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IDENTIFICATION OF DIETARY PATTERNS AND RELATIONSHIP WITH WEIGHT AND HEALTH OUTCOMES IN OLDER ADULTS

A Dissertation in

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by

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ABSTRACT

The proportion of older adults (≥ 65 years old) is dramatically increasing. The first of the Baby Boomer generation (adults born between 1946 and 1964) turned 65 years old in 2011. The prevalence of obesity among this age group is higher than ever. According to data from the National Health and Nutrition Examination Survey (NHANES) 2007-2008, 34% of women and 37% of men aged ≥ 60 years old are obese. Obesity is clearly related to a number of adverse health outcomes, including cardiovascular disease (CVD), type 2 diabetes mellitus, hypertension, and metabolic syndrome (MetSyn). However, the role that diet plays related to these outcomes in an aging population is less clear. The prevalence of nutrition-related chronic disease outcomes is higher among low socioeconomic and rural populations. These at-risk populations are not readily sampled in national nutritional surveys. Studies characterizing populations of rural, older adults are needed to better understand the role of dietary patterns and health disparities. In particular, limited data are available for the old-older person aged 80 years and above. Data that are available suggests that many obese older adults consume poor quality diets and that dietary practices may influence health outcomes even in populations of old-older individuals.

Advances in dietary pattern research have focused on investigation of the association between specific dietary patterns and disease outcomes. Commonly used methodologies for deriving dietary patterns include both *a priori* (e.g., diet indices, such as the Healthy Eating Index-2005) and *a posteriori* methods (e.g., factor or cluster analysis). More recently, other techniques such as reduced rank regression and finite mixture modeling have also been employed.

The objectives for this dissertation were three-fold: 1) to explore the association between dietary patterns and obesity-related health outcomes; 2) to examine the association between dietary patterns and diet quality in relation to obesity and weight change; and 3) to explore the use of a novel approach, finite mixture modeling, in determining dietary patterns in a sample of older adults. The first two objectives were carried out using data from the Geisinger Rural Aging Study (GRAS) and the third using data from the University of Alabama at Birmingham (UAB) Study of Aging.

The GRAS is a longitudinal cohort of > 20,000 community-dwelling older adults (≥ 65 years old) living in rural Pennsylvania, initiated to examine the relationship between health outcomes and nutritional status. Cluster analysis, utilizing data from 24-hour dietary recalls, was used to derive dietary patterns in a subset of 449 participants from the GRAS (mean age: 76.5 ± 5.1 years). Prevalence (5-year follow-up) of CVD, type 2 diabetes mellitus, hypertension, and MetSyn and weight measurements were extracted from the outpatient electronic medical records using a validated data extraction process. Logistic regression, adjusting for relevant covariates, was used to examine the associations between dietary patterns and health outcomes. Cox proportional hazards regression models were used to examine the relationship between weight change and dietary patterns.

The ‘Sweets and dairy’, ‘Health-Conscious’, and ‘Western’ dietary patterns were identified at baseline. Compared to the ‘Health-Conscious’ pattern, those in the ‘Sweets and dairy’ pattern had increased odds of hypertension; adjusted odds ratio (95% CI) was 2.17 (1.11-4.27). Only after stratification by gender was there a significant association between weight change and dietary pattern. Women characterized by the ‘Sweets and dairy' and the 'Western' dietary pattern were three and two times more likely to lose 10 pounds, respectively, compared to those in the 'Health-conscious' dietary pattern.

In the UAB Study of Aging (n = 416), finite mixture modeling identified three dietary patterns: a 'Low produce, high sweets', a 'Western-like', and a 'More healthful' dietary pattern. The most notable finding was the significant interaction found between body mass index (BMI) and gender for probability of dietary pattern membership which suggested that there was a stronger relationship between BMI and dietary pattern for women compared to men.

In conclusion, finite mixture modeling was able to identify dietary patterns in a sample of older adults. Additionally, dietary patterns in the GRAS subset were significantly associated with hypertension, but not the other obesity-related outcomes of interest. The GRAS dietary patterns were also significantly related to weight loss, but only after stratifying by gender. The gender interaction seen in both the GRAS and UAB Study of Aging samples highlight that the relationship between weight and dietary pattern varies between the sexes. Unfortunately, due to sample size, we were limited in the ability to analyze meaningful subgroups for dietary pattern identification, such as gender. Additionally, our study was unable to address the potential benefits of adopting a prudent diet earlier in life.

Research presented in this dissertation furthers the body of knowledge on older adults, dietary patterns and relationship to health outcomes and weight. Findings suggest that clinicians may be warranted to consider prescription of more liberalized, rather than overly-restrictive diets, for some old-older persons, especially when food intake may be inadequate. Future research should ensure investigation of larger samples of old-older adults, paying special attention to analysis by gender and measurement of dietary patterns longitudinally.

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95% CI	95% confidence interval
ADL	activities of daily living
AHEI	Alternate Healthy Eating Index
AI	Adequate Intake
ATP	National Cholesterol Education Program's Adult Treatment Panel
BIC	Bayesian Information Criterion
BMI	body mass index
CHD	coronary heart disease
CR	chart review
CVD	cardiovascular disease
DASH	Dietary Approaches to Stop Hypertension
DQI	Diet Quality Index
DEXA	dual energy x-ray absorptiometry
EDE	electronic data extraction
EMR	electronic medical records
FDA	Food and Drug Administration
FMM	finite mixture modeling
GDS	Geriatric Depression Scale
GRAS	Geisinger Rural Aging Study
HEI-2005	Healthy Eating Index-2005
HPFS	Health Professionals Follow-up Study
HR	hazard ratio
IADL	independent activities of daily living
ICC	intraclass correlation coefficient
ICD	International Classification of Diseases
IL	interleukin
IRB	Institutional Review Board
MDS	Mediterranean Diet Score
MetSyn	metabolic syndrome
MI	myocardial infarction
MMSE	Mini-Mental State Examination
MONICA	MONItoring of Trends and Determinants in CArdiovascular Diseases
NDSR	Nutrition Data System for Research
NHANES	National Health and Nutrition Examination Survey
NIH	National Institutes of Health
OR	odds ratio
PASE	Physical Activity Score for the Elderly
PCA	principal components analysis
PNNS-GS	Programme National Nutrition Sante guideline score
RDA	Recommended Dietary Allowance
RFS	Recommended Food Score
RR	relative risk
RRR	reduced rank regression
SAS	Statistical Analysis System
SD	standard deviation
SUN	Seguimiento Universidad de Navarra – University of Navarra Follow-up
UAB	University of Alabama at Birmingham

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Chapter 1

INTRODUCTION

The rate of obesity is expected to rise in the United States, with the latest reports projecting that 42% of Americans will be obese by 2030 (1). Older adults are not exempt from this obesity epidemic. According to data from the National Health and Nutrition Examination Survey (NHANES) 2007-2008, 34% of women and 37% of men aged ≥ 60 years old are obese (2).

It is well-documented that obesity is associated with many chronic diseases, including cardiovascular disease (CVD), type 2 diabetes mellitus, hypertension, and some cancers. It is generally believed that diet plays a role in these obesity-related health outcomes; however much of the research has focused on mixed-age groups (≥ 18 years old). It is less clear how diet affects weight and chronic diseases in the old (≥ 65 years) and old-older (≥ 80 years) populations.

Initially, nutrition research investigated the relationship between single nutrients (e.g., vitamin A) and health conditions. Numerous observational studies have examined the effect of nutrients or food groups in isolation on disease outcomes. While this traditional approach has its merits, it does not account for the interrelationships that exist among known and unknown dietary components that likely affect health. From an epidemiological perspective, nutrients are not consumed in isolation. They are consumed within a variety of foods, and foods are consumed as a part of meals. It may not be appropriate to simply adjust for confounders as dietary components are likely to relate in complex ways. Addressing these limitations has led to a growing interest in examination of total diet (i.e., dietary patterns) to describe associations between diet and disease. Conceptually, studies of overall diet better reflect how individuals eat in the real world.

Findings from dietary pattern analyses may also potentially be more easily communicated as public health messages since the focus is on overall patterns of eating.

In general, the term dietary pattern has been used to describe data-reduction techniques that capture the quality, proportion, and often frequency of foods and beverages consumed. Two common approaches have been applied to identify dietary patterns. *A priori* approaches are score-based and address prevailing hypotheses about diet and disease, whereas *a posteriori* methods use data-driven techniques. More recently, other techniques, such reduced rank regression and finite mixture models, have been used to derive *a posteriori* dietary patterns (3, 4).

Each of these fundamentally distinct approaches has strengths and limitations. Score-based approaches could include assessment of nutrient adequacy, food variety or index-based summary scores, which usually evaluate adherence to a set of dietary guidelines. Some examples of *a priori* approaches include the Diet Quality Index (DQI), the Mediterranean Diet Score (MDS), and the Alternate Healthy Eating Index (AHEI). These scores are thought to characterize total diet; however, they are limited by current knowledge about diet and disease. Results from *a priori* dietary patterns can be reproducible and comparable across study populations. *A posteriori* methods are often described as techniques that “let the data do the talking”. Data collected from dietary recalls, food frequency questionnaires, or dietary records can be used to mathematically derive dietary patterns using empirical approaches like factor or cluster analysis. These techniques are valuable for exploratory analysis when it might not be known how dietary variables group together into patterns and how individuals may fall into these various patterns.

No single approach has been determined to be superior and researchers have occasionally combined methods (5). A common limitation for both *a priori* and *a posteriori* methods is that subjectivity is introduced at various points along the course of identifying dietary patterns. With score-based methods, researchers must interpret existing dietary guidelines to construct the index. For example, researchers must decide if all components of a summary score should be weighted equally, which would imply that each dietary component affects the outcome of interest equally and proportionately. With *a posteriori* methods (e.g., cluster analysis), the final number of dietary patterns that are derived can be based on both objective statistical testing as well as interpretation and meaning of the dietary patterns.

Dietary pattern analyses, using both *a priori* and *a posteriori* approaches, are promising methodologies as they are able to capture the complexities of dietary exposure. The field of nutritional epidemiology will likely continue to see advances with these techniques. For additional details on the strengths, limitations, and research considerations for these methods, refer to Moeller et al. (6).

OBJECTIVES

In 2010, almost two million people ≥ 65 years old lived in the state of Pennsylvania, ranking it fifth highest in percent of older adults, following only Florida, California, New York, and Texas (7). According to recent data from the Centers for Disease Control and Prevention, the rate of obesity among adults in Pennsylvania is approaching 30% (8).

The Geisinger Rural Aging Study (GRAS) is a longitudinal cohort of > 20,000 community-dwelling older adults (≥ 65 years old) residing in rural Pennsylvania, designed to evaluate nutritional risk. GRAS was initiated in 1994 and is the result of collaborative efforts of the Geisinger Health System, The Pennsylvania State University, and Tufts University, and is supported by funds from the United States Department of Agriculture. GRAS participants were enrolled in a Medicare-managed health management organization administered through Geisinger Medical Center (Danville, Pennsylvania), which provides services to many individuals living in rural areas (any area with a population of ≤ 2,499 residents) (9). Older adults residing in rural areas have been shown to be particularly at risk for nutritional inadequacies (10). Isolating factors that may contribute include poor access to transportation, and health-and nutrition-related services, and a limited food supply.

The literature on dietary patterns and the association with obesity-related health outcomes in older adults is sparse. The unprecedented increase in obesity in older adults observed in Pennsylvania make it an ideal geographical area of the United States to investigate diet in relationship to obesity-related outcomes.

Two objectives were explored for partial fulfillment of the requirements of this dissertation research.

Objective 1: To explore the association between dietary patterns and obesity-related health outcomes

Objective 2: To examine the association between dietary patterns and diet quality in relation to obesity and weight change

Although the complete GRAS cohort consists of > 20,000 older adults, two subsets were randomly selected for additional examination. The first subset was recruited from 1997-1998 (GRAS-1997). The second subset was recruited from 2004-2005 (GRAS-2004). Studies describing selection criteria and characterizing these subsets have been previously published (11, 12).

A series of 24-hour dietary recalls were collected in both GRAS-1997 and GRAS-2004, during their respective recruitment years. Dietary data from both subsets were combined and used to derive the dietary patterns that are described in Chapter 3.

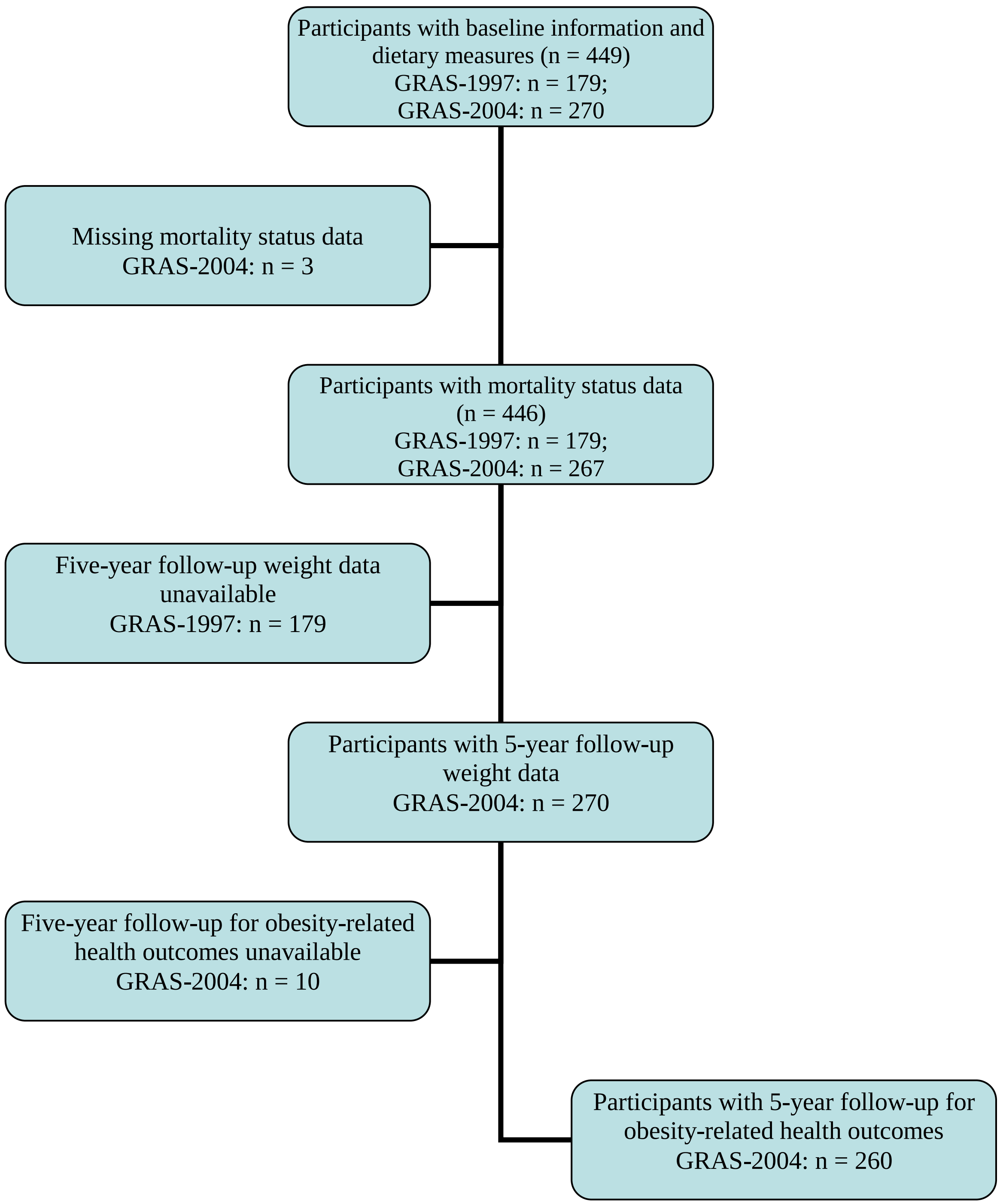
The Geisinger Health System currently utilizes an electronic medical record (EMR) system to document and manage health information. Use of the EMR system allows health information, such as weight measurements, clinical laboratory values, and disease prevalence information, to be abstracted. This data extraction process has been validated in a randomly selected subset of the GRAS cohort (**Appendix B**). Because use of the EMR was not initiated throughout the Geisinger Health System until 2001, only health information for GRAS-2004 participants was available for extraction. Therefore, the analyses pertaining to health outcomes (Chapter 3) and weight (Chapter 4) were only performed in the GRAS-2004 subset. Mortality data, accessed through both the EMR and the Social Security Death Index data were available for almost all participants of GRAS-1997 and GRAS-2004 subsets (**Figure 1-1**).

In addition, to the aforementioned objectives, an exploratory study was conducted to examine the use of a novel approach, finite mixture modeling (FMM), to identify dietary patterns in a cohort of older adults in Alabama (Chapter 5).

DISSERTATION CONTENT AND FORMAT

This dissertation begins with a review of the literature pertaining to dietary patterns in relation to CVD, type 2 diabetes, hypertension, and metabolic syndrome (Chapter 2). This chapter also consists of a review of the literature on dietary patterns in older adults in relation to body mass index (BMI), which has previously been published in the *Journal of Nutrition in Gerontology and Geriatrics*. Chapters 3 and 4 describe the findings of Objectives 1 and 2, respectively. Chapter 5 details the results from a secondary data analysis, which characterizes dietary patterns using a novel approach, finite mixture modeling, in a subset of the University of Alabama at Birmingham Study of Aging participants. Content from Chapter 5 has been accepted for publication by the *Journal of Nutrition, Health and Aging*. Tables, figures, and a list of references are provided at the end of each chapter. With the exception of Chapter 5, all chapters are written in the style required for the *American Journal of Clinical Nutrition*, a premier journal in the field of nutritional sciences.

Figure 1-1. Diagram of GRAS participant eligibility for inclusion in study analyses



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Chapter 2

REVIEW OF THE LITERATURE

This section of the dissertation presents a review of the literature on dietary patterns in relation to obesity-related health outcomes, with particular focus on cardiovascular disease (CVD), type 2 diabetes mellitus, hypertension, and metabolic syndrome (MetSyn). Additionally, literature on the association between body mass index (BMI) and dietary patterns in older adults will be examined.

DIETARY PATTERNS AND OBESITY-RELATED HEALTH OUTCOMES

Cardiovascular disease

The leading cause of death in the United States, for both men and women, is diseases of the heart (1). From 2008 to 2030, the proportion of older Americans is expected to increase from 13% to nearly 20% of the total U. S. population (2). An expected consequence of this rapid population growth will be an increased burden on health care resource utilization and spending for this aging segment.

Population-based epidemiological research, especially over the last decade, has established the link between diet and non-communicable diseases (3). Observational cohort studies have identified associations between both single nutrients and food groups and CVD. Specifically, higher consumption of fruit and vegetables (4), whole grains (5-7), and fish (8) have been linked to reduced rates of coronary heart disease (CHD). Using more recent approaches, dietary pattern analyses, which account for possible interactions and synergistic relationships between nutrients and foods, have been used to examine the association between overall dietary patterns and both CVD risk and CVD mortality.

In the Health Professionals Follow-up Study (HPFS), men, aged 45-75 years were followed for 8 years. Using factor analysis to derive two dietary patterns, a higher 'Prudent' dietary pattern factor score was significantly and inversely associated with risk of CHD, even after adjustment for age, smoking and other CHD risk factors. Moreover, after adjusting for covariates, a higher 'Western' factor score was significantly and positively associated with CHD risk (9). These associations were also examined in women in the Nurses' Health Study and analyses revealed similar findings (10). To test the predictive value of two dietary scores developed to predict chronic disease risk, the Alternate Healthy Eating Index (AHEI) and the Recommended Food Score (RFS) were calculated for the two large aforementioned cohorts. The AHEI, a 9-component score, was developed to measure adherence to a diet that has been shown to reduce risk of chronic diseases. The RFS was calculated as a sum of the number of healthy foods consumed from a predetermined list (11). Compared to those who scored lowest, those who scored in the highest quintile for AHEI had a 39% (RR = 0.61; 95% CI: 0.49, 0.75) and 28% (RR = 0.72; 95% CI: 0.60, 0.86) decreased risk of CVD for men and women, respectively. In the multivariate-adjusted analysis, a weaker association was found for the RFS and CVD risk in men (RR = 0.77; 95% CI: 0.64, 0.93) and a non-significant association was found for women.

In a multi-center, multiracial cohort, including Non-Hispanic whites, blacks, Asians and Hispanic adults (aged 45-84 years) dietary patterns, derived using principal components analysis (PCA), were associated with incident CVD (12). Four dietary patterns were identified in this sample of racially diverse middle- and older aged adults: 1)'Fats and processed meat'; 2) 'Vegetables and fish'; 3) 'Beans, tomatoes, and refined grains'; and 4) 'Whole grains and fruit'. Compared to the lowest quintile, those in quintile five of the 'Whole grains and fruit' dietary score had significantly reduced risk of CVD and results remained robust after adjusting for age, sex, race, energy intake and a number of other lifestyle factors (RR = 0.54; 95% CI: 0.33, 0.91). In addition to CVD as a study endpoint, others have found that CVD risk factors (e.g., plasma lipid levels, high blood pressure) were associated with dietary patterns in men (13, 14), women (15) and older adults (16, 17).

Replication of findings using comparative evaluation of dietary patterns derived using additional approaches can validate results. Using factor analysis, a significant association between CHD incidence and mortality was found in a population-based sample of Italian men (aged 45-64 years old) (18). The factor which was characterized by higher intakes of breads, cereals, vegetables, fish, potatoes, and oils, was inversely and significantly associated with 20-year CHD incidence (HR = 0.88; 95% CI: 0.73, 0.96). Findings from this study were then validated using PCA and results were substantially similar.

Besides cluster and factor analysis, the more common *a posteriori* methods of deriving dietary patterns, newer approaches are being explored. In a population-based case-control study (cases n = 820; controls n = 2,196), finite mixture modeling (FMM) was used to explore the relationship of dietary patterns and acute myocardial infarction (MI) in a Southern European population (19). FMM is a model-based approach that aims to explain associations between groups of observed variables. In contrast to cluster analysis, which assigns individuals into mutually-exclusive clusters, with FMM, each individual has a probability of membership into each identified dietary pattern.

Additional explanation of FMM can be found in Fahey et al. (20). Using FMM, those characterized by a ‘Low fruit and vegetables’ dietary pattern (OR = 1.85; 95% CI: 1.01, 3.39) and a ‘Red meat and alcohol’ pattern (OR = 1.91, 95% CI: 1.17, 3.12), had almost twice the odds of experiencing acute myocardial infarction (MI) compared with the ‘Healthy’ pattern. Reduced rank regression (RRR) is another dietary pattern analysis approach that has been gaining interest (21). RRR cannot be classified as neither an *a priori* or *a posteriori* approach, but rather a hybrid approach. RRR has an advantage over the more commonly used methods because it uses *a priori* knowledge, often in the form of response variables (e.g., biomarkers which are risk factors for health outcomes) to determine dietary patterns. Specific to CVD, RRR was used to derive dietary patterns in a sample of middle-aged men participating in the ‘MONItoring of Trends and Determinants in CArdiovascular Diseases’ (MONICA) Project (22). C-reactive protein, interleukin (IL)-6, and IL-18 concentrations measured in serum were used as response variables since they are markers of inflammation thought to be links between diet and heart disease. A dietary pattern characterized by relatively higher consumption of meat and beer and lower intakes of fruits, vegetables, breads and cereals/muesli, nuts, sweet bread spread, and tea was significantly associated with higher risk of CHD in the multivariate model; however, after adjustments were made for smoking status, this relationship was non-significant.

The Mediterranean dietary pattern in particular has been studied broadly in relationship to heart disease. A meta-analysis, which included 12 prospective cohort studies with 1,574,299 subjects followed for a time ranging from three to 18 years, concluded that greater adherence to the Mediterranean diet was associated with a significant reduction in overall mortality, including CVD mortality, suggesting that following a diet characterized by intakes of vegetables, fruits, legumes, cereals, fish and moderate alcohol intake, may have a role in preventing major chronic diseases (23).

A relationship between dietary patterns and CVD is not always evident. A number of studies have found weak (24) or non-significant relationships between *a priori*-defined dietary patterns (25, 26) and data-driven patterns (26, 27). Results are also not consistent among the clinical trials. In the Lyon Diet Heart Study, 605 post-MI patients were randomized to follow either a Mediterranean or a prudent post-MI dietary pattern (28). At 46-months, those following the Mediterranean diet had a 1.24% rate per year of cardiac death and nonfatal MI compared 4.07% in those following a prudent diet. In the Women's Health Initiative Randomized Controlled Dietary Modification Trial, 48,835 postmenopausal women were randomly assigned to either a low-fat dietary pattern (total fat < 20%), that emphasized 5 servings of fruits/vegetables per day and at least 6 grain servings per day or to the control group (received Dietary Guidelines for Americans materials) (29). After > 8 years of follow-up, there were no significant differences in CHD, stroke or CVD risk between the intervention and control group. Compliance was likely an issue over the relatively long time period.

In sum, most of the studies that have examined the association between CVD and dietary patterns in older adults have focused on Mediterranean dietary patterns (17, 30-32). Further research is needed in older adults to elucidate if other dietary patterns might also be associated with CVD.

Type 2 diabetes mellitus

There has been a marked increase in the prevalence of type 2 diabetes in the developed world, with the most appreciable rise in older adults ($\geq$ 65 years old) (33). Since obesity is a major risk factor for type 2 diabetes, the higher prevalence is likely due to a combination of genetic susceptibility and environment factors, such as an increase in sedentary lifestyle and an increase in intake of food energy (34).

Increased consumption of energy-dense foods, along with an increase in portion size are dietary factors that have been targeted as playing a role in the development of type 2 diabetes (35). Nevertheless, studies exploring energy balance and risk of developing type 2 diabetes have been inconsistent. Several clinical intervention studies found a positive relationship between energy intake and increased risk of type 2 diabetes (36-38). However, when free-living populations have been observed, the association between energy intake and type 2 diabetes has been weak (39) or non-significant (40, 41). This inconsistency may be due to difficulty in reliably measuring energy intake and indicates a need to go beyond exclusively targeting energy intake as a dietary aim for prevention and treatment of diabetes.

Dietary fiber, fat and alcohol have also been examined in relationship to the prevalence of type 2 diabetes with epidemiological evidence suggestive of a protective effect of fruits and vegetables. In the Nurses' Health Study, total dietary fat intake was not associated with risk of type 2 diabetes after controlling for important covariates. Intake of polyunsaturated fatty acids was significantly associated with a reduced risk of type 2 diabetes and intakes of dietary cholesterol and *trans* fatty acids were positively associated with diabetes risk (42).

Because food is not consumed as isolated components or nutrients, it is important to examine the relationship between type 2 diabetes in the context of whole diet (i.e., dietary pattern analyses). Evidence from epidemiological studies suggests that several dietary patterns are favorably associated with reduced risk for type 2 diabetes. Dietary patterns described as 'Prudent', which were characterized by higher intakes of fruits and vegetables, whole grains, and poultry, were associated with lower risk of developing diabetes (43), whereas 'Western' or 'Less healthy' dietary patterns have been associated with increased risk (44-48). These 'Western' diets are often relatively higher in processed and red meats, refined grains and lower in fruits and vegetables. Data from 43,176 Chinese adults showed that in 'Never smokers', a 'Vegetable, fruit, and soy-rich' pattern was associated with decreased risk of incident type 2 diabetes (Quintile 5 HR = 0.77; 95% CI: 0.65, 0.92) and a 'Dim sum and meat-rich' pattern was associated with increased risk (Quintile 5 HR = 1.38; 95% CI: 1.14, 1.66) (49).

Although evidence suggests that dietary patterns, particularly those that are highly plant-based, are associated with reduced risk of type 2 diabetes, data on older adults is limited. To the best of our knowledge, only one older adult population has been investigated in this regard. In a cross-sectional survey, Panagiotakos and colleagues (50) evaluated dietary patterns, using a diet score that was developed to target the Mediterranean dietary pattern. After adjusting for potential confounders, a 10-unit increase in the Mediterranean diet score was associated with a 6% lower odds of diabetes prevalence (P = 0.06).

Hypertension

Hypertension is defined as systolic blood pressure of ≥ 140 mm Hg or a diastolic blood pressure of ≥ 90 mm Hg (51). High blood pressure plays a major etiologic role in the increased incidence of CVD (e.g., stroke, MI and dissecting aneurysm), renal failure, and cognitive impairment (51-54). One in three, or an estimated 68 million adults in the United States are affected by high blood pressure (55). This estimate increases to greater than 60% in adults ≥ 60 years of age. Overall, this translates into $93.5 billion in expenditures due to hypertension-related health care services, medications, and missed days of work (56).

Current national guidelines target diet as one of the lifestyle modifications for the prevention and treatment of hypertension (51). Much of previous research has been limited to examination of single nutrients (e.g., sodium) on hypertension. However, this approach may be oversimplified and unrealistic as it is quite possible that the interactions and synergistic effects of foods and nutrients affect blood pressure and therefore the development of hypertension (57, 58).

Although hypertension is a serious public health concern, limited evidence is available on the association between hypertension and dietary patterns. Several studies using factor analysis found significant relationships between hypertension and dietary patterns. In a Dutch population, a ‘Traditional’ dietary pattern, characterized by higher consumption of red meat, potatoes, and saturated fat, and lower intakes of soy products, low-fat dairy, breakfast foods, tea, and fruit, was associated with higher systolic blood pressure. After adjustments for physical activity, smoking, education, family history of diabetes and MI, and BMI, associations were attenuated, but remained significant. A 'Cosmopolitan' pattern, higher in vegetable oils, garlic, vegetables (fried and salad), rice, pasta, chicken, fish, and wine, and lower intakes of potatoes, was independently associated with lower systolic blood pressure (59). In a nationally-representative population of Chinese adults, a 'Traditional northern' dietary pattern, high in wheat flour products, starchy tubers and low in pork, beef, poultry, aquatic products and milk products, was significantly associated with hypertension prevalence; however, this relationship disappeared after adjusting for BMI. The 'Traditional southern' pattern, characterized by higher intakes of fruit, vegetables, pork, poultry, rice, aquatic products, and nuts, was independently associated with lower prevalence of hypertension (60).

Toledo and colleagues (61) examined the association between incidence of hypertension and 15 different *a priori* dietary patterns in the Seguimiento Universidad de Navarra – University of Navarra Follow-up (SUN) cohort in Spain. Only the Dietary Approaches to Stop Hypertension (DASH) score was found to be significantly associated with hypertension, in that those participants with higher DASH scores (i.e., greater adherence to the DASH diet) had a reduced risk for development of hypertension.

The DASH dietary pattern has been clinically tested in a controlled feeding study of 459 adults ($\geq$ 22 years old) with average systolic blood pressure less than 160 mm Hg and diastolic blood pressure less than 80 to 95 mm Hg (62). After a three-week period of a control diet, participants were randomly assigned to consume, for 8-weeks, either a control diet, high in fruits and vegetables, or a 'combination' diet, rich in fruits, vegetables, low-fat dairy, and lower in saturated and total fat. Body weight and sodium intake were held constant throughout the study. Reduction of systolic blood pressure by

5.5 mm Hg and diastolic blood pressure by 3.0 mm Hg for the ‘combination’ diet group compared to the ‘control’ diet ($P < 0.001$), suggests that following a DASH dietary pattern may be an effective, non-pharmalogical approach to preventing hypertension. It is noteworthy that the magnitude of blood pressure reduction was similar to that observed in a monotherapy drug intervention for mild hypertension (63). As was true for the DASH diet randomized control trial (62), many of the studies on dietary patterns and hypertension have been in populations of younger and middle-aged adults. The few studies available on older adults (≥ 65 years old) (14, 16) highlight the need to understand how dietary patterns in older age affect hypertension.

Metabolic syndrome

MetSyn is described as a cluster of abnormalities which is associated with increased risk of CVD (64) and new-onset type 2 diabetes. The National Cholesterol Education Program’s Adult Treatment Panel (ATP) III defines MetSyn as the presence of at least three of the following five risk criteria: abdominal obesity, given as waist circumference (men > 102 cm; women > 88 cm); elevated triglycerides (≥ 150 mg/dL); low HDL-cholesterol (men < 40 mg/dL; women < 50 mg/dL); raised blood pressure (≥ 130/≥ 85 mm Hg) and fasting glucose ≥ 110 mg/dL (65), or ≥ 100 mg/dL per the American Diabetes Association (66).

An estimated 34% of adults in the United States have been diagnosed with MetSyn (67). This figure increases to > 50% among those aged 60 years and over. These statistics have serious implications for health care professionals and our health care system. Lifestyle modifications, such as diet, have been shown to significantly reduce incidence of MetSyn (68); these studies have mainly focused on modifications of single nutrients or food items in influencing the development of MetSyn (69-71).

In general, *a priori* dietary scores, such as the 2005 Dietary Guidelines for Americans Index (DGAI) (72), Programme National Nutrition Sante guideline score (PNNS-GS) (73) and the scores assessing adherence to the Mediterranean diet (74, 75) are inversely related to MetSyn. Frequently, *a posteriori* patterns, that are characterized by more healthful food choices (e.g., 'Healthy', 'Health-conscious', 'Prudent'), have been associated with lower risk of MetSyn and patterns that are considered to be less healthy ('Western', 'Fast-food/dessert', and 'Empty calorie') have been associated with higher risk of MetSyn (68, 76-80) but with more variability in findings than observed using data-driven approaches. For example, a pattern that was described as 'Traditional' was not associated with MetSyn in a Lebanese sample (78); yet was associated with a higher likelihood of MetSyn in a Puerto Rican sample (81). This subjectivity of naming dietary patterns highlights one of the limitations that are inherent in data-driven methods. In randomized clinical trials, the Mediterranean diet (82) or the Mediterranean diet supplemented with 30 g/day of mixed nuts (83) was associated with improvements in inflammation markers (hs-CRP, IL-6) and decreased insulin resistance (82) as well as decreased 1-year (83) or 2-year prevalence of MetSyn (82).

Studies of dietary patterns in populations of older adults and association with MetSyn are lacking. Interestingly, in two studies that included older adults, an interaction between age and dietary pattern was found. Julia et al. (73) reported that PNNS-GS was inversely associated with MetSyn, but only in adults < 55 years old. Likewise, when

Fogli-Cawley and colleagues (72) stratified the participants into those aged ≥ 55 years old and those < 55 years old, there was no association between DGAI and prevalence of MetSyn in the older individuals. When young adults (19-39 years old) in the Bogalusa Heart study were examined, no differences in incident MetSyn were found between the ‘Western’ and ‘Prudent’ dietary patterns, after controlling for important covariates including BMI (84). These age-related differences highlight the need for studies to be conducted in populations that include sufficient numbers of older adults to allow for analyses by age groups, including older adults.

FOOD INTAKE PATTERNS AND BODY MASS INDEX IN OLDER ADULTS: A REVIEW OF THE EPIDEMIOLOGICAL EVIDENCE

A reprint is contained in the following pages. This manuscript contains the following:

Abstract

Introduction

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Review

Food Intake Patterns and Body Mass Index in Older Adults: A Review of the Epidemiological Evidence

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The relationship between food intake patterns and obesity remains unclear. The objective of the present review was to evaluate the current body of literature on food intake patterns of older adults and their associations with weight status, including obesity and waist circumference. Eleven observational studies were identified and reviewed. Diets characterized by more favorable dietary scores or indices were generally inversely related to body mass index. Results from data-driven approaches were inconsistent. Findings from this literature review suggest that there is no clear relationship between food intake patterns and body mass index or waist circumference in older adults. Limitations, including heterogeneity of food intake patterns and study populations, hinder the ability to make clear comparisons. Continued efforts to elucidate the relationship between food intake patterns and weight status indicators in older adults, including longitudinal analyses and use of novel statistical approaches for food intake pattern identification, are warranted.

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KEYWORDS body mass index, cluster analysis, diet index, food intake patterns, obesity, older adults, principal component analysis, weight

INTRODUCTION

With advances in science, technology, and medicine contributing to increased longevity, the world's aging population is growing at an exceptional rate (1). The unprecedented growth in the number of older adults has far-reaching implications with regard to delivery of health care and aging-related social services. Older adults are not only growing in numbers but they are also growing in body size. In the National Health and Nutrition Examination Survey 2007–2008, the prevalence of obesity, defined by body mass index (BMI) $\geq 30\,kg/m^2$, among older adults ($\geq$60 years) in the United States was 37.1% and 33.6% among men and women, respectively. Rates for overweight (BMI $\geq 25\,kg/m^2$) were 78.4% and 68.6% among older men and women, respectively. When findings were compared across survey cycles (1999–2000 vs. 2007–2008), a significant positive linear trend for obesity was found for men ($p < 0.05$) (2).

Obesity in older adults has been associated with poor nutritional status as evidenced by micronutrient deficiencies (3). Many cross-sectional studies as well as short-term and clinical interventions, point to a relationship between obesity and dietary components, particularly dietary fat (4, 5). However, when data from longer-term experimental trials and prospective studies are examined, findings are inconsistent, suggesting that dietary fat independent of total energy intake is not significantly related to weight change (6–8). These observations support the priority to study food intake patterns in contrast to isolated nutrients with regard to weight. In addition, because individuals do not consume nutrients in isolation, singling out specific dietary components is not optimal for determining the relationship between diet and health.

Food intake pattern analysis can be used to quantify consumption of usual food intake combinations and can be defined as a description of the underlying dietary characteristics of an individual or population of interest (9). In contrast, the term dietary pattern is more broadly and inconsistently used in the literature to refer to approaches that describe both the consumption of nutrients and whole foods as well as temporal distributions of intake (e.g., snacking and meal patterns).

Despite the variability in terminology, there has been considerable interest in the relationships among dietary patterns and health outcomes. Several studies have identified a healthy pattern, generally characterized by higher consumption of fruits, vegetables, whole grains, and low-fat dairy, to be associated with reduced risk of diabetes mellitus (10), metabolic syndrome

(11), cancer (12), cardiovascular disease (10, 13), and mortality (14, 15). However, the link between food patterns and weight status has not been clearly defined.

At present, no gold standard for food intake pattern analysis exists; however, several approaches have been traditionally used. One approach involves calculation of a diet score in which a maximum score describes a favorable diet on the basis of the most current dietary recommendations or guidelines. Other approaches rely on specific data to determine patterns (e.g., cluster and factor analysis). Although approaches may have fundamental differences, the assumption is that relatively higher quality diets, defined by any method, should in theory be associated with a body weight that is characteristic of better health status.

The objective of the present review was to evaluate the current body of literature on food intake patterns of older adults and their associations with markers of weight status and obesity (BMI and waist circumference). BMI and waist circumference are used as proxy measures of obesity in large epidemiologic studies due to their convenience as simple and cost-effective measures of total body fatness (16, 17).

METHODS

Search Strategy and Selection Criteria

A literature search of the PubMed database of the United States National Library of Medicine was conducted to identify human studies of food intake patterns, as defined previously, and BMI or waist circumference in noninstitutionalized older adults (Figure 1). The following keywords were used to identify relevant studies for review: food intake patterns, dietary patterns, diet index, diet score, older adults, elderly, body mass index, weight, obesity, waist circumference, and anthropometrics. The search was limited to include only full-text English language studies published through November 2010. References of identified studies were also examined for relevant articles. For purposes of this review, older adults were defined as individuals $\geq$60 years, with the exception of one article by Robinson and colleagues (18), which included adults aged 59–73 years.

Description of Food Intake Pattern Methodologies

To examine diet quality, a priori methods, also referred to as data-driven approaches, were characterized by use of existing theories or dietary recommendations for health to create indices or scoring systems. Scores in published studies were based on consumption of specific foods, food groups, and/or nutrients or adherence to nutrient- or food-based guidelines that were supported by current, evidence-based nutrition recommendations.

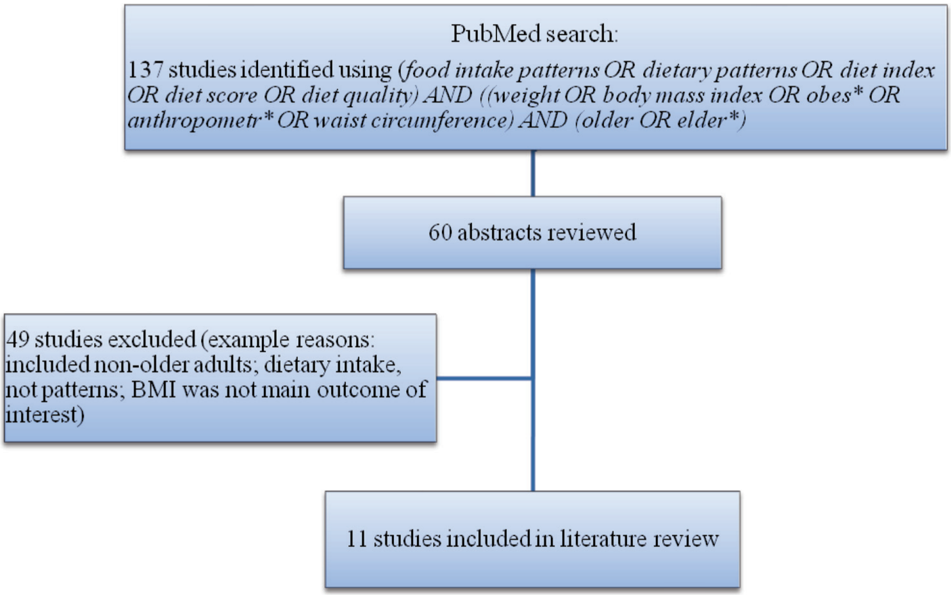

FIGURE 1 Study selection diagram for the PubMed literature search. (Color figure available online.)

These scores were then used to categorize persons or groups as having optimal or poor nutritional status. Several approaches have been used to develop such scores. Examples include the Healthy Eating Index (HEI), the Diet Quality Index-Revised (DQI-R), and the Mediterranean Diet Score (19).

A posteriori methods were characterized by statistical techniques, such as cluster analysis or principal component analysis (PCA), the most common type of factor analysis, and were used to define food or food group patterns using collected dietary information from a population of interest with the purpose being to identify pattern(s) indicative of diet quality. Cluster analysis aggregates individuals into a relatively small number of mutually exclusive groups based on similar dietary intake. Individuals can be categorized into clusters based on dietary intake information in the form of servings per day or percentage energy contribution for each food or food group (20, 21), average grams of food consumed per day (22–24), or standardized nutrient intakes (25). As a statistical method, cluster analysis can be used to answer questions such as, "Is mean BMI/waist circumference higher in one dietary cluster compared to another?" Similarly, PCA is also a data reduction technique; however, in contrast to cluster analysis, PCA uses matrix algebra to produce a reduced set of new variables, or principal components, that account for maximum explained variance between individuals. These identified components represent various food patterns of dietary intake. Several articles were identified with "dietary pattern" or "eating pattern" in the title, but in fact only analyzed single nutrients or consumption patterns (e.g., snack intake patterns, frequency/number of meals) (26, 27) and were not included in this review. Despite their differences, score-based methods as well as data-driven methods are useful in the investigation of food intake patterns. For a more thorough discussion of various methodologies for dietary pattern identification, see Kant 2004 (28).

RESULTS

A total of 11 relevant studies were selected for this review. Tables 1 and 2 highlight the characteristics of these studies. Studies were divided into two categories based on food intake pattern methodology and were presented in order of year of publication.

Findings From A Priori Studies

Four studies were identified that used score-based methodologies to determine diet quality (29–32). A fifth study (33) used both a priori and a

TABLE 1 Characteristics of A Priori Studies and Weight Status (BMI and/or Waist Circumference)*

Reference	Study Population(s)	Design†	Subjects	Dietary Assessment‡
Haveman-Nies et al., 2001§ (33)	FHS; United States SENECA; Europe	CS data from PS	FHS: 828 M/F SENECA: 1282 M/F aged 70–77 y	FHS: 126-item FFQ‖ SENECA: modified DH¶
Maynard et al., 2006 (32)	Boyd Orr cohort; England, Scotland	CS data from PS	672 M + 803 F; aged 61–80 y	113-item FFQ‖
Panagiotakos et al., 2007 (29)	Cyprus	CS	53 M + 97 F; aged ≥65 y	FFQ (1 year)
Shannon et al., 2007 (30)	MrOS; United States	CS	5928 M; aged 65–100 y	96-item reduced length version of Block FFQ
Tyrovolas et al., 2009 (31)	MEDIS study; Greece, Cyprus	CS	553 M + 637 F; aged ≥65 y	FFQ**

*Abbreviations are as follows: BMI, body mass index; FHS, Framingham Heart Study; SENECA, Survey in Europe on Nutrition and the Elderly: A Concerted Action; CS, cross-sectional; PS, prospective study; M, males; F, females; FFQ, Food Frequency Questionnaire; DH, diet history; MrOS, Osteoporotic Fractures in Men Study.

†Measured anthropometric measurements were used, except in the Maynard et al. study (32), where participants self-reported adult height and weight.

‡Reference period for FFQ listed when available.

§Study used both a priori and a posteriori methodology.

‖FFQ validated in a separate study population.

¶Diet history included three-day estimated food record and frequency checklist of foods.

**FFQ validated within study population.

TABLE 2 Characteristics of A Posteriori Studies and Weight Status (BMI and/or Waist Circumference)*

Reference	Study Population(s)	Design†	Subjects	Dietary Assessment‡
Tucker et al., 1992 (34)	United States	CS	233 M + 447 F; aged ≥60 y	3-day food record
Haveman-Nies et al., 2001§ (33)	FHS; United States SENECA; Europe	CS data from PS	FHS: 828 M/F SENECA: 1282 M/F aged 70–77 y	FHS: 126-item FFQ‖ SENECA: modified DH¶
Lin et al., 2003 (36)	MAHES; United States	CS	825 Hispanic and non-Hispanic white M/F; aged 60–92 y	118-item FFQ (3 months)
Ledikwe et al., 2004 (37)	GRAS; United States	CS	81 M + 98 F; aged 66–87 y	5, 24-h recalls**
Bamia et al., 2005 (35)	EPIC—Elderly cohort; Europe	CS data from PS (multicenter)	34086 M + 65658 F; aged ≥60 y	FFQ††(1 year)
Robinson et al., 2009 (18)	HCS; United Kingdom	CS data from PS	3217 M/F; aged 59–73 y	FFQ‖
Anderson et al., 2010 (38)	Health ABC, United States	CS data from PS	831 M + 978 F; aged 70–79 y	108-item FFQ

*Abbreviations are as follows: BMI, body mass index; CS, cross-sectional; M, males; F, females; FHS, Framingham Heart Study; SENECA, Survey in Europe on Nutrition and the Elderly: A Concerted Action; PS, prospective study; FFQ, Food Frequency Questionnaire; DH, diet history; MAHES, Massachusetts Hispanic Elderly Study; GRAS, Geisinger Rural Aging Study; EPIC, European Prospective Investigation into Cancer and Nutrition; HCS, Hertfordshire Cohort Study; Health ABC, The Health, Aging and Body Composition study.

†Measured anthropometric measurements were used, except in the Bamia et al. study (35), where participants from centers in France, Oxford, and Norway self-reported height and weight. (Actual measures were only obtained for a fraction of these participants.)

‡Reference period for FFQ listed when available.

§Study used both a priori and a posteriori methodology.

‖FFQ validated in a separate study population.

¶Diet history included three-day estimated food record and frequency checklist of foods.

**24-h dietary recalls were collected over a 10-month period.

††FFQ validated within study population.

posteriori methods (Table 3). Food intake information from food frequency questionnaires (FFQs) or a diet history was used to calculate dietary scores, with higher scores indicative of higher diet quality. Generally, dietary scores were inversely related to BMI and/or waist circumference (29–31, 33). Tyrovolas et al. (31) found that a 10-point increase in MedDietScore was associated with a 57% lower likelihood of obesity (OR per 1 point MedDietScore = 0.92, 95% CI = 0.83–1.00) while Panagiotakos et al. (29) only found a 12% lower likelihood of obesity associated with a 10-point increase in MedDietScore ($p = 0.001$). In a sample of community-dwelling older men, diet quality was found to be significantly inversely related to BMI (30). In addition, an interaction was found between BMI and education level. For men with a high school education or less, lowest mean modified DQI-R scores were observed among those with the lowest BMI ($\leq$20 kg/m^2). Conversely, for men who completed graduate school, highest mean scores were observed among the leaner men. This relationship may reflect food insecurity for those in the lowest education category and access to better quality foods by men with higher education. Interestingly, the only study that examined longitudinal data in relationship to dietary quality and health-related factors (32) found that childhood vegetable consumption was positively associated with adult Healthy Diet Score (HDS). However, a relationship between BMI and adult HDS was not found, although HDS was lower for those individuals with BMI >30 kg/m^2 than for those with BMI values <25 kg/m^2 ($p = 0.81$). In addition, longitudinal analyses found that childhood vegetable consumption was positively associated with adult HDS when assessed individually and when included in a multivariable model ($p < 0.05$).

Findings From A Posteriori Studies

Six studies that used data-driven approaches to identify food intake patterns were included in this review (18,34–38). Of these studies, four employed cluster analysis to examine the relationship between diet and weight status (34,36–38), one used PCA (18), and one used both cluster analysis and PCA (35) (Table 4). Studies identified as few as two patterns (18, 35, 37) and as many as six (38). Similar to findings from a priori-based studies, Ledikwe and colleagues (37) found that older adults with a higher quality diet, as characterized by higher levels of nutrient dense foods (e.g., vegetables, fruits, milk, yogurt, cereals, poultry, fish, beans), had lower waist circumference ($p < 0.05$) and BMI values ($p = 0.075$). In addition, older adults with the "Low-nutrient dense" pattern, as characterized by higher intakes of bread, processed meats, eggs, fat/oils, and sweets, had twice the odds of being categorized as obese (BMI >30 kg/m^2) (OR = 2.03, 95% CI = 0.98–4.20) or having a waist circumference above the National Institutes of Health (39) high risk cutoff for obesity-associated risk factors (men >102 cm; women >88 cm) (OR = 2.33, 95% CI = 1.16–4.69). Cluster analysis performed on data from the U.S. Framingham

TABLE 3 Diet Index/Score and Weight Status (BMI and/or Waist Circumference)*

Reference	Study Population(s)	Diet Index	Results
Haveman-Nies et al., 2001 (33)†	SENECA; Europe FHS; United States	HDI and FS-MDS	For both diet scores, WC was highest for the groups representing lowest diet quality. BMI was lowest for the high quality diet scored by HDI, but this relationship was not seen with the FS-MDS score.
Maynard et al., 2005 (32)	Boyd Orr cohort; England, Scotland	HDS	CS: The relationship between BMI and HDS score was not statistically significant.
Panagiotakos et al., 2007 (29)	Cyprus	MedDietScore	MedDietScore was inversely correlated with BMI ($p = 0.02$). A 10-unit increase in MedDietScore was significantly associated with a 12% lower odds of obesity ($p = 0.001$).
Shannon et al., 2007 (30)	MrOS; United States	Modified DQI-R	Modified DQI-R was significantly inversely related to BMI. BMI, along with age, total caloric intake, education, race/ethnicity, study site, smoking status, and supplement use were independent predictors of modified DQI-R scores.
Tyrovolas et al., 2009 (31)	MEDIS study; Greece, Cyprus	MedDietScore	A 10-unit increase in the MedDietScore was associated with $1.2\,kg/m^2$ decrease in BMI levels and with 57% lower likelihood of being obese (OR per 1 unit = 0.92, 95% CI = 0.83–1.00). A higher MedDietScore was independently associated with lower likelihood of obesity.

*Abbreviations are as follows: BMI, body mass index; SENECA, Survey in Europe on Nutrition and the Elderly: A Concerted Action; FHS, Framingham Heart Study; HDI, Healthy Diet Indicator; FS-MDS, Framingham-SENECA Mediterranean Diet Score; WC, waist circumference; HDS, Healthy Diet Score; CS, cross-sectional; MrOS, Osteoporotic Fractures in Men Study; DQI-R, Diet Quality Index, Revised; OR, odds ratio; CI, confidence interval.

†Study used both a priori and a posteriori methodology.

TABLE 4 Cluster/Principal Component and Weight Status (BMI and/or Waist Circumferance)*

Reference	Study Population(s)	Pattern Methodology†	Description of Identified Clusters/ Principal Components	Results
Tucker et al., 1992 (34)	United States	Cluster; 16 food groups; percentage of energy intake	(1) Alcohol: 19.5% mean energy intake from alcohol (2) Milk, cereal, fruit (3) Bread, poultry (4) Meat, potatoes	Those in the Bread, poultry cluster had lowest reported energy intakes but paradoxically had the highest mean BMI. Individuals characterized by the greatest alcohol consumption had the highest energy intakes but the lowest average BMI.
Haveman-Nies et al., 2001 (33)	SENECA; Europe FHS; United States	Cluster; 11 food/ nutrient groups; grams per day	(1) Sugar: Sugar and sugar products, legumes, nuts, seeds (2) Fish and grain (3) Meat, eggs, and fat (4) Milk and fruit: high intakes of vitamins and calcium (5) Alcohol: lowest intakes of vitamins and calcium	BMI was significantly higher for those in the "Meat, eggs, and fat" and Alcohol clusters.
Lin et al., 2003 (36)	MAHES; United States	Cluster; 32 food groups; percentage of energy intake	(1) Fruit, breakfast cereal: lowest energy contributions from added fats, meats, and soft drinks (2) Starchy vegetables (3) Rice: rice, added fats (cooking oil), beans, and poultry (4) Milk:>20% total energy from whole milk (5) Sweets: Baked sweets, bread, pasta, meat, potatoes, candy and	Hispanic elders consuming the Rice pattern had greater BMI and WC scores compared to the other groups. Individuals classified in the Milk pattern had lower BMI scores compared with the other groups. Individuals in the Rice pattern had higher WC scores compared to those in the Fruit and Cereal cluster.‡

			sugars, dairy desserts, processed meat, eggs, and alcohol	
Ledikwe et al., 2004 (37)	GRAS; United States	Cluster; 29 food groups; servings per day	(1) Low-nutrient dense: higher intakes from the bread, cereal, rice, and pasta and the fats, oils, and sweets groups (2) High-nutrient dense: higher intakes from the vegetable; fruit; and milk, yogurt, and cheese groups	The low-nutrient dense pattern was associated with a higher BMI. After controlling for covariates, WC was found to be lower for those in the high-nutrient dense pattern.[§] Those in the low-nutrient dense cluster were twice as likely to be obese (BMI $>30\,kg/m^2$) and have a WC greater than the NIH risk cutoff.
Bamia et al., 2005 (35)	EPIC—Elderly cohort; Europe	PCA; 17 main groups, 124 subgroups; grams per day	PC (1) Vegetable-based: vegetables, vegetable oils, fruits, pasta, rice and other grains, legumes PC (2) Sweet- and fat-dominated: cereals, cakes, condiments/sauces, margarine, sugar and confectionary, dairy products	The Vegetable-based pattern was positively associated with higher BMI values. The Sweet- and fat-dominated pattern was associated with lower BMI values and waist:hip ratios.
Robinson et al. (2009)	HCS; United Kingdom	PCA; 51 food groups; weekly frequencies	(1) Prudent: high intakes of fruit, vegetables, oily fish, wholemeal cereals; low intakes of processed foods and high fat dairy (2) Traditional: high intakes of green, root, salad, and other vegetables; red, processed and organ meat, fish and puddings; low intakes of milky drinks, reduced fat spread, and breakfast cereal	Neither pattern was associated with BMI in men or women.

(*Continued*)

TABLE 4 Continued

Reference	Study Population(s)	Pattern Methodology[†]	Description of Identified Clusters/ Principal Components	Results
Anderson et al. (2010)	Health ABC, United States	Cluster; 40 food groups; percentage of energy	(1) Meat, snacks, fats, and alcohol (2) Sweets and desserts (3) Refined grains (4) Breakfast cereal (5) Healthy foods: higher intakes of low-fat dairy products, fruit, whole grains, poultry, fish, and vegetables; lower intake of red meat, sweets, added fats, and high-calorie drinks (6) High-fat dairy products	No significant differences were found between individuals in the Healthy foods cluster and other clusters for BMI. When stratified by genotype, there were no significant differences for body composition measures, including BMI, for PPAR-γ Pro/Pro homogenous individuals in the Healthy foods cluster compared to the other clusters. Conversely, men with the Ala allele in the Healthy cluster had a significantly lower BMI than those in the Meat, snacks, fats, and alcohol and the Breakfast cereal cluster.

[*]Abbreviations are as follows: BMI, body mass index; SENECA, Survey in Europe on Nutrition and the Elderly: A Concerted Action; FHS, Framingham Heart Study; MAHES, Massachusetts Hispanic Elderly Study; WC, waist circumference; Geisinger Rural Aging Study, GRAS; EPIC, European Prospective Investigation into Cancer and Nutrition; PCA, Principal component analysis; PC, Principal component; HCS, Hertfordshire Cohort Study; Health ABC, The Health, Aging and Body Composition study; PPAR-γ, peroxisome proliferator-activated receptor-γ.

[†]Treatment of the food variables provided when available.

[‡]These significant associations remained even after adjusting for age, sex, poverty, education, family size, and acculturation status.

[§]Adjustments for energy intake, age, sex, tobacco use, and alcohol use.

Heart Study and the European SENECA study (33) found that BMI was significantly higher for individuals with the "Meat, eggs, and fat" and the "Alcohol" food group patterns compared to older adults with the "Sugar," "Fish and grain," and "Milk and fruit" patterns (after adjusting for age, sex, smoking, activity, and country). Similar relationships between waist circumference and diet scores were observed in this sample. In a sample of Hispanic older adults (36), BMI ($OR = 1.05$, 95% $CI = 1.02–1.09$, $p < 0.05$) and waist circumference ($OR = 1.03$, 95% $CI = 1.01–1.04$, $p < 0.05$) were highest for those in the "Rice" cluster while older adults in the "Whole milk" cluster had relatively lower BMI values ($OR = 0.95$, 95% $CI = 0.91–0.99$, $p < 0.05$) after adjusting for several confounders including socioeconomic status and acculturation. The "Rice" pattern was also high in fat; the authors noted that cooking oils were the second greatest source of energy intake. A food intake pattern characterized by relatively higher intakes of alcoholic beverages was identified in several studies. Two studies found that BMI values were significantly higher for individuals with the alcohol-dominant pattern (33, 38). However, this relationship for Anderson et al. (38) was only evident when individuals were stratified by peroxisome proliferator-activated receptor-γ (PPAR-γ) polymorphism; men with the Ala allele and the "Meat, snacks, fats and alcohol" pattern had significantly higher BMI values than those with the "Healthy" pattern ($p < 0.05$). In contrast, Tucker et al. (34) identified an "Alcohol" pattern, characterized by 19.5% of mean energy intake from alcoholic beverages. Although mean energy intake was highest for older adults in the "Alcohol" cluster, individuals in this cluster had the lowest mean values for BMI ($p < 0.05$). The Hertfordshire Cohort Study (HCS) (18) observed that BMI was not associated with the "Prudent" pattern (higher intakes of fruits, vegetables, wholemeal cereals, and oily fish and lower intakes of white bread, added sugar, full-fat dairy products, chips, and processed meats), although many correlates were, such as leaving full-time education at the age of 15 years or later, higher social class, and being a nonsmoker. The lack of relationship for BMI and dietary pattern was also true for the "Traditional" food pattern, which was characterized by higher intake of vegetables, processed and organ meats, fish, red meats, and puddings and lower consumption of milk-based drinks, reduced fat spreads, and breakfast cereals.

DISCUSSION

Of the 11 studies reviewed for associations between food intake patterns and weight status in older adults, three studies showed an inverse relationship between diet score and BMI (29, 30, 33), two studies showed no relationship (18, 32), two studies reported a negative but statistically insignificant relationship (31, 37), and four studies showed significant but inconsistent relationships between BMI and diet (34–36, 38). Based on the current literature review, an inconsistent relationship between obesity, as measured by BMI and/or waist circumference, and food intake patterns exists (i.e., higher quality diets not always associated with better weight status). Current food-based guidelines support a diet that is relatively higher in fruits, vegetables, whole grains, and low-fat dairy and lower in added sugars, saturated fat, and refined grains (40). Based on the limited evidence available, it is not apparent if this recommended pattern is related to a healthy body weight among older adults.

Of the a priori studies that found a significant relationship between BMI and food intake pattern, diets characterized by higher dietary scores or indices (i.e., "better quality") were inversely related to BMI and/or waist circumference (29, 30, 33). Results from studies that used a posteriori methods were less clear. A lower BMI was linked to an "Alcohol" cluster (34), a "Milk" cluster (33, 36), and "Sweet- and fat-dominated" pattern (35). The relationship for patterns characterized by alcohol and BMI are inconsistent. Tucker et al. (34) reported that those in the Alcohol cluster had lowest average BMI values, while Haveman-Nies et al. (33) found that mean BMI was highest for those in the Alcohol cluster. It would be of particular interest to distinguish the type of alcohol consumed (e.g., beer vs. wine or spirits).

Robinson et al. (18) found no relationship between food intake pattern and BMI for either men or women. This sample of older adults was relatively educated, with 81% of men and 82% of women reporting leaving full-time education at the age of 15 years or later; more than 70% were married or living with a partner. One explanation for this lack of relationship could be related to the relatively homogenous sample, affecting ability to detect distinct components. Although Anderson and colleagues (38) did find a significant relationship between body composition measures, including BMI, and food intake pattern, this was not evident until participants were stratified by PPAR-γ genotype. Findings that were meaningful, but nonsignificant, were in line with current beliefs about dietary recommendations for health (40).

A number of limitations exist regarding methodology: (a) cross-sectional nature of analyses, (b) inherent limitations with food intake pattern identification, (c) diet underreporting, and (d) responder bias. A major limitation among all studies examined was the cross-sectional nature of analyses. It is not possible to establish causality between weight status (BMI and waist circumference) and food patterns among older adults given the cross-sectional nature of the studies. The one study examined in this literature review that did include longitudinal data (32) did not find a relationship between child HDS and adult HDS or adult HDS and BMI. It is noteworthy that height and weight were self-reported in this study and that child dietary data were collected at the household level and therefore may not accurately capture individual childhood diet.

Fundamentally, a priori and a posteriori approaches are inherently different. A posteriori methods are usually based on data from food intake alone, whereas a priori methods are rarely based on just data at the food group level—they are almost always based on both food group (e.g., fruits, vegetables) and nutrient (e.g., saturated fat, calcium) data. This distinct difference in approach may be a reason why studies vary with regard to findings for overall associations with weight status. Both approaches have well-known limitations that can influence results, making it difficult to make comparisons across studies. Especially for a posteriori approaches, numerous subjective decisions, made by researchers before data analysis even begins, can influence reported food intake patterns, including the form of the food/food group input variables (e.g., grams, number of servings, proportion of energy intake) (20, 41), the number of clusters or factors to extract, whether patterns should be derived for subgroups separately, selection of analysis methods including what confounders to control for, and which patterns will be reported and how they will be named.

In addition, score-based methods are not without drawbacks. While diet scores or indices will give an indication of where an individual or population of interest lies on a spectrum (e.g., the MedDietScore gives indication of how one is adhering to a Mediterranean dietary pattern), scores may not have cutoff points that indicate what is considered an "adequate" quality diet. Many scores do not account for energy intake or nutrient/energy density. Therefore, eating a larger quantity of food or increasing variety would yield a higher diet quality score, unless kilocalories are taken into account. An example of a diet quality score that is density-based is the HEI-2005, which results in a diet score that is independent of energy intake. It is also unknown whether high diet scores for indices like the HEI are associated with favorable health outcomes (19). Scores seldom include behavioral indicators (e.g., eating breakfast, skipping meals), which could be important in determining optimal dietary patterns, especially in older adults. Furthermore, if a score is measuring adherence to a specific diet (e.g., the Mediterranean diet), a high score is indicative of consumption of a Mediterranean-like diet; however, a low score is not necessarily indicative of a unhealthy diet but should be carefully interpreted as indicative of another type of diet (that may also be considered "healthy" but just not Mediterranean-like).

A possible explanation for inconsistent findings across studies for the relationship between BMI and food intake patterns in older adults could be related to the disparity of the samples evaluated. Some of the studies reported generally healthy samples (18, 30, 31, 33, 34, 38), while others reported relatively higher proportions of participants with adverse health conditions, such as diabetes and hypertension (29, 36). Moreover, the studies examined included populations of interest from the United States (30, 33, 34, 36–38) and both Northern and Southern Europe (18, 29, 31, 33, 35) and included non-Hispanic Whites (37), African Americans (30, 38), Asian-Americans (30), and Hispanics (36). Two major dietary profiles emerged from the studies that included European populations (33, 35)—a "Northern" and "Southern" profile. Shannon et al. (30) highlighted that ethnicity was not a significant predictor of diet quality until it was examined in a multivariate analysis that adjusted for geographic location among other characteristics. The possibility of an interaction between race/ethnicity and geographic location and dietary intake should be considered.

Similarly, food intake patterns identified differed among studies of European populations versus those from the United States. Studies that included samples exclusively from the United States identified clusters characterized by alcohol (34, 38); milk, fruit, and cereal (34, 36, 38); and carbohydrate intake, including bread (34), starchy vegetables (36), and refined grains (38). European studies, using PCA, typically only reported two food intake patterns, usually including a "Prudent" pattern characterized by relatively higher intakes of vegetables, fruit, and grains and a pattern distinguished by relatively higher intakes of sweets and fat (18, 35).

FFQs are the most common diet assessment methodology used in large-scale epidemiology studies. Two studies included in this review used methods to assess diet other than an FFQ (34, 37). In addition, substantial variation existed among the FFQs used in the remaining studies (e.g., population-specificity, number of items, administration method), and these distinctions make it difficult to compare results.

Self-reported dietary intake is subject to both random and systematic measurement error (42). An example of systematic error that is consistently demonstrated in dietary data collection in epidemiologic studies is the underreporting of food or beverages (types, amounts) by certain population groups (42). There is evidence that underreporting energy intake is more common among women (43–45), older adults (46–48), and those with elevated body weight (49–52). All the studies in this review reported mean BMI values $>25\,kg/m^2$ (18, 29, 34, 36, 38) or a relatively higher proportion of overweight or obese individuals (29–33, 37). The relatively high proportions of those with elevated BMI values in these studies may have possible implications on the interpretation of findings. Several studies did include consideration of implausible energy reporters (32, 36, 38). A reporting bias of foods that are not perceived as healthy (e.g., high-carbohydrate foods, such as cakes and confectionary items) has been documented previously (53). In the study by Robinson et al. (18), it is possible that women were more likely to underreport frequency or amount consumed of carbohydrate-rich or high-fat food items, thereby increasing "Prudent" diet scores. In contrast, Bailey et al. (54) conducted a cluster analysis on a sample in which implausible reporters were both included and excluded and observed substantially similar food intake patterns in both analyses. According to a review by Trabulsi and Schoeller (42), misreporting of energy intake did not differ by type of dietary assessment methodology (e.g., FFQ, 24-hour recall, diet record). They concluded that psychological factors, such as restrained eating and physical characteristics of participants, likely were determinants of implausible energy reporting. However, findings regarding underreporting and type of dietary assessment method are inconsistent (55–57).

The existence of a possible "healthy responder" bias may have affected findings. Many of the studies recruited relatively healthy individuals (18, 30, 31, 33, 34, 38), of which a considerable proportion were also educated and therefore, results may not be representative of the general older adult population. Robinson et al. (18) suggest that this is not likely as no systematic differences were found between those who fully participated in the HCS (i.e., participated in all study aspects, which included home interviews, clinic visits, and Dual-energy X-ray absorptiometry scans) and those who did not. Studies that included less healthy populations (e.g., studies examining cancer or cardiovascular disease) often included non-elderly participants and therefore were not examined in this literature review. Another inherent limitation of this review is that findings of unpublished studies were not considered.

Considerations and Future Directions for Food Intake Pattern Analysis in Older Adults

Most of the studies we reviewed investigated the relationship between BMI and food intake patterns focused on participants from Europe and North America. Food intake pattern research in older adults would be strengthened by the consideration of diverse populations. Although the special group of older adults known as the Centenarians ($\geq$100 years old) has been studied extensively, literature on the examination of food intake patterns and weight status in this group, as well as the older-old ($\geq$80 years), is limited (58). Because there is evidence to support that diet may modify the relationship between disease risk and genetic susceptibility (59, 60), additional research relating dietary patterns in combination with gene polymorphisms to weight is needed; our search resulted in only one such study (38).

Besides the commonly used data-driven approaches such as principal components and cluster analysis, more recently, reduced rank regression (RRR) has been used to explore food intake patterns (61). RRR is considered a hybrid method that combines data-driven procedures with a priori knowledge. However, this literature search did not identify any article that used RRR in relation to dietary patterns and weight status in the older adult population. Another promising novel statistical method for modeling food intake patterns is finite mixture modeling of the conditional Gaussian distribution—a model-based approach that may have advantages over standard multivariate statistical methods (e.g., factor analysis, cluster analysis). Compared to traditional methodologies, finite mixture modeling allows for goodness-of-fit statistics for model evaluation, posterior probabilities, and results that give rise to mutually exclusive patterns (the latent variable from factor analysis is continuous). To our knowledge, only one publication has reported use of a finite mixture modeling approach using dietary data (62), but the population of interest was not older adults.

Additional longitudinal and prospective research in older adults is necessary to provide a more comprehensive picture of what food intake patterns exist and their associations with weight status and obesity-related health outcomes. Although several of the studies examined were longitudinal in nature, statistical analyses were limited to relating anthropometrics to cross-sectional dietary data, usually collected at baseline. Additionally, the findings from longitudinal studies that did not focus on older adult populations have been inconsistent with regard to examined food intake patterns in relation to weight changes (4, 63, 64). In studies involving older adults, researchers should consider examining the younger-old separately from the older-old ($\geq$80 years) to possibly capture the effect of age-associated differences on BMI and other health outcomes of interest (65, 66).

Results from this literature review of food patterns of older adults and weight status demonstrate that findings from the available studies are inconclusive and more research is needed. Because older adults are not immune to the obesity epidemic, elucidating the relationship between food intake patterns and weight can provide evidence for the development of appropriate and timely food-based interventions and health promotion strategies that may be critical for prevention of chronic disease. Such interventions may be able to help maintain quality of life and reduce health care–related resource consumption for the older adult population.

TAKE AWAY POINTS

- Both a priori and a posteriori methods are useful in examining the associations between food patterns and weight among older adults.
- Differences across studies, including populations of interest, dietary assessment methods, and choice of methodology to identify patterns, as well as the inherent subjective nature of food pattern analysis (especially with data-driven techniques) hinders the ability to draw conclusions about the relationship between food intake patterns and weight in older adults.
- Based on this review, no consistent relationship between weight status, as measured by BMI and/or waist circumferance, and food intake patterns in older adults could be identified.
- More research, including longitudinal studies, investigation of the relationship of genetic polymorphisms, and relationship to dietary patterns and the use of novel statistical methods to derive food intake patterns is warranted.

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Chapter 3

DIETARY PATTERNS AND RELATIONSHIP TO OBESITY-RELATED HEALTH OUTCOMES AND MORTALITY

INTRODUCTION

The first of the Baby Boomer generation (adults born between 1946 and 1964) turned 65 years old in 2011. By 2030, 30% of older adults are projected to be obese, and more than 60% will be managing more than one chronic condition (1). Of particular concern are increasing rates of obesity-related chronic diseases, namely cardiovascular disease (CVD), diabetes mellitus, hypertension, and metabolic syndrome (MetSyn).

Longitudinal prospective trials have reported that the consumption of 'healthy', 'prudent' or 'Mediterranean-like' diets are associated with decreased risk of CVD (2, 3), diabetes mellitus (3-5), hypertension (6, 7), and MetSyn (8, 9). These studies were predominately in adult mixed-aged samples (≥ 18 years old). In studies that included mixed-aged samples, results from older adults differed from that of the younger adults (10, 11). Studies of the association between dietary patterns and obesity-related chronic diseases in exclusively older adult populations are fewer (12-14) and focus mainly on European populations.

The Geisinger Rural Aging Study (GRAS) is a longitudinal cohort that was initiated in 1994 as a nutrition-risk screening study of > 20,000 community-dwelling older adults living in rural Pennsylvania (15). Since the mean age of GRAS participants is 76.5 years old (range: 66-95 years), this cohort provides a unique opportunity to study old-older persons. Therefore, the objectives of this study were two-fold: 1) to identify the dietary patterns in a sample of American old-older adults using cluster analysis; and 2) to examine the association between the derived dietary patterns and prevalence of obesity-related outcomes, namely CVD, diabetes mellitus, hypertension, and MetSyn, and mortality over a 5-year follow-up period.

SUBJECTS AND METHODS

Participants

GRAS participants were enrolled in a Medicare-managed health management organization administered through Geisinger Health System (Danville, PA), which provides services to many individuals living in rural areas (any area with a population of ≤ 2,499 residents) (16). Participants (n = 449) for this study were randomly selected from the GRAS cohort. Study selection criteria were described elsewhere (17). Two subgroups of the GRAS cohort were used for these analyses. The first subgroup (GRAS-1997) had in-home baseline measurements from 1997-1998 (n = 81 males, 98 females), while clinic baseline measurements for the second subgroup (GRAS-2004) were taken from 2004-2005 (n = 113 males, 157 females).

All study procedures were approved by the human Institutional Review Board (IRB) at the Geisinger Health System and an IRB-approved Data Sharing Agreement was in place with The Pennsylvania State University. Additional study details have been published elsewhere (17).

Study measures

At the baseline visit, height, weight (light clothing, no shoes), and waist circumference measurements were taken. Body mass index (BMI) was calculated as (weight in kg)/(height in m)^2 and categorized as < 18.5 = underweight; 18.5-24.9 = normal weight; 25-29.9 = overweight; and ≥ 30 = obese. Cognitive impairment and depression were assessed using the Mini-Mental State Examination (MMSE) and the Geriatric Depression Scale (GDS), respectively. Cigarette smoking was categorized as 'current smoker' or 'non-current smoker'. Education was coded as 'elementary school, 'some high school', 'graduated from high school or GED', or 'some college or more'. Marital status was collapsed into 'married' or 'not married'. Self-reported number of prescribed medications was queried. Participants also completed health questionnaires, including the Physical Activity Score for the Elderly (PASE) (only GRAS-2004) to determine level of activity. The PASE measures self-reported weekly household, occupational, and leisure activities, with a higher score indicative of a higher level of physical activity (18). Functional status was recorded as self-report of difficulty with ≥ 1 Activities of Daily Living (ADL) or Independent Activities of Daily Living (IADL) versus no reported difficulties. Frequency of dieting was queried and coded as 'always', 'usually', 'sometimes', or 'never'.

Dietary intake assessment

At baseline, four (GRAS-2004) or five (GRAS-1997) 24-hour dietary recalls were collected via telephone by trained interviewers at The Pennsylvania State University Diet

Assessment Center (University Park, PA) using the Nutrition Data System for Research (NDSR 403.31, NDSR-2005, and NDSR-2010, Nutrition Coordinating Center, Minneapolis, MN). Dietary recalls were collected over a 10-month period to reduce seasonal bias (19). Energy cut-offs of > 5000 kilocalories (kcal) and < 500 kcal were used to exclude implausible energy reporting. Averages of the food and nutrient variables were used in these analyses. Foods were categorized into 29 food groups based on similarity of nutrient composition (**Table 3-1**). The percentages of total energy from each food subgroup were calculated for each participant using NDSR summary files. Mean food subgroup and nutrient data were also used to calculate the Healthy Eating Index-2005 (HEI-2005) summary score (GRAS-2004 only), which reflects how well an eating pattern adheres to recommendations from the Dietary Guidelines for Americans (20). Energy density was calculated for each participant as kcal per gram of food weight (21).

Health outcomes and mortality

For a subset of the sample, health outcome data were available (n = 260 from GRAS-2004). A validated electronic data extraction (EDE) process was used to obtain prevalence data on CVD, diabetes, hypertension and MetSyn from the electronic medical records (EMR) of participants maintained through the Geisinger Health System. To validate the electronic data extraction process, the EMRs of 48 participants (24 males, 24 females) from GRAS-2004 were randomly selected for review. Only outpatient visits were accessed for data extraction. A manual chart review (CR) of the EMRs was completed by a trained auditor starting at date of study entry (CR process). The CR process included an audit of demographics, diagnoses codes, laboratory data, past medical history, medications, progress notes, and physician comments (**Appendix A**).

For the EDE of EMRs, data available electronically were extracted and stored in Statistical Analysis System (SAS) version 9.2 data files (EDE process). A combination of International Classification of Diseases (ICD)-9 codes, current medication use, as well as biochemical measures and clinic-measured anthropometrics (heights and weights) were used to define these outcomes (**Table 3-2**). The EDE process and the CR process were independently used to identify individuals with criteria for the outcomes of interest. Disagreements between results from each method were reviewed to identify and correct human error. Cohen's Kappa was calculated to assess statistical agreement and was ≥ 90% for all diagnoses (**Appendix B**). For the health outcomes analyses, follow-up time was defined as the time period that extended from the baseline visit until the date of the 'first mention' of the outcome of interested in the EMR, the end of the follow-up period (July 31, 2011), or death.

Deaths were identified using EMR and the Social Security Death Index data through July 2011. Mortality status was available for almost the complete sample (n = 446).

Determination of dietary patterns

Dietary patterns were derived using cluster analysis (PROC FASTCLUS using the SAS version 9.2, SAS Institute, Inc., Cary, NC). Briefly, K-means cluster analysis utilizes Euclidean distances between observations to estimate a user-specified number of mutually-exclusive clusters (K). The objective is to aggregate groups of individuals together on the basis of shared dietary characteristics. Since cluster analysis is sensitive to outliers, data were standardized and outliers were winsorized (i.e., observations ≥ 5 standard deviations were assigned to the next highest observation) (22, 23). Eighty-seven data points in 28 food subgroups were winsorized, which represents less than 0.7% of data. PROC FASTCLUS requires that the number of clusters be specified in advance. To determine the number of clusters, solutions testing 2 – 6 clusters were examined. Examination of each cluster solution, including inspection of canonical plots (to visually examine separation of clusters), cluster size for statistical power for subsequent health outcome analysis, comparison of the between-cluster versus within-cluster ratios (24), and ease of interpretation of the clustered dietary characteristics, pointed to a 3-cluster solution (i.e., 3 dietary patterns).

Mean percent total energy contribution from each food subgroup, selected nutrients, and socio-demographic variables were compared across clusters using chi-square analyses (or Fisher's exact test) and generalized linear models (including pair-wise contrast tests) for categorical and continuous variables, respectively. Clusters were labeled according to representation of food groups contributing a greater proportion of the total energy intake for each pattern.

The association between dietary pattern membership and mortality was assessed using Cox proportional hazards regression models with the PHREG procedure in SAS. Associations between dietary pattern membership and prevalence of health outcomes during the 5-year follow-up period were evaluated using logistic regression, controlling for relevant covariates.

In longitudinal studies of age-related health outcomes, there are high rates of attrition due to mortality among older populations. Therefore, the analysis was repeated examining the relationship between dietary pattern and health outcomes adjusting for selective attrition due to mortality. It is especially important to address this potential bias when the selection (e.g., mortality) is influenced by both the risk factor (e.g., dietary patterns) and the outcome (e.g., CVD). Inverse-probability-weighting methods were used to control for survival bias (25). Logistic regression was used to model and estimate probability of mortality, based on observed covariates (age, gender, number of prescribed medications, current smoking status, mean energy intake, physical activity score, marital status, education level, weight, self-reported general health and functional status, number of overnight hospital visits over the past year, MMSE score, GDS, history of cancer (yes/no), waist circumference, and frequency of dieting). These probabilities were then used to create weights that represent the inverse probability of selective attrition from mortality in the study, calculated as 1/p(death) and 1/[1-p(death)]. Individuals with covariate profiles associated with a high probability of mortality, but who did not die, were “upweighted” and those with a high probability of mortality, and who did die, were "downweighted." Thus, those that did the opposite of what was expected based on the covariate profiles were upweighted and vice versa. Although weights were calculated for each individual, only individuals not coded as missing for the respective health outcome were included in examination of each outcome. Finally, these weights were used in a logistic regression, to test the association between the derived dietary patterns and the health outcomes. Only individuals who had complete covariate information were included in multivariate models.

Final results were reported as odds ratios (OR) and 95% confidence intervals (95% CI). Data were analyzed using the SAS statistical software package, version 9.2 (SAS Institute, Inc., Cary, North Carolina). The Bonferroni adjustment was used to correct the significance level for multiple comparisons.

RESULTS

Three distinct dietary patterns were derived using cluster analysis and labeled based on the food subgroups which contributed the largest percentage of total energy (**Table 3-3**). The 'Sweets and dairy' pattern (n = 230; 51.2% of the sample) was characterized by largest proportions of energy from the baked goods, milk, sweetened coffee and tea, and dairy-based desserts food groups, and lowest intakes of poultry. The 'Health-conscious' group (n = 105; 23.4% of the sample) was characterized by relatively higher intakes of pasta, noodles, rice, whole fruit, poultry, nuts, fish, and vegetables, and lower intakes of fried vegetables, processed meats, and soft drinks. Those in the 'Western' pattern (n = 114; 25.4% of the sample) had higher intakes from the bread, eggs, fats, fried vegetables, miscellaneous (sauces, condiments, etc.), alcohol and soft drinks, and lowest intakes of milk and whole fruit.

Mean nutrient intakes differed across the 3 dietary patterns (**Table 3-4**). The 'Health-conscious' dietary pattern had more favorable nutrient intakes, reporting highest intakes of protein, fiber, vitamins B6, B12, C, D, and calcium, magnesium, and potassium. They also reported lowest intakes of energy; total, saturated, and *trans* fat; and added sugars. Highest fat (total, saturated, and *trans*) and lowest fiber, vitamins B6, C, D, folate, calcium, magnesium, potassium, and iron intakes distinguished the 'Western' dietary pattern. Although the 'Sweets and dairy' pattern was characterized by highest intakes of energy and added sugar, they were not significantly different from those in the 'Western' dietary pattern. The 'Western' dietary pattern had the highest energy density and the lowest HEI-2005 total score, while the 'Health-conscious' group showed the opposite relationship.

There were no significant differences for age, education, BMI, waist circumference, or number of self-reported prescribed medications across dietary patterns (**Table 3-5**). Though not significant, those characterized by the 'Sweets and dairy' pattern had the highest percentage of males, the highest percentage of overweight individuals, the lowest physical activity level and the lowest percentage of married individuals. Though not significant, there were more females in the 'Health-conscious' dietary pattern and the greatest prevalence of obesity was found in the 'Western' dietary pattern ($P > 0.05$).

Table 3-6 reports the prevalence of obesity-related health outcomes. During the 5-year follow-up period, the overall prevalence of having CVD, type 2 diabetes mellitus, hypertension, or MetSyn were 26.9%, 29.6%, 76.5%, and 56.2%, respectively. Among the obesity-related disease outcomes investigated, only prevalence of hypertension was significantly different among dietary patterns ($P < 0.05$).

Table 3-7 presents adjusted point estimates associated with being in the 'Sweets and dairy' or 'Western' dietary pattern compared to the 'Health-conscious' pattern for CVD, type 2 diabetes mellitus, hypertension, MetSyn and mortality. There were no statistically significant differences among dietary patterns for prevalence of CVD, diabetes mellitus, or MetSyn before or after adjustment for covariates. Compared to the

‘Health-Conscious’ pattern, those in the ‘Sweets and Dairy’ pattern had increased odds of hypertension; odds ratio (OR) (95% CI) for the fully-adjusted model was 2.18 (1.11-4.30). Over the 5-year follow-up period, almost 30% of this aged sample died. No association was found for mortality and dietary pattern, both independently or after adjusting for potential confounders.

Point estimates for the analysis which controlled for selective attrition due to mortality are presented in **Table 3-8**. The magnitude of the ORs generally increased for CVD, hypertension, and MetSyn and decreased for diabetes compared to the analysis that did not control for survivorship bias; however no outcomes achieved statistical significance with these adjustments.

DISCUSSION

The present study used cluster analysis to identify three distinct dietary patterns: a ‘Sweets and Dairy’, a ‘Health-Conscious’, and a ‘Western’ pattern. Those characterized by the ‘Sweets and dairy’ dietary pattern had a 2-fold higher odds of hypertension compared to the ‘Health-conscious’ pattern. These effects remained even after adjustment for age, gender, physical activity, smoking, waist circumference, education and marital status. Mortality was not significantly associated with dietary pattern. Even after controlling for selective attrition due to mortality, results were similar.

The dietary patterns identified in this sample have also been described in other studies. Many studies have previously reported a two dietary pattern solution, consisting of a more prudent pattern and a less healthy pattern, that has often been labeled a

‘Western’ dietary pattern because it reflects dietary practices of more developed nations (e.g., higher fat and energy, etc.). The ‘Health-conscious’ dietary pattern described in this study resembles the Dietary Guidelines for Americans, 2010. In addition to these two common patterns, the current study also characterized a ‘Sweets and dairy’ pattern, that reflects a preference for baked goods, dairy-based desserts, milk products and sweetened beverages. Similar patterns have also been previously reported by others (3, 12, 26-28). A majority of the GRAS sample (51.2%) was characterized by the ‘Sweets and dairy’ pattern. Similar to the present study, a ‘Sweets-type’ pattern was the most prevalent (29, 30) or second most prevalent cluster (31, 32) among other studies with derived dietary patterns.

Only the ‘Sweets and Dairy’ dietary pattern was significantly associated with 5-year prevalence of hypertension among this sample of older adults. Results were not appreciably attenuated by adjusting for confounders. Hypertension is a significant risk factor for CVD and coronary heart disease (33). Previous studies have reported an inverse relationship between blood pressure and a healthy or prudent dietary pattern, probably the most notable of which is the Dietary Approaches to Stop Hypertension (DASH) (34). DASH is a therapeutic lifestyle change that includes consumption of a diet that is relatively higher in fruits and vegetables, low-fat dairy products, fish, poultry, and whole grains and lower in red meat, sweets, total and saturated fat, and cholesterol. A clinical trial testing the effects of the DASH diet significantly lowered systolic blood pressure by 11 mm Hg in patients with hypertension compared to a control diet (6). Our findings are consistent with the DASH trial. Compared to the ‘Health-conscious’ dietary pattern, the ‘Sweets and dairy’ dietary pattern had higher odds of hypertension (OR = 2.17; 95% CI:

1.11, 4.27). The ‘Western’ pattern also had higher odds of hypertension (OR = 1.94; 95% CI: 0.87, 4.33); however this finding did not reach statistical significance. Despite the fact that we might have expected that differences in sodium intake would explain the variance in rates of hypertension (35), the mean sodium level for the ‘Health-conscious’ dietary pattern, although it was the lowest, was not statistically different from the other dietary patterns. This suggests that sodium intake may only partially explain the association in this older age group and it is likely a combination of nutrient/food interactions (e.g., potassium, magnesium, calcium) that contribute to this association and highlights the importance of emphasizing a total diet approach (e.g., dietary pattern analysis) as opposed to only considering single nutrients. In the present study, the significant association for hypertension and the ‘Sweets and dairy’ dietary pattern may also be partially explained by lower consumption of fruits and vegetables, nuts and fish, which have been shown to have protective effects in other dietary pattern studies. In contrast, Lopez and colleagues (36) found that a ‘Sweets’ dietary pattern was associated with having normal systolic blood pressure levels. This study used cross-sectional, nationally representative National Health and Nutrition Examination Survey (NHANES) data only from women ≥ 50 years old and included African Americans.

Interestingly, although not statistically significant, type 2 diabetes was associated with lower odds of being characterized by the ‘Sweets and dairy’ and the ‘Western’ dietary patterns. In comparison to the other outcomes examined, type 2 diabetes is most acutely affected by diet (i.e., increase in glucose after eating). In clinical practice, diagnosis and treatment of diabetes is often accompanied by relatively more intensive nutrition education compared to CVD or hypertension, for example. This finding suggests that those with diabetes may be more prudent with their dietary habits and therefore are less likely to consume the 'Sweets and dairy' or 'Western' dietary pattern. It may also mean that they are more likely to report healthy dietary patterns that they do not actually follow (37).

While among geriatric medicine practitioners it has long been suggested that overly restrictive dietary restrictions may not be appropriate for older persons, there has actually been little evidence basis for this recommendation. The absence of strong associations between dietary patterns and health outcomes and mortality in "old older" persons observed in the present study suggests that clinicians may indeed be warranted in avoiding overly restrictive diet prescriptions for some old-older persons, especially where food intake may be inadequate. Despite the lack of a significant association between dietary patterns and CVD, diabetes mellitus, and MetSyn, this study does not address whether changing from a less healthy to a more prudent diet at an advanced age would ultimately lead to improved health outcomes or overall prognosis. It is still possible that adopting a prudent diet at advanced age may be beneficial. This study also does not address the potential benefits of adopting a more prudent diet at a younger age.

It is critical to note that before any dietary restrictions are adopted by older adults, a thorough evaluation of the risk/benefits ratio should be considered in conjunction with a comprehensive health assessment by a qualified healthcare practitioner. It is also possible that subtle dietary modifications may positively influence overall quality of life.

Limitations

Other potential limitations with this study should be noted. Although GRAS is a longitudinal cohort study, our analyses were limited to the examination of the prevalence of CVD, diabetes mellitus, hypertension, and MetSyn of a smaller subset of old-older persons over a limited period of follow-up. Due to the nature of available data, we were unable to examine disease incidence. However, because the mean age of this sample at baseline was 76.5 years old, low rates of incident disease are expected this late in life. Findings from this study can only address the potential relationships between derived dietary patterns and these four obesity-related outcomes of interest. It is possible that there may be relationships between these dietary patterns and other health conditions that were not examined. While it is generally thought that dietary patterns are relatively stable among older persons, causality between dietary patterns and health outcomes could not be determined in the present study due to the cross-sectional nature of these diet assessment analyses. Additionally, because the GRAS sample was predominately non-Hispanic white, educated, and relatively independent, our findings may not be generalizable to the older adult population as a whole.

Selective attrition, in the form of survival bias, is often a concern in epidemiological studies of aging populations. Although there were no statistically significant differences in mortality status by dietary pattern ($P = 0.260$), statistical methods for controlling for a possible survival bias (25) were employed in these analyses. Although admittedly, the relatively wide 95% confidence intervals suggest that the sample size may have been inadequate to perform this analysis.

Using cluster analysis to derive dietary patterns is becoming increasingly popular in research. However, cluster analysis, involves a number of subjective decisions. Although a gold standard for deciding the optimal number of clusters has not been established (26), a number of tests were used to evaluate the strength of this cluster solution (e.g., canonical discrimination plots, comparison of the natural log-transformed between-cluster versus within-cluster ratios). Because dietary pattern approaches such as cluster analysis, are exploratory in nature (i.e., it has no statistical basis on which to draw statistical inferences about a sample to a population), researchers should take care to employ objectivity into the process where possible (38).

Several strengths exist in the present study. This investigation is one of the very first to look at the associations between obesity-related outcomes and dietary patterns in such an aged cohort. The sample size used in these analyses is relatively large considering that participants were old-older adults. Multiple days of dietary data were collected and analyzed using a very systematic approach, which included the use of highly trained interviewers and a random, unannounced, multiple-pass approach to reduce recall bias. Collection of the data over a 10-month period also reduced the possibility of any seasonal bias. The use of high-quality health outcome data abstracted from EMRs (versus self-reported) increases confidence in our ability to determine prevalence of health outcomes of interest since data were not necessarily affected by participant dropout, particularly important with an elderly population.

In conclusion, this study characterized dietary patterns of a sample of old-older adults living in rural Pennsylvania. Although dietary patterns were significantly associated only with hypertension in this study, older adults should still be encouraged to consume balanced diets that enhance quality of life while also providing pleasure from food. This study does not address the potential benefits of adopting a prudent diet earlier in life. It is likely that a range of experiences and lifestyle behaviors throughout the lifecycle, including dietary patterns, dictate risk for developing these chronic conditions. There is a need to understand how evidence-based science can be translated into appropriate dietary recommendations for older adults. Future research should seek to prospectively examine stability in food patterns over time, examining earlier life stages, and relationship to incident health outcomes later in life.

Table 3-1. Description of the 29 food subgroups used in the cluster analysis

Food group	Foods included
Baked goods	Cakes, cookies, pies, pastries, Danish, doughnuts and cobblers
Bread	Loaf bread, buns, bagels, English muffins
Cereal	Ready-to-eat cereals (non-presweetened and sweetened)
Cheese	Cheese—all types (full fat, reduced fat, low-fat and fat-free)
Dairy-based desserts	Frozen dairy dessert (ice cream, frozen yogurt), pudding, sweetened yogurt
Dark-green, deep-yellow vegetables	Broccoli, spinach, salad greens, carrots, sweet potato, yams, squash
Eggs	Eggs and egg substitute
Fats	Cream, shortening, butter and other animal fats, gravy
Fish	Fresh and smoked fish, shellfish
Fried vegetables	Fried vegetables, fried potatoes (French fries, hash browns, pan-fried potatoes)
Juice	Juice, including citrus juice
Legumes	Legumes (cooked dried beans)
Milk	Milk, flavored milk, milk-based beverages
Miscellaneous	Sauces, condiments (e.g., mustard, ketchup, barbeque sauce), pickled foods (e.g., pickles, sauerkraut), soup broth
Nuts	Nuts and seeds, including nut and seed butters
Oils	Margarine, oil, salad dressing
Other vegetables	Tomato, eggplant, green and string beans, peppers, cabbage, asparagus, cauliflower, Brussels sprouts, turnip greens, cucumber, celery, mushrooms, iceberg lettuce, vegetable juice
Pasta, noodles and rice	Pasta (pierogies, ravioli), noodles, rice, oatmeal
Poultry	Poultry (e.g., chicken, turkey), fried chicken
Processed meats	Cured pork, cold cuts and sausage
Red meats	Beef, lamb, pork, game, organ meats (e.g., liver)
Snacks	Chips, crackers, snack bars, pretzels, popcorn
Starchy vegetables	White potatoes, other starchy vegetables
Sweets	Frozen nondairy dessert (popsicles, sorbet), sugar (as an addition), syrup, honey, jam, jelly, preserves, dessert sauces, chocolate candy, non-chocolate candy, frosting or glaze, gelatin-based desserts
Whole fruit	Fruit including citrus fruit, avocado, fried fruits
Alcoholic beverages	Beers and ales, distilled liquor, wine
Soft drinks	Sweetened soft drinks, nondairy-based sweetened meal replacement/supplements (e.g., Gatorade)
Sweetened fruit drinks	Sweetened fruit drinks (e.g., lemonade, cranberry cocktail, fruit punch)
Sweetened coffee & tea	Sweetened tea, sweetened coffee

Table 3-2. Criteria used to identify health outcomes of interest from electronic medical records using an electronic data extraction process

Outcome	Criteria extracted from outpatient records of EMR using electronic data extraction process
Cardiovascular disease	ICD-9 410: Acute myocardial infarction ICD-9 411: Other acute and subacute forms of ischemic heart disease ICD-9 412: Old myocardial infarction ICD-9 414: Other forms of chronic ischemic heart disease Evidence of treatment with statin drugs
Type II diabetes	ICD-9 250: Diabetes mellitus ICD-9 362: Diabetic retinopathy ICD-9 366.41: Diabetic cataract Hemoglobin A1C > 6.0 Evidence of treatment with antidiabetic drugs (insulin, sulfonylureas, biguanides)
Hypertension	ICD-9 401: Essential hypertension 2 outpatient visits with hypertension as the diagnosis Evidence of treatment with antihypertensive drugs
Metabolic syndrome	ICD-9 277.7: Metabolic syndrome 3 of 5 criteria[1] below: a. Triglycerides ≥ 150 mg/dL b. HDL-cholesterol: Men < 40 mg/dL; Women < 50 mg/dL c. Systolic blood pressure ≥ 130 mm Hg or Diastolic blood pressure ≥ 85 mm Hg d. Glucose ≥ 110 mg/dL e. BMI > 30 kg/m^2

[1] The ATP III criteria for metabolic syndrome were used with the exception of the waist circumference criteria because waist circumference is less available with this population.

Table 3-3. Mean (± SD) percent energy contribution from food groups by dietary pattern

Food group	Sweets & dairy (n = 230)	Western (n = 114)	Health-conscious (n = 105)
Baked goods[1]	**10.8 ± 0.08[a]**	8.2 ± 0.07[b]	4.6 ± 0.05[c]
Bread[1]	12.2 ± 0.05[a]	**15.0 ± 0.06[b]**	10.4 ± 0.05[c]
Cereal[1]	**4.1 ± 0.04[a]**	1.5 ± 0.05[b]	3.6 ± 0.04[a]
Cheese	3.3 ± 0.03	3.7 ± 0.03	3.4 ± 0.03
Dairy-based desserts[1]	**4.8 ± 0.05[a]**	3.2 ± 0.04[b]	2.7 ± 0.04[b]
Dark green, deep yellow vegetables[1]	0.57 ± 0.01[a]	0.52 ± 0.01[a]	**1.8 ± 0.02[b]**
Eggs[1]	0.98 ± 0.01[a]	**2.8 ± 0.03[b]**	1.2 ± 0.01[a]
Fats[1]	2.7 ± 0.03[a]	**4.1 ± 0.03[b]**	2.1 ± 0.02[c]
Fish[1]	0.71 ± 0.01[a]	0.85 ± 0.02[a]	**2.5 ± 0.03[b]**
Fried vegetables[1]	0.92 ± 0.02[a]	**2.3 ± 0.03[b]**	0.30 ± 0.01[c]
Juice	2.3 ± 0.03	1.8 ± 0.02	2.8 ± 0.03
Legumes	1.3 ± 0.02	0.77 ± 0.02	1.1 ± 0.02
Milk[1]	**7.2 ± 0.06[a]**	3.3 ± 0.03[b]	5.5 ± 0.04[c]
Miscellaneous[1]	0.53 ± 0.00[a]	**1.0 ± 0.01[b]**	0.56 ± 0.01[a]
Nuts[1]	1.3 ± 0.02[a]	1.3 ± 0.03[a]	**3.2 ± 0.06[b]**
Oils	5.9 ± 0.03	7.1 ± 0.04	7.2 ± 0.04
Other vegetables[1]	1.5 ± 0.01[a]	1.6 ± 0.01[a]	**2.5 ± 0.02[b]**
Pasta, noodles, rice[1]	6.1 ± 0.05[a]	5.4 ± 0.04[a]	**9.7 ± 0.07[b]**
Poultry[1]	2.0 ± 0.02[a]	3.6 ± 0.03[b]	**4.7 ± 0.04[c]**

Processed meats[1]	4.1 ± 0.04[a]	**4.6 ± 0.04[a]**	1.9 ± 0.02[b]
Red meats	6.0 ± 0.04	6.9 ± 0.05	5.4 ± 0.06
Snacks	2.8 ± 0.04	2.8 ± 0.03	2.4 ± 0.03
Starchy vegetables	3.8 ± 0.03	2.9 ± 0.02	3.9 ± 0.03
Sweets	3.9 ± 0.04	3.7 ± 0.04	3.0 ± 0.04
Whole fruit[1]	5.4 ± 0.04[a]	3.5 ± 0.03[b]	**9.3 ± 0.06[c]**
Alcoholic beverages[1]	0.29 ± 0.01[a]	**3.2 ± 0.06[b]**	0.61 ± 0.02[a]
Soft drinks[1]	0.98 ± 0.02[a]	**2.5 ± 0.04[b]**	0.42 ± 0.01[c]
Sweetened fruit drinks	0.86 ± 0.02	0.40 ± 0.01	0.57 ± 0.02
Sweetened coffee & tea[1]	**0.73 ± 0.02[a]**	0.16 ± 0.01[b]	0.11 ± 0.00[b]

[1] Overall mean significantly different across dietary pattern at *P* < 0.001. (Significance level corrected for multiple comparisons using Bonferroni adjustment.)
Means with differing subscripts across rows are significantly different from each other (*P* < 0.05); Within each row, clusters with the highest percent energy contributions from each food group are in bold, and clusters with the lowest percent energy contribution from each food group are underlined.

Table 3-4. Energy-adjusted (per 1000 kcal) nutrient, energy density and Healthy Eating Index-2005 means (± SD) by dietary pattern

Nutrient[1,2]	Sweets & dairy[3] (n = 230)	Western[3] (n = 114)	Health-conscious[3] (n = 105)
Energy, kcal	**1590.0 ± 455.3[a]**	1566.6 ± 467.9[a]	1385.7 ± 391.8[b]
Protein, g	39.1 ± 9.6[a]	40.1 ± 11.4[a]	**46.2 ± 11.2[b]**
Fat, g	35.4 ± 8.3[a]	**39.8 ± 11.3[c]**	32.7 ± 10.6[b]
Saturated fat, g	12.5 ± 3.8[a]	**13.5 ± 4.6[c]**	10.2 ± 3.9[b]
Trans fat, g	2.5 ± 0.9[a]	**2.8 ± 1.2[c]**	1.9 ± 1.1[b]
Added sugar, g	**36.2 ± 14.2[a]**	33.9 ± 17.8[a]	28.6 ± 18.7[b]
Fiber, g	10.4 ± 3.6[a]	8.6 ± 2.9[c]	**13.5 ± 4.2[b]**
Vitamin B6, mg	1.1 ± 0.5[a]	0.95 ± 0.5[c]	**1.3 ± 0.6[b]**
Vitamin B12, mg	3.1 ± 2.1	2.9 ± 2.9	4.1 ± 3.9
Vitamin C, mg	56.0 ± 30.6[a]	46.0 ± 26.0[c]	**81.3 ± 45.7[b]**
Vitamin D, mcg	2.9 ± 1.5[a]	2.0 ± 1.1[b]	**3.2 ± 2.1[a]**
Folate, mcg	330.2 ± 157.2	282.6 ± 201.9	360.0 ± 166.7
Calcium, mg	491.1 ± 178.4[a]	396.3 ± 243.0[b]	**520.3 ± 193.5[a]**
Magnesium, mg	158.1 ± 44.6[a]	138.2 ± 39.7[c]	**190.7 ± 46.4[b]**
Sodium, mg	1696.4 ± 450.7	1756.6 ± 544.9	1667.8 ± 490.8
Potassium, mg	1555.7 ± 415.2[a]	1396.9 ± 381.2[c]	**1901.0 ± 507.6[b]**
Iron, mg	9.3 ± 4.1	8.1 ± 5.1	10.1 ± 3.9
Zinc, mg	6.4 ± 3.6	5.8 ± 3.4	7.3 ± 3.9
Energy density, kcal/g	1.47 ± 0.3[a]	**1.60 ± 0.3**[c]	1.23 ± 0.3[b]
HEI-2005 total score[4]	63.9 ± 10.4[a]	59.4 ± 10.6[c]	**73.0 ± 9.8**[b]

[1] With the exception of energy (kcal), nutrient means were energy-adjusted (per 1000 kcal).
[2] Overall means significantly different across dietary patterns for all nutrients (with the exception of vitamin B12, folate, sodium, iron, and zinc) at $P < 0.003$. (Significance level corrected for multiple comparisons using Bonferroni adjustment.)
[3] Means with differing subscripts across rows are significantly different from each other ($P < 0.05$); Within each row, clusters with the highest percent energy contributions from each food group are in bold, and clusters with the lowest percent energy contribution from each food group are underlined.
[4] HEI-2005 was only available for GRAS-2004 participants (n = 270).

Table 3-5. Selected baseline characteristics by dietary pattern[1]

	Sweets & dairy (n = 230)	Western (n = 114)	Health-conscious (n = 105)	*P*-value
Age (years)	76.6 ± 5.0	76.0 ± 5.3	76.8 ± 4.9	0.402
Males	45.7 (105)	46.5 (53)	34.3 (36)	0.107
Graduated from high school or greater	82.2 (189)	82.5 (94)	78.1 (82)	0.610
Married	67.4 (155)	70.2 (80)	70.5 (74)	0.798
BMI (kg/m^2)	28.0 ± 4.6	28.4 ± 5.4	28.2 ± 4.8	0.805
BMI category				0.346[2]
Underweight (< 18.5 kg/m^2)	2.2 (5)	0	0	
Normal (18.5-24.9 kg/m^2)	23.5 (54)	27.2 (31)	28.6 (30)	
Overweight (25-29.9 kg/m^2)	44.8 (103)	36.8 (42)	40.0 (42)	
Obese (≥ 30 kg/m^2)	29.6 (68)	36.0 (41)	31.4 (33)	
Waist circumference (cm)				
Female	90.9 ± 13.3	90.6 ± 13.3	91.2 ± 11.9	0.966
Male	102.6 ± 9.9	103.3 ± 14.9	101.1 ± 11.8	0.685
Current smoker	9.1 (21)	7.9 (9)	4.8 (5)	0.384
No. of self-reported prescribed medications	3.6 ± 3.0	3.3 ± 3.1	3.8 ± 3.0	0.445

[1] Values are means ± SD for continuous variables and percentages (n) for categorical variables.
[2] Fisher's exact test was used.

Table 3-6. Prevalence of obesity-related health outcomes and mortality by dietary pattern

Health outcome[1, 2]	Overall	Sweets & dairy	Western	Health-conscious	*P*-value
Cardiovascular disease (n = 70)	26.9 (70)	50.0 (35)	30.0 (21)	20.0 (14)	0.198
Type 2 diabetes mellitus (n = 77)	29.6 (77)	49.4 (38)	22.1 (17)	28.6 (22)	0.881
Hypertension (n = 199)	76.5 (199)	52.3 (104)	24.6 (49)	23.1 (46)	0.042
Metabolic syndrome (n = 146)	56.2 (146)	52.1 (76)	21.9 (32)	26.0 (38)	0.561
Deceased[3] (n = 131)	29.4 (131)	32.8 (75)	26.8 (30)	24.8 (26)	0.260

[1] Values are percentages (n).
[2] Health outcomes only available for a subset of the sample (n = 260).
[3] Mortality status was unavailable for three participants.

Table 3-7. Point estimates[1] and 95% confidence intervals for prevalence of chronic disease by dietary pattern for GRAS-2004 participants

Health outcome	Sweets & dairy[2] (n = 128)	Western[2] (n = 62)	*P*-value[3]
Cardiovascular disease (n = 70)			
Model 1	1.51 (0.75-3.04)	2.05 (0.93-4.50)	0.203
Model 2	1.43 (0.69-2.93)	2.06 (0.92-4.65)	0.215
Model 3	1.50 (0.72-3.12)	2.28 (1.00-5.23)	0.146
Type 2 diabetes mellitus (n = 77)			
Model 1	0.92 (0.49-1.73)	0.82 (0.39-1.75)	0.881
Model 2	0.81 (0.41-1.57)	0.76 (0.34-1.68)	0.750
Model 3	0.80 (0.41-1.59)	0.79 (0.35-1.80)	0.795
Hypertension (n = 199)			
Model 1	2.17 (1.11-4.27)	1.94 (0.87-4.33)	0.045
Model 2	2.17 (1.11-4.27)	1.94 (0.87-4.33)	0.065
Model 3	2.18 (1.11-4.30)	1.95 (0.87-4.35)	0.065
Metabolic syndrome (n = 146)[4]			
Model 1	1.23 (0.68-2.22)	0.90 (0.45-1.78)	0.561
Model 2	1.24 (0.69-2.25)	0.90 (0.45-1.80)	0.553
Model 3	1.24 (0.69-2.26)	0.92 (0.46-1.85)	0.583
Mortality (n = 131)[5, 6]			
Model 1	1.20 (0.76-1.89)	1.00 (0.59-1.69)	0.594
Model 2	1.03 (0.65-1.64)	0.95 (0.55-1.62)	0.928
Model 3	1.02 (0.64-1.63)	0.95 (0.55-1.63)	0.947

[1] Odds ratios for cardiovascular disease, type 2 diabetes mellitus, hypertension, and metabolic syndrome. Hazard ratios for mortality.
[2] Referent group was the 'Health-conscious' dietary pattern (n = 70).
Model 1: unadjusted model
Model 2: adjusted for age, gender, physical activity (PASE score), smoking, and waist circumference
Model 3: additionally adjusted for same covariates as model 2 with the addition of marital status and education
[3] Type 3 *P*-value.
[4] Analyses for metabolic syndrome were not adjusted for waist circumference as this is included in the diagnosis criteria.
[5] Models 2 and 3 were not adjusted for physical activity as this information was unavailable for n = 179.
[6] Analysis used n = 446.

Table 3-8. Estimates of odds ratios (OR) and 95% confidence intervals for prevalence of chronic disease by dietary pattern for GRAS-2004 participants after adjusting for selective attrition due to survivorship bias

Health outcome	Sweets & dairy[1] (n = 128)	Western[1] (n = 62)	*P*-value[2]
Cardiovascular disease (n = 70)			
Model 1	1.55 (0.59-4.09)	2.21 (0.73-6.69)	0.357
Model 2	1.43 (0.55-3.70)	2.22 (0.75-6.60)	0.373
Model 3	1.69 (0.72-3.12)	2.69 (0.95-7.61)	0.187
Type 2 diabetes mellitus (n = 77)			
Model 1	0.81 (0.26-2.54)	0.60 (0.17-2.08)	0.681
Model 2	0.68 (0.23-2.03)	0.44 (0.14-1.37)	0.379
Model 3	0.52 (0.17-1.60)	0.40 (0.11-1.42)	0.414
Hypertension (n = 199)			
Model 1	3.37 (1.51-7.52)	3.34 (1.24-8.96)	0.015
Model 2	3.37 (1.46-7.78)	4.41 (1.29-13.31)	0.015
Model 3	3.34 (1.45-7.69)	4.13 (1.31-13.05)	0.015
Metabolic syndrome (n = 146)[3]			
Model 1	1.09 (0.44-2.70)	1.17 (0.38-3.67)	0.962
Model 2	1.63 (0.63-4.17)	1.49 (0.55-4.02)	0.596
Model 3	1.51 (0.60-3.83)	1.41 (0.52-3.84)	0.682

[1] Referent group was the ‘Health-conscious’ dietary pattern (n = 70).
Model 1: unadjusted model
Model 2: adjusted for age, gender, physical activity (PASE score), smoking, and waist circumference
Model 3: additionally adjusted for same covariates as model 2 with the addition of marital status and education
[2] Type 3 *P*-value.

[3] Analyses for MetSyn were not adjusted for waist as this is included in the diagnosis criteria.

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Chapter 4

ASSOCIATION BETWEEN WEIGHT AND WEIGHT CHANGE AND DIETARY PATTERNS

INTRODUCTION

There is a growing prevalence of obesity among the older adult population (1). Obesity and overweight have been associated with increased morbidity (2, 3) and mortality (4) among older adults. Additionally, obesity and weight gain among obese women have been related to functional decline (5, 6). Also of concern, is non-volitional weight loss among the elderly, as it often is associated with serious underlying medical conditions and precedes adverse health outcomes (7). Such weight loss is also associated with higher rates of mortality (8, 9). Yet, less is known about the relationship between weight gain and weight loss and dietary patterns in older adults, especially the very old. Epidemiological studies have suggested that weight change might be at least as important as weight status itself (10-13).

Influences of dietary intake have been investigated in relation to both weight loss and weight gain. Findings from clinical trials demonstrate a link between dietary fat and weight (14); however, this same relationship is inconsistent in prospective, observational studies (15, 16).

Recent findings from epidemiological research have shifted the focus from single nutrients to the investigation of overall diet quality, namely dietary patterns. Examining dietary patterns allows one to account for complex nutrient interactions and issues with nutrient bioavailability that are not necessarily captured in studies of single nutrients. Dietary pattern approaches may more appropriately reflect the cumulative effects of total diet (17). In studies of mostly middle-aged adults, ‘Prudent’ dietary patterns have been associated with smaller gains in body mass index (BMI) and waist circumference (18) and adoption of a ‘Western’ dietary pattern or an ‘Empty calorie’ pattern have been associated with weight gains and development of overweight, respectively (19, 20).

Obesity is highly prevalent among those in their 60s and 70s. From 1991 to 2000, the prevalence of obesity in those ≥ 70 years old, increased from 11.4% to 15.5%, representing a 36% increase in less than 10 years (21). The objectives of the current study were to examine the association of dietary patterns with obesity and 5-y weight loss and weight gain in a cohort of community-dwelling older adults (mean ± SD age: 78.6 ± 3.9 years). A better understanding of modifiable risk factors, such as dietary patterns, may guide public health interventions and help to better target nutritional messages.

SUBJECTS AND METHODS

Study population

A subset of participants (n = 270) were selected from the Geisinger Rural Aging Study (GRAS), a longitudinal cohort study to characterize the nutrition risk of rural older adults (≥ 65 years old) living in Pennsylvania. Participants were randomly selected from a managed-risk Medicare program of the Geisinger Health System. Eligibility criteria included a Mini-Mental State Examination (MMSE) > 24 and a Geriatric Depression Scale (GDS) score ≤ 6. Additional information on GRAS and selection criteria has been previously published elsewhere (22). Participants provided written consent to take part in the study. All study procedures were approved by the Geisinger Health System and The Pennsylvania State University Institutional Review Boards.

Dietary assessment

At baseline (2004-2005), diet was assessed using four 24-hour dietary recalls, collected via telephone by trained interviewers of The Pennsylvania State University Diet Assessment Center (University Park, PA). Recalls were collected over a 10-month period to reduce error due to seasonal bias (23). Participants were randomly called and asked to report all foods and beverages consumed over the previous 24-hour period. Two-dimensional visuals were provided to participants to be used as a reference for estimation of portion sizes (Nutrition Consulting Enterprises, Framingham, MA). To facilitate recall, a multiple-pass technique was used (24). Dietary recalls were collected using the Nutrition Data System for Research (NDSR-2005, Nutrition Coordinating Center, Minneapolis, MN).

Anthropometric measures

At the baseline visit, height, weight and waist circumference of participants were measured by trained health professionals with participants in light clothing and wearing no shoes. BMI was calculated as weight in kilograms divided by height in meters squared. BMI was categorized as underweight (< 18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese ≥ 30 kg/m^2). Because of the low prevalence of underweight (n = 5), BMI categories for underweight and normal weight were combined.

Weight measurement data over the 5-year follow-up period were obtained from the electronic medical record (EMR). An electronic data extraction process (EDE) was used to acquire weight measurements starting from study entry (2004-2005) until August

2011. Although it is standard procedure to weigh participants at clinic appointments, the number of clinic visits varied by participant. Therefore, each participant may have provided a differing number of weight measurements. There were 6,284 measurement occasions and at least 74% of the sample had weight measurements for at least 10 occasions. The mean (SD) and median number of measurement occasions was 23.3 (16.8) and 22.5, respectively.

Change in body weight

Change in weight was calculated as the difference between baseline weight and the most recent weight recorded. Weight change was also categorized as 10-pounds gained (yes/no) or lost (yes/no) and as a 10% weight loss or 10% weight gain (25).

Assessment of other covariates

Questionnaires were used to obtain information on demographics, socioeconomic variables, lifestyle behaviors (e.g., smoking, physical activity) and health history. Information about age, gender, education, smoking (current smoker, non-smoker) and marital status (married, not married), self-reported number of prescribed medications and vitamin/mineral supplements, and physical activity (assessed by the Physical Activity Scale for the Elderly (PASE), (a relative measure of physical activity without units) (26) were used in this study. Frequency of dieting for weight loss (coded as ‘Never’, ‘Sometimes’, ‘Usually’, or ‘Always’) and functional limitations (coded as self-report of difficulty with ≥ 1 Activities of Daily Living (ADL) or Independent Activities of Daily Living (IADL) or 'no reported difficulties') were queried. MMSE was used to determine cognitive impairment and the GDS measured depression. Disease burden can also explain changes in weight; therefore, the Charlson Index, was calculated using International Classification of Diseases (ICD)-9 codes from the EMR (27). Charlson Index was analyzed as a categorical variable (0, 1, 2, or ≥ 3).

Statistical analyses

Foods were aggregated into 29 food subgroups. Nutrients from all food groups were averaged and energy-adjusted (per 1000 kilocalorie). The Healthy Eating Index-2005 (HEI-2005) was calculated using methods described by Miller et al. (28). Energy density was calculated as average kilocalorie per gram of food (excluding beverages) (29).

Cluster analysis was performed on the 29 food subgroups. Three dietary patterns were identified in this sample. Additional information about the identification of the dietary patterns can be found in Chapter 3.

The outcomes of interest for this particular study were: 1) a 10-pound weight loss; 2) a 10-pound weight gain; 3) a 10% weight loss; and 4) a 10% weight gain. To examine associations between dietary pattern and weight change, Kaplan-Meier plots (unadjusted for confounders) and Cox proportional hazards regression models (PROC PHREG in the Statistical Analysis System (SAS) version 9.2) were used. These methods capture measurement of an event from a defined starting point, for example, time from study entry to a 10-pound weight loss. Additionally, Cox proportional hazards regression models have advantages over standard statistical approaches, such as logistic regression, because they account for the unequal entry and follow-up time that we have with the current sample. Two-sided *P*-values derived from the log-rank statistic are presented for the comparison between dietary pattern groups for the Kaplan-Meier plots. Variables that were statistically significant at the $P \leq 0.20$ to 0.25 level, as well as those thought to be potential confounders, were considered for inclusion in the final multivariate models for the Cox proportional hazards regression. Results are expressed as incident weight change with a hazard ratio and 95% confidence intervals.

To confirm fit of the final multivariate models, the likelihood ratio test was performed using a stepwise procedure. Covariates that were considered in the multivariate models included gender, age, disease burden (Charlson Index), BMI at baseline, physical activity level (PASE), smoking status, and education level. Potential effects of the interaction terms, mainly between dietary pattern and age, and dietary pattern and gender, were also assessed using the likelihood ratio test.

All data analyses were performed using the SAS, version 9.2 (SAS Institute, Inc., Cary, North Carolina). A threshold of $\alpha = 0.05$ was used for all analyses.

RESULTS

Mean follow-up time was 3.8 ± 1.8 years. Participants did not differ across dietary patterns for most baseline characteristics, including age, gender, BMI, waist circumference, educational attainment, and cognitive level (MMSE) (**Table 4-1**).

However, mean total HEI-2005 scores were significantly different. Not surprisingly, the 'Health-conscious' dietary pattern had the highest score, representing higher dietary quality (mean 73.0 ± 9.8), and the 'Western' pattern had the lowest mean score (mean 59.4 ± 10.6). There were also no differences across variables that are often thought to be proxies for a healthy lifestyle, for example, non-smoker status, physical activity, reported use of prescribed medications and of vitamin/mineral supplements.

Overall mean weight change during follow-up was -5.6 pounds (min. -75.7 pounds, max. 34.9 pounds, SD: 12.3) (**Figure 4-1**). When stratified by gender, there was a significant difference in weight change by dietary pattern for females (**Figure 4-2**). Almost 75% of total participants did not change BMI categories across the follow-up period (**Table 4-2**).

Overall, when examining weight change as a 10-pound loss or gain, 39.3% of participants lost 10 pounds at some point over the 5-year follow-up period and 23.3% of participants gained 10 pounds. Only 5% of participants both lost 10 pounds and gained 10 pounds over the 5-year follow-up period (weight cyclers). When examining weight change as a percent change, 21.1% had a 10% weight loss, while only 10 participants (3.7%) gained 10% body weight (**Table 4-1**).

To examine the relationship between weight loss and weight gain and dietary patterns, Kaplan-Meier plots were inspected and are presented in **Figure 4-2**. It appears that women who are characterized by the 'Health-conscious' dietary pattern are less likely to lose 10 pounds compared to their counterparts (Log-rank $P = 0.02$). No significant relationship was found for weight loss or weight gain and dietary pattern for men (**Figure 4-2**). The predicted hazard ratios from Cox proportional hazards analyses confirm these findings (**Table 4-3**, **Table 4-4**, **Table 4-5**, **Table 4-6**). In the unadjusted model, 5-year weight loss (10 pounds) was not associated with dietary pattern (**Table 4-3**). However, when stratified by gender, after adjusting for covariates, females who are characterized by the 'Sweets and Dairy' and the 'Western' dietary pattern are three and two times more likely to lose 10 pounds, respectively, compared to their counterparts in the 'Health-conscious' dietary pattern. Total energy intake was unrelated to weight change (+/- 10 pounds); therefore, energy intake was not included in the models.

When weight change was examined as a percent weight change, after stratifying by gender, females in the 'Sweets and dairy' dietary pattern were associated with almost a 3-fold hazard for a 10% weight loss ($P = 0.017$). Females characterized by the 'Western' pattern had a 2.5 times greater hazard of losing 10% body weight ($P = 0.051$). Both unadjusted as well as adjusted models revealed no significant differences for weight gain, either examined as 10-pound or 10% gain, in relation to dietary pattern (**Table 4-5 and Table 4-6**).

DISCUSSION

Within this sample of community-dwelling older adults, overall weight loss was not associated with dietary pattern. However, there was an association after stratification by gender. This finding suggests that the relationship between dietary pattern and weight is modified by gender. This has been reported in other studies (30, 31).

Women in the 'Sweets and dairy' and the 'Western' dietary pattern had a 3-and 2-fold higher hazard ratio of losing 10 pounds, respectively, compared to women in the

‘Health-conscious’ pattern. While this may seem counterintuitive, in the context of older adults, non-volitional weight loss is associated with higher morbidity (7) and mortality (32). This finding might be reflective of underlying disease or inflammatory condition that the Charlson Index was not able to capture. These findings are supported by distinctions that suggest that those characterized by the ‘Sweets and dairy’ dietary pattern might indeed be less healthy. Although not statistically significant, participants in the ‘Sweets and dairy’ dietary pattern reported a greater amount of weight cycling, the greatest mean weight change from baseline, and had a higher percentage reporting functional deficiencies ($P > 0.05$). In fact, it has been previously reported that weight instability was associated with poor health status in the aging (33) and weight stability was associated with lower mortality risk (34).

Weight gain was not associated with dietary patterns even after adjustments for important covariates were made. At the end of the 5-year follow-up period, the mean age of our sample was > 80 years old. Even in the absence of disease, obesity is less likely to develop in the very elderly (35). So, even though there is a growing prevalence of obesity among older adults, the current study suggests that weight loss rather than weight gain may be a more prevalent public health concern in the very old. It is also possible that the number of participants with weight gain (of either 10 pounds or 10% body weight) was too small to be able to draw definitive conclusions. Other studies suggest that weight gain is relatively common into the fifth and sixth decades of life, but then falls off (36, 37). Our findings are consistent with these previous results.

Only a quarter of the sample experienced considerable weight change (+/- 10% change). The intraclass correlation coefficient (ICC) was calculated in our sample for weight measurements over time. The ICC is a descriptive measure that gives indication of how much measurements within a group resemble each other (i.e., variance). The proportion of between-person variance was 95%. This means that only 5% of the variance in weight measurements over time was within-person, suggesting that weight was relatively stable in this sample and/or that the measurement error for weight was relatively small. This finding is consistent with other studies of weight and BMI in older cohorts (33, 38). In the Health, Aging, and Body Composition Study, weight loss was more prevalent than weight gain; however, similar to our study, many of their participants maintained stable weight over the follow-up period (33).

We observed a significant association between baseline BMI and weight loss. This finding is not surprising given that with larger individuals, they are more likely to experience weight loss. BMI has been identified as a strong predictor of weight change in adulthood by others (39).

Strengths

The present study is unique because we have evaluated a sample of older adults (baseline mean age ≥ 75 years) who were followed over a short period of time with multiple weight measurements for each participant. Unlike other observational studies that used self-reported weights (40, 41), our analysis was strengthened by the use of EMR-extracted weights. Therefore, our results were not affected by potential underreporting of weight and overreporting of height that is often observed in self-reported measurements (42-44). Additionally, we utilized a systematic approach to capture dietary intake that likely decreased bias from memory recall.

Limitations

We would be remiss not to highlight potential limitations in this study. The GRAS sample was relatively small and mostly overweight at baseline, which is consistent with most community-dwelling populations of older adults. These factors have the potential to affect the power of our statistical analyses. Non-volitional weight loss is associated with adverse health outcomes in older adults in developed countries (45). In the current analyses, we were unable to determine if weight changes were deliberate or not. However, to address this, we did examine frequency of self-reported dieting habits and found that dieting prevalence (‘Always’ or ‘Usually’ dieting) was relatively low (< 10%) and did not differ among dietary patterns ($P = 0.076$).

Body composition is an important factor when examining weight change, especially in light of the prevalence of sarcopenic obesity among the aging population (46). Unfortunately, we did not have body composition measurements over time in this sample; hence our ability to consider this potentially important factor related to weight change was limited. Since there is well-known decline in muscle mass with aging, it is probably reasonable to assume that even though weight appeared to be relatively stable in this sample, changes in body composition probably occurred.

In conclusion, in a sample of community-dwelling older adults, baseline BMI is a stronger predictor of subsequent weight change over a 5-year follow-up period than are patterns of dietary intake. Dietary patterns were only associated with a weight loss in females. Future investigation of the relationship between dietary patterns and weight in older adults should also concurrently investigate measures of body composition and longer follow-up.

Table 4-1. Selected baseline characteristics stratified by dietary pattern[1]

	Overall (n = 270)	Sweets & dairy (n = 131)	Western (n = 67)	Health-conscious (n = 72)	*P*-value
Mean age (y)	78.6 ± 3.9	78.6 ± 3.7[1]	78.7 ± 4.0[1]	78.4 ± 4.1[1]	0.868
Males	41.9 (113)	43.5 (57)	43.4 (29)	37.5 (27)	0.682
Mean BMI (kg/m^2)	28.0 ± 5.3	27.8 ± 4.9	28.0 ± 5.9	28.5 ± 5.2	0.665
BMI category					0.090[4]
Underweight (< 18.5 kg/m^2)	1.9 (5)	3.8 (5)	0	0	
Normal (18.5-24.9 kg/m^2)	28.9 (78)	24.4 (32)	35.8 (24)	30.6 (22)	
Overweight (25-29.9 kg/m^2)	40.0 (108)	46.6 (61)	31.3 (21)	36.1 (26)	
Obese (≥ 30 kg/m^2)	29.3 (79)	25.2 (33)	32.8 (22)	33.3 (24)	
Mean weight change in pounds	-5.6 ± 14.3	-7.2 ± 16.0	-4.8 ± 12.1	-3.3 ± 11.5	0.165
Lost 10 pounds	39.3 (106)	45.8 (60)	38.8 (26)	27.8 (20)	0.042
Gained 10 pounds	23.3 (63)	25.2 (33)	19.4 (13)	23.6 (17)	0.659
Both lost and gained 10 pounds	5.2 (14)	6.1 (8)	3.0 (2)	5.6 (4)	0.723[4]
10% weight loss	21.1 (57)	23.7 (31)	23.9 (16)	13.9 (10)	0.215
10% weight gain	3.7 (10)	3.8 (5)	4.5 (3)	2.8 (2)	0.918

Mean waist circumference (cm)	96.0 ± 14.2	96.4 ± 13.4	95.0 ± 17.2	96.3 ± 12.5	0.795
Females	92.0 ± 13.6	92.4 ± 14.1	89.3 ± 13.6	93.6 ± 12.8	0.330
Males	101.6 ± 13.1	101.5 ± 10.5	102.5 ± 18.8	100.8 ± 10.7	0.892
Waist circumference > NIH risk cutoff (cm)[2]	56.7 (153)	59.5 (78)	49.3 (33)	58.3 (42)	0.364
Frequency of dieting to lose weight[3]					0.076[4]
Never	66.7 (178)	65.4 (85)	71.2 (47)	64.8 (46)	
Sometimes	23.6 (63)	25.4 (33)	19.7 (13)	23.9 (17)	
Usually	5.6 (15)	7.7 (10)	6.1 (4)	1.4 (1)	
Always	4.1 (11)	1.5 (2)	3.0 (2)	9.9 (7)	
Graduated from high school or greater	82.2 (222)	81.7 (107)	86.6 (58)	79.2 (57)	0.945
Current smoker	5.2 (14)	6.1 (8)	2.8 (4)	2.8 (2)	0.600
Mean PASE	131.8 ± 61.5	129.9 ± 64.8	130.1 ± 59.5	136.9 ± 57.3	0.720
Married	65.9 (178)	62.6 (82)	67.2 (45)	70.8 (51)	0.481
Mean Healthy Eating Index-2005	65.2 ± 11.4	63.9 ± 10.4	59.4 ± 10.6	73.0 ± 9.8	<0.0001
Mean number of prescribed medications	4.2 ± 3.2	4.3 ± 10.4	4.0 ± 10.6	4.3 ± 9.8	0.850

Mean number of self-reported vitamin/mineral supplements	2.2 ± 2.0	2.3 ± 1.9	1.9 ± 2.0	2.2 ± 2.0	0.363
Reported needed assistance with 1 or more ADL or IADL	8.2 (22)	9.2 (12)	6.0 (4)	8.3 (6)	0.738
GDS	1.5 ± 1.5	1.5 ± 1.6	1.6 ± 1.6	1.3 ± 1.5	0.636
MMSE	28.2 ± 1.6	28.1 ± 1.6	28.1 ± 1.7	28.3 ± 1.6	0.865
Mean Charlson Index	1.1 ± 1.4	1.1 ± 1.3	1.0 ± 1.3	1.1 ± 1.7	0.835

[1] Variables are means ± SD for continuous variables and percentages (n) for categorical variables.
[2] Cutoffs were 102 cm for men and 88 cm for women (47).
[3] Dieting frequency were unavailable for 3 participants.
[4] Fisher's exact test was used.

Figure 4-1. Overall (n = 270) mean weight change (in pounds) and by dietary pattern

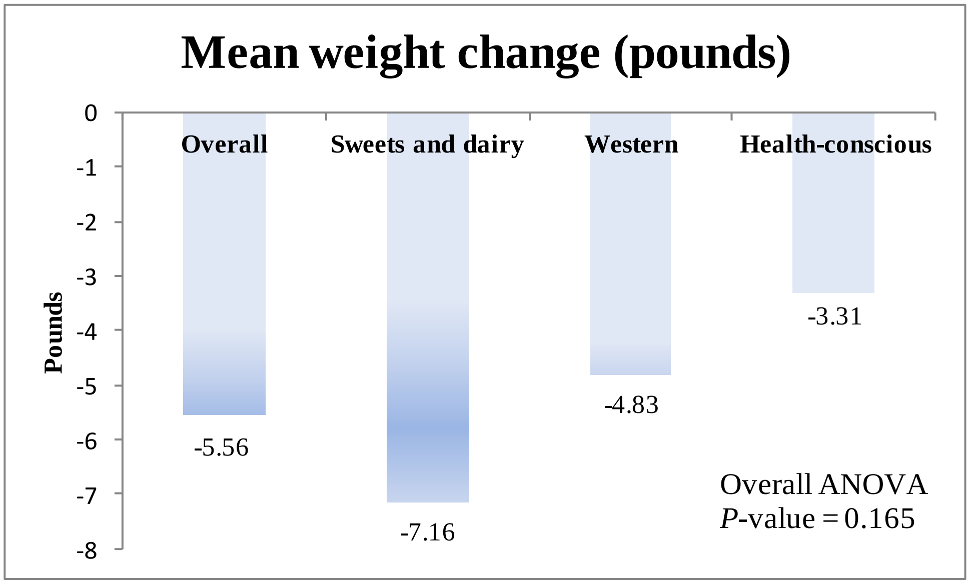
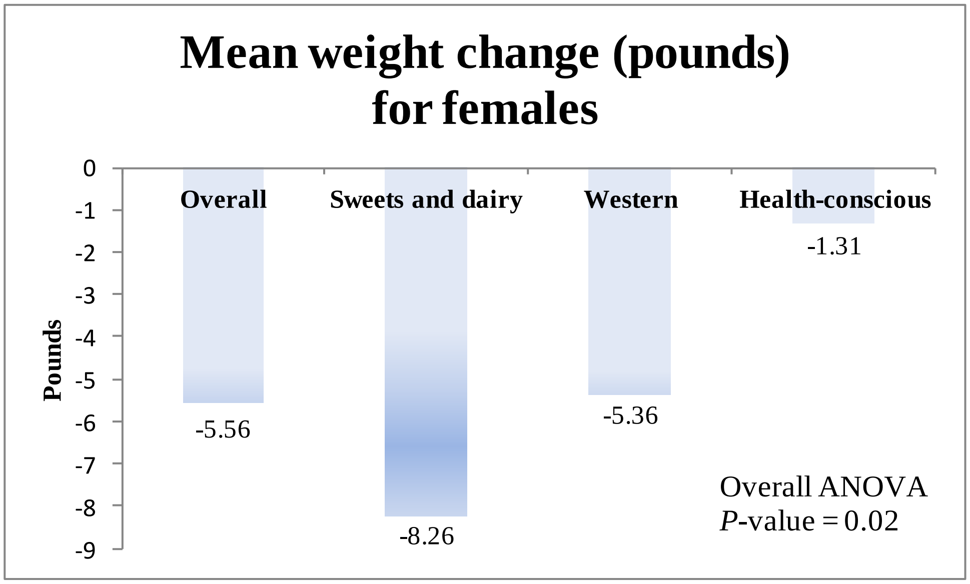


Figure 4-2. Mean weight change by dietary pattern stratified by gender



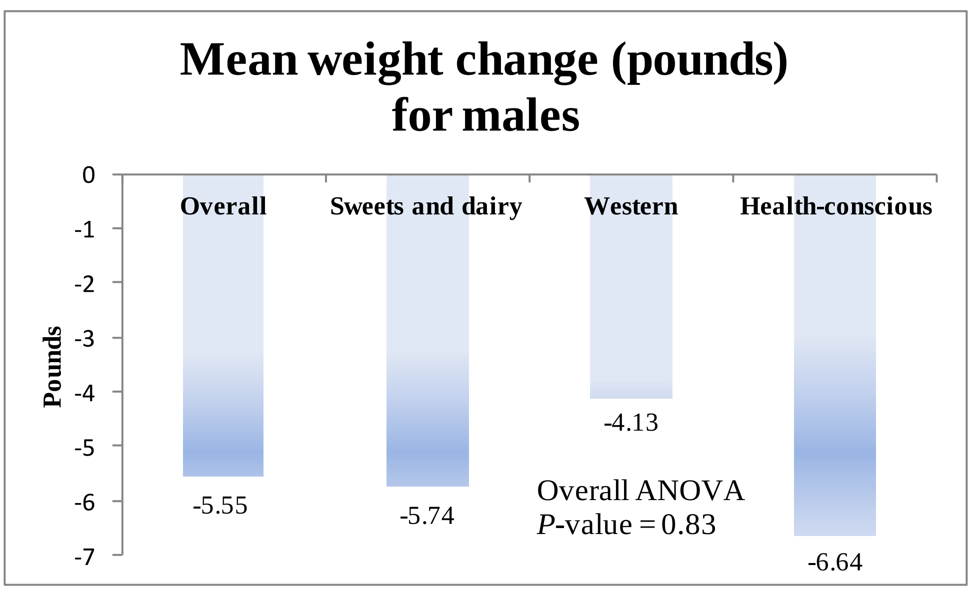
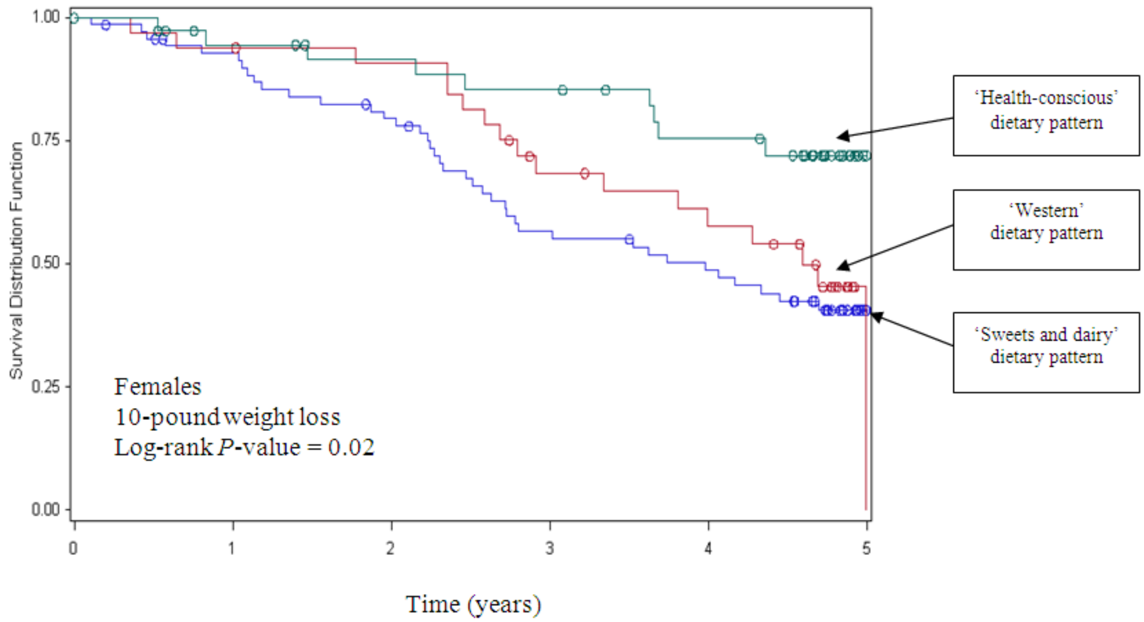


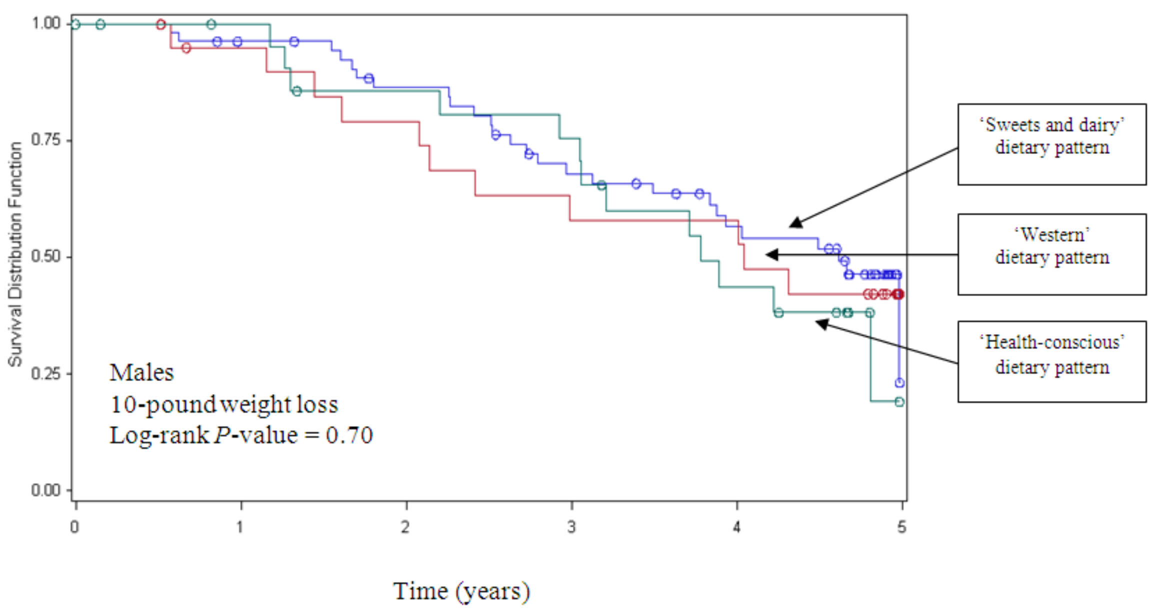
Table 4-2. Five-year BMI category comparison[1,2]

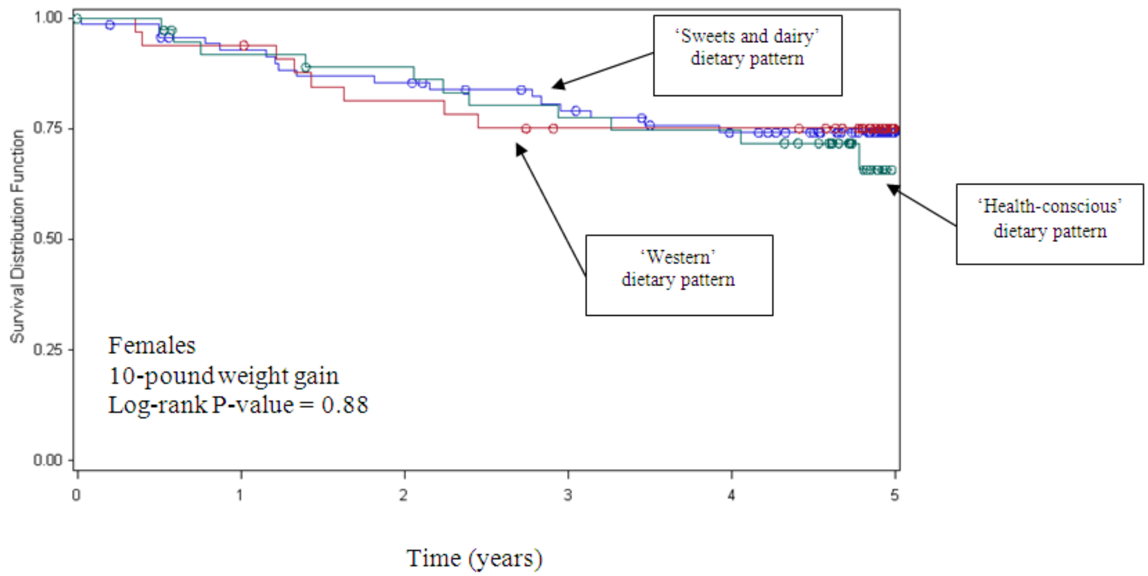
	Normal BMI at end	Overweight BMI at end	Obese BMI at end
Normal BMI at baseline	28.2 (68)	2.9 (7)	0.4 (1)
Overweight BMI at baseline	9.1 (22)	27.0 (65)	4.6 (11)
Obese BMI at baseline	0 (0)	8.3 (20)	19.5 (47)

[1] Values are percentages (n).
[2] 29 participants only had 1 weight measurement and therefore are not represented.

Figure 4-3. Kaplan-Meier survival curves of GRAS participants (n = 270) for weight loss and weight gain according to gender and dietary pattern[1]



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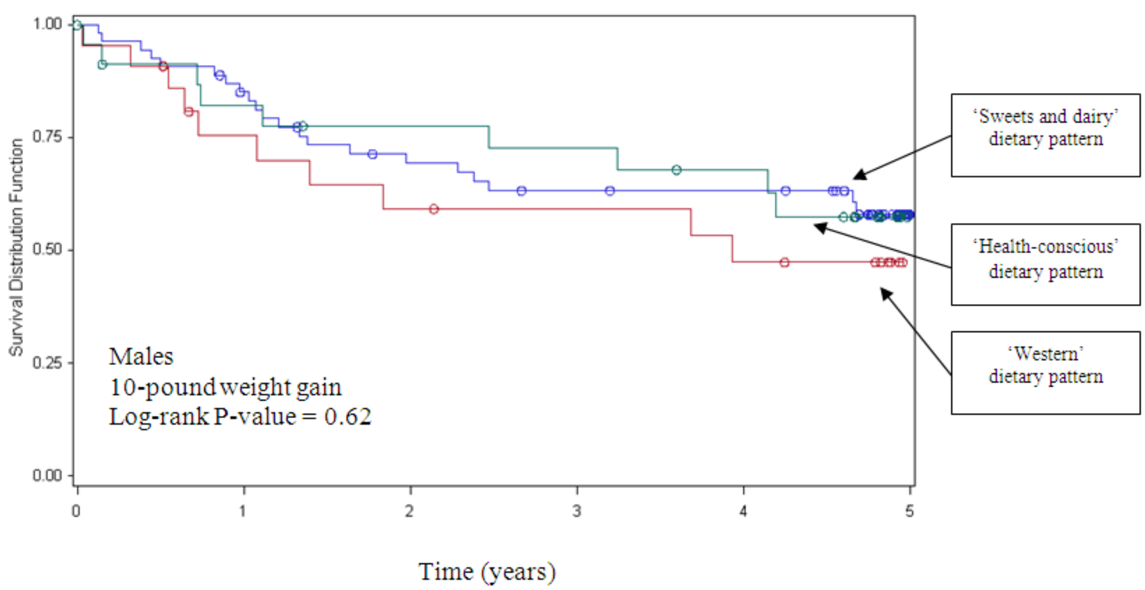
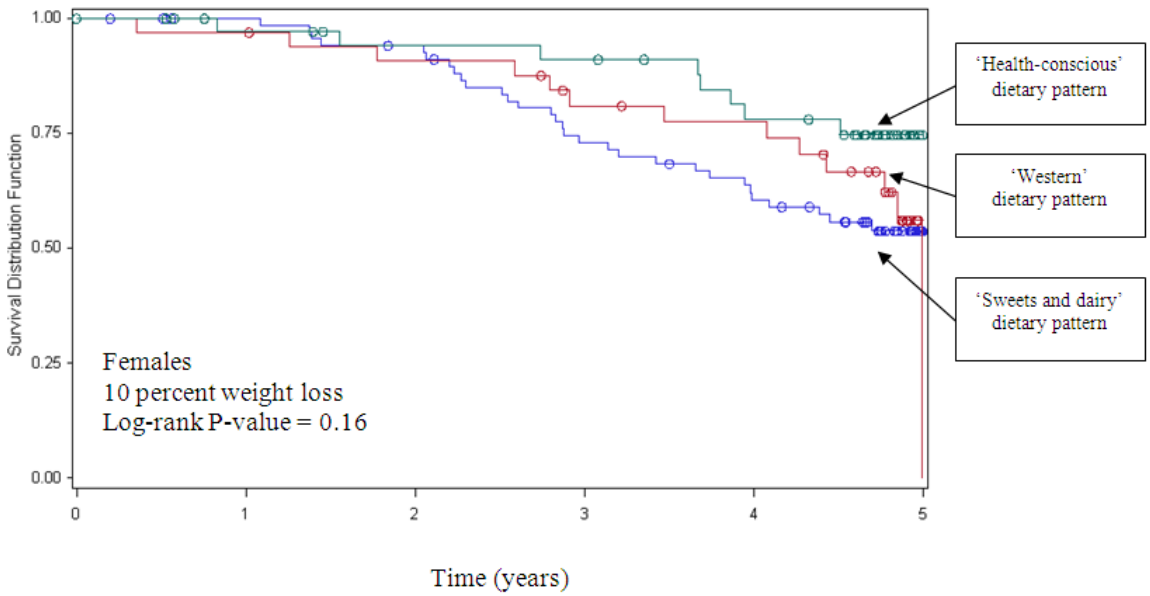
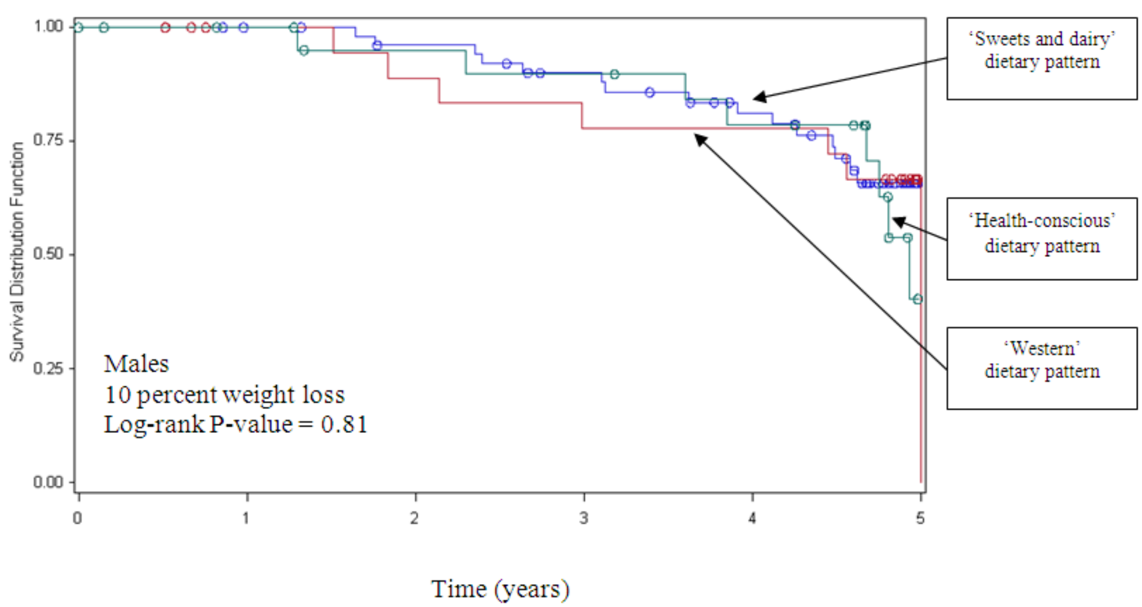
'Sweets and dairy' dietary pattern
'Health-conscious' dietary pattern
'Western' dietary pattern
Females
10-pound weight gain
Log-rank P-value = 0.88
Time (years)

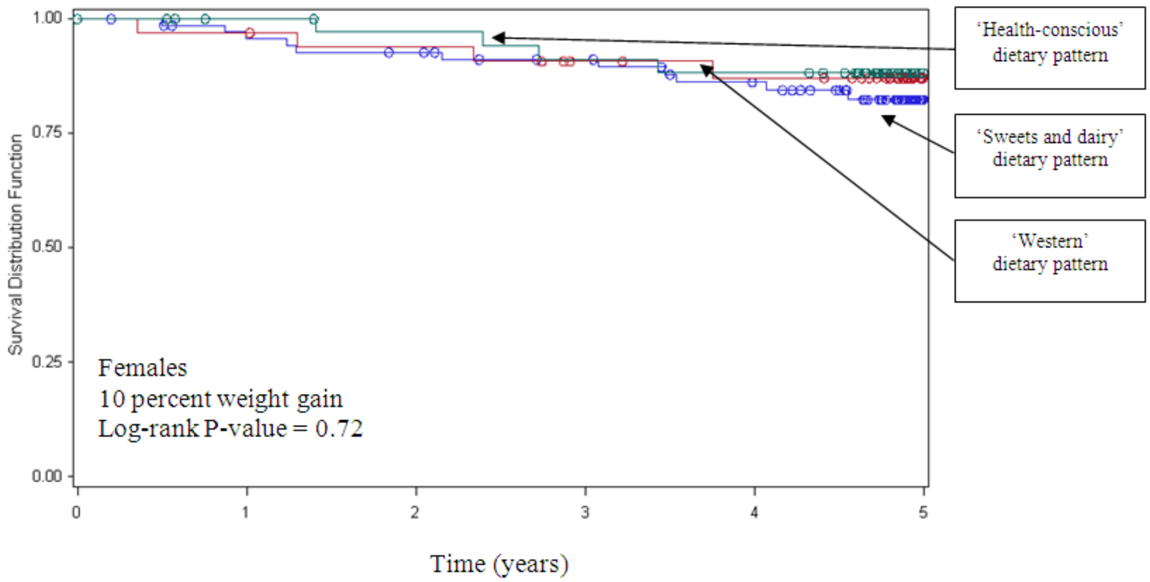

1.00
0.75
0.50
0.25
0.00
Survival Distribution Function
0
1
2
3
4
5
'Sweets and dairy' dietary pattern
'Health-conscious' dietary pattern
'Western' dietary pattern
Males
10-pound weight gain
Log-rank P-value = 0.62
Time (years)

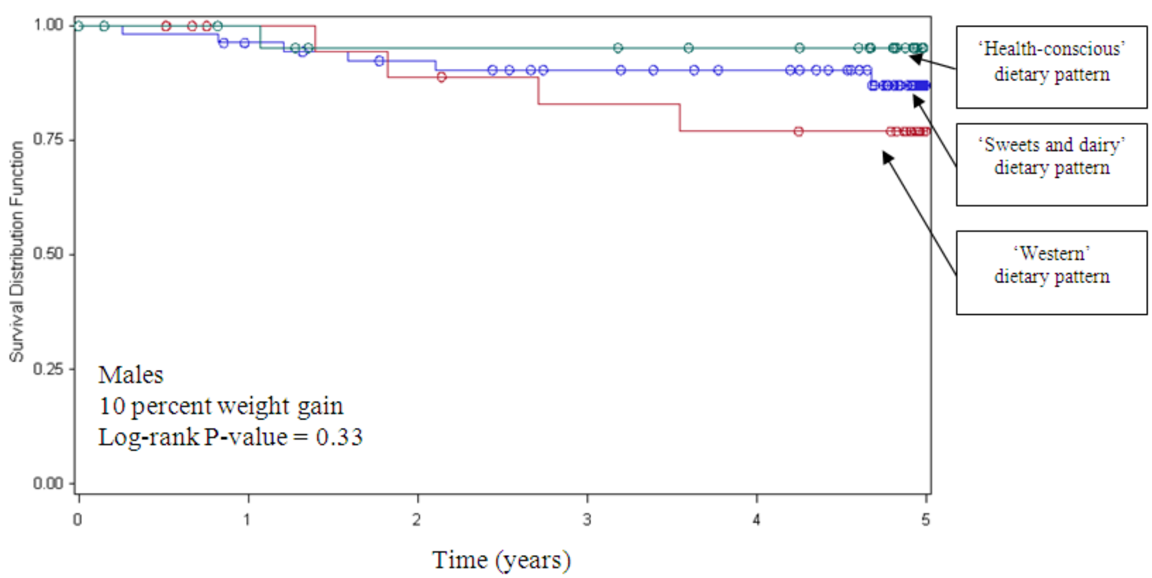


Survival Distribution Function
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
5
Females
10 percent weight loss
Log-rank P-value = 0.16
'Health-conscious' dietary pattern
'Western' dietary pattern
'Sweets and dairy' dietary pattern
Time (years)



Survival Distribution Function
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
5
Males
10 percent weight loss
Log-rank P-value = 0.81
'Sweets and dairy' dietary pattern
'Health-conscious' dietary pattern
'Western' dietary pattern
Time (years)





[1] Circles represent censored data.

Table 4-3. Cox proportional hazards analysis of 5-year weight loss (10 pounds) as a function of dietary pattern and selected covariates. Hazard ratio (HR) with 95% confidence intervals (95% CI) for time to lose 10 pounds[1]

	β	SE	HR (95% CI)	*P*-value
Model 1-Unadjusted				
Sweets & dairy	0.44	0.25	1.55 (0.95-2.51)	0.077
Western	0.38	0.28	1.46 (0.84-2.56)	0.183
Model 2-Adjusted				
Sweets & dairy	0.40	0.25	1.49 (0.91-2.45)	0.117
Western	0.39	0.29	1.48 (0.84-2.61)	0.170
Gender	-0.03	0.21	0.97 (0.65-1.46)	0.895
10-year increase in age	0.21	0.27	1.24 (0.73-2.09)	0.422
Charlson index	0.13	0.09	1.14 (0.96-1.35)	0.137
5 kg/m^2 increase in BMI	0.42	0.10	1.52 (1.25-1.84)	<0.0001
10 unit increase in PASE	-0.03	0.02	0.97 (0.94-1.01)	0.104
Model 3-Females				
Sweets & dairy	1.15	0.38	3.15 (1.49-6.67)	0.003
Western	0.89	0.42	2.43 (1.06-5.57)	0.036
10-year increase in age	0.26	0.32	1.30 (0.69-2.44)	0.415
Charlson index	0.25	0.12	1.28 (1.01-1.62)	0.043
5 kg/m^2 increase in BMI	0.55	0.13	1.73 (1.34-2.24)	<0.0001
10 unit increase in PASE	-0.03	0.02	0.97 (0.93-1.02)	0.276

Model 3-Males

Sweets & dairy	-0.41	0.35	0.66 (0.33-1.31)	0.238
Western	-0.24	0.42	0.79 (0.35-1.79)	0.569
10-year increase in age	0.23	0.45	1.26 (0.53-3.03)	0.599
Charlson index	0.04	0.12	1.04 (0.82-1.32)	0.757
5 kg/m^2 increase in BMI	0.32	0.16	1.37 (0.99-1.89)	0.054
10 unit increase in PASE	-0.03	0.03	0.97 (0.92-1.02)	0.205

[1] Reference is the 'Health-conscious' dietary pattern.
Model 1 is the unadjusted model.
Model 2 is adjusted for gender, age, disease burden (Charlson Index at baseline), BMI at baseline and physical activity (PASE).
Model 3 is adjusted for the covariates in model 2 (with the exception of gender) and is further stratified by gender.

Table 4-4. Cox proportional hazards analysis of 5-year weight gain (10 pounds) as a function of dietary pattern and selected covariates. Hazard ratio (HR) with 95% confidence intervals (95% CI) for time to gain 10 pounds[1]

	β	SE	HR (95% CI)	*P*-value
Model 1-Unadjusted				
Sweets & dairy	-0.06	0.28	0.94 (0.55-1.62)	0.831
Western	0.07	0.33	1.07 (0.57-2.02)	0.839
Model 2-Adjusted				
Sweets & dairy	-0.07	0.28	0.93 (0.54-1.61)	0.797
Western	0.12	0.33	1.13 (0.59-2.13)	0.719
Gender	-.050	0.04	0.61 (0.38-0.98)	0.040
10-year increase in age	0.10	0.32	1.10 (0.59-2.05)	0.761
Charlson index	0.22	0.10	1.25 (1.02-1.53)	0.033
5 kg/m^2 increase in BMI	0.08	0.01	1.09 (0.88-1.34)	0.437
10 unit increase in PASE	0.01	0.02	1.01 (0.98-1.05)	0.486
Model 3-Females				
Sweets & dairy	-0.09	0.39	0.91 (0.42-1.98)	0.814
Western	-0.18	0.47	0.84 (0.33-2.10)	0.704
10-year increase in age	-0.28	0.46	0.76 (0.31-1.86)	0.545
Charlson index	0.20	0.16	1.22 (0.88-1.68)	0.228
5 kg/m^2 increase in BMI	0.07	0.14	1.08 (0.82-1.41)	0.606
10 unit increase in PASE	0.02	0.03	1.02 (0.96-1.09)	0.484

Model 3-Males

Sweets & dairy	-0.12	0.41	0.89 (0.40-1.99)	0.771
Western	0.28	0.48	1.32 (0.51-3.39)	0.567
10-year increase in age	0.53	0.51	1.70 (0.62-4.61)	0.301
Charlson index	0.23	0.14	1.26 (0.95-1.66)	0.104
5 kg/m^2 increase in BMI	0.15	0.18	1.16 (0.82-1.64)	0.401
10 unit increase in PASE	0.02	0.03	1.02 (0.97-1.07)	0.534

[1] Reference is the 'Health-conscious' dietary pattern.
Model 1 is the unadjusted model.
Model 2 is adjusted for gender, age, disease burden (Charlson Index at baseline), BMI at baseline and physical activity (PASE).
Model 3 is adjusted for the covariates in model 2 (with the exception of gender) and is further stratified by gender.

Table 4-5. Cox proportional hazards analysis of 5-year weight loss (10-percent) as a function of dietary pattern and selected covariates. Hazard ratio (HR) with 95% confidence intervals (95% CI) for time to lose 10-percent of baseline body weight[1]

	β	SE	HR (95% CI)	*P*-value
Model 1-Unadjusted				
Sweets & dairy	0.33	0.29	1.39 (0.78-2.45)	0.262
Western	0.29	0.34	1.34 (0.70-2.59)	0.382
Model 2-Adjusted				
Sweets & dairy	0.42	0.30	1.51 (0.84-2.74)	0.171
Western	0.41	0.34	1.50 (0.77-2.94)	0.235
Gender	0.36	0.25	1.44 (0.88-2.37)	0.151
10-year increase in age	0.31	0.32	1.36 (0.73-2.53)	0.336
Charlson index	0.18	0.10	1.19 (0.97-1.47)	0.090
5 kg/m^2 increase in BMI	0.38	0.10	1.46 (1.20-1.78)	0.001
10 unit increase in PASE	-0.02	0.02	0.98 (0.94-1.03)	0.457
Model 3-Females				
Sweets & dairy	1.04	0.43	2.83 (1.21-6.62)	0.017
Western	0.94	0.48	2.55 (1.00-6.56)	0.051
10-year increase in age	0.49	0.36	1.64 (0.82-3.30)	0.166
Charlson index	0.24	0.14	1.28 (0.97-1.68)	0.087
5 kg/m^2 increase in BMI	0.50	0.13	1.64 (1.27-2.12)	0.0001
10 unit increase in PASE	-0.01	0.03	0.99 (0.93-1.04)	0.600

Model 3-Males

Sweets & dairy	-0.29	0.46	0.75 (0.31-1.83)	0.524
Western	-0.29	0.57	0.75 (0.25-2.28)	0.612
10-year increase in age	0.13	0.62	1.14 (0.34-3.83)	0.833
Charlson index	0.12	0.16	1.12 (0.82-1.54)	0.472
5 kg/m^2 increase in BMI	0.17	0.20	1.19 (0.81-1.75)	0.376
10 unit increase in PASE	-0.01	0.03	0.99 (0.92-1.06)	0.697

[1] Reference is the 'Health-conscious' dietary pattern.
Model 1 is the unadjusted model.
Model 2 is adjusted for gender, age, disease burden (Charlson Index at baseline), BMI at baseline and physical activity (PASE).
Model 3 is adjusted for the covariates in model 2 (with the exception of gender) and is further stratified by gender.

Table 4-6. Cox proportional hazards analysis of 5-year weight gain (10-percent) as a function of dietary pattern and selected covariates. Hazard ratio (HR) with 95% confidence intervals (95% CI) for time to gain 10-percent of baseline body weight[1]

	β	SE	HR (95% CI)	*P*-value
Model 1-Unadjusted				
Sweets & dairy	0.52	0.51	1.62 (0.62-4.55)	0.308
Western	0.60	0.57	1.82 (0.60-5.57)	0.292
Model 2-Adjusted				
Sweets & dairy	0.65	0.51	1.92 (0.70-5.24)	0.202
Western	0.67	0.57	1.96 (0.64-6.00)	0.238
Gender	0.41	0.41	1.51 (0.68-3.36)	0.311
10-year increase in age	-0.50	0.55	0.60 (0.20-1.79)	0.363
Charlson index	0.25	0.16	1.29 (0.94-1.78)	0.120
5 kg/m^2 increase in BMI	-0.03	0.18	0.97 (0.68-1.37)	0.853
10 unit increase in PASE	0.05	0.03	1.05 (0.99-1.12)	0.101
Model 3-Females				
Sweets& dairy	0.62	0.59	1.85 (0.58-5.89)	0.297
Western	0.15	0.72	1.17 (0.29-4.77)	0.832
10-year increase in age	-0.52	0.69	0.59 (0.15-2.31)	0.453
Charlson index	0.10	0.24	1.11 (0.70-1.75)	0.671
5 kg/m^2 increase in BMI	0.11	0.21	1.12 (0.75-1.69)	0.582
10 unit increase in PASE	0.09	0.04	1.10 (1.02-1.19)	0.019

Model 3-Males

Sweets & dairy	1.14	1.11	3.14 (0.36-27.36)	0.301
Western	1.96	1.14	7.12 (0.76-67.07)	0.086
10-year increase in age	-1.14	1.04	0.32 (0.04-2.46)	0.273
Charlson index	0.57	0.29	1.76 (1.00-3.10)	0.049
5 kg/m^2 increase in BMI	-0.54	0.44	0.59 (0.25-1.38)	0.219
10 unit increase in PASE	0.01	0.05	1.02 (0.92-1.12)	0.765

[1] Reference is the 'Health-conscious' dietary pattern.
Model 1 is the unadjusted model.
Model 2 is adjusted for gender, age, disease burden (Charlson Index at baseline), BMI at baseline and physical activity (PASE).
Model 3 is adjusted for the covariates in model 2 (with the exception of gender) and is further stratified by gender.

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Chapter 5

DIETARY PATTERNS AND DIET QUALITY AMONG DIVERSE OLDER ADULTS: THE UNIVERSITY OF ALABAMA AT BIRMINGHAM STUDY OF AGING[1]

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Hsiao PY, Mitchell DC, Coffman DL, et al. Dietary patterns and diet quality among diverse older adults: The University of Alabama at Birmingham Study of Aging. J Nutr Health Aging. (Accepted).

INTRODUCTION

Although aging is associated with declines of physiological and cognitive functions that contribute to ill health, longitudinal studies suggest that nutrition may be an important determinant of successful aging (1). Historically, studies have examined nutrients in isolation. Because nutrients are consumed in combination and foods are consumed as a component of meals, there has been considerable interest in the investigation of total diet (versus single, isolated nutrients).

Little research has been done on dietary patterns of older adults, and even less that reflects the diversity of older adult populations in the United States. Yet, it is well-established that obesity is a major public health concern among older adults, with close to 35% being obese. For older African Americans, the obesity rates are even more alarming and are particularly high for women (50%) (2). Understanding the dietary practices of older adults may help target interventions to improve diet and weight status. The primary aim of this study was to identify food patterns in a sample of community-dwelling older adults living in Alabama.

Previous evidence suggests that socio-demographic characteristics are associated with dietary quality (3). However, the complexity of these relationships has not been well studied in older Americans. Therefore, a secondary aim was to determine predictors of diet quality (defined by both dietary patterns and Healthy Eating Index-2005 (HEI-2005)), including an examination of the association between body mass index (BMI) and dietary patterns.

METHODS

Subjects

The University of Alabama at Birmingham (UAB) Study of Aging is a longitudinal, observational study designed to investigate racial disparities in life-space mobility associated with aging (4). Participants from the UAB Study of Aging initially included 1,000 community-dwelling older non-Hispanic whites and African-Americans (≥ 65 years old) recruited between late 1999 to February 2001 from a stratified random sample (stratified by county of residence, gender, and race) of Medicare beneficiaries living in rural and urban areas in five counties of central Alabama (4). Study procedures were approved by the UAB Institutional Review Board.

In 2004 (year 4), 733 surviving participants who were not living in a nursing home were eligible to participate in a follow-up in-home assessment. Of these, 622 (84.9%) agreed to participate in the home interview and provided complete dietary data. Nonparticipants did not differ from participants in terms of gender, urban/rural residence, or race ($P > 0.05$). However, nonparticipants were older, had lower levels of education and household incomes, lower life-space mobility, more chronic conditions and had lower scores on a cognitive screening test ($P > 0.05$) (5-7).

For the current analyses, we excluded those with symptoms suggestive of depression (Geriatric Depressive Score (GDS) ≥ 6; n = 28) or cognitive assessment test score < 24 (n = 147) or both (n = 27), and four participants who were missing height and/or weight measurements (5, 8). Analyses were performed with year 4 data from the remaining 416 individuals; 183 males and 233 females, respectively.

Data collection

In-home interviews were conducted at baseline to collect general health, anthropometric measures (height and weight), and socio-demographic information and to assess factors affecting life-space mobility. Counties classified as Metropolitan Statistical Areas at the time of data collection were considered urban as defined by the U.S. Office of Management and Budget (9). Diet was assessed during year 4 of the study using three unannounced 24-hour dietary recalls conducted by trained interviewers. Food intake data was entered into the Nutrition Data System for Research software (NDSR; Nutrition Coordinating Center, Minneapolis, MN), food database version 34 and 35, nutrient database version 4.06 and 5 and regenerated in NDSR 2008 for analysis. One of the features of NDSR is the ability to reanalyze data that is reflective of the marketplace at the time of data collection but with updated nutrient and other aspects of analysis, such as food group data, that was not available at the time of the original data collection. Data collected on vitamin and mineral supplement use was not included in analyses. Food and beverage codes were assigned to items in the individual food file dataset. Energy density was calculated as average energy (kcals) divided by average food weight (grams) (10). Overall HEI-2005 scores, which act as a summary measure of diet quality, were calculated for each individual using methods described by Miller et al. (11). Foods were aggregated into 13 groups on the basis of nutritional similarity and frequency of intake among the sample (**Table 5-1**). Food intake patterns were derived on the basis of average servings per 1000 kcal. Servings were based on the Dietary Guidelines for Americans, 2005 for foods that have recommendations (12). Food and Drug Administration (FDA) serving sizes were used for those without current recommendations (e.g., cookies, fruit drinks).

Statistical analyses

Statistical analyses for identification of food intake patterns were conducted using latent class cluster analysis (more generally known as finite mixture modeling (FMM)) in Latent Gold (version 4.5, Statistical Innovations Inc., Belmont, MA). FMM was performed to examine the clustering of dietary intake based on frequency of intake (servings per 1000 kcal). FMM is a data-reduction technique that uses a K-class latent variable to explain associations among a group of observed variables. In this particular case, each latent class is assumed to represent a dietary pattern. Dietary pattern models were evaluated for solutions specifying K = 2-10. Selection of the model was based on comparison of the Bayesian Information Criterion (BIC) and interpretability of dietary patterns (13). There has been evidence of high levels of low-energy reporting among older adults (14). Implausible energy reporters were identified in this sample using procedures described by McCrory et al. (15), which compares predicted energy expenditure with reported energy intake.

FMM, unlike cluster analysis, does not divide individuals into exclusive dietary patterns, such that each person only belongs to one and only one pattern, but rather, each individual has a probability of membership into each of the derived dietary patterns. Therefore, participants were assigned into patterns based on highest respective posterior class-membership probabilities. The average and median individual posterior class-membership probabilities ranged from 0.85 to 0.90 and 0.92 to 0.97, respectively. Model-predicted mean energy-adjusted servings and evaluation of nutrient intakes by food intake pattern were used to interpret and label the food patterns. Analysis of food patterns was also attempted by gender and race separately, but the sample sizes were insufficient to assure model stability.

Differences of nutrient intakes, socio-demographic and health characteristics across the food intake patterns were compared using chi-square and analysis of covariance for categorical and continuous variables, respectively using the Statistical Analysis System (SAS version 9.2, SAS Institute, Inc., Cary, NC). To examine the association between dietary pattern (dependent variable) and body mass index (BMI), including the interaction between BMI and gender, we performed latent class multiple regression analysis using Latent Gold, adjusting for important covariates, including race, income, cognitive score, education and age. To investigate the probability of being classified into one dietary pattern versus another, the association between dietary pattern and BMI by gender was investigated using logistic regression and was plotted using estimated conditional probabilities (from Latent Gold output), based on model covariates mentioned above and odds ratios were calculated. An alpha-level of 0.05 was used as the threshold for statistical significance.

RESULTS

Sample characteristics

Our sample was 39% African American and 56% female. A total of 69% completed high school or greater, 46% lived in rural areas and 53% were married. Mean age (± standard deviation) of the 416 participants was 76.8 ± 5.2 years and mean BMI (kg/m^2) was 28.3 ± 5.4 and 28.3 ± 6.2 for men and women, respectively (P = 0.94) (**Table 5-2**). BMI did vary across race and gender, with African American women being the heaviest (mean BMI = 31.1 ± 6.8 kg/m^2, $P < 0.001$). (Data not shown.)

Description of the dietary patterns

Food patterns derived with only those identified as plausible energy reporters (n = 344) were similar to the overall sample, thus, results from the full sample (n = 416) are presented. There were no statistically significant differences for gender, marital status, or self-reported health between those characterized as implausible and plausible energy reporters (data not shown). Ultimately, a three-class solution was selected. Mean servings of food groups per 1000 kilocalories across dietary patterns are shown in **Table 5-3**. The "Western-like" dietary pattern (41.3% of the sample) was characterized by a relatively higher intake of fats and oils, refined grains, poultry and fish and a relatively lower intake of dairy products compared to the overall sample. The second dietary pattern was represented by low intake of fruits and vegetables, including starchy vegetables and highest intake of sweets and therefore was labeled the "Low produce, high sweets"

(40.4% of the sample) pattern. The third dietary pattern (18.3% of the sample) included individuals with relatively higher intakes of fruits, vegetables, whole grains, other protein sources (eggs, nuts, legumes) and dairy products. This group consumed a relatively healthier pattern and was therefore labeled “More healthful”. Although those in the “Western-like” pattern reported higher poultry and fish consumption, it is noteworthy that these foods were more likely to be fried in comparison to the “More healthful” pattern.

Table 5-3 shows the mean daily nutrient intakes for the food intake patterns. Those in the “Western-like” dietary pattern reported significantly lower vitamin B12 and calcium intakes compared to the other patterns. The “Low produce, high sweets” pattern was characterized by high saturated fat, and low dietary fiber and vitamin C intakes. The “More healthful” pattern reported higher micronutrient and lower fat and saturated fat intakes and also had the lowest energy density (1.43 kcal/g ± 0.33) compared to the other food patterns. Although the “Western-like” pattern reported the lowest energy intake, it was not statistically different from that reported by the “More healthful” pattern. The mean reported nutrient intakes for all dietary patterns in the present study, including the “More healthful” pattern, were all below Dietary Reference Intakes (**Table 5-3**). Irrespective of the dietary pattern, fewer than 10% of participants exceeded the 2005 Recommended Dietary Allowance (RDA) and Adequate Intake (AI) recommendations for fiber, vitamin D and magnesium.

Dietary patterns and socio-demographic characteristics

We observed significant differences in demographic and health characteristics across the three patterns (**Table 5-4**). Gender distribution across dietary patterns was significantly different, with more females in the “More healthful” dietary pattern. Those in the “More healthful” dietary pattern were also more likely to be better educated, Non-Hispanic white, report higher incomes and better quality diets (higher and more favorable HEI-2005 scores) compared to the other two dietary patterns. There were no statistically significant differences across patterns for age, mean BMI, marital status or GDS. Although not statistically different, those characterized by the “More healthful” dietary pattern reported higher levels of physical activity, better health, and were more likely to be “never smokers”.

In examining the association between dietary patterns and BMI, we found that there was a significant interaction with gender when controlling for race, income, cognitive status, education, and age (P = 0.02). **Figure 5-1** illustrates the relationship between probability of being classified into a dietary pattern and BMI for males and females. For men, there was an inverse relationship between BMI and the probability of being characterized by the “Western-like” dietary pattern, such that as BMI increased, the probability of being classified into this pattern decreased. A similar relationship was seen for the “Low produce, high sweets” dietary pattern and BMI for men. In contrast, for women, a positive relationship was seen between BMI and the probability of being characterized by the “Western-like” dietary pattern, such that as BMI increased, this probability increased. This relationship also was similar for the “Low produce, high sweets" pattern. Odds ratios were also calculated. As an example, the odds of being in the "Western-like" dietary pattern, compared to the "More healthful" pattern, was 1.63 for males for individuals at the mean BMI (28.3 kg/m^2) and decreased to 1.44 for males with a BMI value of 35 (National Institutes of Health (NIH) Class I obesity cut-off). On the other hand, for a female with the mean BMI (28.3 kg/m^2), the odds of being classified in the "Western-like" dietary pattern was 1.07; however, when BMI increased to 35, these odds increased to 1.52.

DISCUSSION

In this study of older adults in the UAB Study of Aging, we identified three dietary intake patterns: "Western-like", "Low produce, high sweets" and "More healthful". Relationships of the patterns of food intake to differences in diet quality as measured by the HEI-2005 were evaluated, both as total HEI score and as individual component scores. The "More healthful" dietary pattern was associated with the highest total HEI-2005 score compared to the other two patterns. When HEI-2005 component scores were examined (data not shown), the "More healthful" pattern had significantly more favorable scores for total and whole fruit, whole grains, milk, oils, sodium, and calories from solid fats, alcoholic beverages and added sugars, therefore contributing to an overall higher HEI-2005 total score. Higher component scores for fruits and vegetables for those in the "More healthful" dietary pattern were consistent with the low energy density (1.43 kcal/g ± 0.33). Mean overall total HEI-2005 score for all three dietary patterns was 57.9 ± 12.4 which was comparable to adults from the National

Health and Nutrition Examination Survey (NHANES) 2001-2002 (mean HEI-2005 = 58.2, 95% CI: 56.6, 59.9) (16). However, when our sample was compared to only the older adults (≥ 65 years old) of the 2001-2002 NHANES data, the mean HEI-2005 total score from the UAB Study of Aging participants was 10 points less (57.9 UAB vs. 67.6 NHANES) (17). These observations are comparable to a previously reported sample of multi-ethnic older adults in the South that had a mean total HEI-2005 score of 61.9 (18), suggesting that the dietary quality of older adults living in the South may be more compromised than that of a national sample.

Examination of socio-demographic and lifestyle characteristics by dietary pattern revealed that the strongest predictors of better diet quality were female gender and non-Hispanic white race. Perhaps our most important observation was that the significant interaction found between BMI and gender for probability of dietary pattern membership suggested that there was a stronger relationship between BMI and dietary pattern for women compared to men. This supports other studies which highlight that the relationship between dietary pattern and BMI might vary between sexes (19-21). Schulze and colleagues (20) described a positive relationship between BMI and the “Alcohol” dietary pattern for men. However, for women in this same study, a positive relationship between BMI and dietary pattern was found for the “Plain cooking”, “Bread and sausage” and “Low fat dairy” dietary patterns. Findings from this and other studies, suggests that food choice may be mediated by gender. The gender difference could also be explained by differences in marital status. A much higher percentage of males in the sample were married (79%) and fewer widowed (14%) compared to females (married: 32%; widowed: 58%). Other studies have indicated that marital status and living arrangements are related to diet quality (22, 23). Previous work using the UAB Study of Aging data derived from baseline data (N = 1,000) found that African American women experienced the greatest nutritional risk, and that each ethnic-gender groups' nutritional risk was influenced by different factors (24). Although in our study, we were not able to analyze patterns by gender due to sample size constraints.

Although not significantly associated, those who reported higher levels of physical activity and excellent/good health and were "never smokers" were more likely to be characterized by the "More healthful" dietary pattern. Relationships among food intake and socio-demographic characteristics suggest that sound dietary choices are associated with a healthier lifestyle. These findings are similar to previous studies that show positive associations between education, income and diet quality (25, 26). Our current study differs from the aforementioned papers in that food intake was defined by dietary patterns, an approach that is thought to capture total diet, and that results are limited to only older adults.

The differences in reported energy consumption among the 3 dietary patterns are noteworthy. The relatively high energy intake of the "Low produce, high sweets" pattern is likely a reflection of intake of dessert-like (high energy-dense) foods and lower consumption of high water content (and therefore low energy dense) fruits and vegetables. Interestingly, the pattern labeled "Western-like" was characterized by the lowest energy intake. While we did perform an analysis to screen for implausible energy reporting using the McCrory equation (15), it remains possible that there was greater underreporting of energy intakes among those classified by the "Western-like" dietary pattern. It is unclear whether this procedure is valid in this population as the equation has only been validated in weight-stable samples (15). (In our sample, 34% and 25% of participants reported gaining or losing weight in the last six months, respectively, suggesting that this group is not weight stable. (Data not shown.) However, when Bailey et al. assessed the effect of underreporting energy intake on dietary patterns and weight status in a sample of older adults, they found that including implausible energy reporters did not significantly affect derived dietary patterns compared to patterns derived using only plausible reporters (27).

While it is difficult to make direct comparisons among dietary pattern studies, findings from our study were similar when compared to other dietary pattern studies of older adults in that more favorable dietary patterns are associated with higher diet quality (18, 28, 29). Schroder and colleagues (29) reported that older adults consuming a low energy density diet were more likely to meet recommended intakes for total and saturated fat, cholesterol, fiber, vitamins C, E and B6 and thiamin, riboflavin, folate, calcium, and magnesium.

Methodological aspects

To the best of our knowledge, our study was the first to illustrate the utility of FMM as an approach to dietary pattern analysis in a sample of older adults. FMM offers advantages over the more traditional methods of dietary pattern analysis. Unlike cluster analysis, FMM produces model fit statistics, such as the BIC to help determine the appropriate number of classes (i.e., dietary patterns). Conceptually, the goals of FMM and cluster analysis are similar in that the aim is to classify individuals into groups (i.e., dietary patterns). However, instead of "assigning" individuals exclusively into only one food pattern as in cluster analysis, FMM produces posterior probabilities of class membership for each individual, which can be used for model evaluation. Nagin (30) provides > 0.7 as an acceptable cut-point for posterior membership-class probability values. In our study, median posterior probabilities ranged from 0.92 to 0.97. Furthermore, the use of FMM has a major advantage over food frequency questionnaires in that it examines all foods and quantities consumed as a part of the whole diet.

Limitations of this investigation include an inadequate sample size to suitably examine dietary patterns by subgroups (e.g., gender, race). Our use of cross-sectional data limits our ability to determine causal relationships between dietary and lifestyle factors in this population. Although our sample resided in Alabama, they were all Medicare beneficiaries; and since over 95% of the United States older adult population receives Medicare benefits, it can be argued that they are representative of Medicare recipients of that region (31, 32). Despite these limitations, our study used multiple 24-h recalls to measure diet and includes a representative, diverse sample of older adults who are thought to be at nutritional risk.

This study identified three meaningful dietary patterns using FMM. It is noteworthy that for each dietary pattern characterized, the percentage of individuals meeting nutrient recommendations was generally below 50%, often much lower. These findings suggest that improvement in diet quality among these older adults is warranted. Future studies should attempt to examine changes in dietary patterns over time and relationships to health outcomes and longevity.

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Conflict of Interest

There are no conflicts of interest to report.

Author Contributions

All authors participated in the study concept, design, editing, and revision of the manuscript. PYH, DCM, DLC, GLJ, TJH also contributed to the analysis and interpretation of the data.

Sponsor’s Role

Sponsors provided research funding only.

Table 5-1. Description of food groupings used to derive dietary patterns of the UAB Study of Aging

Food group name	Food items
Fruit	Citrus fruit and juice, fruit juice, other fruit
Vegetables	Dark green and deep yellow vegetables, tomatoes, vegetable juice, other vegetables (celery, cabbage, squash, cucumber, mushrooms, cauliflower, okra, etc.), fried vegetables, vegetable-based savory snack
Starchy vegetables	White potatoes, fried potatoes, peas, lima beans, corn
Whole grains	Flour, bread, rolls, quick breads, corn muffins, tortillas, crackers, pasta, cereal, snack bars, and snack chips made with whole grain or some whole grain; and popcorn
Refined grains	Flour, bread, rolls, quick breads, corn muffins, tortillas, crackers, pasta, cereal, snack bars, and snack chips made with refined grains
Sweets	Cakes, cookies, pies, pastries, frozen dairy dessert, pudding, sweet sauces, candy (chocolate and non-chocolate), syrup, honey, jam, jelly, preserves, sugar, frosting and glaze
Meats	Beef, pork (fresh and cured), lamb, game, organ meats, cold cuts and sausage
Poultry, fish	Poultry, fish, shellfish
Other protein sources	Legumes, eggs, egg substitute, nuts and seeds, nut and seed butters
Dairy products	Milk, milk beverages, flavored milk, yogurt, cheese
Miscellaneous	Salad dressing, sauces, condiments, pickled foods, non-dairy creamer
Oils	Margarine, oil
Fats	Butter, shortening, gravy and cream

Table 5-2. Characteristics of the UAB Study of Aging participants (n = 416)[a, b]

Characteristics	Men	Women
No. of subjects	44% (183)	56% (233)
Age, y	76.3 ± 5.0	77.1 ± 5.5
BMI, kg/m^2	28.3 ± 5.4	28.3 ± 6.2
BMI categories		
Underweight, BMI < 18.5 kg/m^2	1.6% (3)	1.7% (4)
Normal, BMI 18.5-24.9 kg/m^2	26.8% (49)	30.9% (72)
Overweight, BMI 25-29.99 kg/m^2	40.4% (74)	34.3% (80)
Obese, BMI ≥ 30 kg/m^2	31.2% (57)	33.0% (77)
Race		
Non-Hispanic white	60.1% (110)	62.2% (145)
African American	39.9% (73)	37.8% (88)
Living in rural area	44.8% (82)	47.2% (110)
Education		
< High school	31.7% (58)	30.9% (72)
Graduated from HS	26.8% (49)	32.2% (75)
Some college or greater	41.5% (76)	36.9% (86)
Married[c]	78.7% (144)	32.2% (75)
Self-reported physical activity[c]		
Not active/minimally active	15% (27)	24% (57)
Moderately active	36% (65)	35% (81)
Active	50% (91)	41% (95)

Self-reported health		
Fair/poor	14% (26)	20% (47)
Good	68% (124)	62% (145)
Excellent/very good	18% (33)	18% (41)
Smoking status[c]		
Never smoker	31.2% (57)	64.4% (150)
Former smoker (quit > 4 y ago)	53.6% (98)	29.2% (68)
Former smoker (quit ≤ 1 y ago)	5.5% (10)	1.3% (3)
Current smoker	9.8% (18)	5.2% (12)

[a] Characteristics are from Year 4 of Study of Aging, when dietary data was collected.
[b] Values are means ± SD for continuous variables and percentages (n) for categorical variables.
[c] Significantly different, $P < 0.05$

Table 5-3. Daily Servings of Food, Nutrient Intakes and Percent of UAB Study of Aging Participants (n = 416) Meeting Nutrient Recommendations by Dietary Pattern

	By dietary pattern		
	Western-like (n = 172)	Low produce, high sweets (n = 168)	More healthful (n = 76)
Mean servings per 1000 kcal/day ± SD[a]			
Fruit	1.07 ± 1.29	0.85 ± 0.65	1.64 ± 1.10
Vegetables	1.20 ± 0.79	0.79 ± 0.44	1.59 ± 1.30
Starchy vegetables	0.55 ± 0.55	0.31 ± 0.24	0.37 ± 0.39
Whole grains	0.44 ± 0.63	0.87 ± 0.77	1.71 ± 0.83
Refined grains	2.80 ± 1.07	2.18 ± 0.84	1.35 ± 0.69
Sweets	0.94 ± 0.93	1.13 ± 0.72	0.85 ± 0.58
Meats	1.61 ± 1.20	1.40 ± 0.82	0.97 ± 0.67
Poultry, fish	1.66 ± 1.47	1.19 ± 1.00	1.07 ± 0.81
Other protein sources	0.54 ± 0.53	0.53 ± 0.47	0.76 ± 0.77
Dairy products	0.29 ± 0.29	0.66 ± 0.44	1.01 ± 0.69
Miscellaneous	0.84 ± 0.87	0.65 ± 0.39	0.83 ± 0.73
Oils	1.35 ± 1.14	0.95 ± 0.56	0.80 ± 0.79
Fats	0.74 ± 0.70	0.43 ± 0.35	0.43 ± 0.46
Energy-adjusted (per 1000 kilocalories) mean nutrient intakes ± SD[b, f]			
Total energy, kcal	1150.77 ± 385.52[c]	1370.48 ± 380.91[d]	1242.31 ± 342.07[c]
Carbohydrates, % energy	47.44 ± 8.51[c]	48.98 ±6.94[c]	52.16 ± 8.77[d]
Protein, % energy	16.63 ± 4.04	15.85 ± 3.27	16.40 ± 3.03
Fat, % energy	36.97 ± 6.68[c]	35.99 ± 5.57[c]	33.27 ± 7.76[d]

Saturated fat, % energy	11.41 ± 2.62[b]	12.10 ± 2.53[d]	10.54 ± 2.88[e]
Alcohol, % energy	0.28 ± 1.82	0.70 ± 2.67	0.68 ± 2.08
Fiber, g	9.95 ± 3.90[c]	8.98 ± 2.65[d]	12.52 ± 3.89[e]
Folate, µg	305.80 ± 126.89[c]	310.89 ± 141.19[c]	396.93 ± 236.18[d]
Vitamin B_6, mg	0.96 ± 0.32[c]	0.99 ± 0.40[c]	1.32 ± 0.69[d]
Vitamin B_{12}, µg	2.20 ± 1.39[c]	3.54 ±4.49[d]	3.78 ± 3.23[d]
Vitamin C, mg	54.41 ± 54.06[c]	40.00 ± 27.52[d]	72.30 ± 42.95[e]
Vitamin D, µg	2.56 ± 3.42[c]	3.04 ± 1.75[cd]	3.53 ± 2.23[d]
Vitamin E, mg	4.24 ± 2.06[c]	5.42 ± 10.04[c]	8.08 ± 10.18[d]
Calcium, mg	331.36 ± 121.12[c]	416.64 ± 149.48[d]	602.16 ± 327.47[e]
Iron, mg	7.97 ± 2.46[c]	8.35 ± 2.99[c]	10.10 ± 5.80[d]
Magnesium, mg	135.74 ± 33.07[c]	136.07 ± 30.19[c]	180.08 ± 40.69[d]
Zinc, mg	5.46 ± 2.53[c]	6.13 ± 3.52[c]	7.19 ± 4.33[d]
Energy density, kcal/g	1.66 ± 0.40[c]	1.74 ± 0.31[d]	1.43 ± 0.33[e]
HEI-2005 score[g]	53.7 ± 11.7[c]	56.7 ± 10.6[d]	70.3 ± 9.8[e]
Percent of participants meeting nutrient recommendations[g]			
Fiber[h]	2.9% (5)	1.2% (2)	9.2% (7)
Folate[h]	26.2% (45)	45.8% (77)	48.7% (37)
Vitamin B_6[h]	12.8% (22)	25.6% (43)	43.4% (33)
Vitamin B_{12}[h]	41.9% (72)	68.5% (115)	68.4% (52)
Vitamin D	1.7% (3)	0.6% (1)	0% (0)
Calcium[h]	0.6% (1)	4.8% (8)	7.9% (6)
Magnesium	1.2% (2)	0.6% (1)	2.6% (2)
Iron[h]	52.3% (90)	72.6% (122)	75.0% (57)

Zinc[h]	10.5% (18)	25.6% (43)	36.8% (28)

[a] All mean servings were significantly different across dietary pattern at $P < 0.05$.
[b] Values in the same row with different superscript letters ([c, d] and [e]) were significantly different, $P < 0.05$.
[f] Analysis is adjusted for multiple comparisons using Bonferroni correction.
[g] Nutrient cut-offs based on 2005 Recommended Dietary Allowances and Adequate Intakes for vitamins and minerals.
[h] Significantly different, $P < 0.05$

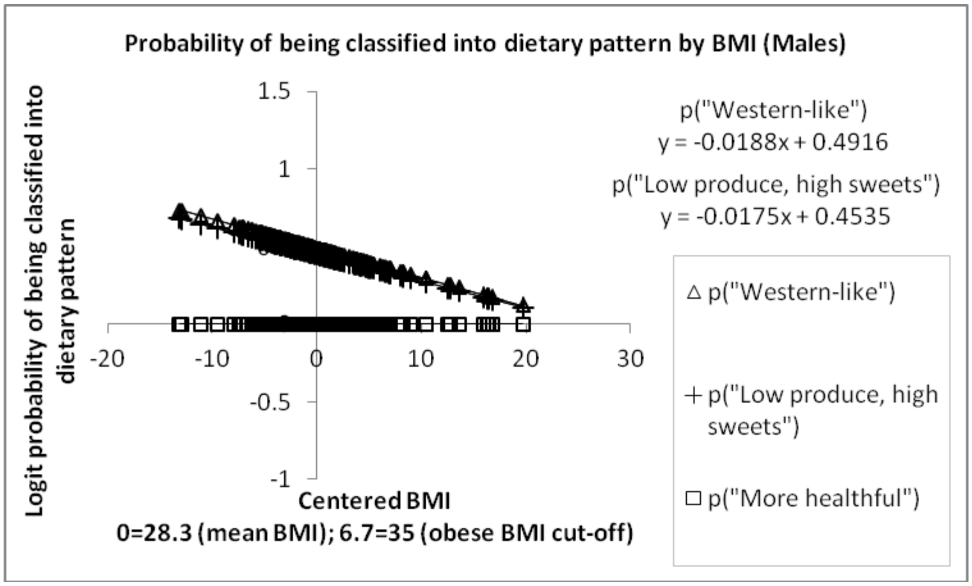
Table 5-4. Selected Characteristics across the 3 Dietary Patterns among Participants of the UAB Study of Aging (n = 416)[a]

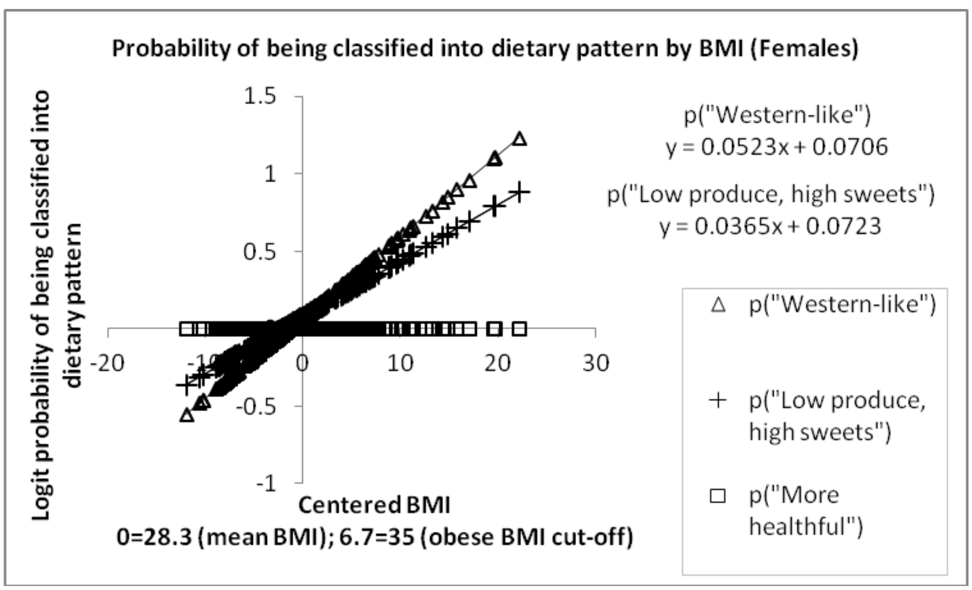
Characteristic[b]	Western-like (n = 172)	Low produce, high sweets (n = 168)	More healthful (n = 76)	*P*-value
Female*	52% (89)	55% (92)	68% (52)	0.047
Age, y	76.7 ± 5.2	76.8 ± 5.4	77.0 ± 5.4	0.948
Non-Hispanic White*	47% (80)	68% (114)	80% (61)	<0.001
BMI, kg/m^2	28.8 ± 6.4	28.1 ± 5.6	27.6 ± 5.4	0.269
BMI category[c]				
Normal, BMI 18.5-24.9 kg/m^2	27% (45)	32% (53)	31% (23)	0.568
Overweight, BMI 25-29.9 kg/m^2	37% (62)	36% (60)	43% (32)	
Obese, BMI ≥ 30 kg/m^2	36% (61)	32% (53)	27% (20)	
Education*				
< HS	39% (67)	27% (46)	22% (17)	0.011
Graduated from HS	31% (54)	27% (46)	32% (24)	
Some college or greater	30% (51)	45% (76)	46% (35)	
Income*				
Less than $12,000	39% (64)	19% (30)	18% (13)	<0.0001
$12,000-29,999	42% (69)	44% (68)	35% (25)	
$30,000-49,999	12% (19)	21% (32)	21% (15)	
$50,000 or more	7% (11)	16% (25)	25% (18)	
Lives alone	27% (47)	25% (42)	33% (25)	0.440

Self-reported physical activity				
Not active/minimally active	23% (39)	20% (33)	16% (12)	0.736
Moderately active	32% (56)	37% (62)	37% (28)	
Active	45% (77)	43% (73)	47% (36)	
Self-reported health				
Fair/poor	20% (35)	13% (22)	21% (16)	0.178
Good	61% (105)	71% (120)	58% (44)	
Excellent/very good	19% (32)	15% (26)	21% (16)	
Lives in rural area	52% (90)	40% (67)	46% (35)	0.07
Married	52% (90)	57% (96)	43% (33)	0.138
Smoking status				
Never smoker	48% (83)	49% (83)	54% (41)	0.596
Former smoker	43% (74)	43% (72)	43% (33)	
Current smoker	9% (15)	8% (13)	3% (2)	
Cognitive Score*	27.1 ± 1.9[a]	27.7 ± 1.8[b]	28.0 ± 1.7[b]	0.0003
GDS	1.5 ± 1.2	1.5 ± 1.4	1.5 ± 1.3	0.996

[a] Characteristics are from Year 4 of Study of Aging, when dietary data was collected.
[b] Values are means ± SD for continuous variables and percentages (n) for categorical variables. Values in the same row with different superscript letters were significantly different, $P < 0.05$.
[c] Underweight BMI category was excluded due to extremely small frequency.
* Significantly different, $P < 0.05$

Figure 5-1. Probability of being characterized by dietary pattern based on BMI and gender





Note: Y-axis is the logit probability from the logistic regression.

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Chapter 6

CONCLUSIONS

SUMMARY OF RESEARCH FINDINGS AND IMPLICATIONS

The Geisinger Rural Aging Study (GRAS) is a longitudinal study of > 20,000 community-dwelling older adults (≥ 65 years old) living in rural Pennsylvania. Prior investigations on the GRAS cohort have not only characterized the growing prevalence of obesity among this aging population, but also the increased nutritional risk among overweight and obesity in older adults (1).

Research presented in this dissertation builds on previous findings. Ledikwe et al. (2) described the existence of a low-nutrient dietary pattern, characterized by relatively higher intakes of bread, pasta, desserts, processed meat, eggs and fats/oils and a high-nutrient dense pattern with higher intakes of cereals, vegetables, fruit, milk, poultry, and fish. To further validate earlier results, the current study completed dietary pattern analysis on a relatively larger subgroup from the GRAS cohort. Chapter 3 describes the three dietary patterns identified using cluster analysis. A 'Health-conscious' dietary pattern was characterized by relatively higher intakes of pasta, noodles, rice, whole fruit, poultry, nuts, fish, and vegetables. The 'Sweets and dairy' pattern was distinguished by intakes of baked goods, milk, sweetened coffee and tea, and dairy-based desserts, whereas the 'Western' dietary pattern was relatively higher in reported consumption of bread, eggs, fats, fried vegetables, processed meats, alcohol, and soft drinks. When these dietary patterns were related to selected health outcomes of interest, a significant relationship was only found for hypertension, in that, those characterized by the 'Sweets and dairy' dietary pattern had higher odds of hypertension (OR = 2.17; 95% CI: 1.11, 4.27) compared to the 'Health-conscious' dietary pattern. When sodium intake was examined, there were no significant differences among the three dietary patterns. There were however, significant differences for all other selected nutrients examined, including potassium, calcium, and magnesium, suggesting that it is a combination of dietary components that might explain the differences.

Chapter 4 examined the association between the derived dietary patterns and weight change. Weight change was defined in several ways: 1) a 10-pound weight loss; 2) a 10-pound weight gain; 3) a 10% weight loss; 4) a 10% weight gain. No significant relationships between dietary pattern and weight change were found until the analysis was stratified by gender. Compared to the ‘Health-conscious’ dietary pattern, females characterized by the ‘Sweets and dairy’ and the ‘Western’ dietary patterns, were two and three times more likely to lose 10 pounds, respectively. While weight loss in an obese adult may be desirable, in an older person, non-volitional weight loss might be reflective of poor health status and/or inflammatory condition.

Chapter 5 explored use of a novel statistical approach to derive dietary patterns, finite mixture modeling (FMM). To the best of our knowledge, FMM has only been applied to dietary data in two other instances (3, 4). Three dietary patterns, a ‘Low produce, high sweets’, a ‘More healthful’ and a ‘Western’ dietary pattern were identified using FMM in a sample of diverse older adults from central Alabama. Similar to results from the GRAS dietary pattern analysis, a significant interaction was found between dietary pattern and body mass index (BMI) for gender.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Limitations of our study sample should be noted. The GRAS cohort was predominantly Non-Hispanic white with a mean BMI of 28 kg/m^2. There were only five participants who were underweight (BMI < 18.5 kg/m^2). It is possible that the homogeneity of race and weight status limited our ability to find differences among our sample. While our sample size was adequate to perform cluster analysis on the entire group, we were limited in our ability to analyze meaningful subgroups (e.g., gender, weight status) or perform more sophisticated approaches like FMM.

The use of data extracted from an electronic medical record (EMR) provided a rich data source from which to draw from. We did not have to rely on self-reported weight measurements which is often a drawback for other studies. Although GRAS participants were all enrolled in a Geisinger Medicare risk program, it is possible that healthcare visits occurred at non-Geisinger facilities, which therefore, would not be captured in the Geisinger EMR. Weight changes that happened between clinic visits were also not reflected in the EMR. Our data extraction process was limited to outpatient visits and did not include emergency room or hospital inpatient contacts, potentially underestimating the prevalence of more serious disease. A further limitation of our data extraction process was that we were unable to determine disease incidence. Therefore, we are unable to make causality statements about diet and disease.

When examining weight change in our sample, almost all of the variance in weight was between-person suggesting that the measurement error for weight was very small (i.e., weight is relatively stable among this sample). However, in an aging cohort, weight stability can mask sarcopenia (5), the loss of lean body mass that accompanies normal aging. More recently, sarcopenic obesity, the progressive loss of lean body mass and gain in body fat (6), has been associated with functional decline (7, 8) in older adults. Unfortunately, our study lacked data on body composition changes. Future studies should examine associations between dietary patterns and changes in body composition in old age.

We are only able to address the selected health outcomes of interest (i.e., cardiovascular disease, type 2 diabetes mellitus, hypertension, and metabolic syndrome). It is possible that the identified dietary patterns may be related to other outcomes we did not investigate. Our original intent was to also examine the association between dietary pattern and additional obesity-related health outcomes, namely osteoarthritis, liver disease, sleep apnea, and depression, but low prevalence rates limited our ability to do so.

Epidemiological studies, including the current study, often assume relative stability of lifestyle factors, such as diet and physical activity. Because diet assessment was only completed at baseline, we made the assumption that dietary patterns remained stable over the 5-year follow-up period. Some (9, 10), but not all studies (11, 12), have demonstrated relatively stable dietary habits over time. Dietary habits are especially likely to be stable in older persons (9, 13). Future research should consider examination of changes in dietary patterns longitudinally including starting in younger cohorts (< 65 years of age) through advanced age (i.e., Centenarians).

Although our study adjusted for survivorship bias that is possible in longitudinal studies of age-related outcomes, when mortality was examined across dietary pattern, there were no differences ($P = 0.260$). Therefore, it may not have been necessary to adjust for selective attrition due to mortality. It is reasonable to assume that the GRAS subsets sampled could have already been affected by survival bias, representing a population that was more resistant to the adverse effects of obesity and other age-related disease.

In conclusion, research presented in this dissertation has furthered the body of knowledge on older adults and dietary patterns. In particular, this study contributed an understanding of a less studied population, old-older adults. The number of older adults, especially those 85 years and older, is projected to rapidly increase. Research that can elucidate best dietary practices to balance the nutritional needs and quality of life in an aging population are warranted.

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Appendix A

GRAS Validation Study Manual Chart Review Form

Geisinger Rural Aging Study (GRAS): Validation Study
Manual Chart Review

Each SHIP participant's electronic medical record will be reviewed for selected diagnoses. Chart review will focus on *Physician Notes, Graphs, Snapshot/Problem List*

Today's date ________________ Auditor initials ________

Patient's name __________________________________ Sex M / F Deceased (circle if Y)

Age ____ DOB ____/____/____ (MM/DD/YYYY) MRN ______________________

SHIP ID _________ Range of dates reviewed ______________________________

	YES	NO	Date of documentation	Comments	Data abstraction results
Cardiovascular disease					
Diabetes					
Hypertension					
Obstructive Sleep Apnea					
Osteoarthritis					
Depression					
Liver dysfunction					
MetSyn* (3/5 criteria below)					
a. Triglycerides ≥ 150 mg/dL					
b. HDL M <40 mg/dL W <50 mg/dL					
c. Blood pressure ≥130/≥85 mm Hg					
d. Glucose ≥110 mg/dL					
*e. BMI>30 kg/m² **					

*Based on ATP III and WHO criteria (Grundy 2004; NHLBI/AHA Conference Proceedings) **used BMI (WHO) instead of WC (ATP III) because WC is less available with this population.

Hypercholesterolemia Y / N Dyslipidemia Y / N Hypothyroidism Y / N

Additional comments

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Rev 4/6/10

Appendix B

Using Electronic Data Extraction to Identify Subjects with Metabolic Syndrome: A Validation Using Manual Chart Review[2]

[2] This abstract was presented at the 17th annual HMO Research Network conference in Boston, MA (March 2011).

Using Electronic Data Extraction to Identify Subjects with Metabolic Syndrome: A Validation Using Manual Chart Review

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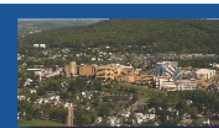


BACKGROUND

Metabolic syndrome (MetS) is a group of interrelated risk factors that greatly increase risk for cardiovascular mortality. According to a recent national survey[1], approximately 34% of U.S. adults met the criteria for MetS. However, MetS is rarely recorded as a clinical diagnosis, making it challenging to identify patients with MetS.

OBJECTIVES

- To calculate the percent of subjects with an ICD-9 diagnosis code for MetS.
- To calculate and compare the percent of subjects that meet National Cholesterol Education Program Expert Panel in Adult Treatment Panel III (ATP III) guidelines for MetS using two methods: an electronic data extraction (EDE) process and a manual chart review (CR)

METHODS

Electronic health records (EHR) of 48 older adults (24 males, 24 females; age ≥65) were randomly selected for review. Participants were originally recruited for the Geisinger Rural Aging Study (GRAS), a large, longitudinal nutritional-risk screening study involving rural Pennsylvanians who were enrolled in a Medicare risk program. MetS was defined as the presence of three (3) of the five (5) criteria based on ATP III guidelines. However, since waist circumference was not available for all individuals, BMI >30 kg/m² was used.

EHRs were manually reviewed by a trained auditor for a 48-month period, starting at date of GRAS study entry (i.e. CR process). Included in the audit:

- demographics
- diagnoses codes
- laboratory data
- past medical history
- medications
- progress notes
- physician comments

Data available electronically were extracted and stored in SAS version 9.2 data files (i.e. EDE process). The EDE process and the CR process were independently used to identify individuals with criteria for MetS (i.e. triglycerides, HDL-cholesterol, glucose, blood pressures, and measured height and weight). Other diseases (e.g. cardiovascular, diabetes, hypertension, etc.) were reviewed for future research. Disagreements between results from each method were reviewed to identify and correct human error. Cohen's Kappa was calculated to assess statistical agreement.

RESULTS

- Only 2 of 48 individuals (4%) had an ICD-9 diagnoses code for MetS (ICD-9 277.7).
- Based on CR, 27 individuals (56%) met criteria for MetS based on ATP III guidelines.
- Based on EDE, 25 of the 27 individuals found from CR were also identified. The two cases that were missed had abnormal glucose values that were not available from the EDE.
- Agreement between the CR and the EDE for MetS was almost perfect (κ=0.92).
- Agreement rates for other diseases was >90%.

Table 1. Criteria used to identify health outcomes of interest in the EHR

Outcome	ICD-9 codes identified from the active problem list diagnoses recorded at outpatient visits	Additional criteria*
Metabolic syndrome	ICD-9 277.7: Metabolic syndrome	3 of 5 criteria** below: a. Triglycerides ≥150 mg/dL b. HDL-cholesterol: Men <40 mg/dL; Women <50 mg/dL c. Systolic blood pressure ≥130 mm Hg or Diastolic blood pressure ≥85 mm Hg d. Glucose ≥110 mg/dL e. BMI >30 kg/m² Mention in Physician Notes
Cardiovascular disease	ICD-9 410: Acute myocardial infarction ICD-9 411: Other acute and subacute forms of ischemic heart disease ICD-9 412: Old myocardial infarction ICD-9 414: Other forms of chronic ischemic heart disease	Evidence of treatment with statin drugs Mention in Physician Notes
Type II diabetes	ICD-9 250: Diabetes mellitus ICD-9 362: Diabetic retinopathy ICD-9 366.41: Diabetic cataract	Hemoglobin A1C >6.0 Evidence of treatment with antidiabetic drugs Mention in Physician Notes
Hypertension	ICD-9 401: Essential hypertension	Systolic blood pressure ≥130 mm Hg or Diastolic blood pressure ≥85 mm Hg Evidence of treatment with antihypertensive drugs Mention in Physician Notes
Obstructive sleep apnea	ICD-9 780.57: Sleep apnea, obstructive	Mention in Physician Notes
Osteoarthritis	ICD-9 715.16: Osteoarthritis, knee	Mention in Physician Notes
Depression	ICD-9 296: Major depression ICD-9 311: Depression, NOS	Mention in Physician Notes
Liver disease	ICD-9 571.8: Non-alcoholic fatty liver disease	Mention in Physician Notes

*Criteria for both manual chart review and the EDE process were identical except for "Mention in Physician Notes" which was only used as a criterion for the manual chart review.
**The ATP III criteria for metabolic syndrome were used with the exception of the waist circumference criteria because waist circumference is less available with this population.

Table 2. Selected self-reported baseline characteristics for a subgroup of the Senior Health in Pennsylvania (SHIP) sample

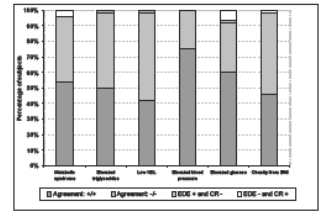
Characteristics	All (n=48)	Males (n=24)	Females (n=24)
Age in years (mean [SD])	79.1 [4.6]	78.8 [3.1]	79.4 [5.8]
Race (n)			
Non-Hispanic white	47	24	23
African-American	1	0	1
Education (n [%])			
≤ Elementary school	5 [10.4]	2 [8.3]	3 [12.5]
Some high school	5 [10.4]	2 [8.3]	3 [12.5]
Graduated from high school or GED	17 [35.4]	7 [29.2]	10 [41.7]
Some college or more	21 [43.8]	13 [54.2]	8 [33.3]
Marital status (n [%])			
Married	24 [50.0]	13 [54.2]	11 [45.8]
Widowed	19 [39.6]	7 [29.2]	12 [50.0]
Separated	1 [2.1]	1 [4.1]	0
Divorced	3 [6.2]	3 [12.5]	0
Never married	1 [2.1]	0	1 [4.2]
Employment status (n [%])			
Working for pay	6 [12.5]	4 [16.7]	2 [8.3]
Not employed	42 [87.5]	20 [83.3]	22 [91.7]

Table 3. Rate of agreement between electronic data extraction (EDE) and manual chart review (CR) for various diagnoses*

		Agreement			Non-agreement			
	n	EDE = YES CR = YES	EDE = NO CR = NO	Percent agreement	EDE = YES CR = NO	EDE = NO CR = YES	Percent non-agreement	Cohen's kappa
Metabolic syndrome	48	54%	42%	96%	0%	4%	4%	0.916
Cardiovascular disease	48	38%	54%	92%	0%	8%	8%	0.830
Type II diabetes	48	35%	65%	100%	0%	0%	0%	1.000
Hypertension	48	83%	13%	96%	0%	4%	4%	0.851
Osteoarthritis	48	6%	83%	90%	1%	0%	10%	0.492
Depression	48	8%	83%	96%	0%	4%	4%	0.778

*Liver disease and obstructive sleep apnea were examined but prevalence was too low for analysis.

Figure 1: Rate of agreement between electronic data extraction (EDE) and manual chart review (CR) for various metabolic syndrome criteria.



CONCLUSION

This validation study provides evidence that an EDE for identifying MetS has substantial agreement with the gold standard, a manual review of EHRs.

IMPLICATIONS

Using this process has the advantage of quickly querying large amounts of data that may be missed by manual chart review and can aid in collection of data for health outcomes research.

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SELECTED PUBLICATIONS

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HONORS AND AWARDS

2011 PSU Kligman Graduate Fellowship Endowment
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2011 ASN Nutrition Epidemiology RIS Student Poster Competition finalist
2011 First place, Health and Life Sciences, PSU Graduate Exhibition
2011 Student representative, Nutritional Sciences Council of the ASN
2010 Liaison, ASN Student Interest Group & the Graduate & Professional Education Committee
2010 Travel award, PSU Nutrition and Dietetics Alumni Society
2010 Finalist, Clinical Emerging Leaders oral competition, Experimental Biology conference
2009 PSU Woot-Tsuen Wu Leung Scholarship in Nutrition
2009 AND Foundation Scholarship
2008 PSU Woot-Tsuen Wu Leung Scholarship in Nutrition
2006 Campbell's Soup Company Scholarship