ratio was scored using an algorithm, then

added to determine the total HEI score (261, 262). The mean HEI scores were used to compare the diet quality of the HDM to the diet quality of the foods used to complement it (referred to as complementing foods/diet hereafter), and to compare the diet quality of meal recipients to no-meal recipients and controls.

Calculating the mean average intake of the aforementioned food groups and components to examine quantity is different from examining the HEI food components to assess dietary quality. For example, in examining quantity, the figures are not adjusted for energy intake, and they are compared to MyPyramid and DRI of the DGA-2010. For examining quality using the HEI-2010, the figures are energy adjusted to reflect density, and the maximum scores attained for each component use recommendations that are more lenient than the DGAs. For example, the USDA food patterns recommend 2 cups/2000 kcal of fruit, which would be 1.0 cups/1000 kcal if used to reflect maximum score for fruit. However, the assigned maximum score for the total fruit component in HEI-2010 is ≥0.8 cups/1000 kcal.

Radar plots were constructed to help visualize individual HEI components contributing to the overall HEI score (242). The plots were created to examine 1) the density of HEI component scores of the HDM and that of complementing foods in meal recipients, and 2) the density of HEI component scores of meal recipients, no-meal recipients and the control group. The plots display the percentage of total points received by each HEI component, such that the HEI score increases (diet quality increases) as the plot moves from the center outwards (242).

To examine dietary quantity, male and female recipients' mean intakes of total proteins, fruit, dairy, vegetables, fiber, grains (whole grains and refined grains), sodium, saturated fats and added sugar were calculated using the two 24-hour recalls. The contribution from the meal and the complementing food by meal recipients were plotted on a bar graph as a percentage of the

2010 DGA (34). A similar graph displayed mean total intakes of meal recipients, no-meal recipients and controls.

Results

Sample characteristics

The mean age of meal recipients, no-meal recipients and controls was 81.7, 82.5 and 81.0 years, respectively, and the majority of them were females, non-Hispanic white, had a high school education or lower, were widowed, separated, divorced or never married, and were able to walk (**Table 11**). Compared to the other two groups, fewer no-meal recipients were non-Hispanic white (52.7% vs. 75.7% for both meal recipients and controls) and more were non-Hispanic black (33.0% vs. 14.8% and 16.83% in meal recipients and control, respectively). Approximately half of no-meal recipients had less than high school education, compared to 37.7% and 36.9% in meal recipients and controls, respectively. More meal recipients and no-meal recipients (74.7 and 76.4%, respectively) lived in an urban setting, compared to controls (55.4%). Compared to meal recipients and controls, more no-meal recipients were food insecure (19.8% and 16.5% vs. 39.3%) and had a poor/fair appetite (26.4% and 26.5% vs. 40.1%) (**Table 12**).

Mean HEI of meal recipients, no-meal recipients and the control group

The mean HEI score of meal recipients, no-meal recipients and control groups is 63.4, 52.6, 60.8, respectively, on the day(s) of the 24-hour recall (data not shown). These represent the diet quality of food components consumed by HDM recipients, per 1000 calories on the day of the interview. The mean HEI score was significantly higher (better diet quality) in meal recipients compared to no-meal recipients ($p<0.0001$). This was reflected in higher scores for total vegetables ($p=0.004$), and SoFAAS ($p=0.015$). There was no statistically significant

difference in total HEI score between meal recipients and controls, but meal recipients had a significantly better score for dairy (p=0.006) than the control group (**Figure 7**). Additionally, no-meal recipients had a significantly lower overall diet quality compared to the control group (p=0.0001) reflected in higher intake by controls for total vegetables (p=0.006), and seafood and plant protein (p=0.001). Overall, the scores for sodium and whole grains were quite low for all groups, indicating high sodium and low whole grain intakes (Figure 7). The correlation between the HEI-2010 and HEI-2015 total scores was 0.96 (data not shown).

Mean HEI of the meal and complementing foods of meal recipients

The HEI component scores of the HDM and the scores of the food consumed to complement the meal are shown in **Figure 8**. The total mean HEI scores of the meal and that of the complementing foods showed no statistically significant difference. However, when examining individual HEI components of both, HDMs had significantly better scores for total vegetables ($p < 0.0001$), greens and beans ($p < 0.0001$), and a better score for energy from SoFAAS (p=0.009), compared to the complementing diet. The complementing foods' quality was better for total fruit (p=0.006), whole grains ($p<0.0001$), seafood and plant proteins ($p<0.0001$), and sodium ($p<0.0001$).

Mean dietary intake of meal and complementing foods of meal recipients compared to the 2010 DGA

Recipients' mean intakes from the meal and the complementing foods compared to the DGAs are shown in **Figures 9 and 10**. The HDM is mandated to provide at least one third of the DGAs, and, ideally, individuals consume complementing foods to satisfy the remaining two thirds. In this study, the HDM provided more than the 33% recommendations for total protein and vegetables for male and female recipients. For males and females, the meal met

approximately a fourth of the recommendations for dairy, fruit, and grains, less than 20% of recommendations for fiber, and less than 10% of the guidelines for whole grains. The HDM, alone, exceeded a third of the upper limit of consumption for refined grains (49% and 45% for males and females, respectively), sodium (90% and 77% for males and females, respectively), and added sugar (51% and 67% for males and females, respectively). Additionally, meals surpassed the upper limit of consumption for saturated fat (102% and 106% for males and females, respectively).

Males and females complemented their HDM by more than two thirds of the DGAs for protein. The complementing diet fell considerably short of the DGAs for vegetables (26% and 23%), dairy (36% and 24%), whole grains (23% and 28%) and fiber (28% and 37%). Females' mean intakes for fruit were double that of males (56% vs. 24%, respectively), yet it did not meet the recommendations. The complementing diet well exceeded the recommendations for saturated fat, sodium and added sugar for both sexes. (Figures 9 and 10)

Mean dietary intake of meal recipients, no-meal recipients and controls compared to the DGA 2010

Meal recipients, no-meal recipients and the control group were only able to meet the DGAs for total protein intake, and fell short of the DGAs for fruit, vegetables, dairy, grains, whole grains and fiber (**Figures 11 and 12**). Mean intakes of males and females for vegetables and whole grains were highest for meal recipients, followed by controls and no-meal recipients. For meal recipients, females consumed more of the adequacy components than male recipients except for vegetables (67% for males and females) and dairy (58% and 43% for males and females, respectively). For no-meal recipients, males consumed more of the adequacy components than females, except for fruit (56% and 58%), whole grains (13% and 23%) and

fiber (51% and 58%). As for mean intake of items for moderate consumption, male and female, meal recipients, no-meal recipients and controls exceeded the upper limit of mean consumption for saturated fats, refined grains, and sodium. Added sugar was highest among meal recipients, followed by no-meal recipients, and stayed close to the upper limit of consumption for the control group.

Discussion

This is the first national study that we are aware of that evaluates the food that HDM recipients eat to complement the HDM, and foods that they eat on the day(s) when recipients do not receive a meal in comparison to a control group. Results show that HDM recipients who received a meal had a significantly better diet quality, compared to the no-meal group but similar to the control group. The similar diet quality for meal recipients and controls could arguably be the result of the matching process which did not use the homebound status as one of its matching criteria (4), and hence, the control group, although vulnerable, may be somewhat more able to access food than meal recipients. Homebound older adults tend to have a poorer diet quality than non-homebound individuals (57), and so this selection bias may have concealed possible differences in food access and diet quality. The no-meal group had a lower diet quality than both the meal recipients and the control group. This highlights a group of HDM recipients who might be more vulnerable when they do not receive a HDM.

The HDM and the complementing foods were fairly similar in overall quality; the meal had better quality in certain food groups/nutrients while the complementing diet had better quality in others. The quality of the overall diet for all groups still requires improvement for several food groups/nutrients such as whole grains, fatty acid ratio, sodium and SoFAAS. Compared to the 2010 DGAs, the content of the meal and the complementing diet were low in

whole grains, dairy, and fiber, and they surpassed the upper limit of consumption for saturated fats, refined grains, sodium and added sugar. Nutrition education of this population group may be warranted especially that the majority of recipients have at least two chronic conditions that would benefit from special diets. Analysis of HDMs in the different LSP locations and their modifications to better align with the dietary guidelines may be necessary.

Results from the nationally representative evaluation study in 1993-1995 showed that HDM recipients' diets were considered nutrient dense, yet their caloric intake was below their energy needs, and so the intake of some nutrients fell below the recommendations (263). Findings from the literature show better diet quality of HDM recipients although the studies tended to be not representative of the US population and/or included a small sample size (50, 54, 55, 264). The Outcomes Evaluation Study showed that HDM recipients had a poorer diet quality compared to controls. However, researchers did not distinguish between recipients who received a HDM and those who did not receive a meal on the day of their 24-hour recall(s) (4).

No-meal recipients had a lower total mean HEI score compared to controls. It may be that recipients in the OAANSP rely mostly on the HDM and do not consume much outside of the meals provided (67).This is supported by findings from the Outcomes Evaluation Study, which showed that 14% of HDM recipients reported skipping meals on days when they do not receive a HDM, and 92% reported that the HDM represent more than one third of their daily intake on the day when they receive a HDM (4). It is not possible, from this study, to determine the reason why some recipients did not receive a meal on the day of the 24-hour recall(s). The Outcomes Evaluation Study results show that 34% of HDM recipients receive less than five meals per day (4). This suggests that the no-meal group may be at a higher nutritional risk compared to controls and may signify that the program is targeting individuals in most need who may not consume

nutritious meals if they were not participating in the HDM program. Such findings are timely, noting the budgetary battles that the OAANSP continues to fight, and the gap in literature on the national effectiveness of the program (265). Increasing program funding to support increasing the number of local service providers (LSPs) that offer HDM on weekends, and those that provide more than one meal per day may improve the diet quality of recipients. Only 12% of all LSPs provided weekend meals in 2015, and only 4% and 15% offered breakfast or dinner in addition to lunch, respectively (250). Gollub and colleagues have shown a positive impact on the nutritional intake of recipients by expanding the OAANSP services in five states to provide two meals a day, breakfast and lunch (53).

Protein was the one food group that was consumed in more than adequate amounts by all groups. There is an ongoing scientific debate regarding protein recommendations for older adults. It is argued that the current protein recommendations are not sufficient to meet the needs of older adults and should be increased to guard against muscle wasting, falls and fractures in this population (266-269). This study shows that the overall average protein intake surpasses recommendations by more than 30% in meal recipients, but it is close to the current recommendations in the no-meal recipients, who appear to be the most vulnerable population for malnutrition. Further studies may be necessary to examine protein adequacy using the different recommendations proposed, and its association with relevant health outcomes.

The HDM and the complementing diet did not meet the DGAs for fruits, vegetables, dairy, grains, whole grains, and fiber. Previous studies have shown that diets of older adults were also unable to meet the recommendations for several food groups/components and showed similar patterns as the current study (251, 270, 271). In this study, intakes of saturated fat, sodium and added sugar were more than 150% of the DRIs, and the HDM contributed

significantly to these figures. Sodium content of meals continues to be an issue, as shown by an earlier study that analyzed meals delivered to homebound older adults (272). It should be noted that meal content varies in different LSP sites, and, therefore, diet analysis at the different meal locations is advised to correct possibly high levels of saturated fat, sodium and added sugar. These findings also suggest specific topics for nutrition counseling/education of older adults, a nutrition service that is also provided by the OAANSP.

Mean intakes of various food groups/components showed that meal recipients, no-meal recipients and controls fell short for fruit, vegetables, dairy, grains, whole grains and fiber, but mean intakes were typically higher for meal recipients compared to no-meal recipients. Similar to our study, Frongillo and Wolfe's longitudinal study of HDM recipients in NYC found that compared to the no-meal group, meal recipients had better vegetable, dairy, energy and protein intake, and an increase in the number of servings from fats and sweets (55).

This nationally representative study provides a unique opportunity to assess the diets of HDM recipients and examine the quality and quantity of foods consumed to complement the HDMs. Knowing the reason why some recipients did not receive a meal on the day(s) of the 24-hour recall may provide additional insights, which could be used to advocate for an increase in program funding and allow for expanded coverage and/or usage of the OAANSP services by this targeted vulnerable population. Intervention trials may be needed to examine the nutritional and health impact of expanding the program to weekends and/or to include more than one meal per day. The results also shed light on the vulnerability of the population of older adults who are not part of the HDM program. Exploring why this group of older adults do not participate in the OAANSP CM or HDM programs may offer guidance on potential ways to reach them. A limitation of this study is that using two 24-hour dietary recalls to calculate population level HEI

scores can estimate mean usual intakes on a population level, yet it does not reflect usual intakes on an individual level. However, at this time there is no developed and tested method to evaluate the HEI usual intake.

Table 9: The Healthy Eating Index- 2010 score and food components

HEI- 2010 component[1] (maximum points)	Standard for maximum points	Standard for minimum points
Adequacy (higher score indicates higher consumption)		
Total Fruit[2] (5)	≥ 0.8 cup equiv. / 1,000 kcal[10]	No Fruits
Whole Fruit[3] (5)	≥ 0.4 cup equiv. / 1,000 kcal	No Whole Fruits
Total Vegetables[4] (5)	≥ 1.1 cup equiv. / 1,000 kcal	No Vegetables
Greens and Beans[4] (5)	≥ 0.2 cup equiv. / 1,000 kcal	No dark-green vegetables, beans, or peas
Whole Grains (10)	≥ 1.5 ounce equiv. / 1,000 kcal	No Whole Grains
Dairy[5] (10)	≥ 1.3 cup equiv. / 1,000 kcal	No Dairy
Total Protein Foods[6] (5)	≥ 2.5 ounce equiv. / 1,000 kcal	No Protein Foods
Seafood and Plant Proteins[6,7] (5)	≥ 0.8 ounce equiv. / 1,000 kcal	No Seafood or Plant Proteins
Fatty acids ratio[8] [(MUFA + PUFA)/SFA]* (10)	≥2.5	≤1.2
Moderation (higher scores indicate lower consumption)		
Refined grains (10)	≤ 1.8 ounce equiv. / 1,000 kcal	≥ 4.3 ounce equiv. / 1,000 kcal
Sodium (10)	≤ 1.1 gram / 1,000 kcal	≥ 2.0 grams / 1,000 kcal
Empty Calories[9] (20)	≤ 19% of energy	≥ 50% of energy

[1] Intakes between the minimum and maximum standards are scored proportionately.
[2] Includes 100% fruit juice.
[3] Includes all forms except juice.
[4] Includes any beans and peas not counted as Total Protein Foods.
[5] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.
[6] Beans and peas are included here (and not with vegetables) when the Total Protein Foods standard is otherwise not met.
[7] Includes seafood, nuts, seeds, soy products (other than beverages) as well as beans and peas counted as Total Protein Foods.
[8] MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SA, saturated fatty acid.
[9] Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is > 13 grams/1,000 kcal.
[10] Equiv. = equivalent, kcal = kilocalories.

Table 10: MyPyramid guidelines and dietary reference intakes of food groups/items for individuals 50 years or older by sex, adapted from the 2010 Dietary Guidelines for Americans.

Food groups/items	Dietary Guidelines for Americans	
	Males	**Females**
Total protein (g)	56	46
Dairy (cups)	3	3
Fruit (cups)	2	1.5
Vegetables (cups)	2.5	2
Grains (oz)	6	5
Whole grains (oz)	3	2.5
Fiber (grams)	28	22
Saturated fat (% of kcal)	10	10
Refined grains (oz)	3	2.5
Sodium (mg)	1500	1500
Added sugar (% of kcal)	10	10

Table 11: Sociodemographic characteristics of the study sample.

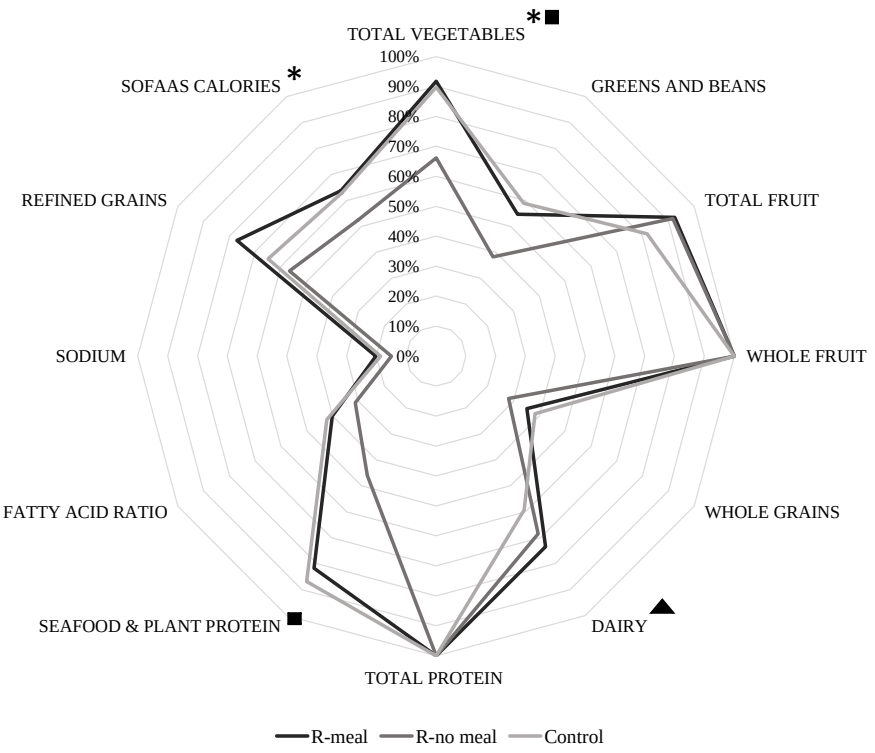
Characteristics	**Meal recipients** n=429	**No-meal recipients** n=68	**Controls** n=508	***p* value**
	%[1]	**%**	**%**	
Age (in years) mean ± SD	81.7 ± 0.7	82.5 ± 1.5	81.0 ± 0.6	0.200
Sex				
Male (vs. female)	30.71	40.28	24.06	0.067
Ethnicity				
non-Hispanic white	75.66	52.69	75.74	0.017
non-Hispanic black	14.80	33.02	16.83	
Other	11.54	14.29	7.43	
Education				
Less than 12th grade	37.66	50.73	36.87	
High school graduate/GED or equivalent	27.75	31.97	28.66	0.242
Some college or Associate degree, college graduate or above	34.59	17.30	34.47	
Marital status				
Married/living with a partner (vs. widowed/divorced/separated/ never married)	24.27	23.03	26.67	0.747
Residence				
Urban (vs. rural)	74.69	76.35	55.38	<0.001
Mobility				
Able to walk (vs. bedbound/ wheelchair/chair bound)	87.32	92.18	95.94	0.001

[1]Values represent weighted percentages unless otherwise specified.

Table 12: Nutrition and health-related characteristics of the study sample.

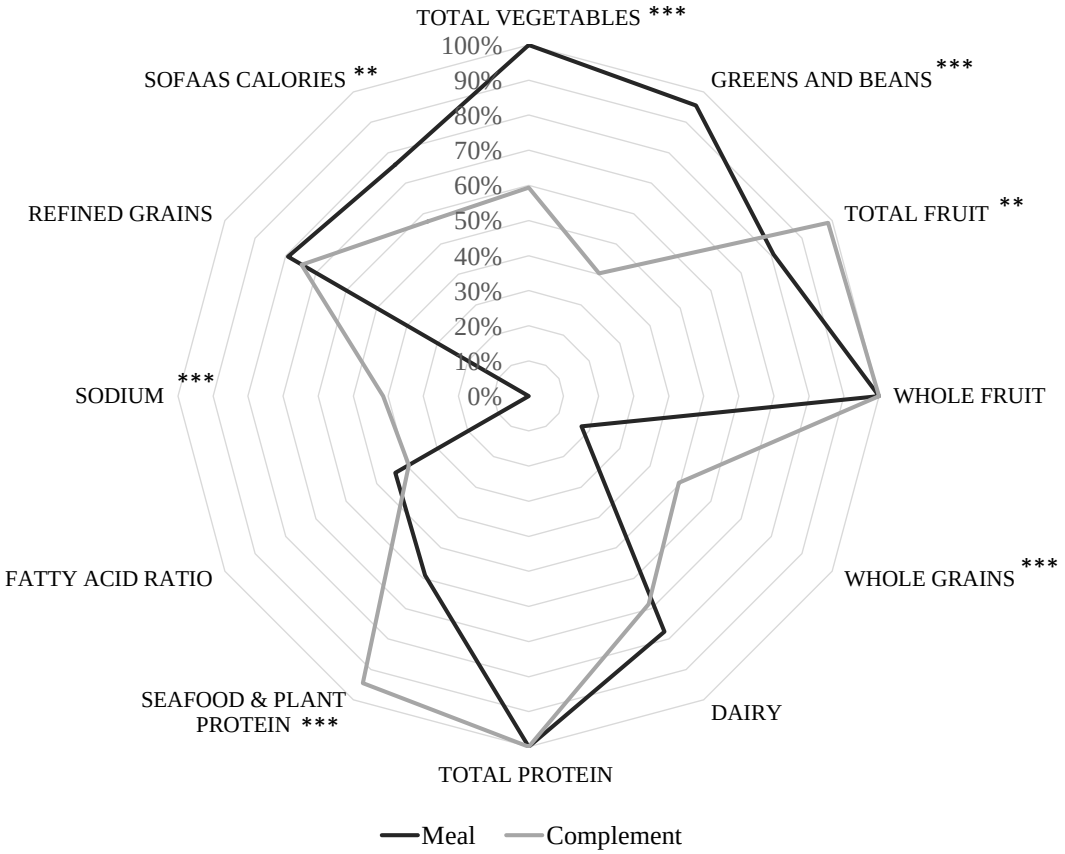
Characteristics	Meal recipients N=429	No-meal recipients N=68	Controls N=508	*p* value
	%[1]	%	%	
Food security				0.011
Food insecure (vs. food secure)	19.81	39.27	16.45	
Meals per day				0.741
≤2 (vs. ≥3)	34.53	39.66	36.17	
Appetite				0.051
Excellent	27.69	11.78	29.35	
Good	45.79	45.14	44.19	
Fair/poor	26.52	40.03	26.46	
Dental problems				0.427
yes (vs.no)	24.72	32.36	21.85	
Self-rated health				0.083
Excellent/very good	21.28	6.5	28.86	
Good	35.04	30.93	29.71	
Fair/poor	43.69	62.57	41.43	
Chronic diseases				0.151
≤2 (vs. >2)	22.22	11.13	17.51	
Healthy Eating Index				0.015
Mean ± SD	63.4 ± 1.6	52.5 ± 1.5	60.8 ± 1.2	

[1]Values represent weighted percentages unless otherwise specified.



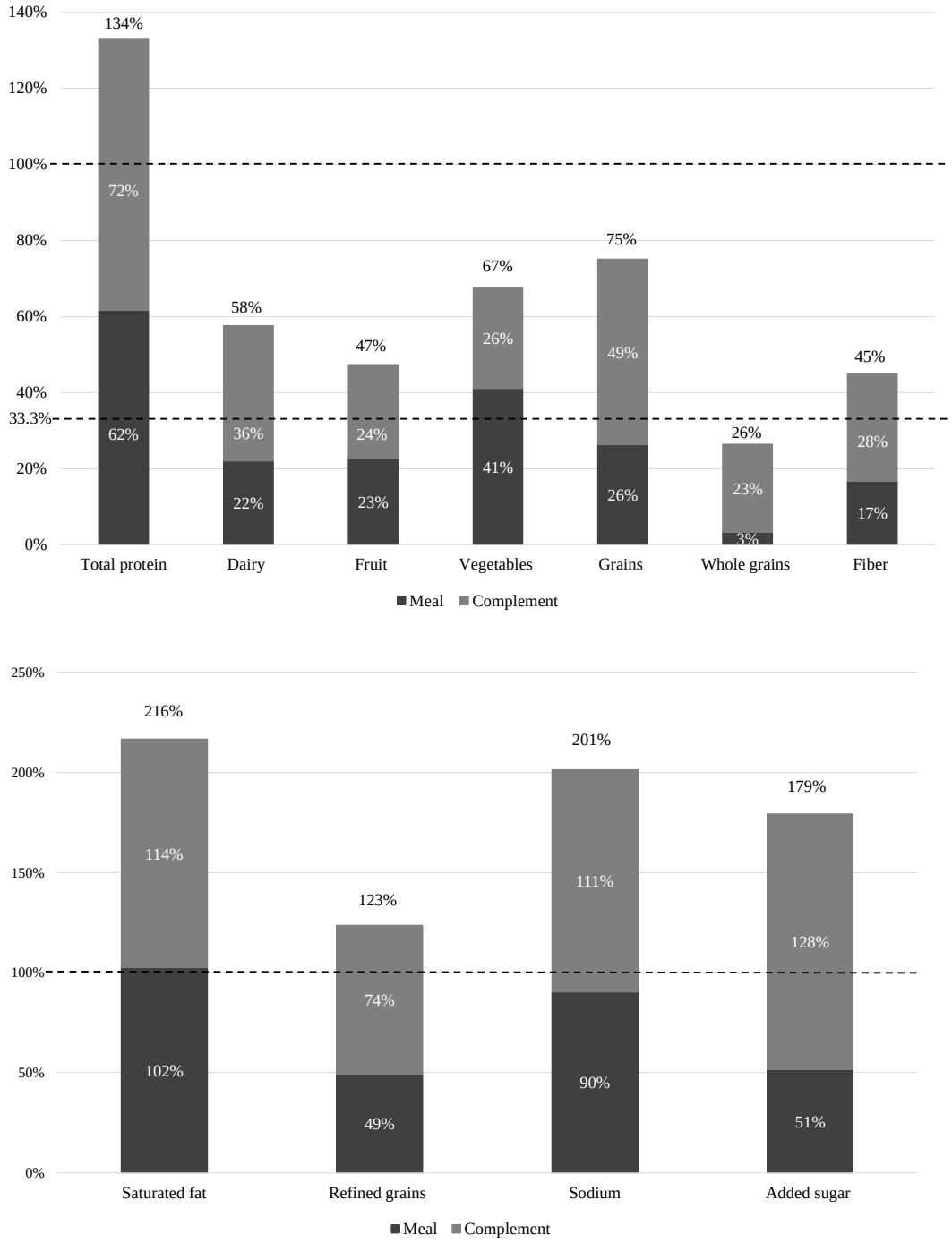
Asterisk, triangle and square denote significant differences between meal recipients and no-meal recipients, meal recipients and controls, and no-meal recipients and controls, respectively.

Figure 7: Radar map showing the HEI scores of meal recipients (black), no-meal recipients (dark grey), and the control group (light grey).



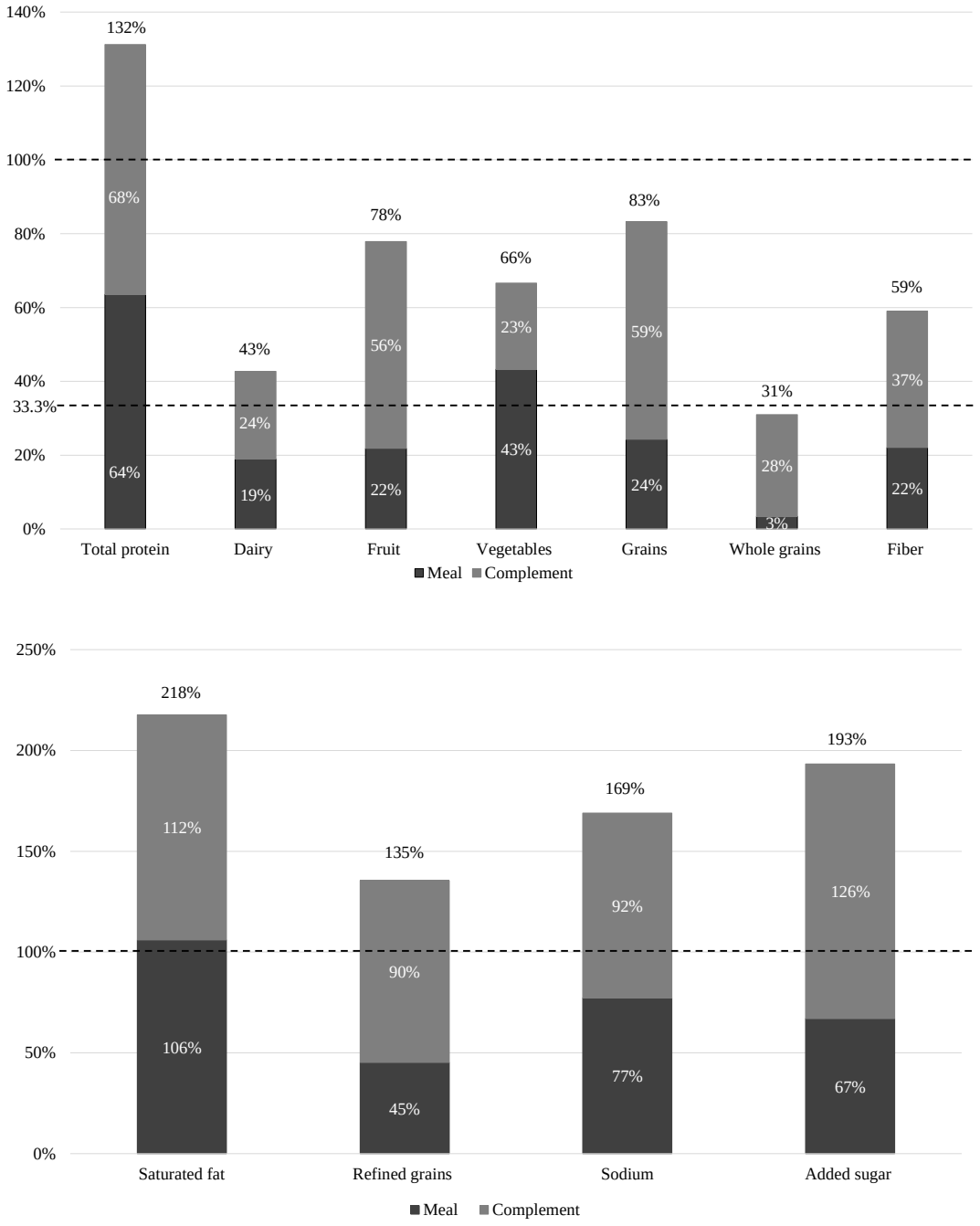
p≤0.001,*p≤0.0001

Figure 8: Radar plots displaying the HEI scores of HDM (black) and complementing foods (grey) for meal recipients.



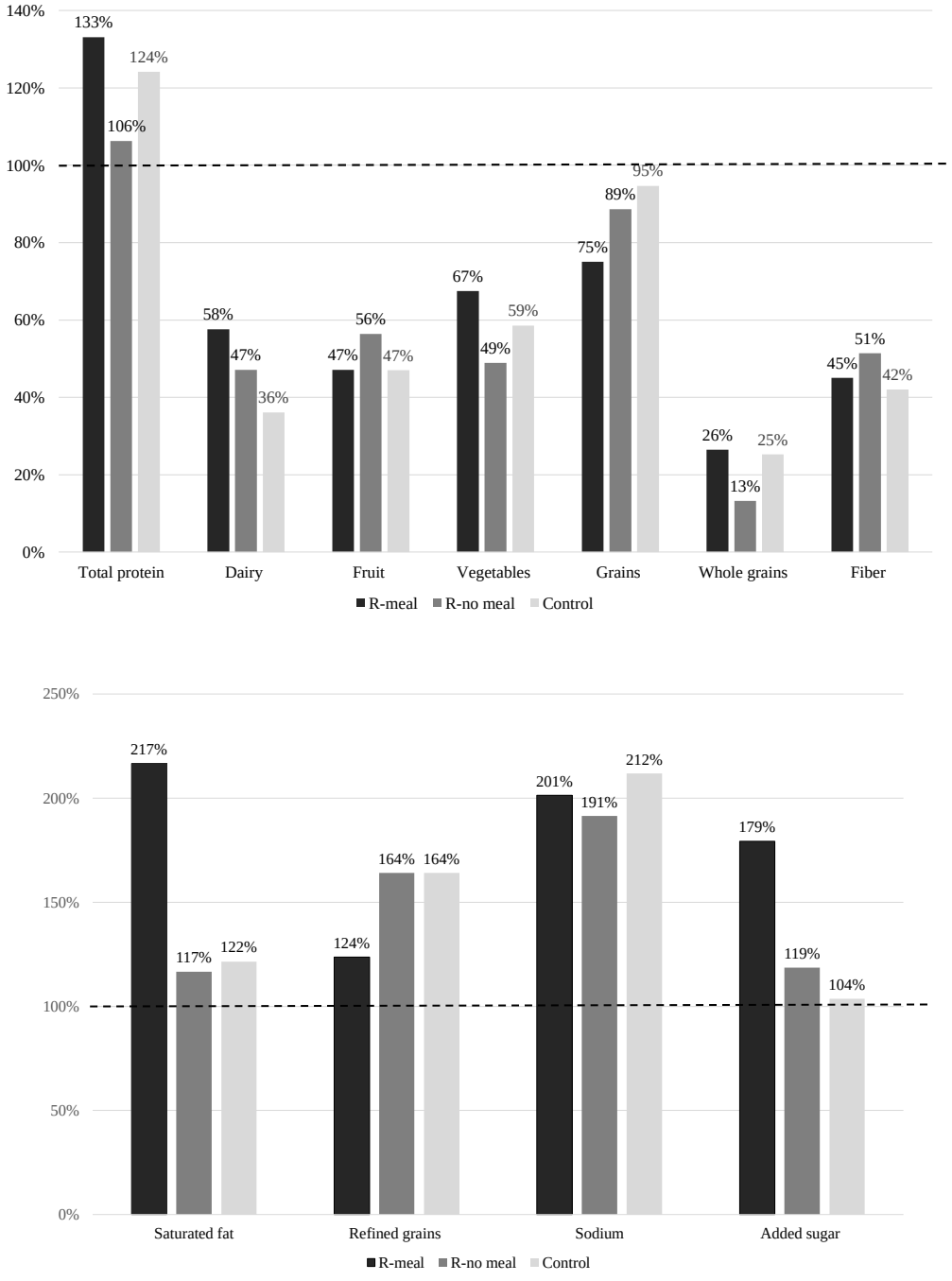
Protein and fiber are presented in grams, dairy, fruits and vegetables are presented in cups, and total grains and whole grains are presented in ounces. Saturated fat and added sugar are presented as percentages of calories, refined grains are presented in ounces, and sodium in milligrams.

Figure 9: Male home-delivered meal recipients' meal (black) and complementing diet (grey) as a percentage of the Dietary Guidelines for Americans 2010 for adequacy (top) and moderation components (bottom).



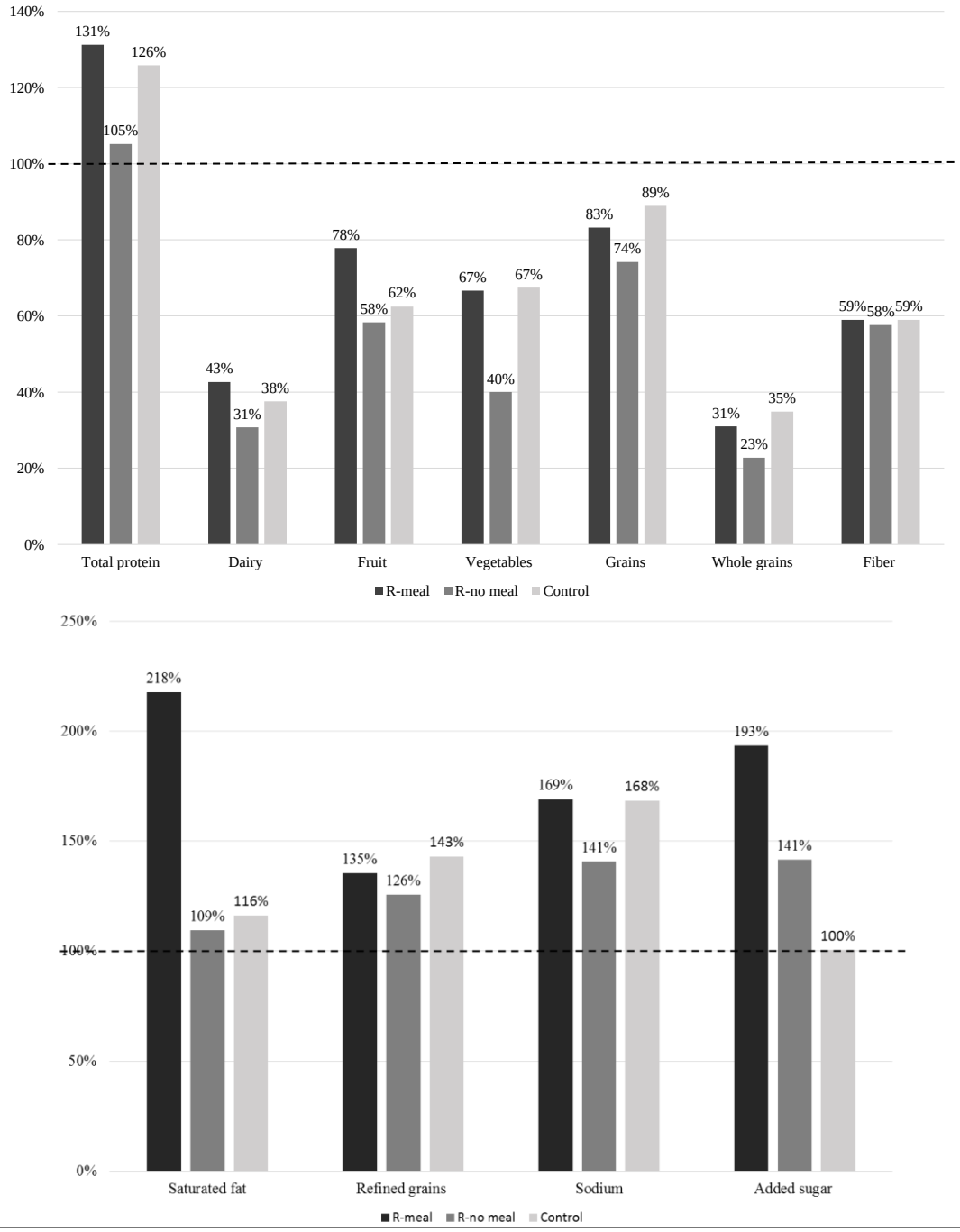
Protein and fiber are presented in grams, dairy, fruits and vegetables are presented in cups, and total grains and whole grains are presented in ounces. Saturated fat and added sugar are presented as percentages of calories, refined grains are presented in ounces, and sodium in milligrams.

Figure 10: Female home-delivered meal recipients' meal (black) and complementing diet (grey) as a percentage of the Dietary Guidelines for Americans 2010 for adequacy (top) and moderation components (bottom).



Protein and fiber are presented in grams, dairy, fruits and vegetables are presented in cups, and total grains and whole grains are presented in ounces. Saturated fat and added sugar are presented as percentages of calories, refined grains are presented in ounces, and sodium in milligrams.

Figure 11: The mean intake of food groups/components for male meal recipients (black), no-meal recipients (dark grey), and the control group (light grey) as a percentage of the Dietary Guidelines for Americans 2010 for adequacy (top) and moderation components (bottom).



Protein and fiber are presented in grams, dairy, fruits and vegetables are presented in cups, and total grains and whole grains are presented in ounces. Saturated fat and added sugar are presented as percentages of calories, refined grains are presented in ounces, and sodium in milligrams.

Figure 12: The mean intake of food groups/components for female meal recipients (black), no-meal recipients (dark grey), and the control group (light grey) as a percentage of the Dietary Guidelines for Americans 2010 for adequacy (top) and moderation components (bottom).

B) Food Insecurity, Diet Quality and Their Associations with Social Relationships and Depression in Home-Delivered Meal Programs in the United States: A Path Analysis

Introduction

Nearly half of adults in the United States report a lack of daily, meaningful, social interactions with others or report feelings of loneliness (273), and an alarming eight million adults over 50 years old are considered socially isolated (274). Social isolation and loneliness have profound consequences on the physical and psychological well-being of individuals with evidence of their association with coronary heart disease, depression and increased risk of mortality (275-277). Older adults may find themselves particularly susceptible to social isolation because of retirement (losing the socialization function of employment), institutionalization, physical limitations, frailty, bereavement (278), and/or reduced capacity to engage with others (279). Those vulnerable to social isolation or lack social relationships are those who live alone (280), males, widows (281), those with poorer health and less economic resources (282).

Social isolation, loneliness and lack of social support have all been linked to food insecurity (FI) and poor diet quality in the older adult population (96, 97, 99, 102, 123, 124, 203). In fact, those who lack social relationships share some of the risk factors of those with FI and malnutrition (2, 40, 282), the latter being an important risk factor for disability, hospitalization and institutionalization (283-285). FI is defined as the lack of "adequate physical, social or economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (45).

The variety of constructs that can be considered under the umbrella of social relationships, and the various ways in which they are defined and measured may be some of the reasons that hindered our study and understanding of the true connections between social

constructs and nutrition (167, 174). However, psychologists have underscored the importance of examining several aspects of social relationships at a time (133), especially that they may have independent pathways to nutrition (96-99). To examine some of these social constructs, this study used data collected as part of the Outcomes Evaluation Study of the Nutrition Service Program under the Older Americans Act (referred to as the OAANSP thereafter). OAANSP is considered the largest federal program for community-based and home-based nutrition services for older adults in the United States (33). The Outcomes Evaluation Study collected dietary and social data on a nationally representative sample of homebound older adults receiving home-delivered meals (HDM) and other nutrition related services and their controls, to evaluate the impact of the OAANSP program on their nutrition and well-being. The social constructs that were measured included social participation, eating alone, instrumental social support, loneliness, depressive symptoms, FI status and diet quality. This Outcomes Evaluation Study provides an opportunity to examine those social constructs with FI and dietary intake.

Social participation which refers to the involvement of individuals in social activities (103) was associated with better diet quality (99, 286) while the lack of it was linked to higher nutritional risk and poor diets in the older adult population (99, 167, 202-204). Participating in social activities may offer opportunities for older adults to eat with company (commensal eating), which was also shown to be associated with better diet quality (119, 287-289). It may also alleviate FI and/or loneliness (290, 291), and may at times be a resource for social support (292-294). Homebound older adults may not have the same opportunities for social participation as a result of their homebound status, however, the literature examining social isolation in this vulnerable population is relatively scarce (9, 196).

Social support, which refers to one's ability to rely on others effectively in potentially stressful situations (107, 123, 124, 295-299), involves three main types of support; instrumental social support, involving the provision of goods and/or services; informational support; providing knowledge and information that could be useful for the individual; and emotional support (300). The literature suggests that social support could directly influence diet quality (124, 301). Additionally, social support can provide a safety net against FI (107, 123, 124, 295-299). Having available social support can also alleviate feelings of loneliness and/or depression (100, 302), both of which have negative impacts on diet quality (100-102, 303). The literature provides evidence of positive associations between the informational and emotional components of social support and diet quality, but it is inconsistent for instrumental social support (107, 125, 295).

Low or absent social participation or social support can also increase older adults' sense of loneliness (100, 101, 302, 304). Loneliness refers to the distressing feeling that ensues when a person perceives his/her social relationships to be less in quantity and quality than he/she desires (130). Various studies have shown loneliness to be associated with malnutrition, poorer food choices and diet quality, and increased nutritional risk (96, 97, 102, 131, 305-307). However, feelings of loneliness do not always mirror the individual's reported social connectedness or support, as they have separate pathways to nutrition (96, 131). Therefore, it is important to distinguish between the different elements of social relationships in older adults, and understand their degree of correlation in the context of the population in which they exist (133, 134, 163-167).

In addition to their links to diet quality, the lack of social participation and instrumental social support, eating alone, loneliness and FI have all been associated with poorer mental health,

namely, depression, yet the nature and extent of these relations have been found to be inconsistent in the older adult population (154-161). Depression, in turn, has been commonly associated with poor nutritional status (124, 131, 203, 308, 309). This creates an additional challenge, noting that depression is prevalent in about 44%, of homebound older adults, compared to 4.2% to 10.6% in the general older adult population (143, 310). Furthermore, depressed older adults are more likely to eat alone (162). Older age, female, living alone, having chronic diseases, physical disabilities and functional limitations, loneliness, lack of social support and being at an economic disadvantage have all been shown to increase older adults' risk for depression (311-315).

Homebound older adults receiving HDM are a vulnerable and commonly overlooked population of older adults who are older, sicker and have more physical limitations compared to non-homebound older adults (4). Although many of the risk factors for inadequate dietary intake described above were examined individually, few studies examined these relationships together. Therefore, the objective of the current study is to examine the direct and indirect relationships that social participation, eating alone, instrumental social support, loneliness and depressive symptoms have with one another and with FI and diet quality using path analysis.

Methods

Sample design

This study obtained data from the Outcomes Evaluation Study, which was conducted between 2015- 2016 (4). The study used a multistage clustered sampling design to collect a nationally representative sample of HDM recipients and a matched control group of non-program participants (n=1027). Individuals had to be at least 67 years old, and propensity scores were used to match HDM recipients to the control group based on age, sex, ethnicity, Medicare

eligibility, chronic conditions, and dual eligibility for Medicare and Medicaid. However, it is important to note that the control group was not matched on homebound/mobility status. Individuals in the control group were excluded if they 1) participated in the OAANSP within the past year, 2) lived in a nursing home or a similar long-term care facility, and/or 3) did not have the same zip code as their matching recipients. Respondents who did not have complete dietary recall information (n= 11) and those with calculated energy intakes ±3SD of the mean (n= 11) were excluded from the OAA Outcomes Evaluation Study with a final sample of 1005 participants (n= 497 HDM recipients and n=508 controls). Details on recruitment and sampling technique can be found elsewhere (4).

The Outcomes Evaluation Study collected data using 1) Client Outcomes Survey and 2) two 24-hour dietary recalls. The client outcome survey collected information on demographic characteristics, food security status, health insurance coverage, self-reported health status, self-reported, physician diagnosed chronic conditions, depressive symptoms, loneliness, history of participation in the HDM program, and types of services received (221). Dietary data were collected using two interviewer-administered 24-hour recalls. The first 24-hour recall was collected from the full sample of HDM recipients and controls, and the second was collected on a non-consecutive day from a randomly selected subsample of HDM recipients (n=123). A meal was not always received on the day of the 24-hour recall and this was specified in the recall data.

Variables

Diet quality

The 24-hour dietary recalls were collected and analyzed using the Automated Self-Administered 24-hour (ASA24®) Dietary Assessment Tool, version 2014, developed by the NCI, Bethesda, MD (229). The 24-hour dietary recall is a structured interview that is designed to collect detailed

information about all the foods and beverages consumed by an individual in the past 24 hours (230). ASA24® analyzes the nutrient values from the Food and Nutrient Database for Dietary Studies (version 4.1), and food group values from MyPyramid Equivalent Database (version 1.0) (233, 234).

Food insecurity

Household food security status was assessed using the validated six-item short form of the U.S. Household Food Security Survey Module (HFSSM) (222, 223). This tool assesses the sufficiency of household financial resources to obtain food during the past 30 days. The sum of affirmative responses to the six items in the module is the household's raw score. The tool classifies households as having high or marginal food security (0-1 affirmative responses), low food security (2-4 affirmative responses), or very low food insecurity (5-6 affirmative responses). These categories were combined to form a dichotomous variable; food secure versus food insecure (moderately and severely food insecure). Additionally, the food security score was used as a continuous variable as discussed in the statistical analysis section below.

Social participation, eating alone, instrumental social support, loneliness and depressive symptoms

Social participation was assessed by inquiring about whether the respondents belonged to any religious or social groups, book clubs, or special interest groups, or other organizations and was coded as a dichotomous variable (yes/no). Eating alone (yes/no) was examined as a distinct construct. Received instrumental social support was assessed based on seven questions. These items asked if, in the last six months, the respondent received help or partook in any of the following; 1) adult care program; 2) personal care services for help with dressing or bathing; 3) visiting nurse or therapist to provide physical, occupational, or speech therapy; 4) case

management services; 5) free or discounted housing; 6) homemaker or housekeeping services to help with light housework, preparing meals, or shopping; and 7) chore services to help with heavier housecleaning or yard work. These dichotomous questions (yes/no) were combined to form one variable representing receiving instrumental social support. An affirmative response (yes) to any of the seven items was interpreted as receiving instrumental social support, and negative responses (no) to all of the items was coded as not receiving instrumental social support. Few respondents answered affirmatively to any of the single items, and therefore, it was not possible to examine the items individually.

Loneliness was examined by asking respondents how often they feel 1) a lack of companionship, 2) left out, and 3) isolated from others. In this abbreviated three-item scale, which was validated by the University of California, Los Angeles (UCLA) (224, 225) each item has a three-point response (1=hardly ever, 2=some of the time and 3=often). The total scale is created by summing the scores of the three items, ranging from one to nine, so that the higher the score, the greater the feeling of loneliness. This score was used as a continuous variable. Loneliness was also examined as a dichotomous variable, with a score greater than three (versus three or less) signifying greater feelings of loneliness (224).

Screening for depression was measured using the short form of the validated Patient Health Questionnaire-2 (PHQ) (226). Respondents were asked if, in the past two weeks, 1) the respondent had little interest or pleasure in doing things; and 2) if he/she felt down, depressed or hopeless. Each item has a response that ranges from zero to three (Not at all = 0, several days = 1, more than half of the days = 2, nearly every day = 3) and the total score is generated by summing the scores of the two items. The score ranges from zero to six; higher scores denote greater depressed mood and anhedonia (227, 228). There is no agreed upon cut off, however,

based on research findings, a score of three or greater balances specificity with sensitivity (227, 228). This score was used as a dichotomous variable, and as a continuous variable.

Sociodemographic and health-related covariates

The sociodemographic data used were age, sex, ethnicity, level of education, marital status, residence and household size. Age was tested as a continuous variable. Race/ethnicity was categorized into three groups; non-Hispanic black, non-Hispanic white, and Hispanic/Latino and Other). Educational attainment was classified as 1) less than 12^{th} grade; 2) high school graduate/GED or equivalent; and 3) some college or associate degree, college graduate or above, and was used as a proxy measure for socioeconomic status. Marital status was classified as 1) married or living with a partner; 2) separated, widowed, divorced, or never married. Area of residence of the respondents and the US Census Bureau geographic boundaries were used to group respondents as rural or urban residents (260).

Self-reported, physician-diagnosed chronic diseases included dichotomous questions on 10 chronic diseases/conditions; hypertension, coronary heart disease, diabetes mellitus, cancer, allergies and other breathing or lung problems, stroke, high cholesterol, anemia, osteoporosis, and kidney disease. Affirmative responses from these 10 questions were added together to form a continuous variable, the total number of physician-diagnosed, self-reported chronic diseases for each respondent. Oral health was measured using a single dichotomous question on whether the respondent currently had trouble eating due to conditions related to teeth, gums or other dental issue.

Statistical analysis

Descriptive statistics were used to examine the characteristics of study participants. Chi-square tests for categorical data and two-tailed independent sample *t*-tests for continuous data

were used to evaluate differences between groups. Data were examined for outliers and normality prior to analysis. The level of significance was set to $\alpha = 0.05$. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC), R (version 3.5.0) and MPlus version 7.3 (Muthén & Muthén, Los Angeles, CA).

Estimates for usual dietary intake (total vegetables) were obtained using the National Cancer Institute's statistical modeling method (243). This method was used to adjust for intrapersonal variability of dietary intake (243), by collecting a second non-consecutive 24-hour dietary recall from, at least, a subsample of the population (241). The food security raw score (HFSSM) does not necessarily represent equal intervals of severity. Therefore, the single-parameter logistic measurement model (Rasch model) was used to estimate the underlying severity of the respondent's latent trait (in this case, FI), which is an approximation of an equal-interval scale that can then be used as a continuous variable in subsequent analyses.

Structural equation modeling (SEM) was utilized to examine the direct relations depicted in the hypothesized structural model and the extent to which effects within the model are indirectly associated with usual vegetable intake through other variables. Conditional process modeling was undertaken to examine the mediation and moderation effects in the model. A path diagram, the visual statistical depiction of the hypothesized relations in the conceptual model, is shown in the **supplemental material** (**Figure S.1**).

SEM can be viewed as a series of concurrent regression equations, with multiple advantages over the traditional multivariate statistical analysis techniques, including offering an assessment of goodness-of-fit for the hypothesized model (how well the sample data fit the model) to the sample data, thereby facilitating theory testing (246). Maximum likelihood estimation was used, resulting in estimates of 1) model fit and 2) path coefficients (parameter

estimates) to assess the indirect, direct and total effects in the multi-group analysis. The structural model was estimated separately among HDM recipients and controls. Reported goodness-of-fit indices include the standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), and comparative fit index (CFI). The goodness-of-fit indices' target criteria were: SRMR>0.8, CFI >0.95, and a RMSEA <0.06. Parameter estimates were evaluated for HDM recipients and controls, and differences between HDM recipients and controls were examined using a z-score test statistic.

Results

Sample characteristics

The mean age of HDM recipients was 81.8 years old and the majority were females (68.0%), non-Hispanic white (70.9%), had low educational attainment (39.4% with less than 12^{th} grade education), widowed/separated/divorced/never married (75.5%), living in an urban setting (74.9%), and were able to walk (87.9%) (**Table 13**). HDM recipients and their controls were matched according to various sociodemographic and health indicators, however, significantly fewer controls were males, lived in an urban setting, and were bedbound or chairbound. FI was prevalent in 22.4% of HDM recipients and 16.5% of controls but there was no statistically significant difference in FI between groups. Compared to controls, a significantly higher prevalence of HDM recipients felt lonely (61.8% vs. 48.3%, respectively; p<0.001) and ate alone (69.1 vs. 55.8%, respectively; p=0.002). (**Table 14**).

Model fit and parameter estimation

There was good model fit of the data for HDM recipients and controls as indicated by goodness-of-fit indices in **Table 15**. **Table 16** presents the *direct* estimated pathways of the hypothesized model for HDM recipients and controls. For HDM recipients, the interaction of FI

and depressive symptoms was associated with a decrease in usual vegetable intake (p=0.03), which was significantly different from the control group (p<0.0001) (**Figure 14**). For the control group, receiving instrumental social support was directly associated with greater feelings of loneliness (p=0.02). Additionally, higher FI was associated with more depressive symptoms (p=0.01), and less usual vegetable intake (p=0.003) (Figure 14). The inverse association between FI and usual vegetable intake was significantly different between HDM recipients and controls (p<0.0001). The *indirect* relationships with usual vegetable intake through other variables were insignificant for HDM recipients and controls. Additional descriptive information on the relationships between the variables modeled can be found in the supplemental material (**Table S.2**).

Discussion

This is the first nationally representative study of older adults to examine the direct and indirect relations between FI, diet quality, different aspects of social relationships, and depressive symptoms. In this study, there was a significant and inverse association between FI and usual vegetable intake. Although prevalence of FI was similar in HDM recipients and controls, FI was associated with usual vegetable intake in controls but in HDM recipients this relationship existed among those with depressive symptoms as indicated by the interaction between FI and depressive symptoms. No direct relationship between FI and diet quality in HDM recipients may be an outcome of the protection from program participation. Other studies have indeed found a relationship between FI and dietary quality (46, 47). Although, in an obese population of adult females, who were predominantly African-American, the overall diet quality was poor, and FI was associated with lower protein and lean meat consumption and higher

carbohydrate intake but showed no significant associations with other food groups (such as vegetables) or major food items (such as sodium, refined grains, sweetened beverages (316).

FI was also positively associated with depressive symptoms in the control group. Evidence from the literature supports an association between FI and depression in older adults (317, 318). A recent study by Brooks and colleagues found an associations between varying food insecurity levels and clinically relevant depressive symptoms in older adults (319). It should be noted here that the current food security measurement tool is an evaluation of the economic access to food. In older adults, food access may be hindered by physical limitations (320), and cognitive impairment (321). Therefore, a more comprehensive tool for measuring FI may be necessary to understand the true relationship between FI, depressive symptoms and diet quality in this population.

Our results indicate that receiving instrumental social support was positively associated with loneliness in the control group but not in HDM recipients. HDM program could serve as the conduit for many other services provided to them. The Outcomes Evaluation Study did not collect information on informal support. So instrumental support in our study refers to structured/formal sources. Yi and colleagues showed no evidence of a relationship between perceived instrumental support and loneliness, but they did not identify the source of support (322). Conversely, a study in Canadian older adults showed that receiving formal support was associated with lesser feelings of loneliness (323). Researchers proposed that formal support gave older adults a greater sense of independence, allowing them to stay at home, without placing what they perceived to be unnecessary demands for socioemotional support on their family (323). Results of a systematic review of social support and loneliness showed that older adults were much more likely to receive support from family, followed by friends, and that

receiving informal instrumental social support from family was inversely associated with loneliness (281). Therefore, evidence suggests that the relationship between loneliness and social support differs according to the source of support (324). Reaching out to formal sources of instrumental social support may also be associated with a lack of other less formal support, the latter guarding against the feelings of loneliness (281). Information on when individuals seek formal and informal instrumental social support, in relation to when loneliness ensues, and whether informal sources of instrumental social support existed for study participants was not available. In addition, the literature examining social support and loneliness does not always differentiate between actual and perceived social support (96, 170, 325), making it difficult to draw conclusions regarding the nature of this relationship.

There was a significant positive correlation between loneliness and depressive symptoms in both HDM recipients and controls. Depression is one of the most prevalent mental health problems of older age (143). In a study investigating the association between old age depression and loneliness, Peerenboom and colleagues only found a significant relationship between depression and emotional loneliness (a lack of people with whom a person is able to form an emotional attachment) but not social loneliness (when an adequate social network is lacking) (326). Loneliness was also associated with cognitive decline in older adults, drawing attention to the potential ramifications of persistent loneliness (327). In a randomized control trial, Thomas and colleagues showed that HDM recipients were less lonely than their controls (153). In this study, there was a significantly higher prevalence of loneliness among HDM recipients compared to controls. Loneliness may have been considered a priority for participation in the HDM program, however this information is not available. The literature provides evidence on the bidirectional nature of the relationship between loneliness and depression, drawing attention

to the need to examine and address these two issues simultaneously in older adults.

The main limitation of this study is its cross-sectional nature, which prevented the assertion of causality in any of the hypothesized pathways. Longitudinal studies that ascertain directionality in the relationships proposed and/or qualitative data will provide a greater depth of understanding of those relationships. Another limitation of this study is that social participation was measured using a single item. A validated measure for social participation is suggested in future evaluation studies. Nevertheless, this is the first nationally representative study that simultaneously examines the relationships between the dietary and social aspects of the OAANSP. The associations between FI, depressive symptoms, and diet quality; and between received instrumental social support, loneliness and depressive symptoms underscore the importance of including a battery of validated and comprehensive assessment tools of social relationships that account for both the subjective and perceived dimensions. This study also highlights the vulnerability of a group of older adults who are not on the OAANSP, the control group.

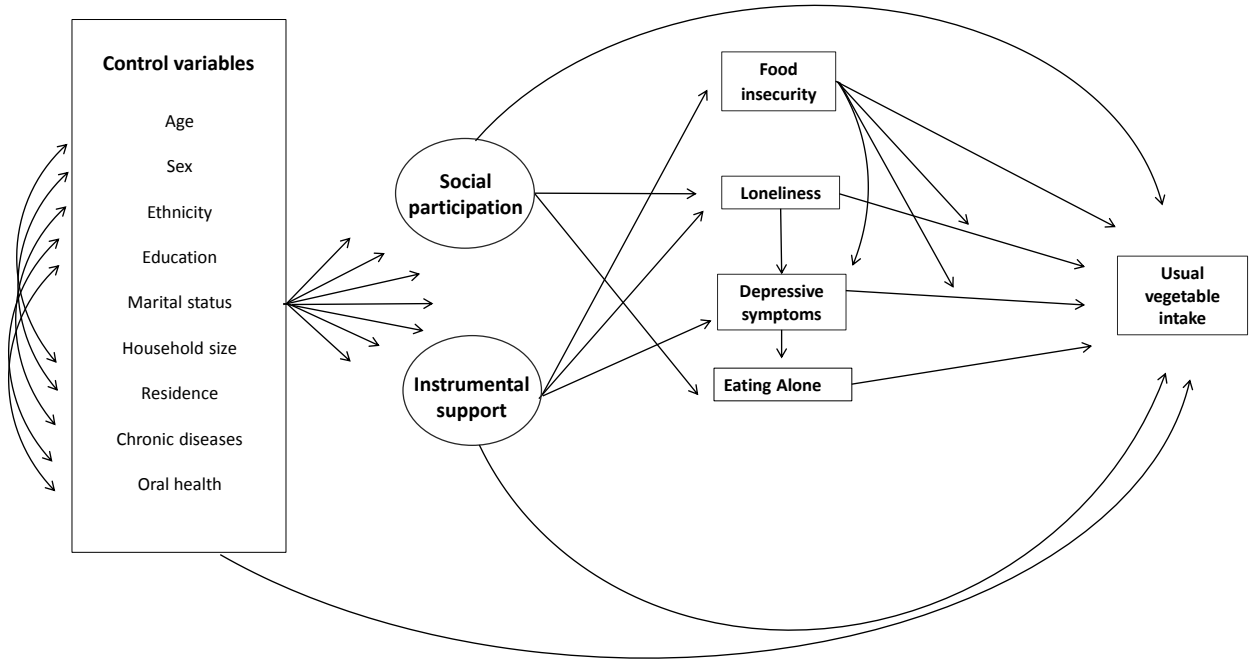


Figure 13: Conceptual model of the proposed links between diet quality (usual vegetable intake), food insecurity, loneliness, depressive symptoms, eating alone, instrumental social support and social participation. Latent constructs (F) are shown in ellipses and observed variables (V) are represented by a square. Lines with arrows represent the path or direction of influence, double-headed arrows represent covariances.

Table 13: Sociodemographic characteristics of the study sample.

Characteristics	**HDM recipients** n=497 **%**[1]	**Controls** n=508 **%**	***p* value**
Age			
mean ± SD	81.8 ± 0.7	81.1 ± 0.6	0.561
Sex			
male (vs. female)	32.0	24.1	0.021
Ethnicity			
non-Hispanic white	70.9	75.7	
non-Hispanic black	17.2	16.8	0.399
all others	11.9	7.5	
Education			
less than 12th grade	39.4	39.9	
high school graduate/GED or equivalent	28.3	28.7	0.860
some college or Associate degree, college graduate or above	32.3	34.4	
Marital status			
married/living with a partner (vs. Widowed/Divorced/Separated/Never married)	24.5	26.7	0.784
Residence			
urban (vs. rural)	74.9	55.5	<.0001
Mobility			
able to walk (vs. chair or bedbound)	87.9	96.0	0.002

[1]Values represent weighted percentages unless otherwise specified.

Table 14: Nutritional and psychosocial characteristics of the study sample.

Characteristics	HDM recipients	Controls	*p* value
	%[1]	%	
Food insecurity			
yes (vs. no)	22.4	16.5	0.137
Social participation			
yes (vs. no)	48.0	54.3	0.168
Instrumental support			
yes (vs. no)	16.7	11.4	0.160
Loneliness			
>3 (vs.≤3)	61.8	48.3	0.001
Depressive symptoms			
yes (vs. no)	19.3	13.5	0.118
Eating alone			
yes (vs. no)	69.1	55.8	0.002
Usual vegetable intake (cups)			
mean ± SD	1.3 ± (0.2)	1.2 ± (0.2)	0.426

[1]Values represent weighted percentages unless otherwise specified.

Table 15: Goodness-of-fit indices of the models for home-delivered meal recipients and controls.

Model fit indices	Models	
	HDM recipients[1, 2]	Controls
RMSEA	<0.001	<0.001
CFI	1.00	1.00
SRMR	<0.001	<0.001
Chi square	<0.001	<0.001
model df	0	0

[1]Root mean square error of approximation; RMSEA, Comparative fit index; CFI, standardized root mean square residual; SRMR, degrees of freedom; df.
[2] Cut off for RMSEA is <0.06, CFI is >0.95, and SRMR is >0.8.

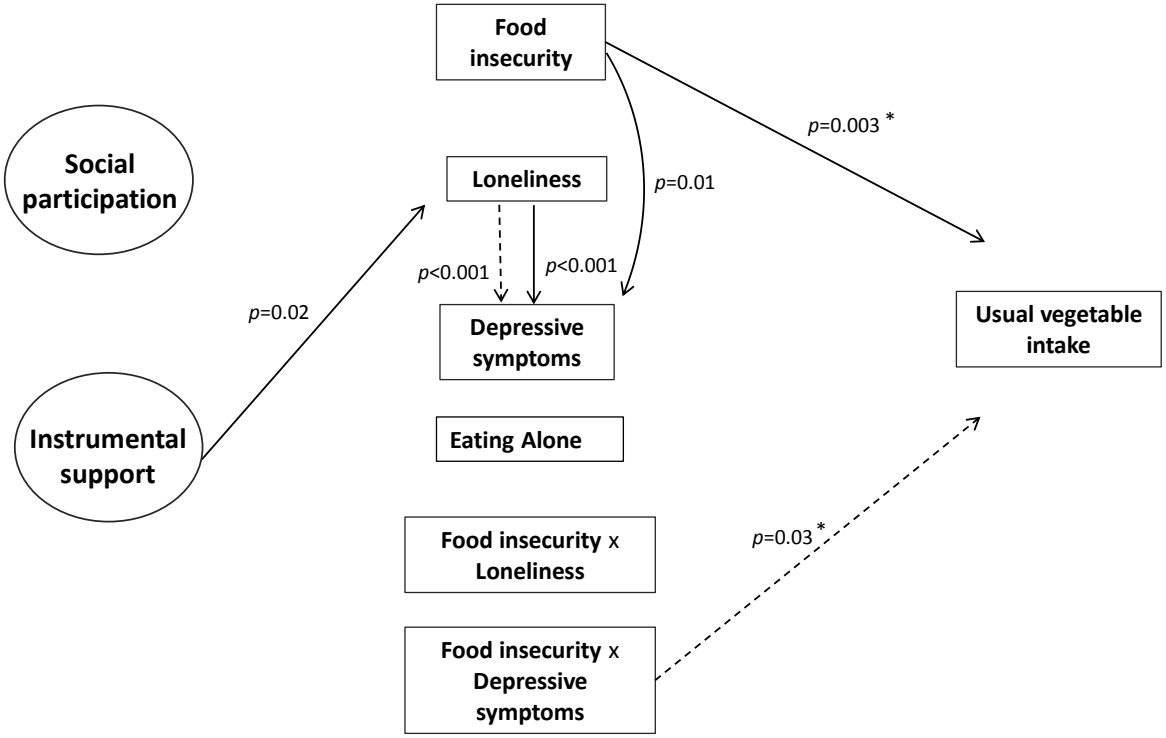


Figure 14: Significant pathways in home-delivered meal recipients (dotted line) and controls (solid line). Latent constructs are shown in ellipses observed constructs are represented by a square, and an asterisk indicates inverse associations.

Table 16: Structural equation modeling standardized and unstandardized estimates of the PATH coefficients for home-delivered meal recipients and their controls.

PATH	HDM recipients (group 1)				Controls (group 0)				group 0-group 1
	Standardized estimate	Unstandardized estimate	S.E.[1]	p value[1]	Standardized estimate	Unstandardized estimate	S.E.[1]	p value[1]	p value
Instrumental social support → Food insecurity	-0.099	-0.555	0.352	0.114	-0.037	-0.194	0.380	0.609	0.486
Instrumental social support → loneliness	0.064	0.299	0.284	0.292	0.156	0.778	0.341	0.022	0.280
participation → loneliness	-0.025	-0.089	0.193	0.646	0.001	0.002	0.188	0.993	0.736
Instrumental social support → depressive symptoms	-0.026	-0.116	0.250	0.642	0.027	0.137	0.381	0.719	0.579
Loneliness → depressive symptoms	0.426	0.405	0.070	<0.0001	0.390	0.391	0.086	<0.0001	0.900
Food insecurity → depressive symptoms	0.089	0.071	0.052	0.169	0.138	0.132	0.052	0.011	0.407
participation → eating alone	0.014	0.014	0.036	0.709	-0.025	-0.025	0.045	0.580	0.499
Depressive symptoms → eating alone	0.000	0.000	0.015	0.997	-0.088	-0.028	0.023	0.230	0.293
Participation → usual vegetable intake	-0.045	-0.030	0.004	0.445	-0.051	-0.030	0.005	0.492	1.000
Instrumental social support → usual vegetable intake	0.032	0.030	0.005	0.597	-0.043	-0.050	0.008	0.568	<.0001
Food insecurity → usual vegetable intake	0.083	0.010	0.001	0.250	-0.186	-0.040	0.001	0.003	<.0001
Loneliness → usual vegetable intake	-0.098	-0.020	0.001	0.211	-0.034	-0.010	0.002	0.648	<.0001
Depressive symptoms→ usual vegetable intake	0.149	0.030	0.002	0.118	-0.066	-0.010	0.002	0.453	<.0001
Eating alone → usual vegetable intake	-0.076	-0.050	0.005	0.278	-0.019	-0.010	0.007	0.853	<.0001

Food insecurity*depressive symptoms → usual vegetable intake	-0.200	-0.150	0.007	0.032	0.167	0.170	0.010	0.074	<.0001
Food insecurity*loneliness → usual vegetable intake	0.007	0.010	0.005	0.909	-0.052	-0.070	0.007	0.299	<.0001

* S.E. and *p* value are for the unstandardized parameter estimates

Supplemental material

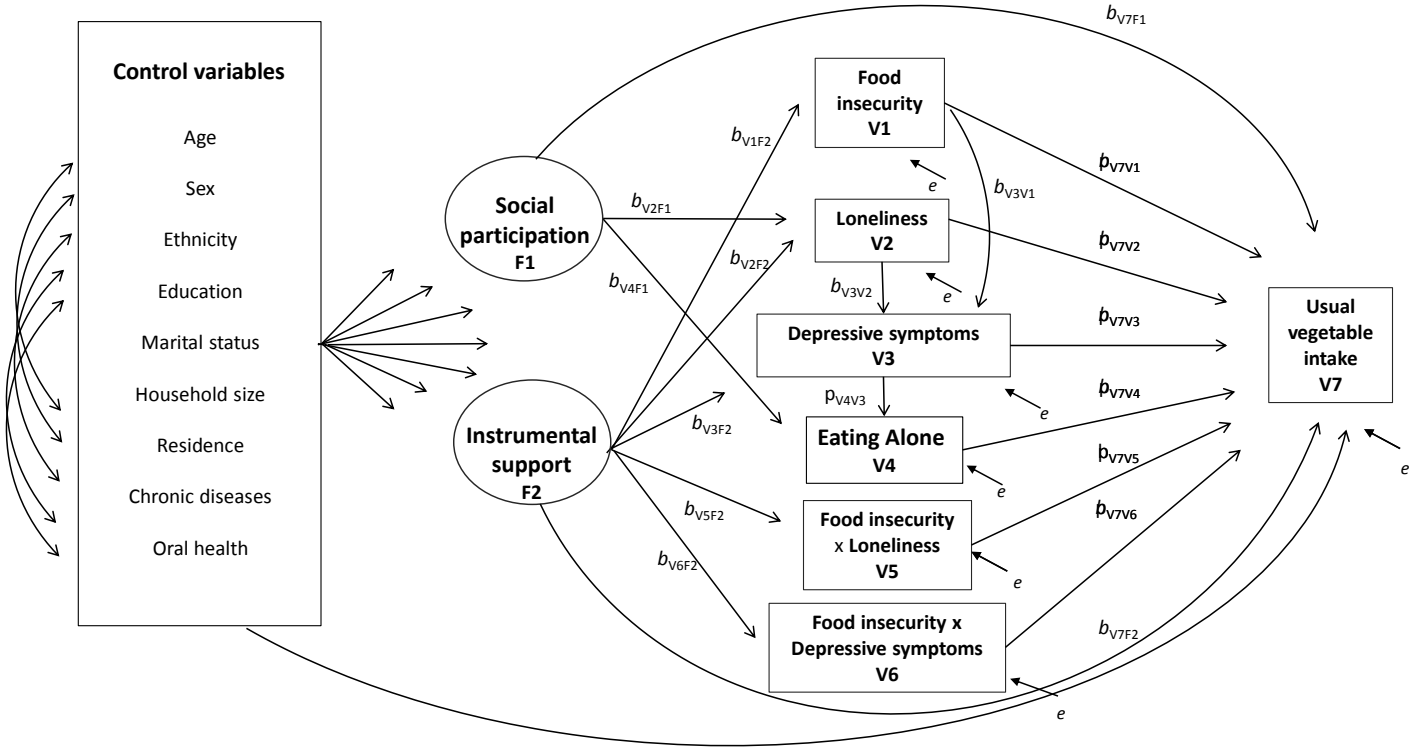


Figure S.1: The measurement model for the hypothesized pathways (p) between diet quality, FI, loneliness, depressive symptoms, eating alone, instrumental support and social participation. Latent constructs are shown in eclipses (F) and observed variables are represented by a square (V). Lines with arrows represent the path or direction of influence, double-headed arrows represent covariances. Residual variance or error terms of observed variables are labeled "*e*".

Table S.1: Correlation between variables of interest for HDM recipients (top) and controls (bottom).

Variable	Social participation	Instrumental social support	Food insecurity	Loneliness	Depressive symptoms	Eating alone	Usual vegetable intake
Social participation	1						
Instrumental social support	0.080	1					
Food insecurity	0.002	0.047	1				
Loneliness	-0.095	0.513	0.223	1			
Depressive symptoms	-0.092	0.031	0.196	0.509	1		
Eating alone	-0.061	0.011	0.035	0.174	0.008	1	
Usual vegetable intake	-0.017	-0.016	-0.034	-0.011	0.015	-0.075	1

Variable	Social participation	Instrumental social support	Food insecurity	Loneliness	Depressive symptoms	Eating alone	Usual vegetable intake
Social participation	1						
Instrumental social support	-0.019	1					
Food insecurity	-0.147	0.015	1				
Loneliness	0.065	0.149	0.186	1			
Depressive symptoms	-0.060	0.166	0.235	0.492	1		
Eating alone	-0.061	0.083	0.049	0.208	0.094	1	
Usual vegetable intake	0.017	-0.041	-0.179	-0.092	-0.040	-0.060	1

C) The Association between Social Relationships, Depressive Symptoms, Usual Protein Intake and Healthcare utilization in Homebound Older Adults: A PATH Analysis

Introduction

The national health expenditure in 2016 was $3.3 trillion ($10,348 per person), forecasted to increase by 5.5% each year, ultimately reaching $5.7 trillion by 2026. This expenditure increase is partly due to the chronic conditions that accompany aging of the US population (2). Additionally, the homebound population of older adults have higher healthcare utilization and expenditures compared to those non-homebound (182). The aging of the population has been driving the need to identify ways to reduce healthcare utilization. One of the strategies has been to provide home-based services in an effort to reduce costs associated with hospitalization and institutionalization (328). Food insecurity (FI) and social factors are two modifiable risk factors that may directly and/or indirectly increase healthcare utilization, likely disproportionately affecting homebound older adults (168, 196, 329-331).

The largest federal program providing community and home-based nutrition services for older adults, the Nutrition Service Program (NSP) under the Older Americans Act (OAA; referred to as OAANSP hereafter), offers meals at senior centers, schools, churches, or other group sites for community-living older adults (Congregate meals), or delivers them to the homes of homebound older adults (Home-delivered meals; HDM). These meals are provided at least five days per week to adults 60 years and over, each meal must be based on the most recent Dietary Guidelines for Americans (DGA), published by the Secretary of Health and Human Services and the Secretary of Agriculture and meet a minimum of one-third of the Dietary Reference Intakes (DRIs), recommendations from the Academy of Medicine (previously known

as the Institute of Medicine) (32). In addition, the OAANSP also offers a range of nutrition-related services such as nutrition education, screening, assessment, and counseling to: 1) prevent hunger and FI; 2) promote socialization; and 3) support the health and wellbeing of older adults (32). Findings from the OAANSP Outcomes Evaluation Study (referred to as the Outcomes Evaluation Study thereafter), conducted to evaluate the impact of the program on healthcare utilization and costs, showed a high prevalence of FI in this vulnerable group of homebound older adults (4, 38). However, whether interrelationships between FI and social relationships exist, and how they potentially relate, directly and/or indirectly, to healthcare utilization in this population has not been previously explored.

FI is defined as the lack of economic, physical and/or social access to adequate and safe nutritious foods that satisfy the dietary requirements and food preferences of individuals to maintain an active and healthy life (332). FI inevitably leads to malnutrition, both being important risk factors for hospitalization, institutionalization, and mortality (42, 193, 283-285). Older adults are at higher risk for malnutrition due to decreased intake, utilization and absorption of food (43). And while energy requirements decrease in older adults, nutrient requirements remain the same or increase for some nutrients.

Protein is a particularly important nutrient for this age group, and low protein intake has been associated with sarcopenia and frailty (68-72), both of which contribute to morbidity and mortality (333-336). Most studies that examined protein intake in older adults focused on special populations (such as critically ill patients), and/or specific outcomes such as sarcopenia, frailty and falls (68-72), rather than on healthcare utilization. Evidence suggests that homebound older adults on the HDM program are approximately three times more food insecure than the national average for older adults (4, 337), have poor diet quality (81) and have increased healthcare care

utilization (182). However, to our knowledge, the relationships between food insecurity, diet quality and healthcare utilization have not been explored simultaneously in HDM recipients.

Psychosocial factors are also closely linked to nutrition, especially in older adults (25, 99, 338); and have been associated with poorer diet quality and greater nutritional risk (89, 109, 339). Social isolation in older adults is particularly problematic because it has also been linked to increased hospitalization, institutionalization and healthcare cost (11, 12, 85). However, the numerous constructs considered in examining social factors, how they are defined and operationalized have not been consistent in the literature (133, 167, 174). These differences in ascertaining and measuring these constructs may obscure our understanding of the true relationship between dietary intake and social factors (89, 96-99). Some of the important constructs of social relationships are social participation, eating alone, received instrumental support and loneliness. Homebound older adults may be more susceptible to a lack or decrease of social relationships because of their physical limitations, and this could have consequences for their appetite and dietary intake (81, 340). However, research on the association between nutritional status and dietary intake and social relationships in this population is limited at best (65, 153, 325, 341).

Social participation can be viewed as the different levels of involvement of the individual with others in social activities (103). Greater participation in social and leisure activities has been shown to be associated with better diet quality in community-dwelling older adults (99, 286), and shorter hospital stay (197). Participating in social activities may also offer opportunities for older adults to eat with company (commensal eating), a construct that is often examined separately in the literature, possibly due to the consistent evidence of its role in diet quality and quantity (119, 287-289).

Instrumental social support, which involves the provision or receipt of goods and/or services, is considered a type or function of social support, the latter defined as one's personal transactions that aims to reduce stress and enhance coping (342). There is some evidence to suggest that social support provides a safety net against FI and potentially improve diet quality (107, 123, 124, 295-299). However, instrumental social support has not always been associated with positive health outcomes (300, 343, 344). Nutrition studies that examined social support often used measures that do not always differentiate between the different types of support (instrumental, informational and emotional) (107, 125, 295). Furthermore, they do not necessarily make the distinction between actual support and perceived social support, the latter being easier to examine (175).

Loneliness is considered an important construct of perceived social isolation. Feelings of loneliness refer to the distressing feeling that ensues when individuals perceive their social relationships to be less in quantity and quality than they desire. The lack of social participation or received instrumental social support is not always reflected in feelings of loneliness (133, 134, 322), which may suggest that perceived aspects of social isolation need to be examined separately. Various studies have shown loneliness to be associated with malnutrition, poorer food choices and diet quality, and increased nutritional risk (96, 97, 131, 305-307). However, the association between loneliness and healthcare utilization has not always been consistent (99, 167, 197, 202-205). The lack of social participation, receipt of instrumental social support and feelings of loneliness have also been associated with depression (143, 203). Depression is particularly prevalent in homebound older adults, 43.9%, versus 4.2%-10.6% in the general older adult population (143, 310), threatening diet quality and increasing healthcare utilization and costs even further (124, 131, 308, 309, 345). Depressed individuals have greater FI, worse

nutritional status and poorer diet quality (346-349), yet the literature examining these relationships in homebound older adults is fairly limited (350-352). Depressed older adults find less pleasure in eating and often eat alone (162, 348, 353), which was also shown to have negative ramifications on dietary intake.

This study was conducted to examine the association between FI, protein intake (as a measure of diet quality), social participation, received instrumental social support, loneliness, depressive symptoms and healthcare utilization of homebound older adults in HDM program participants and their control group using path analysis, utilizing data from the Outcomes Evaluation Study.

Methods

Study design

This study utilized secondary data from the Outcomes Evaluation Study, which was conducted between 2015-2017 to evaluate the impact of the OAANSP on healthcare utilization and costs. The study used a multistage clustered design to collect a nationally representative sample of HDM recipients and a matched control group of non-program participants. Study participants had to be at least 67 years old, and, controls were excluded if they 1) participated in the OAANSP within the past year, 2) lived in a nursing home or a long-term care facility, and/or 3) did not have the same zip code as their matching participant. Propensity scores were used to match HDM recipients to the control group based on age, sex, ethnicity, Medicare eligibility, presence of chronic conditions (as determined from Centers for Medicare and Medicaid Services (CMS) Medicare files), and dual eligibility for Medicare and Medicaid. It is important to note that HDM recipients were not matched by their homebound/mobility status.

Data were collected from 1027 study participants. Excluded from this sample were respondents who did not have any dietary recalls (n=11), those with calculated energy intakes ±3SD of the mean (n=11), and those with managed care plans (n= 364), with a final sample of 641 study participants (306 HDM recipients and 335 controls). Data of Medicare beneficiaries who were enrolled in managed care plans (e.g. Medicare Advantage) were excluded from the analysis, because the Centers for Medicare and Medicaid Services generally do not receive claims data on hospital admissions or emergency department (ED) visits for these beneficiaries (38). Details on recruitment and sampling technique can be found elsewhere (4).

Using computer-assisted personal interviews, data were collected using 1) Client Outcomes Survey, 2) two 24-hour dietary recalls, and 3) Medicare data linkages. The client outcomes survey included a comprehensive set of questions on individuals' socio-demographic characteristics, food security status, health insurance coverage, presence of self-reported, physician-diagnosed chronic conditions, depressive symptoms, loneliness, social participation, history of HDM program participation, and types of services received (221).

Dietary data were collected using two interviewer-administered computer-assisted 24-hour recalls and this data were analyzed using the Automated Self-Administered 24-hour (ASA24®) Dietary Assessment Tool (229). The first 24-hour recall was collected from the full sample of recipients and controls, and the second was collected from a randomly selected subsample (n=123) on a non-consecutive day after their first 24-hour dietary recall. Longitudinal healthcare utilization data (1 year after client outcomes survey) were obtained from the Medicare files of the Center for Medical Services Research Data Assistance Center.

Variables

Food security

Household food security status was assessed using the US Department of Agriculture's validated six-item short form of the U.S. Household Food Security Survey Module (HFSSM) (222, 223). Based on responses, individuals' food security status is categorized as high or marginal food security (score=0-1), low food security (score=2-4), and very low food security (score=5-6). These categories were combined to form a dichotomous variable; food secure and food insecure (combining low and very low food security) for descriptive data. Food security score was also used as a continuous variable.

Social participation, eating alone and instrumental social support

Social participation was assessed by administering one question that inquired about the respondent belonging to any religious or social groups, book clubs, or special interest groups, or other organization. This question was coded as a dichotomous variable (yes/no). Eating alone (yes/no) was examined as a separate construct. Instrumental social support was assessed based on responses to seven questions. These questions asked if the respondent, in the last six months, received help or participated in any of the following; 1) adult care program; 2) personal care services for help with dressing or bathing; 3) visiting nurse or therapist to provide physical, occupational, or speech therapy; 4) case management services; 5) free or discounted housing; 6) homemaker or housekeeping services to help with light housework, preparing meals, or shopping; and 7) chore services to help with heavier housecleaning or yard work. These dichotomous questions (yes/no) were combined to form one variable representing receiving instrumental social support. An affirmative response (yes) to any of the seven questions was considered as receiving instrumental social support, and negative responses (no) to all of the

questions was coded as not receiving instrumental social support. Few respondents answered affirmatively to any of the questions, and therefore, it was not possible to examine the questions separately.

Loneliness and depressive symptoms

To examine loneliness, respondents were asked how often they feel 1) a lack of companionship, 2) left out, and 3) isolated from others. This is an abbreviated three-item scale validated by the University of California, Los Angeles (UCLA) Loneliness Scale. Each item has a three-point response (1=hardly ever, 2=some of the time and 3=often) and the total scale is created by summing the scores on the three items to range between three and nine, such that higher scores indicate a greater feeling of loneliness (224, 225). This score was used as a continuous variable. We also dichotomized loneliness, with a score greater than three (versus three or less) representing greater feelings of loneliness.

Screening for depression was measured using the short form of the validated Patient Health Questionnaire-2 (PHQ-2) (226). Respondents were asked if, in the past two weeks, 1) the respondent had little interest or pleasure in doing things; and 2) he/she felt down, depressed or hopeless. Each PHQ-2 item has a response ranging from zero to three (Not at all = 0, several days = 1, more than half of the days = 2, nearly every day = 3), and the total score ranges from zero to six; higher scores denoting more depressive symptoms. A dichotomous variable with a score of three or higher was used to classify people with depressive symptoms. This cutoff was recommended by researchers as the cutoff that balances sensitivity with specificity (227, 228).

Sociodemographic and health-related covariates

The sociodemographic and health-related data used in the analysis were age, sex, ethnicity, educational attainment, marital status, residence, mobility/difficulty walking, number

of self-reported, physician-diagnosed chronic diseases and oral health. Age was examined as a continuous variable. Ethnicity was classified into three categories; non-Hispanic black, non-Hispanic white, and Hispanic/Latino and Other. Educational attainment was classified as 1) less than 12^{th} grade; 2) high school graduate/GED or equivalent; and 3) some college or associate degree, college graduate or above, and was used as a proxy for socioeconomic status. Marital status was coded as 1) married or living with a partner; 2) separated, widowed divorced, or never married. The study participants' area of residence and the US Census Bureau geographic boundaries were used to classify individuals as either rural or urban residents (260). Household size was used as a continuous variable.

An index was developed to reflect the number of self-reported, physician-diagnosed chronic diseases by combining ten dichotomous questions (yes/no) on hypertension, coronary heart disease, diabetes mellitus, cancer, allergies and other breathing or lung problems, stroke, high cholesterol, anemia, osteoporosis, and kidney disease. Responses were summed to create a continuous variable, ranging from one to ten. Oral health was assessed using a single dichotomous question on whether the respondent has trouble eating due to conditions related to teeth, gums or other dental issue.

Usual protein intake

The Food and Nutrient Database for Dietary Studies and the MyPyramid Equivalents Database were used to analyze the nutrients and food groups from the two 24-hour recalls, respectively (4). This information was used to calculate the usual protein intake for each individual, as discussed below. Protein intake, in grams, was used as a continuous variable.

Healthcare utilization

The Outcomes Evaluation study research team used the 2014 Medicare claims data to match controls to HDM recipients. The team then used Medicare claims data from 2015 to the first quarter of 2017 to construct outcome measures such as hospital inpatient stay, outpatient ED visits and observational stays. For this study, the number of visits were summed to create a continuous variable referred to as hospitalization and merged with the Client Outcomes survey and 24-hour dietary recall data.

Statistical analysis

Descriptive statistics were used to summarize study participants' socio-demographic, nutrition and health-related characteristics. Chi-square test for categorical data and two-tailed independent sample *t*-tests for continuous data were used to evaluate the differences between HDM recipients and controls. Prior to analyses, data were examined for outliers and normality. Analyses were adjusted for complex survey design. The level of significance was set to $\alpha = 0.05$. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC), R (version 3.5.0) and MPlus version 7.3 (Muthén & Muthén, Los Angeles, CA).

To obtain estimates for usual dietary intake, the National Cancer Institute's statistical modeling method was used to adjust for intrapersonal variability in dietary intake (243), by collecting a second non-consecutive 24-hour recall from at least a subsample of the population (241).

Food security score was tested as a dichotomous and a continuous variable. However, because the food security raw score (HFSSM) does not necessarily represent equal intervals of severity, the single-parameter logistic measurement model (Rasch model) was used to estimate

the underlying severity of the latent trait (in this case, FI). This approximation of an equal-interval scale, which can then be used as a continuous variable in the subsequent analyses (244).

Structural equation modeling (SEM) was used to examine the direct and indirect relations between the variables of interest depicted in the hypothesized structural model (Figure 1), and the extent to which effects within the model are indirectly associated with usual protein intake through other variables. Conditional process modeling was undertaken to examine the mediation and moderation effects in the model.

SEM can be viewed as a series of simultaneous regression equations, with several advantages over the traditional multivariate statistical analysis techniques by offering an assessment of goodness-of-fit for the hypothesized model to the sample data (how well the sample data fit the model)(246). The structural model was estimated separately for HDM recipients and controls. A path diagram, the visual statistical depiction of the hypothesized relationships in the conceptual model, is shown in the **supplemental material** (**Figure S.2**).

Maximum likelihood approach was used to obtain 1) model fit and 2) pathway coefficients (parameter estimates) which estimate the indirect, direct and total effects in the multi-group analysis. To examine the invariance of parameters across HDM recipients and controls, estimates for model pathways for both groups were compared, and significant differences were tested using the two-sample z statistic. Age, sex, education, ethnicity/race, marital status, household size, oral health and chronic diseases were included as potential confounders in the model.

Goodness-of-fit indices include the standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA) and comparative fit index (CFI). The cut-off criteria for the goodness-of-fit tests include a SRMR>0.8, CFI >0.95, and a RMSEA <0.06.

Parameter estimation was evaluated for HDM recipients and controls, and the difference in estimates between the groups were also examined using the *Z* score test statistic with significance set at $p<0.05$.

Results

Sample characteristics

The mean age of HDM recipients was 82.2 years old and most were female (68.2%), non-Hispanic white (71.3%), with lower educational attainment (40.2% had less than 12^{th} grade education), and not married or living with a partner (77.1%). HDM recipients and their controls were matched according to various sociodemographic and health indicators, and therefore, these characteristics were not significantly different between HDM recipients and controls. However, significantly more HDM recipients lived in an urban setting (74.8% vs. 56.2%; $p=0.003$) and reported difficulty walking (68.7 vs. 44.9%; $p<0.0001$) (**Table 17)**.

FI was prevalent in one fourth of HDM recipients, but there was no statistically significant difference between HDM recipients and controls. Nearly half of HDM recipients reported participating in any religious or social groups, book clubs, or special interest groups, or other organizations, and approximately 16% reported receiving any instrumental social support in the last six months. Almost 60% of HDM recipients reported feeling lonely, and about one fifth screened positive for depressive symptoms, but there were no statistically significant differences between HDM recipients and controls for any of these variables.

The majority of HDM recipients and controls reported having three or more self-reported, physician-diagnosed chronic diseases. Compared to controls, significantly more HDM recipients ate alone (73.0% vs. 56.7%, respectively; p=0.049) (**Table 18**) and had higher average usual protein intake (33.8 g vs. 31.7 g, respectively; p= 0.01). Finally, HDM recipients had

significantly higher hospitalizations compared to controls (1.7 vs. 1.1, respectively; p= 0.009). Additional descriptive information on the relationships between variables modeled can be found in the supplemental material (**Table S.2**).

Model fit and parameter estimation

The model fit indices indicated good fit for the model for both groups (**Table 19**). The *direct* estimated pathways of the hypothesized model for HDM recipients and controls are shown in **Table 20**. For HDM recipients, results showed that receiving any instrumental social support was directly and significantly associated with lower FI (p=0.03). This relationship was not observed in the control group, showing a statistically significant difference from that of HDM recipients (p=0.017). However, greater severity of FI in the control group was directly associated with more depressive symptoms (p=0.009).

Greater FI of HDM recipients and controls was associated with lower usual protein intake (p=0.047 and p<0.0001, respectively), however, this relationship was significantly stronger in controls (p=0.024). Additionally, usual protein intake in the control group was inversely associated with hospitalizations (p=0.016). Eating alone was also inversely associated with usual protein intake in the control group (p=0.027). Furthermore, eating alone in this group was marginally associated with greater hospitalizations (p=0.057).

Finally, loneliness was positively associated with depressive symptoms in both HDM recipients and controls (p<0.001 and p=0.002; respectively) and in turn, there was a significant association between having more depressive symptoms and eating alone (p=0.046) among HDM recipients. Significant relationships for HDM recipients and controls are shown in **Figure 16**. We examined the indirect associations between variables of interest and hospitalization in HDM recipients and controls, but results were not significant (data not shown).

Discussion

In this study, we found an inverse association between FI and usual protein intake in both HDM recipients and controls, however, this relationship was significantly stronger in the control group. Additionally, in the control group, there was an inverse association between protein intake and hospitalization. The importance of adequate protein intake for vulnerable older adults' is underscored by the inverse relationship between usual protein intake and hospitalization in the control group. Most studies examining protein in older adults and health outcomes either measured protein markers such as albumin and C-reactive protein (as outcomes), examined this relationship among hospitalized patients (354-356), or focused on protein intake in relation to functional outcomes and falls (357, 358). One study showed that lower protein intakes were associated with prolonged hospital stay and mortality in hospitalized, frail older adults (355). Another randomized control trial using protein-enriched foods or supplements recorded decreased mortality and improved indices of nutritional status in hospitalized, malnourished older adults (359). In our study, HDM recipients did not show a similar association between usual protein intake and hospitalization. It should be noted that, in our study, the HDM recipients' mean usual protein intake was still significantly higher than the protein intake of controls.

Usual protein intakes in both HDM recipients and controls indicate that they are at high risk for protein insufficiency. Results from the Outcomes Evaluation Study showed that total protein intake of 99.6% of HDM recipients was within the average macronutrient distribution range of 10-35% of energy intake of adults (4). Examining protein as a percentage of caloric intake may be misinterpreted as adequate, especially in older adults who are at risk of low energy intake (43). By calculating the absolute amount of protein intake, our results show that the mean

usual intake of both HDM recipients and controls are 34 g and 32 g, respectively, well below the recommended intake of 46 and 56 g for females and males, respectively. Furthermore, evidence suggests that dietary protein intakes even greater than the current DRI may serve as a protective factor against sarcopenia and frailty (360, 361).

The inverse association between FI and lower protein intake seen in this study was shown in other studies (362-366). However, this finding is of particular concern in this population. FI prevalence in this study population of HDM recipients and controls is 25.1% and 16.0%; respectively, compared to the national average for older adults (8.9%). These findings characterize this older adult population as not only particularly vulnerable to FI, but also to poor dietary quality. It also draws attention to the control group, a similarly vulnerable population.

Eating alone was also associated with lower usual protein intake and greater hospitalization in the control group. Nevertheless, protein was not a significant mediator in the relationship between eating alone and hospitalization, which may have been a result of sample size limitations. In a recent meta-analysis, Ruddock and colleagues suggested that eating with others increased food intake compared to eating alone (118). Similarly, other studies found that those who eat alone have nutrition intake below recommendation, a lower quality of life (367), and lower self-rated health (119). These findings further underscore the vulnerability of the control group. Some of the older adults in the control group may not qualify for HDM because they may not necessarily be homebound, yet, they also do not participate in the congregate meal program. Congregate meals are offered at senior centers and similar community settings which facilitate commensality and may provide an opportunity for socialization during mealtimes. It is also possible that the control group receive informal support from family and friends, however this information was not collected, It may, therefore, be worthwhile to explore the reasons why

vulnerable older adults such as those in the control group do not participate in the congregate meal program and, potentially, other social services.

The associations between eating alone and mean usual protein intake, as well as the association between eating alone and hospitalization were not significant in HDM recipients, even though this population is vulnerable to social isolation (169), and significantly more reported eating alone than the control group. Eating alone may not be an appropriate measure for social contact in homebound older adults. It is possible that this population resorts to other ways of connecting with others. Social participation assessment tools that have been validated in the homebound older adult population may be useful to incorporate in the evaluation of social relationships.

Results of this study showed that HDM recipients who received instrumental social support had lesser severity of FI. This finding was reported by other studies. In a study of depressed older adults, Greenfield and colleagues found that perceived instrumental social support was associated with lower nutritional risk (350). Receiving instrumental social support from the community was also shown to be associated with lower FI in a population living in a rural setting, however, a clear distinction between perceived and received questions was not made clear (368). In another study, the availability of food assistance programs in vulnerable populations, in the absence of perceived instrumental social support, was not associated with FI (369). The inverse relationship between FI and received instrumental social support is important given the prevalence of FI in HDM recipients and controls, underscoring the potential role received instrumental social support can play in both of these vulnerable populations. Our results also show that approximately only 16% of HDM recipients reported receiving any instrumental social support in the past six months. Future studies exploring why the majority of

HDM recipients do not use these instrumental social support services may offer leads into potential interventions.

In this study, there was no association between instrumental social support and FI in the control group. It is possible that a more informal type of instrumental social support was available for this population, such as that provided through family, friends and neighbors, however, there were no data available on informal types of support or sources of support. In a study of urban households at risk of FI, an inverse relationship between informal instrumental social support and FI was reported (369). This further emphasizes the need to simultaneously examine the range (formal and informal) and potential source(s) of instrumental social support (such as family, friends, and neighbors) to better understand this relationship.

Greater loneliness of HDM recipients and controls was associated with more depressive symptoms. This adds to the body of evidence supporting these findings in older adults (370). Homebound older adults are at higher risk for depression. In fact, in a nationally representative study of homebound and semi homebound older adults, Xiang and colleagues showed that 43.9% of homebound and 28.1% of semi-homebound older adults suffered depressive symptoms, compared to 10% of non-homebound older adults (143). Depressive symptoms have been associated with increased healthcare utilization and mortality (143, 248). The OAANSP may be the first access point that older adults encounter for other home-based services and potentially other resources that may support older adults experiencing depressive symptoms. Furthermore, depressive symptoms were also significantly associated with eating alone in HDM recipients. This could be driven by the large proportion of HDM recipients who eat alone as a result of their homebound status.

To our knowledge this is the first longitudinal study to examine, simultaneously, the goals of the OAANSP, and explore some of the direct and indirect risk factors for hospitalization. One limitation to our study is that there were no Medicare data available for beneficiaries enrolled in managed care plans (e.g. Medicare Advantage), which reduced our sample size and restricted analysis to the fee-for-service Medicare patients. This means that the sample examined in this study may not be representative of older adults receiving the HDM program in the U.S. Another limitation is that we were unable to examine certain variables such as perceived instrumental support and sources of social support which would have increased our understanding of the nature of social relationships in this population. Nevertheless, this is a survey that collected valuable information on a vulnerable population of older adults which is difficult to reach, and hence the limited studies. The results of this study also highlight the value of examining the different aspects of social relationships and indicate the need to develop more standardized ways of evaluating them. This study also draws attention to a unique and possibly overlooked vulnerable population of older adults who are not served by HDM program and are not recipients of congregate meals. While fewer controls may have mobility issues, the prevalence of FI was approximately double that of the national average. Additionally, a larger percentage of the control group reported depressive symptoms and lower usual protein intake; the latter shown to be a risk factor for hospitalization. These results warrant further investigations on how to reach this vulnerable population and explore why they do not participate in the OAANSP.

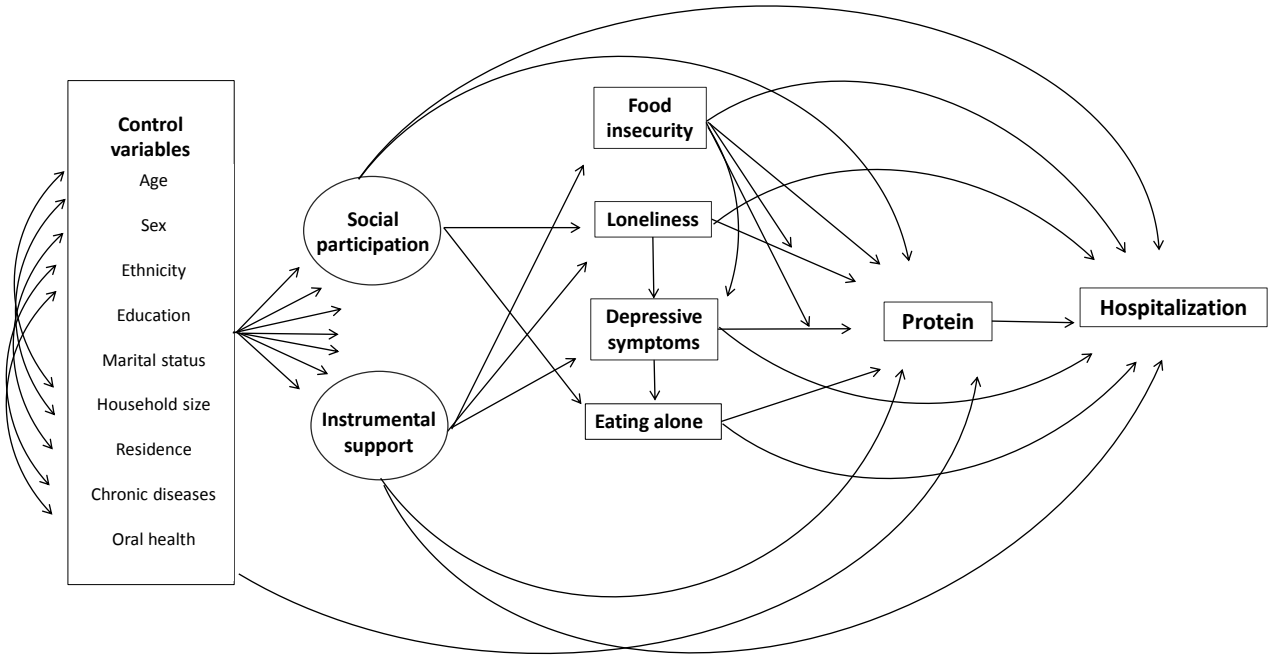


Figure 15: The conceptual model of the proposed links between hospitalization, usual protein intake, food insecurity, loneliness, depressive symptoms, eating alone, instrumental support and social participation. Latent (not directly observable) constructs are shown in ellipses and observed variables are represented by a square. Lines with arrows represent the path or direction of influence, double-headed arrows represent covariances.

Table 17: Socio-demographic characteristics of home-delivered meal recipients and controls.

Characteristics	**HDM recipients** (n=306)	**Controls** (n=335)	***p* value**
	%[1]	**%**	
Age			
mean ± SE	82.2 ± 0.7	81.4 ± 0.8	0.775
Sex			
male (vs. female)	31.8	24.9	0.170
Race/ethnicity			
non-Hispanic black	15.9	17.0	
non-Hispanic white	71.3	77.8	0.117
all others	12.8	5.2	
Education			
less than 12th grade	40.2	36.5	
high school graduate/GED or equivalent	29.1	28.6	0.770
some college or Associate degree, college graduate or above	30.7	34.9	
Marital status			
married/living with a partner (vs. widowed/divorced/separated/never married	22.9	25.6	0.541
Residence			
urban (vs. rural)	74.8	56.2	0.003
Difficulty walking			
yes (vs. no)	68.7	44.9	<.0001

[1]Values represent weighted percentages unless otherwise specified.

Table 18: Health-related characteristics of home-delivered meal recipients and controls.

Characteristics	**HDM recipients** n=306	**Controls** n=335	***p*-value**
	%[1]	**%**	
Food insecurity			
yes (vs. no)	25.1	16.0	0.111
Social participation			
yes (vs. no)	45.9	52.9	0.244
Instrumental social support			
yes (vs. no)	15.9	13.8	0.668
Loneliness			
>3 (vs. ≤3)	57.9	47.3	0.100
Depressive symptoms			
yes (vs. no)	21.1	13.8	0.107
Eating alone			
yes (vs. no)	73.0	56.7	0.049
Chronic diseases			
0-2 (vs. >2)	12.4	7.9	0.208
Usual protein intake (g)			
mean ± SE	34.0 ±0.7	31.8 ±0.5	0.010
Hospitalization (count)			
mean ± SE	1.7 ±0.2	1.1 ±0.2	0.009

[1]Values represent weighted percentages unless otherwise specified.

Table 19: A summary of model fit indices for HDM recipients and controls.

Model fit indices[1,2]	**Models**	
	HDM recipients	**Controls**
RMSEA	<0.0001	<0.0001
CFI	1.000	1.000
SRMR	0.006	0.003
Chi square for model fit	0.814	0.668

[1]Root mean square error of approximation; RMSEA, Comparative fit index; CFI; standardized root mean square residual; SRMR.
[2] Cut off for RMSEA is <0.06, CFI is >0.95, and SRMR is >0.8.

Table 20: Structural Equation modeling standardized, and unstandardized parameter estimates for HDM recipients and controls.

PATH	HDM participants (group 1)				Controls (group 0)				Parameter estimate group 0-group 1
	Standardized parameter estimate	Unstandardized parameter estimate	S.E.	p value	Standardized parameter estimate	Unstandardized parameter estimate	SE	p value	p value
Instrumental social support → Hospitalization	0.05	0.34	0.33	0.31	0.09	0.55	1.02	0.59	0.84
Social participation → Hospitalization	0.00	-0.02	0.29	0.95	-0.01	-0.04	0.33	0.91	0.96
Protein → Hospitalization	-0.03	-0.09	0.24	0.70	-0.13	-0.40	0.16	0.02	0.29
Food insecurity → Hospitalization	0.08	0.09	0.09	0.34	-0.05	-0.06	0.08	0.42	0.22
Loneliness → Hospitalization	0.11	0.15	0.10	0.13	0.11	0.13	0.08	0.12	0.91
Depressive symptoms → Hospitalization	0.09	0.13	0.16	0.39	-0.04	-0.05	0.08	0.56	0.30
Eating alone → Hospitalization	-0.02	-0.11	0.74	0.88	0.12	0.46	0.24	0.06	0.47
Instrumental social support → Food insecurity	-0.19	-1.06	0.49	0.03	0.06	0.26	0.26	0.31	0.02
Instrumental social support → Loneliness	-0.02	-0.17	0.31	0.59	0.05	0.24	0.41	0.56	0.43
Social participation → loneliness	-0.05	-0.10	0.40	0.80	0.03	0.09	0.27	0.75	0.70

Instrumental social support → Depressive symptoms	0.00	0.01	0.36	0.99	0.01	0.02	0.49	0.96	0.98
Food insecurity → Depressive symptoms	0.11	0.09	0.05	0.09	0.21	0.21	0.08	0.01	0.20
Loneliness → Depressive symptoms	0.53	0.49	0.07	<0.0001	0.34	0.33	0.11	0.00	0.19
Social participation → Eating alone	-0.04	-0.04	0.04	0.30	-0.03	-0.03	0.06	0.60	0.96
Depressive symptoms → Eating alone	0.10	0.03	0.01	0.05	-0.08	-0.03	0.03	0.41	0.12
Social participation → Protein	0.07	0.10	1.06	0.35	0.04	0.54	0.09	0.54	0.68
Instrumental social support → Protein	0.01	0.02	1.61	0.89	-0.07	-1.31	0.10	0.19	0.41
Food insecurity → Protein	-0.20	-0.07	0.33	0.05	-0.20	-0.81	0.02	<0.0001	0.02
Loneliness → Protein	-0.02	-0.01	0.37	0.86	0.15	0.57	0.03	0.05	0.12
Depressive symptoms → Protein	0.03	0.01	0.46	0.78	-0.12	-0.48	0.03	0.15	0.29
Eating alone → Protein	0.07	0.11	1.22	0.39	-0.18	-2.30	0.10	0.03	0.05
Food insecurity*Depressive symptoms → Protein	0.18	0.34	2.25	0.13	0.10	2.28	0.17	0.17	0.39
Food insecurity*Loneliness → Protein	-0.07	-0.14	1.41	0.34	0.03	0.76	0.13	0.55	0.53

*S.E. and p value are in reference to unstandardized parameter estimates.

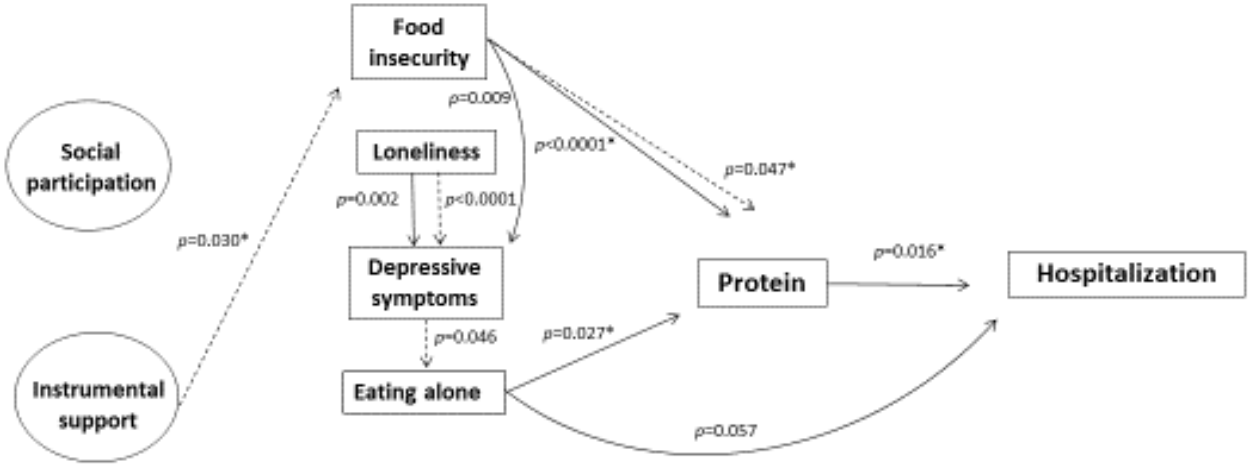


Figure 16: PATH model showing statistically significant positive and inverse associations between hospitalization, usual protein intake, food insecurity, loneliness, depressive symptoms, eating alone, instrumental social support and social participation for HDM recipients and controls. Inverse relationships are denoted by an asterisk, HDM recipients, broken line; controls, solid line.

Supplemental material

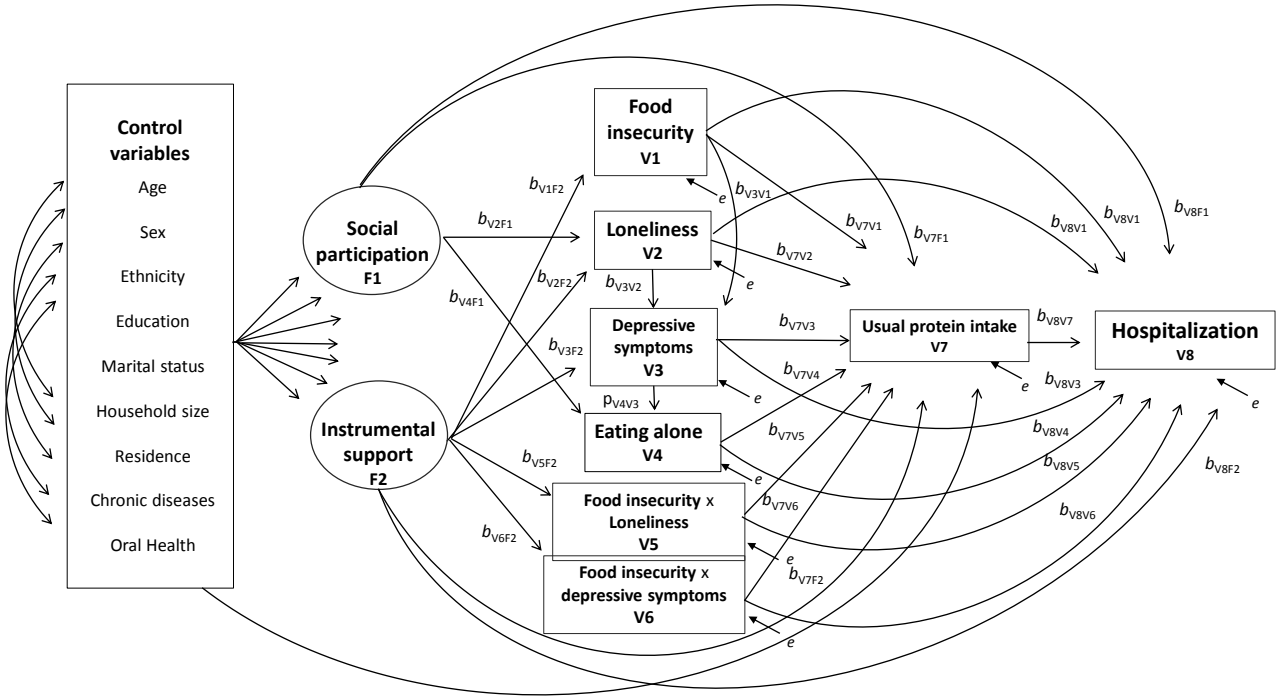


Figure S.2: Measurement model of the hypothesized relationships between hospitalization, usual protein intake, food insecurity, loneliness, depressive symptoms, eating alone, instrumental social support and social participation. Latent (not directly observable) constructs (F) are shown in ellipses and observed variables (V) are represented by a square. Lines with arrows represent the path or direction of influence (p), double-headed arrows represent covariances.

Table S.2: Correlation matrices of the variables of interest for home-delivered meal recipients (top) and the control group (bottom).

Variable	Hospitalization	Protein	Food insecurity	Loneliness	Depressive symptoms	Eating alone	Social participation	Instrumental support	Food insecurity ×Loneliness	Food insecurity ×Depressive symptoms
Hospitalization	1									
Protein	0.07	1								
Food insecurity	0.11	-0.08	1							
Loneliness	0.16	-0.01	0.06	1						
Depressive symptoms	0.18	0.02	0.17	0.54	1					
Eating alone	0.01	0.14	0.04	0.14	0.08	1				
Social participation	-0.05	-0.02	0.04	0.00	-0.02	-0.03	1			
Instrumental support	-0.01	0.01	-0.09	0.00	0.01	0.04	0.06	1		
Food insecurity ×Loneliness	0.16	0.01	0.24	0.23	0.14	-0.06	-0.06	0.00	1	
Food insecurity ×Depressive symptoms	0.16	0.15	0.46	0.11	0.30	-0.02	-0.02	-0.07	0.52	1

Variable	Hospitalization	Protein	Food insecurity	Loneliness	Depressive symptoms	Eating alone	Social participation	Instrumental support	Food insecurity ×Loneliness	Food insecurity ×Depressive symptoms
Hospitalization	1									
Protein	-0.09	1								
Food insecurity	0.02	-0.14	1							
Loneliness	0.13	0.11	0.14	1						
Depressive symptoms	0.02	0.02	0.22	0.43	1					
Eating alone	0.22	-0.09	-0.01	0.18	-0.05	1				
Social participation	-0.02	0.03	-0.12	0.03	0.11	-0.03	1			
Instrumental support	0.09	-0.02	0.09	0.15	0.16	-0.04	-0.04	1		
Food insecurity ×Loneliness	0.03	0.07	0.15	0.04	0.19	0.02	-0.06	-0.03	1	
Food insecurity ×Depressive symptoms	0.10	0.10	0.36	0.16	0.16	0.08	-0.09	0.05	0.62	1

Chapter 5: Conclusion, Recommendations Future Research

5.1. Conclusion and recommendations

Homebound older adults are a vulnerable population, and HDM recipients a group at high risk for FI and poor diet quality. Homebound older adults are also at an increased risk for poor/inadequate social relationships. FI, poor diet quality, depression and social relationships (as measured by social participation, eating alone, instrumental social support, and loneliness) are all potentially modifiable risk factors. The goal of this study was to examine dietary intake of homebound and control participants and the direct and indirect relationships between FI, social relationships and healthcare utilization (hospitalization).

More specifically, in our first study, we examined the quality and quantity of the diets of HDM recipients and their controls and found that HDM recipients who did not receive a meal on the day of the 24-hour dietary recall had poorer diet quality compared to individuals who received a meal and the controls. The meal and the foods complementing the meal were similar in their overall diet quality; the meal had better quality in particular food groups/nutrients and the complementing foods had better quality in others. However, improvement for both the HDM and complementing diet of HDM recipients is warranted, especially for whole grains, fatty acid ratio, sodium, and solid fats, alcohols, and added sugars. Comparing the diets of meal recipients, no-meal recipients and controls to the 2010 DGAs, the three groups fell short of the DGAs for fruit, vegetables, dairy, grains, whole grains and fiber. These results indicate that older adults may not be consuming enough healthy food to satisfy their needs, putting their nutritional status at further risk. Understanding what and how much HDM recipients consume can help support OAANSP's efforts to improve the quality of HDMs. Expanding the program to provide more than one meal per day and/or meals on weekends may also improve the nutritional status and health of

vulnerable populations. These results also highlight the importance of the nutrition education and counseling components offered by the OAANSP and indicate potential education topics (such as improving the quality of complementing foods).

Our second study examined the relationships between FI, diet quality (as measured by usual vegetable intake), social participation, eating alone, receiving instrumental social support, loneliness, and depressive symptoms in HDM recipients and controls. The prevalence of FI was 22.4% and 16.5% in HDM recipients and controls, respectively, (compared to 8.9% for the general older adult population) indicating that the controls were a similarly vulnerable group of older adults. Exploring why individuals in the control group, despite their vulnerability, are not participants of the OAANSP may offer insight into ways to reach and support this vulnerable population. Furthermore, it is important to note that the measure of FI used in this study only assesses the economic access to food. Homebound older adults may have physical and/or social limitations precluding their access to sufficient, safe and healthy foods. This implies that there may be more FI individuals than those identified due to economic needs. Additionally, controls were matched to HDM recipients based on several sociodemographic and health-related variables, but not based on mobility and hence there were significantly fewer individuals in the control group with mobility issues. The existing literature provides evidence to support that homebound older adults may have poorer diet quality, but our results showed no difference in diet quality between HDM recipients and controls. Therefore, it is possible that the HDM received was protective against poorer diet quality, compared to controls.

FI was shown to be significantly and inversely associated with diet quality in the control group, but this relationship was significant only in HDM recipients with depressive symptoms. It is possible that HDMs mitigated the direct negative relationship observed between FI and diet

quality. Our results also showed a positive association between receiving instrumental social support and loneliness in the control group, but not in HDM recipients. It is noteworthy to mention that the proportion of HDM recipients who received any instrumental social support in the six months preceding the OAA Outcomes Evaluation Study was modest (16.7%). The OAANSP may serve as an entry point for home-based services and resources for many homebound older adults. Older adults in the control group may not have received the same opportunity. However, there was no data to evaluate other sources of instrumental and informal support. In addition, loneliness was associated with depressive symptoms in HDM recipients and controls. These findings draw attention to the vulnerability of lonely individuals to depression.

Our third and final aim was to understand the relationship between protein intake, FI, social participation, eating alone, receiving instrumental social support, loneliness, depressive symptoms and hospitalization. Both the HDM recipients and control groups had lower absolute usual mean protein intakes than the DRIs. Furthermore, in both groups, an increase in FI was associated with lower usual protein intake; however, this relationship was stronger in the control group. HDMs may improve usual protein intake of program participants, however, our results indicate that both HDM recipients and controls may be at a high risk for protein insufficiency. This may be particularly problematic in older adults, since recent studies have proposed higher protein recommendations in this population to guard against frailty and sarcopenia (360, 361). Another important finding is the relationship between lower usual protein intake, and hospitalization. This association emphasizes the role of diet quality, and protein more specifically, as a risk factor for hospitalization. Additionally, in controls, eating alone was associated with lower usual protein intake and greater hospitalization. These findings highlight the important relationship between eating alone as a risk factor for diet quality and

hospitalization even in a population that may be more mobile, yet still vulnerable. Finally, receiving instrumental social support was associated with lower FI in HDM recipients, and not in the control group. The information collected on instrumental social support in the Outcomes Evaluation Study focused on formal sources of support such as those provided by the OAANSP or similar programs. These findings highlight the potential role that instrumental social support offered may play in protecting against greater severity of FI in HDM recipients. It also draws attention to the need to more accurately define the social constructs of interest, such as social support, within the socioecological model, to identify the potential sources of support that need to be examined.

This dissertation has several limitations. The first study utilized two 24-hour dietary recalls to calculate the average quantities for some major food groups and components, and these figures do not reflect mean usual intake and may not accurately measure usual intake. Although there is a recommended statistical adjustment method to calculate mean usual nutrient intake from multiple 24 hour recalls, this methodology is not applicable for calculating the HEI. Additionally, HDM participants and controls were matched according to several characteristics, but were not matched according to their mobility status and therefore were not necessarily homebound. Another limitation is that no causality can be inferred regarding the relationship between HDM program participation and diet quality, or between the social relationships constructs, FI and diet quality as a result of the cross sectional nature of the data collected. Furthermore, the social relationship constructs available from the OAANSP Outcomes Evaluation Study were limited in scope and some of them were not validated in this population such as received instrumental social support and social participation. Social participation was also examined using a single item and may not reflect individuals' social interactions, especially

if they are homebound. In addition, questions on received instrumental social support in the Outcomes Evaluation Survey did not inquire about non formal sources of support, such as that received from family and friends. Lastly, for the final study, Medicare data was unavailable for beneficiaries who were enrolled in managed care plans. This limited the study's sample size and may have affected the generalizability of the results in the longitudinal study.

Despite the aforementioned limitations, our results draw attention to some of the nutritional risks and social challenges that face this particularly vulnerable group of older adults. The results also indicate the need for validated instruments for assessing social relationships in this population. Findings from this dissertation may be used to inform the OAANSP and the aging network in their future work

5.2. Future research

Our findings shed light on key areas for future research:

i. Developing consensus on a food security measurement tool that is not limited to the economic evaluation of food access, but incorporates the social and physical aspects of access to food.
ii. Developing a statistical method to obtain usual HEI on an individual level.
iii. Developing consensus regarding the definition and measurement of social constructs pertaining to social relationships in older adults
iv. Developing validated measures for social participation in homebound older adults.
v. Developing more robust evidence regarding the relationships between social constructs, FI and diet quality to improve our understanding of these interactions.
vi. Contextualizing interventions aimed towards alleviating social and nutritional risk factors for health and well-being within an established theoretical framework (e.g.

socioecological model). This may assist researchers in better defining their constructs for intervention and measurement.

vii. Understanding the role that different sources of instrumental support play in the relationship with FI.

viii. Examining further the relationship between protein intake and healthcare utilization with particular reference to the different recommendations proposed.

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