ASSOCIATIONS BETWEEN BMI AND DIET QUALITY WITH HEALTH-RELATED QUALITY OF LIFE, MORTALITY, AND HEALTHCARE RESOURCE USE IN THE GEISINGER RURAL AGING STUDY (GRAS)

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ABSTRACT

The number of adults aged ≥ 65 years, and especially ≥ 80 years is rising dramatically. With increasing age there is an associated rise in co-morbid conditions. The average life expectancy has reached 76 years for males and 81 years for females, the highest ever, focusing attention on the increasing healthcare costs incurred by our aging population. In addition to reducing health care costs, promoting health related quality of life (HRQOL) is of interest to older persons. Determining potentially modifiable factors that may positively impact these outcomes is therefore of growing relevance.

Body mass index (BMI) and diet quality are two such factors that warrant additional research. Obesity is a global crisis, and rates of overweight and obesity have continued to increase even in the oldest segment of the population. Dietary guidelines are often not met by older persons, and their calorie needs are frequently exceeded while micronutrient intakes fail to meet requirements. Older adults face additional nutritional concerns due to changes in physiological functions as well as in living and social arrangements. Studies characterizing the associations between BMI and diet quality with HRQOL, healthcare resource use (HRU) and mortality are limited in older adults, particularly in those aged ≥ 80 years. Greater understanding of these associations may help inform recommendations regarding BMI and diet quality in older adults.

The objectives for this dissertation were three-fold: 1) to determine factors that impact diet quality; 2) to assess associations between diet quality and BMI with health-related quality of life; and 3) to examine the associations between diet quality and BMI
with objective health outcome measures including healthcare resource use and all-cause mortality.

The GRAS enrolled more than 20,000 individuals aged ≥ 65 years old living in rural central Pennsylvania in a rolling fashion from 1994-1999. The aim of the GRAS was to evaluate nutritional risk in relation to health outcomes in older adults. In the fall of 2009, the remaining 5,993 participants were contacted; 4,009 returned completed dietary and demographic information (1,722 male, 2,287 female; mean age 81.5 ± 4.4). Of these, 2,995 were also enrolled in the Geisinger Health Plan for at least part of the follow-up (mean=37 months), allowing for extraction of HRU data. Diet-related practices were self-reported at baseline (fall 2009). HRQOL score was determined using the Health and Activity Limitation Index (HALex) which scores individuals on a scale of 0.0 (death) to 1.0 (optimal) based on self-reported health and self-reported functional limitation. HRU was extracted from electronic medical records, and deaths were identified using electronic medical records and the Social Security Death Index. Multivariate linear regression models were used to analyze the associations of BMI and diet-related practices with DST score. The diet-related practices of skipping breakfast, reporting a decline in intake, being food insufficient or experiencing chewing difficulties were associated with poorer DST score. Additionally, participants with a low BMI (<18.5) had significantly poorer diet quality than individuals with a desirable BMI (18.5-24.9).

The next phase of analysis examined the associations between diet quality and BMI with HALex score in multivariate linear regression models. Those participants who had either an ‘unhealthy’ (0.71 95% CI 0.70, 0.72, p<0.0001) or ‘borderline’ (0.72 95% CI 0.70, 0.73, p=.0008) diet had significantly lower HALex scores than those consuming
a ‘healthy’ diet (0.75 95% CI 0.73, 0.77). Additionally, those with class II (0.67 95% 0.64, 0.70, p<0.0001) or class III obesity (0.60 95% CI 0.55, 0.65, p<0.0001) had reduced HALex scores compared to those with a desirable BMI (0.76 95% CI 0.75, 0.77).

The next aim was to determine the association between overall diet quality, fruit and vegetable consumption, and BMI with four healthcare resource use outcomes. Multivariate negative binomial models were used to estimate relative risk (RR) and 95% confidence intervals (95% CI) for each of four HRU outcomes (inpatient hospital visits, inpatient hospital days, emergency room visits and outpatient clinic visits) with diet quality and BMI. Poor diet quality was related to a 20% increased risk for ER visits. The three lowest fruit and vegetable quintiles were associated with increased risk for ER visits (23-31%), and the lowest quintile was also associated with increased risk for inpatient visits (27%). Obesity increased risk of outpatient clinic visits; however, individuals with class I obesity were less likely than normal weight individuals to have ER visits (RR 0.84; 95% CI 0.70, 0.99).

Finally cox proportional hazards models were used to examine the associations of BMI, diet quality, and HRQOL with all-cause mortality after adjusting for relevant covariates. Compared to GRAS participants with BMIs in the normal range, lower BMI (< 18.5) was significantly associated with increased mortality (HR 1.85 95% CI 1.09, 3.14, p=0.02), while a BMI of 25-29.9 was associated with decreased risk of mortality (HR 0.71 95% CI 0.55, 0.91, p=.007). Poor diet quality increased risk for mortality (HR 1.53 95% CI 1.06, 2.22, p=0.02) and favorable HRQOL (i.e. higher HALex score) was strongly inversely associated with mortality risk (HR 0.09 95% CI 0.06, 0.13, p<0.0001).
In conclusion, the diet-related practices of skipping breakfast, reporting a decline in intake, being food insufficient or experiencing chewing difficulties, as well as a low BMI, were associated with poorer diet quality. In turn, poor diet quality was associated with poor HRQOL as well as adverse HRU and mortality outcomes. Obesity classes II and III were also associated with poor HRQOL and increased outpatient clinic visits, while overweight was associated with reduced mortality. Finally, HALex score was strongly associated with decreased rates of mortality. These findings suggest that improving diet quality in rural older adults may have beneficial effects on HRQOL, HRU and mortality rates. Many of these relationships are bi-directional, and without multiple data points we are unable to determine causation.

The research presented in this dissertation expands upon existing knowledge regarding the relationships of diet quality and BMI with HRQOL, HRU and mortality. Findings suggest that recommendations for desirable BMI in older adults be re-visited, with what is currently considered overweight appearing to offer positive health outcomes. Additionally, while diet quality continues to play a role in health outcomes in aging, the results are attenuated from those seen in younger cohorts. Future research should further investigate the oldest segment of the population, focusing on the impact of diet on health outcomes, and ideally measure diet at multiple time points to assess changes over time.
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LIST OF ABBREVIATIONS

95% CI  95% Confidence Interval
ADL   Activity of Daily Living
ARFS  Australian Recommended Food Score
BMI   Body Mass Index
CVD   Cardiovascular Disease
CHD   Coronary Heart Disease
DDS   Dietary Diversity Score
DST   Dietary Screening Tool
ER    Emergency Room
EPIC  European Prospective Investigation into Cancer and Nutrition Study
FFQ   Food Frequency Questionnaire
GRAS  Geisinger Rural Aging Study
HR    Hazard Ratio
HALex Health and Activity Limitation Index
HRU   Healthcare Resource Use
HMO   Health Maintenance Organization
HRQOL Health Related Quality of Life
HALE  Healthy Ageing: a Longitudinal study in Europe
HDI   Healthy Diet Indicator
HDS   Healthy Diet Score
HEI   Healthy Eating Index
IRB   Institutional Review Board
IADL  Instrumental Activity of Daily Living
MAI   Mediterranean Adequacy Index
MDS   Mediterranean Diet Score
MCS   Mental Component Score
NHIS  National Health Interview Survey
NIH   National Institutes of Health
OR    Odds Ratios
ODI-R Overall Dietary Index-Reviewed
PCA   Principal Component Analysis
PCS   Physical Component Score
QOL   Quality of Life
RFS   Recommended Food Score
RRR   Reduced Rank Regression
RR    Relative Risk
SAS   Statistical Analysis System
SENeca Survey in Europe on Nutrition and the Elderly: a Concerted Action
USDA  United States Department of Agriculture
YOL   Years of Life
YOHL  Years of Healthy Life
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Chapter 1

INTRODUCTION
Over the past decade those persons aged ≥ 80 years have been the fastest growing segment of the American population (1). In 2010 they comprised fully 5.4% of the United States population (2). Life expectancy is currently just over 76 years for males and 81 years for females, the highest ever for both sexes (3). With the rapid increase in length of life and in the number of individuals surviving to old age, issues relevant to aging adults have assumed greater importance.

With an aging population, there is an associated increase in co-morbid conditions. At least 80% of individuals over the age of 65 have one or more chronic disease, with 50% reporting two or more (4). As the burden of chronic disease increases with the ‘graying’ of America, there are growing concerns regarding rising health care utilization and health care costs (5). Co-morbidities also negatively impact quality of life in aging adults, so that extension in years of life may not reflect quality living. Identifying and targeting modifiable risk factors that may eliminate or improve the management of chronic conditions to enhance health related quality of life (HRQOL), reduce healthcare resource use (HRU) and ultimately delay all-cause mortality is desirable.

Body mass index (BMI) is a potentially modifiable risk factor for many adverse health outcomes. The association between BMI and chronic disease is well established (6). While in younger adults overweight (BMI 25.0-29.9) and obesity (BMI ≥ 30) are associated with increased all-cause mortality risk (7), the association remains controversial in older adults (8). Evidence suggests that with increasing age, the U-shaped association between BMI and all-cause mortality begins to flatten at higher BMIs, and the nadir shifts upward into the overweight category (9, 10). Underweight (BMI < 18.5) has however been consistently found to have a strong association with increased
all-cause mortality risk in both younger and older adults (11-15). Greater understanding of the desirable BMI for older adults is necessary to inform recommendations.

BMI may also play a role in healthcare resource use. Chronic obesity in middle-aged adults has been shown to increase lifetime Medicare costs (16). Thus far, research has demonstrated that healthcare use and costs increase with increasing BMI in adults 54-69 years old, primarily attributable to greater use of outpatient services (17). The relationship between BMI and healthcare use in adults of more advanced age is less well defined. Some studies suggest that the association between higher BMI and increased outpatient visits attenuates with age, and that risk of inpatient hospital visits (18) and overall medical expenditures are actually lowest in overweight older adults ( > 65 years) (19). Other studies have found increased health care charges among the obese elderly (20). The associations between BMI and healthcare resource use in older adults likely differs from that seen in younger adults, and a better understanding is required to guide recommendations.

HRQOL and BMI are strongly associated. In younger adults, HRQOL is highest in those who are of desirable weight, and decreases with increasing BMI (21, 22). Again, research is limited in older adults. While the relationship between obesity and lower HRQOL appears to persist, some investigators suggest that overweight is no longer associated with decreased HRQOL in older adults (aged ≥ 60 years) (23). More research is clearly warranted to establish BMI recommendations for older adults. Current BMI guidelines have been established for younger adults and may not apply for those of advanced age (24).
Diet quality is of special interest in the aging population due to age-related changes that impact upon nutrient adequacy. In aging, nutrient needs are altered by changes in body composition and organ function (25). Energy requirements decrease while protein needs may rise and many micronutrient requirements remain stable or increase, thus creating a potential need for high quality nutrient dense foods (25). Oral health problems often make it especially difficult for many aging individuals to meet nutrient recommendations (26, 27). In addition to physiological changes, aging adults often face changes in living and socioeconomic status that may impact upon nutritional status. Depression and living and eating alone are common (26). These factors make achieving nutrient adequacy especially difficult for older adults.

Diet quality, independent of BMI, is a potentially modifiable factor that may reduce risk for the development of chronic diseases and attenuate associated complications (28, 29). High intake of fruits and vegetables in particular has been linked to decreased risk of stroke, cardiovascular disease, site-specific cancer, type 2 diabetes mellitus and obesity (30). High quality diets have been associated with healthier BMIs, while poor diet quality has been associated with both underweight and obesity compared to normal weight (31-33). High diet quality may also decrease risk of all-cause mortality in older adults (34). In addition to improving the objective measures of health, high quality diets are also associated with greater health-related quality of life (HRQOL) in older adults (35, 36). Improving HRQOL is of particular interest in older adults due to its association with all-cause mortality and impact on successful aging (37-39).

While evidence for the associations between BMI and diet with HRQOL, HRU and all-cause mortality exists, prior research has been conducted almost exclusively in
younger populations, or in populations that include wide age ranges. Research focusing exclusively on the oldest old (≥74 years) is generally lacking. With the aging of our population, the significant health issues impacting this cohort are of growing interest.

**OBJECTIVES**

While aging is a world-wide phenomenon, within the United States the distribution of older adults varies considerably by state. Pennsylvania boasts the 5th highest proportion of individuals aged ≥ 65 (40). More than two million persons live in the central region of Pennsylvania, of which more than 20% are over 60 years old. Since older adults tend to change location infrequently (41), Pennsylvania offers a special opportunity for longitudinal follow-up of an aging cohort.

The Geisinger Rural Aging Study (GRAS) began in 1994 with more than 20,000 adults aged ≥ 65 years of age enrolled in a Medicare-managed Health Maintenance Organization (HMO). The primary aim of this United States Department of Agriculture (USDA) funded study was to evaluate nutritional risk in relation to health outcomes in older adults. The Geisinger Healthcare System (Danville, Pennsylvania), provides services to a large rural population, with a population density of 14-217 individuals/mile² (20). In addition to the metabolic and physiologic changes of aging that affect nutritional status, rural older adults face additional nutritional concerns including but not limited to social isolation, financial restraints, and mobility and transport issues (42).

Despite the rapid increase in number of older adults and the health concerns that accompany aging, the associations between diet quality and BMI with health-related quality of life, healthcare resource use, and all-cause mortality have received little
investigation. The GRAS provides a well-characterized cohort of older adults (≥ 74 years) in which to examine these associations.

Three primary objectives were examined for partial fulfillment of this dissertation research.

Objective 1: To determine factors that impact diet quality.

Objective 2: To assess associations between diet quality and BMI with health-related quality of life.

Objective 3: To examine the associations between diet quality and BMI with objective health outcome measures including healthcare resource use and all-cause mortality.

More than 20,000 individuals aged ≥ 65 years old were originally enrolled in the GRAS in a rolling fashion from 1994-1999. For the present dissertation investigations, demographic and dietary questionnaires were sent to the remaining 5,993 participants in the fall of 2009. A total of 4,009 participants returned all questionnaires completed in their entirety. This is the cohort analyzed for Chapters 3 and 4 of this dissertation regarding factors impacting diet quality and associations between diet quality, BMI and HRQOL. For chapters 5 and 6, electronic medical records were accessed to obtain healthcare resource use, medical and mortality data. For this phase of the analysis participants were required to be enrolled in the Geisinger Health Plan for at least part of the 37 month follow-up period. This requirement excluded an additional 1,014 participants leaving 2,995 individuals ≥ 74 years of age with complete available information for analysis pertaining to healthcare resource use and all-cause mortality.
Data regarding diet quality was obtained using the Dietary Screening Tool (DST) (Appendix A). This tool is validated for use in determining diet quality in older adults, and was originally developed using the GRAS cohort (32). HRQOL was assessed using the Health and Activity Limitation Index (HALex) (43) with scores derived from self-reported functional limitation and self-rated health (Appendix B). Healthcare resource use and obesity-related co-morbidity data were extracted from electronic medical records. BMI was calculated from self-reported height and weight at baseline assessment in 2009. BMI was assessed per NIH guidelines (44) with BMI < 18.5 considered low, 18.5-24.9 normal, 25-29.9 overweight, 30-34.9 obese class I, 35-39.9 obesity class II and a BMI ≥40 obesity class III. The BMI group of 18.5-24.9 served as the referent group for all analyses. Finally, deaths were identified using electronic medical records and Social Security Death Index data. The last date of data extraction for the present analysis was February 25, 2013.

**DISSERTATION CONTENT AND FORMAT**

This dissertation begins with a review of the literature examining associations between BMI and diet quality with HRQOL, healthcare resource use and all-cause mortality (Chapter 2). This chapter also contains a review of the literature pertaining to the associations between diet quality and all-cause mortality in adults aged ≥ 65 years old, which has previously been published in the Journal of Nutrition in Gerontology and Geriatrics. Chapters 3 and 4 discuss the findings related to objectives 1 and 2 respectively. The work presented in Chapter 3 has been published by Public Health Nutrition, while the content in Chapter 4 has been accepted by The Journal of Nutrition
Health & Aging. Chapters 5 and 6 address objective 3, first discussing the associations between the predictors of interest (BMI and DST) and healthcare resource use outcomes (Chapter 5), and then these same predictors along with HRQOL, and the outcome of all-cause mortality (Chapter 6). The content present in Chapter 5 has been submitted to the Journal of the Academy of Nutrition and Dietetics and that in Chapter 6 to the Journal of Nutrition in Gerontology and Geriatrics.
Figure 1-1: Diagram of eligibility of GRAS participants for inclusion in analyses

Participants surviving at time of rescreening in fall of 2009
N = 5,993

Did not return questionnaires or returned incomplete questionnaires
N = 1,984

Participants with complete screening data for analyses in chapters 3 and 4
N = 4,009

Did not have any participation in Geisinger Health Plan during follow-up
N = 1,014

Participants with complete questionnaire data and health plan information for chapters 5 and 6
N = 2,995
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Chapter 2

REVIEW OF THE LITERATURE
This section of the dissertation presents a review of the literature regarding associations between BMI and diet quality with HRQOL, healthcare resource use, and all-cause mortality.

**BMI AND DIET QUALITY: ASSOCIATIONS WITH HEALTH RELATED QUALITY OF LIFE, HEALTHCARE RESOURCE USE and ALL-CAUSE MORTALITY**

**Introduction**

Adults aged 80 years of age and greater make up the fastest growing segment of the population (1). Obesity remains a global public health crisis from which the oldest old are not exempt, with over 27% of adults aged greater than 75 years considered obese (2). In young and middle-aged adults, obesity is associated with increased risk of chronic diseases (3, 4), healthcare resource use (5-7), and all-cause mortality (8, 9). However, the risks and complications of overweight and obesity are less clear in older adults than in younger cohorts (10). High quality diets have also been associated with reductions in chronic disease (11-13) and all-cause mortality (14, 15) in younger cohorts. The impact of diet quality on health outcomes in older adults has not yet reached consensus (16). BMI and diet quality are two potentially modifiable factors that may strongly influence health outcomes and so warrant further assessment.

These factors are of particular interest in older adults due to the changes in body composition and function that place older persons at nutritional risk. With aging there is a decline in skeletal muscle mass and an increase in total and intra-abdominal body fat.
These changes occur in normal healthy aging, decreasing the number of calories required to maintain body weight (18). Though energy requirements decrease, protein requirements may increase and many micronutrient requirements remain stable or increase, such that nutrient dense meals are desirable to meet recommendations without exceeding calorie requirements (17, 19). Oral health problems, reduced gastrointestinal motility, altered taste and smell, decreased thirst perception, and chronic diseases increase risk of nutrient insufficiency in older adults (20). Finally, social determinants change with increasing age, and financial limitations, social isolation, immobility, widowhood, and depression all pose additional obstacles for aging adults (20, 21). It is therefore a priority to better understand the roles of BMI and diet quality in health outcomes in this vulnerable population to better inform recommendations.

**Body Mass Index and Health Related Quality of Life**

HRQOL is a key indicator of individual well-being that goes beyond objective health measures and considers the impact of health on overall quality of life. There is currently a strong interest in assessing HRQOL, and evaluating and monitoring HRQOL is a goal of Healthy People 2020 (22). In an aging population where chronic conditions are quite prevalent, assessment of HRQOL is of special significance. Traditional measures of health improvement are often objective and difficult to alter in the oldest old (23). Biomedical diagnosis and treatment may not fully benefit aging adults with multiple co-morbidities, and may negatively impact quality of life (24). This subjective measure may be more a more meaningful measure of general health within this population.

HRQOL has been associated with all-cause mortality among older adults. Higher levels of HRQOL assessed by Physical and Mental Component Scores (PCS and MCS)
were associated with decreased 3-year mortality rates (25) in community-dwelling adults aged 65 and older. Otero-Rodriguez and colleagues (26) used the same component summary scores in a non-institutionalized Spanish cohort aged 60 and greater, and found that decreases in HRQOL component scores were strongly associated with increased risk of all-cause mortality, particularly for physical component scores (26). These findings indicate the importance of attaining and maintaining positive health related quality of life in old age. Modifiable factors that contribute to declining HRQOL offer potential opportunities to increase quality years of living in individuals who may no longer benefit from biomedical treatments for their conditions (24).

Associations between BMI and HRQOL have been found, but data focused upon older adults is limited. In studies examining populations with wide age ranges, underweight, overweight and obesity have all been associated with lower HRQOL (27-30). However, these associations may be altered with increasing age. Since the association between elevated BMI and adverse health outcomes may be attenuated at advanced age, it is probable that the BMI range at which the greatest HRQOL is found may also be altered. Because of the associations between BMI and co-morbid conditions, working towards improvements in HRQOL may help improve patient interpretation of conditions present and thus maximize quality adjusted life expectancy (24). In order to improve quality years of living, it will be helpful to determine the BMI range that is associated with the greatest HRQOL in older adults.
Body Mass Index and Healthcare Resource Use

A recent systematic review examining associations between BMI and medical costs found that across multiple age and population groups, obesity created a significant healthcare cost burden (31). Depending on the source of the data, it is estimated that overweight and obesity incur direct medical costs that comprise approximately 5% to 10% of all United States health care expenditures (32). Evidence supporting this relationship is strong in middle-aged adults, but in older adults the associations are not as well studied and findings have differed from those found in younger cohorts (5, 7, 33).

In a sample of adults aged 18 years and older, Wee et al. (7) found that excess healthcare expenditures were strongly associated with overweight and obesity, and that overweight and obesity increased the risk for expenditures in all categories examined (inpatient, outpatient hospital, prescriptions, office visits and emergency room visits). The increase in HRU with increased BMI was strongest for individuals aged ≥ 55 years old (7). This sample included older adults, but it was not further broken down by age subgroups for analysis. Similarly, Raebel and colleagues (5) found that obesity was associated with the greater use of prescription medications, higher prescription drug costs, and hospitalization and overall health care costs than non-obese individuals matched for age, sex, primary outpatient medical office and absence of selected diseases. The age range for this study was 21-84 years, and while age was used as a covariate, HRU outcomes were not assessed by age groups (5). In another analysis of individuals aged 50-69 years, obesity was associated with increased outpatient service use and with using 2 or more prescription medications, but did not affect risk for physician visits or inpatient services (6). Increased use of outpatient services and prescription medications
among persons with obesity likely reflects the presence and management of co-morbid conditions.

Cai et al (34) examined the association of BMI at age 45 with Medicare costs and survival at age 65. Individuals who were obese at baseline had a decreased chance of survival to age 65, and if they did survive, had significantly higher lifetime Medicare costs (34). However, those who were and remained overweight at both time points were not statistically different in terms of survival or healthcare costs over time than those who were and remained at a desirable weight (34). This likely indicates the significance of weight over time, and attaining a healthy weight earlier in life may have a greater impact on healthcare outcomes than later in life. In a study by Wildenschild and colleagues (35), obesity was associated with greater healthcare use over time, but only in the 45-64 year old age group. Results were not significant in those > 65 years of age. Finally, Quesenberry et al. (33) reported increases in inpatient, outpatient and total costs with obesity compared to healthy weight, but results were no longer significant in those aged ≥ 75 years of age. Onwudiwe (36) and Quesenberry (33) found that in adults aged greater than 65 and 75 years respectively, risk for inpatient days and overall medical expenditures were lowest in those who were overweight to mildly obese.

In summary, obesity in younger adults is associated with increased healthcare use and costs over short and long term follow-up. This relationship in individuals aged at least 65 years of age and especially 75 years and older remains unclear. While high levels of obesity may infer risk of healthcare use, it appears that being overweight or mildly obese in an aged population may actually decrease healthcare costs. Though actual healthcare use may increase due to a higher prevalence of chronic disease which may
warrant more medications and frequent outpatient visits, these visits are less costly than inpatient hospital or emergency room visits. These observations may help to explain the variations in findings when looking at cost versus use, and a better understanding of these relationships is warranted.

**Body Mass Index and All-Cause Mortality**

The association between BMI and all-cause mortality has been well characterized in young and middle-aged adults. The lowest all-cause mortality risk for young and middle-aged adults is among those with a healthy BMI (18.5-24.9), while underweight, overweight and obesity all increase risk of mortality (37). The association is less clear in aging individuals, and the BMI range associated with the most positive health and all-cause mortality outcomes remains a controversial topic (10). For older adults, research has consistently shown that a BMI < 18.5 is strongly associated with increased risk of all-cause mortality (38-43). Additionally, non-volitional weight loss in old age is associated with increased all-cause mortality, regardless of initial BMI (44).

There is a growing body of evidence that the ideal BMI for older adults is higher than that recommended for younger adults. In both age groups, a U-shaped curve represents the association between BMI and all-cause mortality, but in older adults the association weakens with increasing BMI (38). Additionally, the nadir of the curve has been consistently higher for older adults than that found in younger cohorts, regularly falling into the overweight range (38, 45).

A recent systematic review and meta-analysis by Flegal et al. (10) assessed studies including all age groups and both sexes, and found that overweight was associated
with decreased all-cause mortality, and grade I obesity was not associated with increased rates of all-cause mortality. It was not until obesity reached levels II and III that risk for all-cause mortality increased. In the sub-set of the sample aged \( \geq 65 \) years, overweight continued to be associated with reduced all-cause mortality, while obesity at all levels did not significantly associate with all-cause mortality (10). Similarly, in a sample of adults aged 80 years and greater, overweight status was associated with decreased risk of all-cause mortality compared to those individuals of normal weight (40). Corrada et al. (44) found that obesity was associated with increased all-cause mortality, but only in adults aged \(< 75\) years of age. Donini et al. (45) conducted a systematic review and determined that while obesity was associated with increased risk of mortality, there was no association between overweight and all-cause mortality. Sample selection is likely a factor in these studies, since older overweight and obese persons are by definition a selected cohort of survivors. It is also possible that overweight and obese individuals who survive to old age are less susceptible to the negative consequences of obesity and that survival during illness or injury may be improved with the metabolic reserve associated with higher BMIs in advanced age (46-48).

Based upon currently available reports it is not possible to make desirable BMI range recommendations for older persons, so further investigation is clearly indicated.

**Diet Quality and Health Related Quality of Life**

There are numerous diet-related changes associated with aging that affect quality of life, including but not limited to deteriorating sense of taste and smell, poor dentition and changes in gastrointestinal functioning (23). Independently, or spurred by the age-
associated changes in functioning, a decline in diet quality may decrease appetite and quality of life and contribute to morbidity and all-cause mortality. Diet quality is a measure of how well dietary intake meets dietary guidelines in terms of adequacy, moderation and variety (49). Diet quality is primarily determined using food consumption data assessed by 24 hour recalls, food records or food frequency questionnaires (FFQs). Assessment of diet quality includes both a priori methods, comparing intake to pre-determined standards, and a posteriori methods, which empirically derive patterns from existing data.

High levels of diet quality in older persons offer potential to improve HRQOL (23). It is difficult to ascertain the directionality of the relationship between HRQOL and diet quality. However, there is evidence that in some cases poor diet quality may precede poor HRQOL (50). A recently published paper by Ruano et al. (51) examined the association between dietary patterns at baseline assessment with HRQOL measured four years later by the Short-Form 36 in a middle-aged Spanish cohort. Factor analysis was used to derive two patterns at baseline; a Western Dietary Pattern and Mediterranean Dietary Pattern (51). While the Western Dietary Pattern was associated with lower HRQOL outcomes at follow-up, those following the Mediterranean Dietary Pattern had higher HRQOL scores (51). Variation in perceived quality of life is likely greater in older adults than in the middle-aged cohort analyzed, so diet may have an even greater impact on HRQOL over longer time periods and in older adults.

Diet quality is likely to have a role in HRQOL outcomes, but the association in older adults has been understudied. Diet quality impacts HRQOL in more than one way. Not only will a high quality diet reduce risk of nutrient deficiencies and attenuate
development and progression of diet-associated chronic diseases, but it also provides sensory and psychological pleasure that may improve overall sense of well-being (23). It is therefore important to understand the role of diet quality in HRQOL in older adults to promote not only improved biological outcomes, but subjective measures of health as well.

**Diet Quality and Healthcare Resource Use**

High quality diets have been associated with decreased development of chronic diseases in younger cohorts, and with lower rates of all-cause mortality (16, 52, 53). Fruits and vegetables in particular have been found to decrease the risk of cardiovascular disease, certain cancers and type II diabetes, and have been associated with a healthier weight (11, 54). Though older adults report consuming a greater quantity of fruits and vegetables than younger adults, the majority still do not meet current dietary recommendations (55).

Despite the strong associations between BMI, chronic disease, all-cause mortality and diet quality, and the additional concerns regarding nutrient adequacy in the elderly (17, 20, 56), data concerning the associations between diet quality and healthcare resource use is limited across all age cohorts. Only two studies specifically examining the associations between diet quality and healthcare resource use were found, with both focusing on middle-aged adults. Collins et al. (57) analyzed dietary intake using the Dietary Questionnaire for Epidemiological Studies (DQES) in a longitudinal cohort of women aged 45-50 years. Usual consumption of 74 foods and six alcoholic beverages over the preceding 12 months was used to calculate an individual score based upon the
Australian Recommended Food Score (ARFS) (57). High ARFS scores indicate adherence to the Dietary Guidelines for Australian Adults. Medicare data for five years of follow-up were available, including both annual health care claims and Medicare expenditures (57). Overall higher (more favorable) ARFS scores were associated with higher total Medicare charges, but with a reduced number of health care claims (57). When sub-groups of the ARFS were examined, only one subgroup demonstrated an association in the expected direction. Low vegetable intake was associated with a trend toward higher Medicare charges (57). In the second identified study, dietary intake was assessed using the comprehensive diet history method in a cohort of men aged 40-56 years at baseline (58). Medicare fee-for service claims data were then collected for participants aged 65 years and greater and mean annual and cumulative charges were assessed for up to 16 years of follow-up (58). Overall, Daviglus and colleagues (58) found that there was an inverse and graded association between consumption of fruits and vegetables in mid-life with health care costs in subsequent older age.

These studies provide mixed results, and no additional analyses relating dietary intake to healthcare resource use have been found. It is necessary to expand upon these relationships found in younger cohorts to better understand the associations in older adults, and to identify whether fruit and vegetable intake remains beneficial in terms of clinical outcomes in the aged.
ASSOCIATION BETWEEN DIETARY QUALITY AND MORTALITY IN OLDER ADULTS: A REVIEW OF THE EPIDEMIOLOGICAL EVIDENCE

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

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Results

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Dietary Assessment Methods and Considerations in Older Adults

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Take Away Point
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Review

Association Between Dietary Quality and Mortality in Older Adults: A Review of the Epidemiological Evidence

DARA WHEELER FORD, RD, GORDON L. JENSEN, MD, PhD, TERRYL J. HARTMAN, PhD, MPH, RD, LINDA WRAY, PhD, and HELEN SMICIKLAS-WRIGHT, PhD

Department of Nutritional Science, The Pennsylvania State University, University Park, Pennsylvania, USA

The population is aging worldwide. Delayed mortality is associated with an increased burden of chronic health conditions, many of which have a dietary component. A literature search was conducted to retrieve and review relevant articles considering quality of diets in association with mortality in older adults aged 60 years and older. In the studies we reviewed, diet quality defined using either a priori methods, which characterize dietary patterns based on existing dietary guidelines, or a posteriori methods, which define dietary patterns through statistical methods met review criteria. Sixteen articles met criteria for review. Generally, dietary patterns that demonstrated greater adherence to diets that emphasized whole fruits and vegetables, whole grains, low-fat dairy, lean meats, and legumes and nuts were inversely associated with mortality. However, a priori methods have not yet demonstrated associations between diet and mortality in older adults in the United States. Development of new methods based on regional variations in dietary intake may offer the best approach to assess associations with mortality.

KEYWORDS aging, diet index, diet quality, diet score, dietary patterns, food patterns, health, mortality, older adults

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INTRODUCTION

With life expectancy trending upward, the population is aging worldwide (1). In the United States, the number of persons 65 years and older is expected to double, and the number of persons 80 years and older is expected to triple by 2030 (2). A number of factors may affect length of life. Males continue to have shorter life expectancies than females (3). Unmarried individuals have a higher relative risk of mortality than do married individuals in all age groups, but most strongly in the 45–64 year age group (4). Race, education, and socioeconomic status also contribute to differences in health status and, in turn, to life expectancy (5). Delayed mortality is associated with increased burden of chronic conditions such as type 2 diabetes mellitus, hypertension, heart disease, arthritis, and some cancers. These chronic conditions are in turn associated with decreased quality of life, so that increased years of life are often not quality years (6, 7). Heart disease, cancer, and stroke are the leading causes of death for older adults, and diet is known to be a contributing factor in these chronic diseases of aging (8, 9). The purpose of this review is to examine the association between diet quality and mortality in older adults. Since poor diet quality has been related to adverse health outcomes, it is reasonable to consider that it might also be associated with mortality.

Diet Quality

Diet quality is a measure of how closely intake matches dietary guidelines in terms of balance, variety, and moderation (10, 11), and is determined by food consumption data assessed primarily by 24-hour recalls, food records, and food frequency questionnaires (FFQs). Analyses of diet quality include both a priori and a posteriori methods of assessment. A priori methods determine the quality of the diet based on predetermined recommendations or dietary guidelines (12). The various a priori methods reflect recommendations that differ based on geographic location and regional variations in diet. These scores have been based on specific foods, food groups, and/or nutrient consumption reflecting adequacy of diet based on recommendations. A priori methods allow for calculation of a single score generated from different predetermined components. By determining individual scores based on a predetermined scale, an individual can be placed into a risk category or can be ranked in a sample (13). Examples of such diet quality scores include the Mediterranean Diet Score (MDS), the Recommended Food Score (RFS), and the Healthy Eating Index (HEI) (14–17).

A posteriori methods use available dietary data to empirically derive patterns through exploratory statistical methods such as cluster analysis or factor analysis, the latter of which encompasses both common factor analysis and principal component analysis (PCA) (18). These methods examine patterns
of intake and account for the intercorrelation of nutrients and interactions of foods within a diet (19). Factor analysis seeks to reduce the number of explanatory variables into factors that capture the primary sources of dietary variation (20). Cluster analysis is subject oriented and groups subjects based on similar dietary patterns into mutually exclusive clusters (19). Both a priori and a posteriori methods have shown that diet quality may be related to health outcomes in older adults.

METHODS

Search Strategy and Selection Criteria

A literature search of the Pub Med database of the United States National Library of Medicine was conducted to identify prospective human cohort studies of diet quality and mortality in noninstitutionalized adults aged 60 years and older. For study inclusion, dietary quality was defined a priori or a posteriori and was assessed through 24-hour recalls, validated FFQs, diet history methods, or weighed food records. The following keywords were used to identify relevant studies for review: diet quality, dietary patterns, food patterns, eating patterns, diet score, diet index, disease, mortality, health, aging, elderly, geriatrics, and older adults. The search was limited to include only English language studies published through April 2012. Selected study citations were also examined for relevant articles. A total of 16 relevant studies were selected for this review with follow-up periods ranging from 4 to 14 years. Nine characterized diet using a priori methods, and seven used a posteriori methods.

RESULTS

A Priori

Table 1 highlights the characteristics of the nine a priori studies. Seven of these scored diet quality using the MDS or a modified version of the MDS (m-MDS), either independently or in combination with other tools (12, 14, 17, 18, 21–23). The original MDS consisted of eight components based on common constituents of a Mediterranean diet pattern, which are classified as beneficial (high vegetable, legume, fruit and nut, and cereal intake) and detrimental (high meat/meat product and dairy intake), with two additional components scored for alcohol intake and monounsaturated: saturated fat ratio (14). The Mediterranean diet, as a pattern of eating and not a specific diet, is utilized as the foundation for scoring due to its association with reduced risk for chronic diseases (24). Dietary components considered beneficial were given a score of 1 if intake was above the sex-specific median for the population sampled, and 0 if intake was below this median (25). Alcohol
<table>
<thead>
<tr>
<th>Author, year (reference)</th>
<th>Study population N</th>
<th>Follow-up Age/sex</th>
<th>Dietary assessment</th>
<th>1. Diet quality tool 2. Scoring cut points</th>
<th>Covariates</th>
<th>Main results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trichopoulou A et al. 1995 (14)</td>
<td>Greek village residents N = 182</td>
<td>5 y 70+ y M,F</td>
<td>FFQ</td>
<td>1. MDS 2. Sex-specific medians</td>
<td>Age at enrollment, sex, current smoking status</td>
<td>↑ composite score associated with ↓ mortality</td>
</tr>
<tr>
<td>Osler M and Schroll M. 1997 (21)</td>
<td>SENECA; Denmark N = 202</td>
<td>6 y 70+ y M,F</td>
<td>Diet history</td>
<td>1. m-MDS 2. Sex-specific medians</td>
<td>Age at enrollment, sex, smoking status</td>
<td>Composite score ≥4 associated with ↓ mortality</td>
</tr>
<tr>
<td>Knoops KTB et al. 2004 (12)</td>
<td>HALE comprised of SENECA and FINE; Europe N = 2,239</td>
<td>10 y 70-90 y M,F</td>
<td>Diet history</td>
<td>1. m-MDS 2. Sex-specific medians</td>
<td>Sex, age at enrollment, marital status, study population, education, region, center, occupation, BMI, waist circumference, use of antihypertensives</td>
<td>Composite score ≥4 associated with ↓ all-cause, CHD, CVD, and other cause mortality</td>
</tr>
<tr>
<td>Trichopoulou A et al. 2005 (23)</td>
<td>EPIC; Europe N = 74,607</td>
<td>7+ y 60+ y M,F</td>
<td>FFQ or 7 or 14 day food record</td>
<td>1. m-MDS 2. Sex-specific medians</td>
<td>Sex, age, education, smoking status, physical activity, W:H ratio, BMI, total energy intake, DM at enrollment</td>
<td>↑ composite score associated with ↓ mortality</td>
</tr>
<tr>
<td>Haveman-Nies A et al. 2002 (22)</td>
<td>SENECA; Europe N = 1,281</td>
<td>10 y 70-75 y M,F</td>
<td>Diet history</td>
<td>1. m-MDS 2. Sex-specific medians</td>
<td>Stratified by country/center</td>
<td>↑ # of unhealthy lifestyle behaviors related to higher mortality rate. Risk for mortality with low-quality diet by sex was not significant. May be additive with other lifestyle factors.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Setting</td>
<td>Population</td>
<td>Exposure</td>
<td>Outcome Measures</td>
<td>Controls</td>
</tr>
<tr>
<td>--------------------------------------------</td>
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</tr>
<tr>
<td>Knoops KTB et al. 2006 (18)</td>
<td>HALE comprised of SENECA and FINE; Europe N = 3,117</td>
<td>10 y 70-90 y MF</td>
<td>Diet history</td>
<td>1. m-MDS, MAI, HDI 2. m-MDS: sex-specific medians MAI: Index computed by dividing sum of Mediterranean food groups by sum of non-Mediterranean food groups. HDI: 1 point for meeting guidelines, 0 otherwise</td>
<td>Sex, age, smoking, education, study center, physical activity, BMI, baseline chronic disease</td>
<td>Combined population: ↑ in score on all tools associated with ↓ risk of mortality. N &amp; S Europe: MDS significant inverse relationship for both, MAI significant inverse relationship for N Europe, HDI no significance</td>
</tr>
<tr>
<td>McNaughton SA et al. 2012 (17)</td>
<td>British Diet and Nutrition Survey; Britain N = 972</td>
<td>14 y 65+ y M,F</td>
<td>4-day weighed food record</td>
<td>1. m-MDS, HDS, RFS 2. HDS: components scored on meeting dietary recommendations m-MDS: sex-specific medians RFS: Meeting g amount of recommended intake</td>
<td>Age, gender, education, study center, smoking status, alcohol consumption, physical activity, BMI, chronic disease at baseline</td>
<td>↑ MDS associated with ↓ mortality ↑ RFS associated with ↓ mortality No association for HDS</td>
</tr>
<tr>
<td>Shahar DR et al. 2009 (16)</td>
<td>HEALTH ABC; United States N = 298</td>
<td>9 y 70-83 y MF</td>
<td>FFQ</td>
<td>1. HEI 2. HEI Scale of 100</td>
<td>Age at enrollment, Region, health status(chronic diseases, self-perceived health, albumin level)</td>
<td>No association between HEI and mortality</td>
</tr>
<tr>
<td>Lee M-S et al. 2011 (27)</td>
<td>Elderly Nutrition and Healthy Survey in Taiwan N = 1,743</td>
<td>10 y 65+ y M,F</td>
<td>24 HR FFQ</td>
<td>1. DDS ODI-R 2. ODI-R—100 points for age/sex-specific serving sizes of food groups DDS—range 1–5 derived from servings</td>
<td>Demographic characteristics, weight, energy intake, self-reported health, cognitive function</td>
<td>ODI-R ≥ 60 significantly ↓ risk for all-cause mortality than ≤50 DDS of 4, 5, or 6 significantly ↓ risk for all-cause mortality than ≤3</td>
</tr>
</tbody>
</table>

Note. Abbreviations are as follows: MDS, Mediterranean Diet Score; PCS, Prospective Cohort Study; FFQ, Food Frequency Questionnaire; SENECA, Survey in Europe on Nutrition and the Elderly; m-MDS, modified Mediterranean Diet Score; 3-d, 3 day; HALE, The Healthy Ageing, a Longitudinal study in Europe; FINE, Finland, Italy, the Netherlands, Elderly Studies; CHD, coronary heart disease; CVD, cardiovascular disease; HALE, The Healthy Ageing, a Longitudinal study in Europe; FINE, Finland, Italy, the Netherlands, Elderly Studies; BMI, body mass index; EPIC, European Prospective Investigation into Cancer and Nutrition Study; DM, Diabetes Mellitus; W/H, waist: hip ratio; HEALTH ABC, Health, Aging, and Body Composition Study; HEI, Healthy Eating Index; MAI, Mediterranean Adequacy Index; HDI, Healthy Diet Indicator; DDS, Diet Diversity Score; ODI-R, Overall Dietary Index–Revised; HDS, Healthy Diet Score; RFS, Recommended Food Score.
was assessed with 1 point given for men consuming 10–50 g, and women consuming 5–25 g of ethanol daily (unless otherwise specified), giving a total possible score of eight (14, 25). Findings with the MDS and m-MDS suggest that greater adherence to a Mediterranean diet is inversely associated with mortality in older adults.

Trichopoulou and colleagues (14) studied 182 Greek village residents and determined from the original MDS that a one unit increase in overall score was significantly inversely associated with mortality (Hazard ratio [HR]: 0.83, 95% Confidence Interval [95% CI]: 0.69, 0.99). When examining individual components, only dairy intake was independently and with borderline significance positively associated with mortality; with increased consumption, the hazard of death was increased (HR: 1.04, 95% CI: 1.01, 1.07). This association is likely due to consumption of dairy in the Greek population consisting primarily of cheese and yogurt, typically high in fat (25). These findings indicate that composite scoring may be more informative than individual dietary components. Subsequent studies using the MDS vary based on modification of the MDS and also expanded beyond the Mediterranean region for investigation.

Although initially it was proposed that this tool would be useful only in a Greek population, several studies have shown significant inverse associations with mortality in other older populations. In a Danish population, Osler and colleagues (21) used a m-MDS with a total possible score of seven by combining vegetable and legume categories and found that a one unit increase in score was associated with a reduced rate of death through six years of follow-up (RR: 0.79, 95% CI: 0.64, 0.98). Trichopoulou and associates (23) expanded on the findings of applicability beyond the Mediterranean region, assessing the m-MDS by replacing monounsaturated fat: saturated fat ratio with a monounsaturated + polyunsaturated fat: saturated fat ratio. This was done to better represent the diet in the nine European countries of study (23). Findings showed that a two unit increase in m-MDS was associated with a significant 8% overall reduction in mortality. Knoops and colleagues (12) found similar outcomes in the HALE project across 11 European countries. Excluding the alcohol component and designating those scoring at least four out of eight on the m-MDS as low risk, Mediterranean diet adherence was associated with decreased risk of all-cause mortality (HR: 0.77, 95% CI: 0.68, 0.88), coronary heart disease mortality (HR: 0.61, 95% CI: 0.43, 0.88), cardiovascular disease mortality (HR: 0.71, 95% CI: 0.58, 0.88), and other causes of death (HR: 0.61, 95% CI: 0.44, 0.85) (12). Finally, Haveman-Nies and colleagues (22) assessed the contribution of the m-MDS independently and in combination with physical activity and smoking, with mortality. For this study, the m-MDS was modified by replacing “legumes” with “legumes/nuts/seeds” and combining fruits and vegetables into one category. Additionally, dairy consumption was considered optimal if between the 25th and 75th percentiles of intake. In this model, diet did
not independently associate with decreased mortality, but the combination of all three healthy lifestyle factors was more strongly related to survival than any one factor alone (22). While diet alone did not infer altered risk, it is likely that those participants who exercised and never smoked also had other healthy lifestyle habits. Overall, these studies suggest an association between improved adherence to a Mediterranean diet and decreased mortality.

Shahar and colleagues examined the association between diet quality and mortality in a U.S. sample (n = 298) of older adults using the HEI (16). This tool is based on the 1992 Dietary Guidelines for Americans with an increased score (on a scale of 0 to 100) indicating greater adherence to sex- and age-specific recommendations for grains, fruits, vegetables, dairy and meat, percentage energy from total fat, percentage energy from saturated fat, cholesterol intake, total sodium intake, and dietary variety (26). In this sample, the total score from the HEI was not associated with mortality in older American adults. Subscales of the HEI were not analyzed. The lack of association between diet quality measured by the HEI with mortality may be due to insufficient variation in scoring due to homogeneity of diet in the sample. The use of a FFQ also limited the ability to accurately represent nutrient intake as required by the HEI. Additionally, unlike the HEI-2005, this original tool did not account for trans fats, monounsaturated fats, omega-3 fatty acids, nuts, whole grains independently of refined grains, or legumes independently of meat and so may not have been precise enough to capture a healthy diet. Finally, Shahar and colleagues (16) controlled for appetite, depression, cognitive status, and eating difficulties in this study; many of the other reviewed articles did not take these factors into consideration. The importance of these covariates may have contributed to attenuation of significant findings.

In addition to those studies that examined outcomes in association with one diet quality assessment tool, three articles examined at least two tools in the same study sample. Lee and associates (27) used the Overall Dietary Index-Revised (ODI-R), based on dietary guidelines for the Taiwanese population with a score range of 0 to 100, and the Dietary Diversity Score (DDS), which counts food groups and is scored 1–6, to score diet quality in older Taiwanese adults. Assessment was conducted via three 24-hour recalls, employing the recommended assessment method for comparing nutrient intakes with dietary recommendations (28). After adjustment for age, compared to those with a low score (<50), individuals who scored higher (60–65, 65–70, or >70) on the ODI-R had lower risk of death (HR: 0.51, 95% CI: 0.34, 0.76; HR: 0.58, 95% CI: 0.41, 0.82; and HR: 0.39, 95% CI: 0.28, 0.53, respectively) (27). Findings were similar with the DDS. In addition to all-cause mortality, risk of death from cancer decreased in the highest category of ODI-R (HR: 0.48, 95% CI: 0.25, 0.93), while risk of death from diabetes also decreased with highest DDS score (HR: 0.31, 95% CI: 0.07, 1.36) (27). No association was found for cardiovascular mortality. The
rigorous method of dietary assessment using three 24-hour recalls may thus be required to translate dietary assessment tools evaluating adherence to dietary guidelines into meaningful measures.

Knoops and colleagues (18) utilized three different tools to score diet quality in a European population based on assessment from a modified diet history; the m-MDS, the Mediterranean Adequacy Index (MAI) and the HDI. The MAI creates a score by dividing the sum of “Mediterranean food groups” by “non-Mediterranean food groups,” while the HDI is calculated based on predetermined scores reflecting the dietary guidelines of the World Health Organization for prevention of chronic disease (18). HDI components include percent of energy from saturated fats, protein, and complex carbohydrates, among others. The scores of all three tools were significantly inversely associated with mortality when looking at the entire population including both Southern and Northern European sites (18). However, emphasizing regional distinctions in dietary intake, variations in strength and significance of association between tools were found by region, with only the m-MDS significantly relating to mortality in both regions independently. In this study, the tool reflecting dietary guidelines (HDI) was not associated as strongly with mortality as the two that were based on food patterns. Finally, McNaughton and associates (17) examined the m-MDS, RFS, and the Healthy Diet Score (HDS) in relation to mortality with diet assessed via a four-day diet record. The RFS is based on frequency of consumption of foods considered healthy by U.S. Dietary Guidelines for Americans, while the HDS is a British adaptation of the HDI, which is based on World Health Organization recommendations (17). The World Health Organization recommendations are more nutrient based than the Dietary Guidelines for Americans, and include components for saturated fats, polyunsaturated fatty acids, total carbohydrates, dietary fiber, fruits and vegetables, pulses and nuts, total non-milk extrinsic sugars (e.g., extrinsic sugars excluding lactose), cholesterol, fish, red meat and meat products, and calcium. For all three tools, participants were grouped by quartiles, and in this British population the m-MDS and RFS were inversely associated with mortality (HR: 0.77, 95% CI: 0.61, 0.97 and HR: 0.67, 95% CI: 0.52, 0.86, respectively) (17). No significant associations were found for the HDS; however, no score ranges or means were given for the quartiles, so the degree of variation in scoring between quartiles cannot be assessed. It is possible that the null results are due to insufficient variation in diet with too few people consuming a diet considered healthy. The HDI, which reflects nutrient recommendations from dietary guidelines, was not as strongly associated with mortality as m-MDS, RFS, MAI, and DDS, which are reflective of whole foods.

A Posteriori

Of the 16 studies reviewed, seven examined diet quality using a posteriori methods. Table 2 highlights those studies describing diet quality using a
Table 2: Characteristics of A Posteriori Studies Assessing Diet and Mortality

<table>
<thead>
<tr>
<th>Author, year (reference)</th>
<th>Study population</th>
<th>Follow up</th>
<th>Age/sex</th>
<th>Dietary assessment</th>
<th>Pattern methodology</th>
<th>Description of patterns</th>
<th>Covariates</th>
<th>Results</th>
</tr>
</thead>
</table>
| Diehr et al. 2003 (30)   | CHS; United States | 10 y      | 65+y    | M, F              | FFQ                  | Cluster analysis        |            | "Unhealthy" significantly ↓ YOL and ↓ YOHL compared to "Healthy"
|                          | N = 4,610        |           |         |                   |                      |                         |            | HiCal significantly ↓ YOL compared to "Healthy" |
|                          |                  |           |         |                   |                      |                         |            | "Healthy" |
| Anderson AL et al. 2011 (31) | Health ABC; United States | 10 y | 70-79 y | M, F | FFQ | Cluster analysis | (1) Healthy Foods: low-fat dairy, fruit, whole grains, poultry, fish and vegetables (2) High-Fat Dairy Products (3) Meat, Fried Foods and Alcohol: meat, fried poultry, liquor, rice, pasta and mixed dishes (4) Breakfast Cereal (5) Refined Grains: processed meat and refined grains (6) Sweets and Desserts | Sex, race, age, education, clinical site, physical activity, smoking and total energy intake | "Healthy Foods" significantly ↓ risk of mortality compared to "High-Fat Dairy Products" & "Sweets and Desserts" |

(Continued)
<table>
<thead>
<tr>
<th>Author, year (reference)</th>
<th>Study population</th>
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<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamer M et al. 2010 (33)</td>
<td>British Diet and Nutrition Survey; Britain N = 1,017</td>
<td>9 y</td>
<td>65-99 y M, F</td>
<td>4-day weighed food record</td>
<td>Exploratory factor analysis</td>
<td>(1) Mediterranean-Style: coffee, salad, raw vegetables, apples, pears, oily fish, nuts and seeds, wine, bananas, other fruit and fruit juice (2) Health-Aware: potatoes, carrots, leafy green vegetables, other vegetables, wholemeal bread, semi-skimmed milk, chicken and turkey (3) Traditional Pattern: white bread, beer, sugar, eggs, bacon, ham, pork dishes, other meat products (4) Sweet &amp; Fat: butter, whole milk, preserves, cream, buns, cakes, pastries, sponge type puddings, chocolate</td>
<td>Age, sex, education, smoking, physical activity, BMI, self-rated health, total energy intake, nutritional supplement use, mutual adjustment for all dietary patterns, medication use</td>
<td>Mediterranean-style significantly ( \downarrow ) risk of mortality. Stratified by age, Mediterranean-style more protective among younger participants (&lt;75). Gender stratified; Mediterranean-style only protective among women</td>
</tr>
</tbody>
</table>
Masala G. et al. 2007 (36) EPIC – Italian Arm N = 5,611

- 60-78 y M, F
- FFQ
- Exploratory factor analysis

1. Prudent: cooked vegetables, legumes, fish, seed oil
2. Pasta & Meat: pasta and other grains, tomato sauce, red and processed meats, added animal fat, white bread, wine
3. Olive Oil & Salad: olive oil, raw vegetables, soups and meat
4. Sweet & Dairy: added sugar, cakes, ice cream, coffee, eggs, butter, milk and cheese

Recruitment center, sex, age, smoking status, education, marital status, log-transformed caloric intake, BMI, waist circumference, physical activity hypertension at enrollment

Olive Oil & Salad significantly ↓ risk of all-cause mortality

Waijers PM et al. 2006 (37) Dutch EPIC – Elderly Cohort N = 5,427

- 60-69 y F
- FFQ
- Principal component analysis

1. Mediterranean-like Pattern: pasta and rice, sauces, fish vegetables with vegetable oils, wine, other cereals
2. Traditional Dutch Dinner Pattern: meat, potatoes, vegetables, eggs, alcoholic beverages
3. Healthy (variant of the) Traditional Dutch Diet: vegetables, fruit, dairy, potatoes, legumes, nonalcoholic beverages

Energy intake, age, smoking status, education, BMI, W:H ratio, physical activity at work, physical activity during leisure time, self-reported DM at enrollment

Healthy Traditional Pattern significantly associated with ↓ mortality rate. Women in highest tertile of this pattern had 30% ↓ risk of mortality compared to those in lowest tertile

(Continued)
TABLE 2  Continued

<table>
<thead>
<tr>
<th>Author, year (reference)</th>
<th>Study population</th>
<th>Follow up</th>
<th>Age/sex</th>
<th>Dietary assessment</th>
<th>Pattern methodology</th>
<th>Description of patterns</th>
<th>Covariates</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bamia C et al. 2007 (35)</td>
<td>Epic-Elderly; Europe</td>
<td>60+ y M,F</td>
<td>FFQ</td>
<td>Principal component analysis</td>
<td>Plant-Based: vegetables, legumes, fruit, pasta/rice/other grains, vegetable oil</td>
<td>Sex, age, education, smoking status, physical activity (occupation and leisure time) W:H ratio, BMI, total E intake stratified by country or by center, DM at enrollment</td>
<td>Negative trend overall and within most countries in proportion of deaths with increasing tertile of score</td>
<td></td>
</tr>
<tr>
<td>Hoffmann K et al. 2005 (38)</td>
<td>2 German Cohorts from EPIC</td>
<td>4–8 y M,F</td>
<td>FFQ</td>
<td>Principal component analysis and Reduced rank regression</td>
<td>PCA patterns (1) Typical German Lunch/Dinner (2) Prudent RRR patterns (1) Detrimental (2) Healthy</td>
<td>Sex, smoking status, education, BMI, W:H ratio, total E intake, physical activity at work and leisure, stratified by center, prevalent cancer, CHD, DM, hypertension</td>
<td>RRR “Detrimental” only significant predictor of mortality in fully adjusted models: high proportion of E from total fat and protein and low proportion of E from carbs was associated with ↑mortality risk</td>
<td></td>
</tr>
</tbody>
</table>

Note. Abbreviations are as follows: CHS, cardiovascular Health Study; PCS, Prospective Cohort Study; CVD, cardiovascular disease; YOL, years of life; YOHL, years of healthy life; hx, history; DM, diabetes mellitus; IADL, Instrumental Activities of Daily Living; BMI, body mass index; HTN, hypertension; EPIC, European Prospective Investigation into Cancer and Nutrition Study; HEALTH ABC, The Health Aging and Body Composition Study; PCA, Principle Component Analysis; W:H, waist to hip ratio; RRR, Reduced Rank Regression; MUFA, monounsatuated fatty acids; CHD, coronary heart disease.
posteriori methods. Two of these studies examined dietary patterns using cluster analysis; while the remaining studies explored patterns through factor analysis, with one study contrasting factor analysis with reduced rank regression (RRR). RRR combines data-driven and a priori methods by using prior knowledge to define response variables that are expected to relate to the health outcome of interest in the study (29). Both Diehr (30) and Anderson (31) used cluster analysis and reported that adherence to a healthier pattern was associated with improved mortality outcomes. Diehr and colleagues (30) had participants sort 99 food cards into five categories of intake frequency (a validated approach for administration of the National Cancer Institute food frequency questionnaire [32]) and from this derived relative intakes of fat, fiber, protein, carbohydrate, and calories. The association of diet with years of life (YOL) over 10 years of follow-up, and years of healthy life (YOHL), determined by self-reported health rating at yearly follow-up, were examined. Five dietary patterns were found using cluster analysis. Compared to individuals following a “Healthy” pattern, those following an “Unhealthy” pattern had a significant decrease in longevity and years of healthy life, while those in the “High Calorie” pattern had a decrease in longevity (Mean YOL: 8.85 and 8.23 P-Value < 0.05; Mean YOHL: 6.92 and 5.95 P-Value < 0.05; Mean YOL 8.85 and 8.30 P-Value < 0.05) (30). The “Low Calorie” and “Low Four” (low in fiber, carbohydrates, protein and calories, but high in fat) clusters were not significantly different from the “Healthy” cluster in association with YOL or YOHL. Anderson and colleagues (31) consolidated 108 FFQ items into 40 food groups to create six clusters. Those in the “Healthy Foods” cluster were found to have a significantly decreased risk of mortality compared to individuals in the “High-Fat Dairy Products” and “Sweets and Desserts” clusters (Relative Risk [RR]: 1.4, 95% CI: 1.04,1.99 and RR: 1.37, 95% CI: 1.02,1.88, respectively) (31). In fully adjusted models, the association of mortality with the “Meat, Fried Foods and Alcohol,” “Breakfast Cereal,” and “Refined Grains” clusters was not significantly different than the “Healthy Foods” cluster. Diehr (30) considered “Healthy” to be high in fiber and carbohydrates and low in fat, while Anderson and associates (31) considered “Healthy” to be high intakes of low-fat dairy, fruit, whole grains, poultry, fish, and vegetables with low intakes of meat, fried foods, sweets, high-energy drinks, and added fat.

Five studies utilized factor analysis to study the association between diet quality and mortality outcomes. Hamer and associates (33) assessed diet in Britain’s National Diet and Nutrition Survey through four-day food records, which were coded into 99 food groups for factor analysis. Four principal components were found to account for 9.8% of total variance. Results showed that the “Mediterranean-Style” of eating, comprised of higher intakes of raw fruits and vegetables, oily fish, and coffee and wine, was associated with a lower risk for mortality (33). Of note, when stratified by age this association was only significant in participants aged ≤75 y (n = 510) and
not in those >75 y (n = 507) (HR: 0.88, 95% CI: 0.51, 0.97 and HR: 0.88, 95% CI: 0.69, 1.14 respectively). The remaining four studies examined different subpopulations of the European Prospective Investigation into Cancer and Nutrition (EPIC), an ongoing multicenter prospective cohort study in 10 European countries (France, Germany, Greece, Italy, The Netherlands, Spain, United Kingdom, Sweden, Denmark, and Norway) (34). Bamia and colleagues (35) assessed the entire EPIC population older than 60 years and examined the principal component, which explained the greatest variance (14.6%). This was considered a “Plant-Based” pattern, and mortality was assessed by tertile of plant-based diet as well as by incremental relationships based on 1 standard deviation. Overall, a 1 standard deviation (SD) increase corresponded to a statistically significant 14% reduction in all-cause mortality (35). However, it warrants attention that tertile designation was made across the total distribution and individuals falling into each tertile varied greatly by country. Most individuals from Greece (>99%), Italy (97%), and Spain (97%) fell in the highest tertile of intake while very few from Sweden (1%) and Denmark (3%) matched that level of adherence (35).

Masala and colleagues (36) grouped 120 items from a FFQ into 55 food groups to create patterns through factor analysis. Using data from the Italian arm of EPIC, a total of four dietary patterns explaining 21% of variance were derived. Overall, the “Olive Oil & Salad” pattern, characterized by high consumption of olive oil, raw vegetables, soups, and poultry, was inversely associated with all-cause mortality, with the highest quartile showing the lowest risk of mortality (HR: 0.50, 95% CI: 0.29, 0.86). Although this pattern appears similar to the Mediterranean diet, the “Prudent” pattern characterized by cooked vegetables, legumes, fish, and seed oil is more similar to the traditional Mediterranean diet but did not have an association with mortality. However, this “Prudent” pattern was also characterized primarily by women with a high prevalence of chronic conditions that may have directed them toward such a diet, and so may have only recently begun following such a diet at the time of study. Waijers and colleagues (37) examined only women in a Dutch cohort of EPIC. In principal component analysis, the FFQ data from the cohort was summarized by 22 food groups. Three components explained 25% of total variance; “Mediterranean-Like,” “Traditional Dutch Dinner,” and “Healthy (variant of) Traditional Dutch Dinner” (37). Only the “Healthy Traditional Dutch Dinner” pattern, characterized by vegetables, fruit, dairy, potatoes, legumes, and nonalcoholic beverages, was associated with a decreased mortality rate, with women in the highest tertile having a 30% reduction in risk (37). Finally, Hoffman and associates (38) examined two German cohorts from EPIC, and used 23 food groups derived from an FFQ to analyze patterns through both PCA and RRR. The goal of this analysis was to determine if the flexibility of RRR, which accounted for percent energy contribution of macronutrients, was more strongly associated with mortality than PCA. The first two patterns with the highest factor loadings
were utilized for both PCA and RRR. The pattern derived from RRR, which indicated a high proportion of energy from total fat and protein and a low proportion of energy from carbohydrate, was the only pattern significantly and positively associated with mortality in adjusted models (RR: 1.2, 95% CI: 1.09, 1.31) (38).

DISCUSSION

Of the 16 studies selected for review, nine utilized a priori methods to score diet quality. Of these, five applied a version of the MDS only, one utilized the HEI, and three used a combination of scores for evaluation. Seven additional studies examined diet quality based on patterns assessed through a posteriori methods. All studies examined all-cause mortality as the primary outcome with several also examining specific cause of death (CHD, CVD, cancer, diabetes) (12, 27). Overall, a posteriori methods demonstrated that greater adherence to a healthier pattern of consumption was inversely associated with mortality. The results of the a priori studies were not as decisive. Although the m-MDS, DDS, MAI, and RFS are all food-based indices that had significant inverse associations with mortality, results were not significant for the HEI, HDS, and HDI in the United States, Britain, and Europe respectively. Unlike other methods, these methods include scoring of single nutrients as well as whole foods.

Limitations in Methods

The observed variations in association between diet and mortality may occur for several reasons. First, a priori and a posteriori methods are innately different. A priori methods consider dietary recommendations and may reflect both nutrients and foods, while a posteriori methods consider available food intake data (39). Both methods are subject to limitations. A posteriori methods require subjective decisions regarding food groupings, are sample-specific based on food intake, and may not represent optimal patterns as they are based on the intake of the sample (19). In contrast, a priori methods may be limited because they are based on knowledge of diet-disease relationships.

Degree of dietary variance within a sample is also important, and while the tools based on dietary recommendations eliminate the problem of sample-based scoring (26, 40), they often have limited variance and were not as strongly associated with mortality as those emphasizing foods or patterns in adults 60 years and older (17, 18). It is also possible that too few individuals consume a healthy diet based on more rigid approaches to scoring and so insufficient variation in scoring attenuates significance. Additionally, tools such as the MDS use sex-specific median scoring methods that vary
by population of study, making extrapolation difficult. Such complexities are inherent in these methods and should be considered in interpretation.

Dietary Assessment Methods and Considerations in Older Adults

Variations in dietary assessment methods used to measure intake should also be noted. Selection of a dietary assessment method is dependent on the research question and considerations for selection include interest in foods or nutrients, need for absolute or relative values of intake, level of accuracy required, time period of interest, characteristics of the study population, cost of tool, and ease of administration (41). Multipass administration of 24-hour recalls or use of food records may provide greater precision in the estimation of quantity of food consumed by individuals. FFQs provide information on usual intake, but are generally not considered detailed enough to garner precise nutrient intake for individuals (28). Variations in methods of determining dietary intake (FFQ, 24-hour recall, etc.) may impact categorization and result in misclassification. Additional issues may be seen when assessing the intake of older adults. These include cognitive impairment (42) and non-responsiveness to questions on FFQ when conducted without assistance (43). Although some of these concerns may be avoided through the use of skilled dietitians to administer diet assessments, such assistance may not be feasible for large-scale application (44).

Importance of Covariates

The identified covariates varied by study. While age, gender, and smoking status were most frequently controlled for, other important variables such as energy adjustment, BMI, study center, physical activity, self-assessment of health, dieting status to account for modification in response to a disease, education, income, marital status, cognitive and physical limitations, and various comorbidities were assessed to different degrees (13, 36). Lee and colleagues (27) noted that survivors had better chewing abilities at baseline, which enables easier consumption of whole fruits and vegetables. Chewing and oral health variables were rarely assessed in the articles reviewed. Consideration must be given to these variables when making interpretations.

Future Directions

Little research has focused on the oldest segment of the aging population (≥80 years). Lasheras and colleagues (45) found that the m-MDS was inversely associated with mortality in institutionalized adults aged 65–80 years, but not in those aged 80–95 years. The authors noted that this may be caused by survivor bias, or that the impact of diet on mortality
may change with age (45). Additionally, Hamer and associates (33) found reduced mortality with a Mediterranean diet pattern, but only in those aged 75 years and younger. Further research should examine this association to determine if dietary pattern remains relevant to mortality outcomes in individuals aged 75 years and older. Attributing long-term outcomes to a cross-sectional snapshot of the diet is also problematic, especially when chronic disease diagnoses may lead to prescribed dietary modifications (e.g., diabetes). While Masala and colleagues (36) did not find a Mediterranean dietary pattern to be protective, they also noted that this pattern was often adopted by women with medical conditions, who may have only recently begun such a consumption pattern. This observation highlights the difficulty with associating diet evaluated at one point in time to long-term outcomes. Length of follow-up also varied among the reviewed studies, and this is an important consideration to adequately capture mortality as the primary outcome. Priorities for future investigations therefore include cohort studies of dietary patterns in relation to long-term mortality.

Conclusions

As life expectancy increases, it is a priority to also increase the quality years of living (46). Maintaining a healthy diet through the lifespan may increase the number of disease and disability-free years (46). Determining the magnitude of impact by diet in older adults should help to guide development of appropriate public health recommendations. A posteriori analyses consistently demonstrate that diet quality is inversely associated with mortality in older adults. Although dependent on characteristics of the sample, thus limiting generalizability, a posteriori analysis provides a foundation for the association of diet with mortality. Utilization of an effective a priori tool simplifies and expands applicability, but currently no broadly validated methods exist for capturing diet quality in the United States. Of the a priori tools discussed, the m-MDS is the only one to consistently demonstrate an inverse relationship between mortality and diet quality. Although this tool has not yet been tested in older Americans, the m-MDS has demonstrated inverse associations with mortality in a younger American population, thus warranting further investigation in an aged cohort (47). In addition, future research will need to assess and control for covariates of interest identified in this review. In all cases, the diets with beneficial effects on mortality include fruits, vegetables, legumes, whole grains, and lean meats or fish, providing the foundation for a new tool, or informing adaptations of current tools. Greater understanding of the impact of diet in older adults can provide needed information to make accurate recommendations that have the potential to increase the quality of life and not just years of living.
TAKE AWAY POINTS

- A posteriori methods indicate that healthier diet patterns are associated with decreased mortality in older adults.
- Although a priori methods vary in degree of association between diet and mortality, the MDS or m-MDS consistently demonstrate inverse associations.
- Based on this review, additional research is warranted in older Americans to determine if an a priori method is associated with mortality.
- This review indicates that overall better diet quality is associated with reduced mortality in older adults, and should inform policy recommendations for the aging population.

REFERENCES


REFERENCES


Chapter 3

DIET-RELATED PRACTICES AND BMI ARE ASSOCIATED WITH DIET QUALITY IN OLDER ADULTS

A reprint of this manuscript can be accessed as a PDF file on this website

Abstract

Introduction

Subjects and Methods

Results

Discussion

Conclusions

Acknowledgements

References
Diet-related practices and BMI are associated with diet quality in older adults

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Abstract

Objective: To assess the association of diet-related practices and BMI with diet quality in rural adults aged ≥74 years.

Design: Cross-sectional. Dietary quality was assessed by the twenty-five-item Dietary Screening Tool (DST). Diet-related practices were self-reported. Multivariate linear regression models were used to analyse associations of DST scores with BMI and diet-related practices after controlling for gender, age, education, smoking and self-proxy reporting.

Setting: Geisinger Rural Aging Study (GRAS) in Pennsylvania, USA.

Subjects: A total of 4009 (1722 males, 2287 females; mean age 81.5 years) participants aged ≥74 years.

Results: Individuals with BMI 18.5–24.9 kg/m² had a significantly lower DST score (mean 55.8, 95% CI 52.9–58.7) than those individuals with BMI 18.5–18.5 kg/m² (mean 60.7, 95% CI 60.1–61.5; P = 0.001). Older adults with higher, more favourable DST scores were significantly more likely to be food sufficient, report eating breakfast, have no chewing difficulties and report no decline in intake in the previous 6 months.

Conclusions: The DST may identify potential targets for improving diet quality in older adults including promotion of healthy BMI, breakfast consumption, improving dentition and identifying strategies to decrease concern about food sufficiency.

Keywords

Diet quality
Ageing
Dietary-related practices

Diets consistent with dietary guidelines that are rich in fruits, vegetables, whole grains, low-fat dairy and lean meats are associated with decreased morbidity and mortality1. Quality of diet becomes increasingly important in old age due to declining physiological function, changes in body composition and decreased energy requirements2,3. Risk of undernutrition is also increased in older adults for some potentially modifiable reasons including financial constraints, appetite decline, poor dentition and functional and cognitive limitations4,5. The Dietary Screening Tool (DST) is a validated tool that utilizes food-based questions developed for use in assessing diet quality in older, rural adults5. It is a simple, self-administered questionnaire containing food- and behaviour-related questions that assess overall dietary quality of older adults6. The objective of the present study was to determine the relationship of the DST with diet-related practices and characteristics known to contribute to nutritional risk among a cohort of adults aged ≥74 years.

Materials and methods

Study participants

The Geisinger Rural Aging Study (GRAS) began in 1994 with adults aged 65 years or older enrolled in a Medicare-managed health maintenance organization. Study details have been published previously6. The participants have been followed as a longitudinal cohort over time with repeated measures of height, weight, medication use, diet-related practices, living environment, self-rated health and functional status. In-depth dietary assessment to estimate usual intakes has been conducted only on small subsets of the cohort in a cross-sectional manner and such data are not available for the entire cohort5,7.

All surviving GRAS participants (n 5993) were mailed demographic and health questionnaires and the DST for the current study in the autumn of 2009. After follow-up, 4009 (67%) participants (1722 males, 2287 females; mean age 81.5 years) returned completed surveys, providing...
information on age, height, weight, smoking status, diet-related practices and dietary information, among other characteristics. Additionally, self-reporting or proxy reporting by someone other than the participant was noted. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Office of Research Protections at The Pennsylvania State University and the Human Research Protection Program of the Geisinger Health Systems Institutional Review Board. Consent was implied by survey completion.

**Dietary screening tool**

Detailed information on the development and validation of the DST has been described elsewhere[5,7]. The DST consists of twenty-five questions originally derived from extensive secondary analysis of the dietary intakes of rural older adults in the GRAS (see online supplementary material). The possible score range is from 0 to 100 points with 5 'bonus' points for multivitamin/mineral supplement use (score could not exceed 100). Responses to questions were then scored according to the previously validated scoring algorithm with a score <60 considered 'unhealthy', 60–75 considered 'borderline' and >75 considered 'healthy'[55]. An example of a DST question is 'How often do you usually eat whole grain breads?' Participants then chose from 'never', 'less than once a week', '1 or 2 times a week' and '3 or more times a week' to classify their intake. Cognitive interviewing was used to ensure understandability of questions for the population of interest[57]. Points were allotted for each question based upon breakdown of major dietary components of the Healthy Eating Index-2005[56]. Dietary quality was established by comparison with nutrient intakes[5,7] and food group intakes[55] derived from multiple 24 h recalls.

**Eating behaviour measures**

Nine total questions identified the presence of problems associated with diet-related practices through yes-or-no responses. All questions were self- or proxy reported. These questions addressed inadequate food or concerns about sufficient food, not eating on one or more days per month, having a decline in intake, eating alone, skipping breakfast, having more than one alcoholic drink per day for women or more than two per day for men, reporting chewing difficulty and mouth pain. Associations between all diet-related practices and DST score were analysed.

**Statistical analyses**

All data were analysed using the Statistical Analysis Software Package 9.3. Descriptive data were generated using PROC MEANS and PROC FREQ for all adults and by gender. Multivariate linear regression models were used to analyse associations of continuous DST score as the dependent variable with BMI and each of the nine diet-related practices after controlling for age (continuous), gender, education (<high school v. ≥high school), smoking (ever/never) and self- v. proxy reporting. BMI was calculated from self-reported height and weight collected in the demographic and health questionnaires, and was assessed both as a continuous variable and categorically according to National Institutes of Health guidelines (<18.5 kg/m², 18.5–24.9 kg/m², 25.0–29.9 kg/m² and ≥30.0 kg/m²). All dietary behaviours that were related significantly to DST score at P<0.05 were retained as potential candidates for the multivariate model. Results are presented as mean DST scores with 95% confidence intervals adjusted for age, gender, self- or proxy reporting, and BMI when BMI was not the independent variable of interest. P values are for the tests of between-group differences from the multivariate models. Interactions between the predictors of interest (diet-related practices and BMI) and each covariate (gender, BMI, age, education, smoking, self- v. proxy reporting) were assessed by including each individual factor (e.g. gender) and its cross-product term in separate models. Significance was considered at P<0.05.

**Results**

Descriptive characteristics of the sample are shown in Table 1. Compared with those who completed the DST, non-responders were older (83.2 v. 81.4 years; P<0.0001) and more likely to be female (OR = 1.3, 95% CI 1.2, 1.5; P<0.0001). Less than 9% (n 333) of participants used proxy reporters and those who did were more likely to be male (OR = 1.5, 95% CI 1.2, 1.9; P = 0.0002), less likely to report education beyond high school (OR = 0.5, 95% CI 0.3, 0.7; P = 0.0002), older (mean 83.7 (sd 5.5) years v. 81.2 (sd 4.1) years; P<0.0001) and had lower DST scores (mean 57.6 (sd 12.3) v. 60.6 (sd 12.7); P<0.0001). The cohort was comprised almost exclusively of non-Hispanic whites (98.7%) with at least a high school degree. Less than half the sample was male (43%). BMI did not differ by gender. Although over half of the respondents lived with a spouse (n 2095), 46% of female respondents lived alone compared with only 20% of male respondents. The mean unadjusted DST score for the sample was 60.3 (sd 12.7), with females (mean 61.9 (sd 12.6)) reporting a significantly higher score than males (mean 58.2 (sd 12.4); P<0.0001).

Participants who had BMI <18.5 kg/m² had significantly lower DST scores (OR = 55.8, 95% CI 52.9, 58.7) than those participants with BMI = 18.5–24.9 kg/m² (OR = 60.8, 95% CI 59.5, 60.9; P = 0.001) after adjustment for age, sex, education, smoking status and self- v. proxy reporting. The adjusted DST score for those participants with BMI <18.5 kg/m² remained significantly lower (OR = 55.8, 95% CI 52.9, 58.7) compared with the DST score for all other BMI classes combined (OR = 60.5, 95% CI 60.1, 60.9; P = 0.002). In contrast, compared with
participants with BMI = 18.5–24.9 kg/m^2, there were no statistically significant differences in DST score for either overweight or obese individuals (see Table 2). There were also no significant associations between BMI and any of the diet-related practices.

Four of the nine diet-related practices were significantly associated with DST score after adjustment for BMI, age, sex, education, smoking status and self- versus proxy reporting (Table 2). Significantly lower DST scores were found in participants who reported a decline in intake over the previous 3 months, skipping breakfast, concern about having enough food and difficulty with chewing or swallowing. The remaining five diet-related practices were not significantly associated with DST score. No meaningful and significant effect modifications were observed between any variables tested (data not presented).

**Discussion**

It was our goal to investigate the associations between BMI, diet-related practices and diet quality in a population

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**Table 1** Characteristics of study participants: rural adults aged ≥74 years, Geisinger Rural Aging Study (GRAS), Pennsylvania, USA, autumn 2009

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Men (n 1722; 43.0%)</th>
<th>Women (n 2287; 57.0%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean or n ± SE or %</td>
<td>Mean or n ± SE or %</td>
</tr>
<tr>
<td>Age (years)*</td>
<td>81.3 ± 4.2</td>
<td>81.5 ± 4.4</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1654 ± 98.2</td>
<td>2234 ± 99.1</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>29 ± 1.7</td>
<td>15 ± 0.7</td>
</tr>
<tr>
<td>Other</td>
<td>1 ± 0.1</td>
<td>4 ± 0.2</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; High school</td>
<td>1327 ± 77.1</td>
<td>1942 ± 84.9</td>
</tr>
<tr>
<td>≥ High school</td>
<td>395 ± 22.9</td>
<td>345 ± 15.1</td>
</tr>
<tr>
<td>BMI (kg/m^2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>14 ± 0.8</td>
<td>59 ± 2.6</td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>460 ± 26.7</td>
<td>696 ± 30.4</td>
</tr>
<tr>
<td>25.0–29.9</td>
<td>814 ± 47.3</td>
<td>839 ± 36.7</td>
</tr>
<tr>
<td>≥30.0</td>
<td>434 ± 25.2</td>
<td>693 ± 30.3</td>
</tr>
<tr>
<td>Ever smoke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>61 ± 3.6</td>
<td>82 ± 3.7</td>
</tr>
<tr>
<td>No</td>
<td>1629 ± 96.4</td>
<td>2159 ± 96.3</td>
</tr>
<tr>
<td>Eat breakfast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1660 ± 96.4</td>
<td>2190 ± 95.8</td>
</tr>
<tr>
<td>No</td>
<td>62 ± 3.6</td>
<td>97 ± 4.2</td>
</tr>
<tr>
<td>Eat alone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>305 ± 17.7</td>
<td>851 ± 37.2</td>
</tr>
<tr>
<td>No</td>
<td>1417 ± 82.3</td>
<td>1436 ± 62.8</td>
</tr>
<tr>
<td>Intake decline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>111 ± 6.5</td>
<td>161 ± 7.0</td>
</tr>
<tr>
<td>No</td>
<td>1611 ± 93.5</td>
<td>2126 ± 93.0</td>
</tr>
<tr>
<td>Excess alcohol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>94 ± 5.5</td>
<td>37 ± 1.6</td>
</tr>
<tr>
<td>No</td>
<td>1628 ± 94.5</td>
<td>2250 ± 98.4</td>
</tr>
<tr>
<td>Food insufficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8 ± 0.5</td>
<td>9 ± 0.4</td>
</tr>
<tr>
<td>No</td>
<td>1714 ± 99.5</td>
<td>2278 ± 99.6</td>
</tr>
<tr>
<td>Enough food each day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1681 ± 97.6</td>
<td>2254 ± 98.6</td>
</tr>
<tr>
<td>No</td>
<td>41 ± 2.4</td>
<td>33 ± 1.4</td>
</tr>
<tr>
<td>No food some days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4 ± 0.2</td>
<td>7 ± 0.3</td>
</tr>
<tr>
<td>No</td>
<td>1718 ± 99.8</td>
<td>2280 ± 99.7</td>
</tr>
<tr>
<td>Chewing difficulty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>69 ± 4.0</td>
<td>87 ± 3.8</td>
</tr>
<tr>
<td>No</td>
<td>1653 ± 96.0</td>
<td>2200 ± 96.2</td>
</tr>
<tr>
<td>Mouth pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>41 ± 2.4</td>
<td>53 ± 2.3</td>
</tr>
<tr>
<td>No</td>
<td>1681 ± 97.6</td>
<td>2234 ± 97.7</td>
</tr>
<tr>
<td>DST score*</td>
<td>58.2 ± 12.4</td>
<td>61.9 ± 12.6</td>
</tr>
<tr>
<td>DST category†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60</td>
<td>917 ± 53.3</td>
<td>925 ± 40.4</td>
</tr>
<tr>
<td>60–75</td>
<td>629 ± 36.5</td>
<td>976 ± 42.7</td>
</tr>
<tr>
<td>&gt;75</td>
<td>176 ± 10.2</td>
<td>386 ± 16.9</td>
</tr>
</tbody>
</table>

DST, Dietary Screening Tool.

*These data are presented as mean and standard error; all other data are presented as number and percentage.

†Categories utilized from previously published data. 

---
of adults aged ≥74 years. There are limited data on dietary quality for large cohorts of older adults, particularly those living in rural areas. Our results indicate that a low DST score is associated with low BMI and poor diet-related practices including chewing difficulties, skipping breakfast, concerns of food sufficiency and decline in intake.

Older adults with low BMI had a much poorer diet quality than all other older adults, including those who were obese. Population studies suggest that risk of mortality is doubled in older adults who have a BMI <18.5 kg/m² compared with 18.5–24.9 kg/m² independent of recent weight change. The association between obesity and mortality in older adults is complex, with overweight and mild obesity being associated with reduced mortality in cohort studies of adults ≥65 years old with follow-up periods ranging from 5 to 18 years.

In a prior investigation within a small subset of the GRAS cohort (n = 179) we found that a low nutrient-dense diet was associated with increased odds of obesity and lower waist circumference was associated with a prudent dietary pattern. In the current study, an association between obesity and diet quality was not detected. Of note, no participants in our previous study had BMI <18.5 kg/m².

Chewing difficulty, skipping breakfast, food insufficiency and decline in intake were associated with poor diet quality. Chewing difficulty is linked to many adverse clinical outcomes, including a variety of morbidities, hospitalization and earlier mortality, and has been shown to affect consistency and selection of food. Skipping breakfast is associated with decreased nutrient intake, which may impact development and progression of chronic disease. In a nationally representative sample of adults aged 60–90 years, those who were food-insufficient consumed significantly less energy, carbohydrate, protein, saturated fat, Fe and Zn among other micronutrients and were more likely to report poor self-rated health than their food-sufficient peers. Decline in intake may lead to unintentional weight loss which is often indicative of underlying disease, and undernutrition in older adults is associated with increased mortality. The DST is able to identify these diet-related practices as targetable areas for improvement in diet quality and potentially other health outcomes in older adults.

A relatively high response rate (67%) in an aged community-dwelling cohort is a major strength of this investigation. However, there are some notable limitations to address. The external validity of the DST remains to be determined in other races and geographic regions. The number of remaining underweight older adults was quite low, likely due to decreased survivorship in elderly individuals with a low BMI. The screening questionnaires rely on self-report, making results subject to recall bias. Additionally, only information regarding age and sex was available for non-responders and so additional comparisons could not be made.

Previously the DST was administered in an out-patient clinic setting, requiring participants to visit their local medical clinic in order to complete the questionnaire. Rural older adults experience many barriers to health care including but not limited to social isolation, lack of transportation and financial constraints. By surveying rural adults in their own homes, we were able to find targetable areas for improvement of nutritional quality. Overall food consumption decreases with age and it becomes increasingly important for older adults to consume high-quality nutrient-dense foods to meet nutrient needs.

### Table 2: Association between adjusted mean DST score, diet-related practices and BMI: rural adults aged ≥74 years, Geisinger Rural Aging Study (GRAS), Pennsylvania, USA, autumn 2009

<table>
<thead>
<tr>
<th>Eating practice*</th>
<th>Adjusted mean DST score</th>
<th>95% CI</th>
<th>( P ) value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skip breakfast</td>
<td>51.7</td>
<td>49.8–53.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Eat breakfast</td>
<td>60.8</td>
<td>60.4–61.2</td>
<td>–</td>
</tr>
<tr>
<td>Eat alone</td>
<td>60.5</td>
<td>59.8–61.3</td>
<td>0.71</td>
</tr>
<tr>
<td>Eat with others</td>
<td>60.4</td>
<td>59.9–60.8</td>
<td>‒</td>
</tr>
<tr>
<td>Intake decline</td>
<td>56.8</td>
<td>55.3–58.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>No decline</td>
<td>60.7</td>
<td>60.3–61.1</td>
<td>‒</td>
</tr>
<tr>
<td>Excess alcohol</td>
<td>58.7</td>
<td>56.5–60.9</td>
<td>0.12</td>
</tr>
<tr>
<td>No excess alcohol</td>
<td>60.5</td>
<td>60.1–60.9</td>
<td>‒</td>
</tr>
<tr>
<td>Food insufficient</td>
<td>53.9</td>
<td>48.0–59.8</td>
<td>0.03</td>
</tr>
<tr>
<td>Food sufficient</td>
<td>60.4</td>
<td>60.0–60.8</td>
<td>‒</td>
</tr>
<tr>
<td>Not enough food each day</td>
<td>58.9</td>
<td>56.1–61.8</td>
<td>0.32</td>
</tr>
<tr>
<td>Enough food each day</td>
<td>60.4</td>
<td>60.0–60.8</td>
<td>‒</td>
</tr>
<tr>
<td>No food some days</td>
<td>57.4</td>
<td>49.7–65.1</td>
<td>0.44</td>
</tr>
<tr>
<td>Always have food</td>
<td>60.4</td>
<td>60.0–60.8</td>
<td>‒</td>
</tr>
<tr>
<td>Chewing difficulty</td>
<td>58.3</td>
<td>56.3–60.2</td>
<td>0.03</td>
</tr>
<tr>
<td>No difficulty</td>
<td>60.5</td>
<td>60.1–60.9</td>
<td>‒</td>
</tr>
<tr>
<td>Mouth pain</td>
<td>59.8</td>
<td>57.2–62.3</td>
<td>0.53</td>
</tr>
<tr>
<td>No mouth pain</td>
<td>60.4</td>
<td>60.0–60.8</td>
<td>‒</td>
</tr>
<tr>
<td>Underweight (BMI &lt;18.5 kg/m²)†</td>
<td>55.8</td>
<td>52.9–58.7</td>
<td>0.001</td>
</tr>
<tr>
<td>Not underweight</td>
<td>60.5</td>
<td>60.1–60.9</td>
<td>‒</td>
</tr>
</tbody>
</table>

*Controlling for sex, BMI, age, smoking status, education and self-v. proxy reporting.
†Represent differences between groups (appetite decline v. no decline, concern about food v. no concern, etc.) after adjustment for covariates.
‡Controlling for sex, age, smoking status, education and self-v. proxy reporting.
Diet practices and quality in older adults

The diet-related practices found to be associated with DST score serve as potential targets for altering behaviour to promote nutrient and energy intakes sufficient to meet requirements. It should also be noted that the mean overall DST score was below optimal (mean = 60) with 86% of participants scoring ≤75 on the DST. According to previous studies, this indicates that 86% of this sample has either unhealthy or borderline diet quality, and so has room for improvement.

Conclusions

Older adults are at increased susceptibility for malnutrition due to age-associated changes in metabolism and physiology, and with the number of aged persons increasing rapidly in our population improving nutritional status is a priority. Low DST scores were associated with low BMI, being food insecure, recent decline in food intake, skipping breakfast and chewing difficulties. These associations may help to identify opportunities for anticipatory guidance and interventions for health-care professionals to promote improvement in diet quality.

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Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1368980013001729

References

Chapter 4

THE ASSOCIATIONS BETWEEN DIET QUALITY, BODY MASS INDEX (BMI) AND HEALTH AND ACTIVITY LIMITATION INDEX (HALEX) IN THE GEISINGER RURAL AGING STUDY (GRAS)

A reprint of this manuscript can be accessed as a PDF file on this website

Abstract

Introduction

Subjects and Methods

Results

Discussion

Conclusions

References
THE ASSOCIATIONS BETWEEN DIET QUALITY, BODY MASS INDEX (BMI) AND HEALTH AND ACTIVITY LIMITATION INDEX (HALEX) IN THE GEISINGER RURAL AGING STUDY (GRAS)


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Abstract: Objectives: To determine the associations between diet quality, body mass index (BMI), and health-related quality of life (HRQOL) as assessed by the health and activity limitation index (HALex) in older adults. Design: Multivariate linear regression models were used to analyze associations between Dietary Screening Tool (DST) scores, BMI and HALex score, after controlling for gender, age, education, living situation, smoking, disease burden and self-vs. proxy reporting. Setting: Geisinger Rural Aging Study, Pennsylvania. Participants: 5,993 GRAS participants were mailed HRQOL and DST questionnaires with 4,009 (1,722 male, 2,287 female; mean age 81.5 ± 4.4) providing complete data. Results: HALex scores were significantly lower for participants with dietary intakes categorized as unhealthy (<60) (0.70, 95% CI 0.69, 0.72, p<0.05) or borderline (60-75) (0.71, 95% CI 0.70, 0.73, p<0.05) compared to those scoring in the healthy range (>75) (0.75, 95% CI 0.73, 0.77) based on DST scores. HALex scores were significantly lower for underweight (0.67, 95% CI 0.63, 0.70, p<0.05) and normal (<75) compared to those with BMI ≥ 18.5-24.9. Conclusions: Poor diet quality, as assessed by the DST, is associated with lower HRQOL in adults ≥ 74 years of age.

Key words: Diet quality, quality of life, HALex, aging.

Introduction

Though life expectancy continues to rise, the increase in length of life does not necessarily equate with an increase in quality years of living (1). Quality of life (QOL) is a broad multidimensional concept based on subjective measures of life (2). More specifically, health related quality of life (HRQOL) encompasses aspects of quality of life that have been shown to affect health including physical and mental health perceptions (2). HRQOL is a research priority in the aging population (2). Evaluating measures for monitoring HRQOL in the United States is a goal of Healthy People 2020 (3, 4). Greater understanding of the factors that impact HRQOL in an aging population with a high prevalence of chronic health conditions can guide interventions to improve QOL (1, 3, 5). The Health and Activity Limitation Index (HALex) is a single measure of HRQOL consisting of two components: perceived health and activity limitation. While both poor diet quality (6) and a BMI ≥ 30 have been shown to contribute to decreased HRQOL (7-9) in older adults, this association has not been well characterized. Furthermore, understanding of the relationship between diet quality and HRQOL is even more limited (10). The objective of this study was to determine the associations between diet quality as assessed by the Dietary Screening Tool (DST), BMI and HRQOL assessed by the HALex in adults aged 74 and older.

Subjects and Methods

The Geisinger Rural Aging Study (GRAS) began in 1994 with more than 20,000 adults > 65 years old enrolled in a Medicare managed health maintenance organization (11). Specific details of subject recruitment have been published previously (11). Participants have been followed as a longitudinal cohort over time. Repeated measures of height, weight, medication use, living environment, self-rated health and functional status are available.

All surviving GRAS participants (n=5,993) were mailed a demographic and health questionnaire and the DST for the current study in fall of 2009. After follow-up 4,009 (67%) (1,722 male, 2,287 female; mean age 81.5 years) participants provided complete information including age, height, weight, smoking status, dietary information, self-rated health and self-reported functional limitations among other characteristics. Additionally, self-report or proxy reporting by someone other than the participant was noted. The study protocol was approved by both the Office of Research Protections at the Pennsylvania State University and the Human Research Protection Program of the Geisinger Health Systems Institutional Review Board. Consent was implied by survey completion.

DST, BMI and HALex

The DST has been described in detail previously (11, 12). Briefly, extensive analysis of the dietary intake of rural older
adults in the GRAS cohort was used to derive 25 food-based questions. All questions were created to capture usual intake and points were allotted for each question based upon breakdown of major dietary components of the Healthy Eating Index (HEI)-2005. The possible score range is from 0-100 points; with five “bonus” points for multivitamin/mineral supplement use (score could not exceed 100). Responses were scored according to the previously validated scoring algorithm with a score < 60 considered ‘unhealthy’, 60-75 “borderline”, and > 75 ‘healthy’ (12). The DST demonstrated good test-retest reliability with a coefficient of 0.83 (p<0.0001) (12) and was validated through analyzing relations between dietary patterns and dietary data derived from multiple 24 hour recalls (11). For this analysis, BMI was assessed per National Institutes of Health (NIH) guidelines with a BMI of < 18.5 considered low, 18.5-24.9 healthy, 25-29.9 overweight, > 30 obese class I, 35-39.9 obese class II and ≥ 40 obese class III.

The HALex is a measure that combines an individual’s report of activity limitation and self-rated health into a single HRQOL score that ranges from 0.00 (death) to 1.00 (optimal health) (13). An individual who reports being in excellent health and having no functional limitations (i.e., no limitations in activities of daily living (ADLs) or instrumental activities of daily living (IADLs)) receives a score 1.00. Scores on this 0-1.00 continuum were derived based on five states of self-rated health (excellent, very good, good, fair and poor) and six levels of activity limitation (not limited, limited-other, limited-major, unable-major, limited in IADL, limited in ADL) (13). The HALex was originally developed using data from the National Health Interview Survey (NHIS) and validated using 41,104 participants with > 18 standardized to 10,000 persons by age and gender group (14). Age was a consideration for placement on the score matrix regarding activity limitation categories (14). In the present analysis, all participants were ≥ 74 years old, so to model findings as closely as possible to those analyses used in tool development, only categories befitting these age groups (not limited, limited in IADL, limited in ADL) were used. The range of present scores is 0.1 to 1.00.

### Statistical Analysis

All data were analyzed using the Statistical Analysis Software Package 9.3 (SAS Institute Inc., Cary, NC). Multivariate linear regression models were used to analyze associations between continuous HALex score as the dependent variable with BMI and DST based on previously derived categories. Results are presented as adjusted mean (LSMEAN) HALex score with 95% CI adjusted for age (continuous), gender, education (< high school v. > high school), smoking status (ever/never), living situation (with spouse, son/daughter, other family, other, alone), self-vs. proxy reporting and disease burden. The disease burden covariate is a continuous variable accounting for self-reported diseases including hypertension, diabetes, high cholesterol, lung disease or breathing problems, cancer, coronary heart disease, heart failure, angina and heart attack. P-values represent the comparison between the indicated group and the referent group. Participants missing any of the aforementioned variables made up a combined total of less than two percent of the sample and were excluded in multivariate analyses. Effect modification by gender, BMI, age, education, smoking, living situation, self-vs. proxy reporting and disease burden was assessed by including the individual factor (e.g., gender) and its cross-product term in separate models with each of the independent variables of interest, DST score and BMI. Effect size was determined using $f^2$ and effect sizes for both models were moderate (0.19) (15). We used Bonferroni’s adjustment for multiple comparisons, and significance was set at P<0.05.

### Results

Descriptive characteristics are presented in Table 1. Compared to those who provided complete information, non-responders and those with incomplete information were older (83.2 vs. 81.4; p<0.05) and more likely to be female (OR: 1.3 95% CI 1.2, 1.50, p<0.05). The entire cohort was comprised of primarily non-Hispanic white, high-school educated, self-reporting individuals. While females had significantly higher diet quality than males (DST scores 61.9± 12.7 vs. 58.2 ±12.5, p<0.05), the inverse was true for HALex scoring (Males: 0.75 ± 0.20, Females: 0.73 ± 0.22, p<0.05). However, this interaction did not reach statistical significance. The mean DST score overall was very close to the ‘unhealthy’ range (60.4 ±12.7). The association between DST score and HALex score was assessed (Table 2). Adjusted HALex score was examined by categorical DST score based on previously defined breakdowns (12). Participants with both ‘unhealthy’ (0.70, 95% CI 0.69, 0.72, p<0.05) and ‘borderline’ diets (0.71, 95% CI 0.70, 0.73 p<0.05) had significantly lower adjusted HALex score than those with a ‘healthy’ diet (0.75, 95% CI 0.73, 0.77) even after correction for multiple adjustments. There were no differences in mean HALex scores between unhealthy and borderline diets (p=0.38). No significant and meaningful interactions were found for any of the potential effect modifiers examined. Additionally, there was no significant interaction effect between DST and BMI.

Differences in HALex score between all BMI categories were examined. BMI categories that differed from the referent group (i.e. BMI 18.5-24.9; 0.76, 95% CI 0.75, 0.77) included those who were underweight (BMI < 18.5; 0.67, 95% CI, 0.63, 0.72, p<0.05) and those with a BMI of 35.0-39.9 (0.68, 95% CI 0.66, 0.71, p <0.05) or ≥ 40.0 (0.62, 95% CI 0.57, 0.67, p<0.05), presenting with much lower HALex scores. Those who were in the BMI ranges of 35-39.9 (p<0.05) and ≥ 40 (p<0.05) had lower HALex scores than those who were in the 25-29.9 range. No significant interaction terms were found for any potential effect modifiers.
### Table 1
Demographic and personal characteristics by gender for Geisinger Rural Aging Study (GRAS)

<table>
<thead>
<tr>
<th>Demographic and Personal Characteristics</th>
<th>Males N (%)</th>
<th>Females N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1722 [43.0]</td>
<td>2287 [57.0]</td>
</tr>
<tr>
<td>Mean Age (y)†</td>
<td>81.3 ± 4.2</td>
<td>81.5 ± 4.5</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1654 [99.2]</td>
<td>2234 [99.1]</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>29 [1.7]</td>
<td>15 [0.7]</td>
</tr>
<tr>
<td>Other</td>
<td>1 [0.1]</td>
<td>4 [0.2]</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School</td>
<td>1246 [74.1]</td>
<td>1677 [75.4]</td>
</tr>
<tr>
<td>Ever Smoke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>61 [3.6]</td>
<td>82 [3.7]</td>
</tr>
<tr>
<td>No</td>
<td>1629 [96.4]</td>
<td>2159 [96.3]</td>
</tr>
<tr>
<td>Self v. Proxy Report</td>
<td></td>
<td></td>
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<tr>
<td>Self-Report</td>
<td>1525 [89.7]</td>
<td>2101 [93.0]</td>
</tr>
<tr>
<td>Proxy</td>
<td>175 [10.3]</td>
<td>158 [7.0]</td>
</tr>
<tr>
<td>Live With…</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spouse</td>
<td>1225 [72.1]</td>
<td>870 [38.7]</td>
</tr>
<tr>
<td>Son or Daughter</td>
<td>77 [4.5]</td>
<td>232 [10.3]</td>
</tr>
<tr>
<td>Other Family</td>
<td>24 [1.4]</td>
<td>52 [2.3]</td>
</tr>
<tr>
<td>Other</td>
<td>30 [1.8]</td>
<td>43 [1.9]</td>
</tr>
<tr>
<td>Alone</td>
<td>344 [20.4]</td>
<td>1050 [46.8]</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
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<tr>
<td>&lt;18.5 (Underweight)</td>
<td>14 [0.8]</td>
<td>59 [2.6]</td>
</tr>
<tr>
<td>≥25-29.9 (Overweight)</td>
<td>814 [47.3]</td>
<td>839 [36.7]</td>
</tr>
<tr>
<td>30-34.9 (Obese Class I)</td>
<td>350 [20.3]</td>
<td>478 [20.9]</td>
</tr>
<tr>
<td>35-39.9 (Obese Class II)</td>
<td>71 [4.1]</td>
<td>159 [7.0]</td>
</tr>
<tr>
<td>≥40 (Obese Class III)</td>
<td>13 [0.8]</td>
<td>56 [2.4]</td>
</tr>
<tr>
<td>Mean HALex Score</td>
<td>0.75 ± 0.20</td>
<td>0.73 ± 0.21</td>
</tr>
<tr>
<td>Mean DST Score</td>
<td>58.2 ± 12.5</td>
<td>61.9 ± 12.7</td>
</tr>
<tr>
<td>DST Categories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unhealthy (&lt;60)</td>
<td>917 [53.3]</td>
<td>925 [40.4]</td>
</tr>
<tr>
<td>Borderline (60-75)</td>
<td>629 [36.5]</td>
<td>976 [42.7]</td>
</tr>
<tr>
<td>Health (≥75)</td>
<td>176 [10.2]</td>
<td>386 [16.9]</td>
</tr>
</tbody>
</table>

1. Number, Percentage; 2. Mean ± St Dev

Table 2
Adjusted Mean HALex Score for DST score and BMI

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted Mean HALex Score (95% CI)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DST Score†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unhealthy (&lt;60)</td>
<td>0.70 (0.69,0.72)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Borderline (60-75)</td>
<td>0.71 (0.70,0.73)</td>
<td>0.0005</td>
</tr>
<tr>
<td>Healthy (≥75)</td>
<td>0.75 (0.73,0.77)</td>
<td>Referent</td>
</tr>
<tr>
<td>BMI‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5 (Underweight)</td>
<td>0.67 (0.63,0.72)</td>
<td>0.01</td>
</tr>
<tr>
<td>18.5-24.9 (Normal Weight)</td>
<td>0.76 (0.74,0.77)</td>
<td>Referent</td>
</tr>
<tr>
<td>25-29.9 (Overweight)</td>
<td>0.76 (0.75,0.77)</td>
<td>1.00</td>
</tr>
<tr>
<td>30-34.9 (Obese Class I)</td>
<td>0.75 (0.73,0.76)</td>
<td>1.00</td>
</tr>
<tr>
<td>35-39.9 (Obese Class II)</td>
<td>0.68 (0.66,0.71)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>≥40 (Obese Class III)</td>
<td>0.62 (0.57,0.67)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

1. Controlling for categorical BMI (18.5-24.9 as referent), disease burden, sex, education, age, smoking status, living situation and self-vs. proxy report (Bonferroni’s Adjustment); 2. Controlling for Sex, categorical DST score (Healthy as referent), disease burden education age, smoking status, living situation and self-vs. proxy report (Bonferroni’s Adjustment)

### Discussion
We found that poor diet quality is inversely associated with HRQOL. These results were not only statistically significant, but clinically meaningful with a moderate effect size (f = 0.19). Other assessments have shown that adherence to higher quality diets is associated with increased HRQOL independent of weight status in 11,015 men and women greater than 18 years of age (16). Recent research found a relationship between adherence to dietary guidelines and both initial mental HRQOL at study baseline and a positive change in physical HRQOL over twelve years of follow-up in adults aged 45-60 years (17). It remains that the relationship between diet and HRQOL in older adults has not been extensively examined, and the association of diet with HALex, has to our knowledge, not previously been studied. Our investigation demonstrates a strong association between higher diet quality and greater quality of life in older adults. Poor diet quality has also been shown to contribute to frailty in older adults (18) and improvement in diet quality, through increased fruit and vegetable consumption and reduction in added fats, sugars and sweets, serve as potential targets for extending quality years of living.

Our results also suggest that underweight and obesity are associated with lower HRQOL. Large cross-sectional analyses of healthy men and women over 18 years (9, 19) have shown that both underweight and obesity are inversely associated with HRQOL. Cross sectional analysis of adults 65 years and older (n=7,080) (20) has also shown that both underweight and obesity are inversely associated with HRQOL. In all of these studies, HRQOL was assessed by varying tools that differed in domains of focus. Prior studies (21, 22) that related poorer HALex scores to elevated BMI examined much younger cohorts and contrary to our results found that associations with lower HALex scores began at BMI of 25-29.9 as opposed to BMI ≥35 in our investigation. These observations highlight the importance of age in the consideration of BMI (21, 22). Major strengths of the present analysis are the large sample and favorable response rate (67%) for an understudied population of rural community-dwelling older adults (≥74 years). There remain some limitations that should be addressed. Health rating, functional limitations, presence of disease, height, weight and dietary data were all self-reported, allowing for the possibility of recall bias. However, as the outcome of interest is an assessment of perceived quality of life, self-reporting of the aforementioned attributes may be more meaningful for interpretation. Of note, only 16% of participants in the present study reported any level of functional limitation compared to national averages of approximately 25% in 75-79 year olds and 50% in those ≥85 years old (23). This could be attributable to a relatively healthy cohort of older community-dwelling adults, or to under-reporting of functional limitations. The DST was developed based on the dietary patterns of a very homogenous sample. Validity of the DST should be tested in...
more diverse populations to broaden its applicability. Lastly, only gender and projected age were available for non-responders, and so further non-responder analysis could not be performed.

The DST is a validated self-administered questionnaire that can be completed in various settings in under ten minutes (11). The HALex is also easily administered and scored. The association between these two variables indicates that diet quality plays a role in HRQOL in older adults independent of BMI; thus, improving diet may help to promote increased quality years of life. Additionally, BMI less than 18.5 or greater than 35 and especially greater than 40 was associated with lower HRQOL supporting previous studies that have suggested that both low and high BMI result in poorer HRQOL (9, 20). In a population where 86% of the sample had a sub-optimal diet (DST <75), there would appear to be opportunity for improvements in diet quality that could benefit many older persons.

Conclusions
The population continues to age, and though associations between aging and lower HRQOL have been found, the impact of age alone is attenuated after controlling for covariates (24). These observations, together with the findings from the present study, indicate that improving diet quality and promoting appropriate weight status in older adults may together maintain or improve HRQOL in aging.

Conflict of Interest Statements: Ford, Jensen, Mitchell and Smiciklas-Wright: Money for this research was paid to my institution through a USDA grant; Hartman: Money for this research was paid to my institution and myself through a USDA grant; Strickler: Money is available from my institution for the analysis of caffeine in beverages consumed in the US population.

References
Chapter 5

DIET QUALITY AND BODY MASS INDEX ARE ASSOCIATED WITH HEALTHCARE RESOURCE USE IN OLDER ADULTS

Abstract

Introduction

Subjects and Methods

Results

Discussion

Conclusions

References
Abstract

Background: With our aging population, healthcare resource consumption is a growing concern; thus, determining modifiable risk factors to reduce healthcare use is critical.

Objective: The objective of this study was to examine the associations between diet quality and body mass index (BMI) with four measures of healthcare resource use (HRU) in a cohort of advanced age: outpatient clinic visits, inpatient visits, inpatient days and emergency room (ER) visits. Design: Cohort study. Participants/setting: Geisinger Rural Aging Study (GRAS), Pennsylvania. 5,993 GRAS participants were mailed demographic and dietary questionnaires in the fall of 2009. After follow-up 2,995 (1,267 male, 1,728 female; mean age 81.4 ± 4.4 years) provided completed surveys and were enrolled in the Geisinger Health Plan for at least part of the 27 month follow-up. Statistical analyses performed: Multivariate negative binomial models were used to estimate relative risk (RR) and 95% confidence intervals (95% CI) of each of the four HRU outcomes determined from electronic medical records with diet quality as assessed by the dietary screening tool (DST) score and BMI determined from self-reported height and weight.

Results: Poor diet quality was related to a 20% increased risk for ER visits. The three lowest fruit and vegetable quintiles were associated with increased risk for ER visits (23-31%); the lowest quintile increased risk for inpatient visits (27%). Obesity increased risk of outpatient visits; however, individuals with class I obesity were less likely than normal weight individuals to have ER visits (RR 0.84; 95% CI 0.70, 0.99). Conclusions: Diets of greater quality, particularly with greater fruit and vegetable intake, have favorable effects on HRU outcomes among older adults. Overweight and obesity are associated with increased outpatient healthcare use and among obese persons, with decreased ER visits.
These findings suggest that BMI and diet quality beyond age 74 continue to effect HRU measures.

**Introduction**

The number of Americans aged $\geq 65$ years is expected to double, while the number $\geq 80$ years is expected to triple by the year 2030. With the number of aged individuals increasing, there is an associated increase in co-morbid disease burden. This is of particular concern in light of the potential for substantial increases in healthcare resource consumption. Nearly half of lifetime medical expenditures occur after the age of 65. There is therefore strong interest in identifying modifiable factors that can prevent or delay the use of healthcare resources in the oldest segment of the population.

The majority of older adults have chronic conditions with adverse outcomes. Diet quality is a potentially modifiable factor that has been associated with chronic conditions. Overall diet quality as well as diet sub-groups including fruits and vegetables, unsaturated fatty acids, low-fat dairy, and whole grains have been associated with reduced risk for chronic disease development. Presence of chronic conditions may lead to increased healthcare resource use, and so diet could potentially mediate these outcomes. High fruit and vegetable intake specifically has been associated with reduced risk for coronary heart disease, stroke and cancer, with a healthier BMI, and with lower rates of all-cause mortality. Research relating diet quality to healthcare resource use is limited, primarily conducted in middle-aged adults, and inconclusive.

Previous research has shown that with increased BMI there is an increase in both outpatient clinic and inpatient healthcare use and in medical expenditures overall. These findings were primarily in middle-aged and young-old adults, with only
quite limited data on the oldest segment of the population. The available evidence for those 75 years or older is mixed, with some data suggesting that for those over 75 years of age obesity is associated with increased medical expenditures, while other studies have suggested that BMI has less adverse impact upon medical expenditures in those aged > 75 years. Surviving beyond the age of 75 years is becoming increasingly common. Average life expectancy in the United States is currently 76 years for males and 81 years for females. Therefore it is pertinent to understand the impact of BMI on healthcare resource use in the aged.

The objective of this study was to determine the associations between BMI and measures of diet quality with the healthcare resource use outcomes including outpatient clinic and emergency room visits and hospital inpatient visits and days in older adults.

**Subjects and Methods**

The Geisinger Rural Aging Study (GRAS) began in 1994 with more than 20,000 participants aged greater than 65 enrolled in a Medicare managed health maintenance organization. The participants are community-dwelling individuals in rural northeastern and central Pennsylvania, residing in an area where the population density is 14-475 individuals/mile² (5-183 individuals/km²). Details of the study have been published previously. The participants have been followed as a longitudinal cohort over time, with repeated self or proxy reported surveys of multiple variables including age, height, weight, smoking status, self-rated health, functional status, dietary information and living situation.

All surviving GRAS participants (n=5,993) were mailed health and demographic questionnaires and the dietary screening tool (DST) in the fall of 2009. After follow-up
2,995 (50%) (1,267 male, 1,728 female; mean age 81.4 ± 4.4 years) participants returned completed surveys, and were enrolled in the Geisinger Health Plan (GHP) for at least part of the follow-up period. The study protocol was approved by both the Office of Research Protections at the Pennsylvania State University and the Human Research Protection Program of the Geisinger Health Systems Institutional Review Board. Consent was implied by survey completion. Surveys were reviewed for completion, and only surveys with complete dietary and BMI data were included in the analyses, for participants with GHP data.

**DST, BMI and Healthcare Resource Utilization**

Detailed information on the Diet Screening Tool (DST) is available. Briefly, this validated tool utilizes 25 food-based questions to assess diet quality in older adults. These questions were originally derived from secondary analysis of multiple 24 hour recalls of GRAS participants. An example of a DST question is “How often do you usually eat fruit as a snack?” In response, participants could select “never”, “less than once a week”, “1 or 2 times a week” or “3 or more times a week” to classify intake. Cognitive interviewing was conducted to ensure clarity of questions in the population of interest. Good test-retest reliability of the DST was shown, with a coefficient of 0.83 (p<0.0001) and comparison with nutrient and food group intakes derived from 24 hour recalls established diet quality. The DST score ranges from 0-100 points with five “bonus” points allotted for multivitamin/mineral supplement use (score could not exceed 100). Responses in the present investigation were scored according to the previously validated algorithm, with point allotment based on breakdown of major dietary components of the Healthy Eating Index-2005 (HEI-2005). For analysis, the
DST is assessed by quintile, with the highest quintile (≥72) serving as the referent group. Sub-components of diet quality scores have been shown to have associations with various outcomes including development of co-morbid conditions and mortality. Because of the association between fruit and vegetable intake with chronic disease the present analysis also examined four fruit and vegetable questions summed as a sub-component of the DST to determine associations between a fruit and vegetable intake and healthcare resource utilization outcomes. The fruit and vegetable sub-score ranged from 0-25 points. Additional sub-groups from the DST including whole grain consumption, dairy intake and sweets were analyzed (data not shown). While whole grain consumption was statistically significantly associated with decreased inpatient visits, the effect was only a 2% decreased risk and so only fruit and vegetable sub-group associations with HRU are presented.

BMI was calculated from self-reported height and weight at baseline. BMI was assessed per National Institutes of Health (NIH) Guidelines with BMI < 18.5 considered low, 18.5-24.9 normal, 25-29.9 overweight, 30-34.9 obese class I, and ≥ 35 combined obesity classes II and III. The BMI group of 18.5-24.9 served as the referent group for all analyses.

Electronic health records were accessed to obtain all healthcare resource use from October 2009 through December 2011. Utilization records are considered complete, with the sample almost exclusively using the Geisinger Health Plan (GHP). Utilization records of interest included outpatient clinic visits, inpatient visits, inpatient days and ER visits. Total counts for each type of utilization were summed, and each measure was analyzed as a separate outcome measure. Data for the presence of seven obesity-related chronic
diseases including diabetes mellitus, hypertension, coronary artery disease, osteoarthritis, obstructive sleep apnea, depression and liver disease at baseline was also extracted from electronic health records. Presence of disease was considered prevalent due to the age of the cohort. A continuous disease burden variable was created by summing the number of diseases present for each participant.

**Statistical Analysis**

All data were analyzed using the Statistical Analysis Software Package (version 9.3, 2011 SAS Institute Inc., Cary, NC). The demographic and health-related characteristics of males and females within the study population were described using means with standard deviations and percentages. Associations of healthcare resource use outcomes with BMI, diet quality, and fruit and vegetable score were assessed using multivariate negative binomial models. This model allows for count variables, provides point and interval estimates of relative risks (RR) with 95% confidence intervals (95% CI) adjusted for potential confounders, and allows for over-dispersion. Each participant’s length of enrollment in GHP, the period of time during which they were ‘at risk’ of utilizing healthcare, was taken into consideration as an offset variable. Two separate models were analyzed for each of the four healthcare use outcomes. Model 1 assessed associations between categorical BMI and DST quintiles with each HRU outcome, controlling for each other and for the demographic characteristics discussed. Model 2 examined associations between categorical BMI and the fruit and vegetable score in quintiles with each HRU outcome, again controlling for the demographic variables and for each other. All models were adjusted for demographic variables including age (continuous), sex, smoking status (ever/never), education (< high school vs.
≥ high school), weight gain (gain greater than 5 pounds self-reported in previous 6 months yes/no) and weight loss (loss greater than 5 pounds self-reported in previous 6 months yes/no). Self-vs. proxy reporting, living situation of participant (alone, with spouse, with son or daughter, with other family or other) and physical activity were all considered but did not contribute significantly to any of the models and so were excluded from analysis. For each model, for BMI, 18.5-24.9 served as the referent group, and for the DST and fruit and vegetable subgroup the highest score quintiles were considered referent (≥72 and ≥ 22 respectively). Results are presented as relative risks with 95% CI. Interactions between predictors of interest (BMI, DST and fruit and vegetable sub-score) and each covariate (age, sex, smoking status, weight gain, weight loss, and education) were assessed by including each individual factor (e.g. sex) and its cross product term in separate models. Interactions between predictors of interest (BMI, DST and fruit and vegetable score) were also assessed. Significance was considered at p <0.05.

Results

Descriptive characteristics are presented in Table 5-1. Of the 5,993 remaining members of the cohort contacted in 2009, 50% (2,995) returned completed questionnaires and had healthcare resource use data and so were considered in our analyses. Compared to these 2,995 participants, non-responders and responders that did not have healthcare resource use data available were significantly older (82.8±4.8 vs. 81.4±4.4, p <0.05) and more likely to be female (OR 1.1 95% CI 1.0, 1.3, p <0.05). The cohort was primarily non-Hispanic white (99%), high school educated (74%) and provided study data without the use of a proxy (91%). Of the 2,995 included in the study, men had significantly greater inpatient visits (0.69±1.1 vs. 0.62±1.1, p <0.05), inpatient days (3.4±7.3 vs.
2.9±6.8, p <0.05), emergency room visits (1.3±1.9 vs. 1.2±2.1, p <0.05) and outpatient visits (35.4±22.7 vs. 35.1±22.2, p <0.05) compared to women. Women reported significantly higher diet quality scores than males (61.6±12.6 vs. 57.8±12.3, p <0.05).

Nearly 90% of the participants had at least one obesity-related chronic disease. As expected, disease burden and BMI were correlated (Pearson correlation = 0.19, p <0.0001), and because controlling for intermediate variables (i.e. disease) may result in biased estimates \(^{33}\), obesity-related disease burden was not included in the models reported. Simple regression showed that as BMI increased, disease burden increased as well (p <0.0001).

The associations between DST, fruit and vegetable score, and BMI with each of the four healthcare resource use outcomes were assessed in the two models for each outcome described above (Tables 5-2 to 5-5). The first model examined the association between DST and each outcome controlling for BMI and demographic covariates, and between BMI and each outcome controlling for overall DST and demographic covariates. Model two examined the association between fruit and vegetable score and each outcome controlling for BMI and demographic covariates, and between BMI and each outcome controlling for fruit and vegetable score and the demographic covariates.

There were no associations between overall DST score and inpatient visits, inpatient days, or outpatient visits in any of the models assessed. Risk of emergency room visit was increased in participants with a low (unfavorable) DST score (RR 1.21 95% CI 1.00, 1.46, p=0.05) compared to those with the highest DST scores (>72). For the fruit and vegetable analyses, the lowest quintile of fruit and vegetable intake was associated with increased inpatient visits (RR 1.27 95% CI 1.00, 1.63, p=0.05). The three lowest
fruit and vegetable quintiles were also associated with an increased risk of ER visits (0-11 points: RR 1.31 95% CI 1.05, 1.64, p=0.02; 12-15 points: RR 1.23 95% CI 1.00, 1.53 p=0.05; 16-18 points: RR 1.26 95% CI 1.01, 1.56, p=0.04). There were no significant interaction terms between any variables in any of the models.

BMI class was analyzed as a predictor of interest in the models for both DST and fruit and vegetable intake, in order to control for both variables in separate models. Fruit and vegetable intake is a sub-component of the DST, and the association between BMI and healthcare resource use did not differ whether controlling for fruit and vegetable intake or complete DST. Therefore, BMI outcomes are discussed controlling for demographic characteristics and overall DST score.

There were no significant associations between BMI and inpatient visits or inpatient days. Obesity class I was associated with a decreased risk for ER visits (RR 0.84 95% CI 0.70, 0.99, p=0.04). Overweight (RR 1.07 95% CI 1.01, 1.13, p=0.02), obesity class I (RR 1.15 95% CI 1.07, 1.22, p <0.01) and combined obesity classes II and III (RR 1.21 95% CI 1.10, 1.33, p <0.01) were all associated with increased risk of outpatient clinic visits. There were no other associations between BMI and healthcare resource use and no interactions were found.

Discussion

We found that poor diet quality was associated with a 21% increased risk of ER visits. The three lowest fruit and vegetable quintiles were associated with increased ER visits (23-31%) while the lowest quintile was associated with increased inpatient visits (27%). Overweight and all levels of obesity increased risk of outpatient clinic visits (7-21%); however, obesity class I was found to decrease risk of ER visits by 16%.
To our knowledge, the present study is the first to examine the association between diet quality and healthcare resource use in such an aged population. The findings do not indicate an association between overall diet quality at baseline and healthcare resource use over two years of follow-up except for a 21% increased risk for emergency room visits for those participants reporting poor diet quality. Because emergency care visits are generally more costly than outpatient visits, and for adults 65 years and older the average expenditure per emergency visit is over $1,062, reducing this type of healthcare use is desirable. Medical nutrition therapy in individuals aged 55-64 years with diabetes or cardiovascular disease resulted in fewer hospitalizations and outpatient visits, and decreased Medicare expenditures over a mean of two years of follow-up. These observations, paired with the current findings, demonstrate a favorable impact of diet quality on health outcomes.

High fruit and vegetable intake has been associated with reduced mortality, decreased development of chronic diseases, and even reductions in physical and mental impairments in older adults. Low fruit and vegetable intake can contribute to the development of oral health problems, and in turn poor dentition may exacerbate issues associated with nutrient intake. Additionally, consumption of fruits and vegetables in an aging population is hampered by cost, social isolation and lack of nutrition knowledge. Despite this, very little research has examined the associations between fruit and vegetable intake with healthcare resource use, with even less focus upon persons of advanced age. In an analysis of 50-55 year old women, Collins et al. found that adherence to the Australian Recommended Food Score (ARFS) was inversely associated with prospective Medicare charges over five years. However, the trend was not
consistent across quintiles of ARFS score. The vegetable sub-group, however, did demonstrate an association in the expected direction, with low vegetable intake associating with higher Medicare charges \cite{18}. Daviglus and colleagues \cite{17} assessed the associations of fruit and vegetable consumption in middle-aged men (40-56 years old) with health care costs after a mean follow-up of over 37 years and found that individuals with a higher fruit consumption (>42 cups per month vs. <14 cups per month) had lower mean annual Medicare charges. While this implies that early adoption of healthful diets may decrease healthcare costs long term, there was no follow-up dietary assessment in the current analysis or by Daviglus et al. \cite{17} and so only assumptions from baseline intake can be made. Additionally, our survey provides only questions on frequency of consumption and not portions, so it is difficult to directly compare level of intake required to see positive outcomes. However, targeting fruit and vegetable intake in all age groups may improve health outcomes. More research on the impact of diet quality on healthcare resource use across age groups is warranted.

Research has suggested that increased BMI is associated with increased risk of healthcare use in middle-aged and older adults \cite{19,20,21,22,25}, but few studies have focused exclusively on those > 74 years of age. Wee et al. \cite{22} found that annual health expenditures rose with increasing BMI, with the largest increase among adults aged 55 years and older. While these findings persisted in those over 65 years, further age group breakdown was not presented. It is also important to note that all BMIs >30 were combined, potentially attenuating the impact of mild versus severe obesity. Additionally, the largest relative rise in increased expenditures was for prescription medications, an outcome not measured in the current analysis \cite{22}. In a report by Quesenberry et al. \cite{19},
increasing BMI was associated with increased outpatient visits, and individuals with a BMI > 35 had the highest usage, but only for those aged < 75 years. For all age groups, including those 75 and older, a J-shaped relationship was found for inpatient days with the lowest risk in those with a BMI of 25-34.9. Onwudiwe et al. determined that the highest rate of Medicare expenditures in adults > 65 years of age was for those who were underweight or morbidly obese, with the lowest expenditure rate occurring in the overweight group. The associations persisted with adjustment for loss-of-height with aging, indicating protective effects of overweight in terms of Medicare costs.

The present analysis suggests that overweight and all levels of obesity increased risk of outpatient visits while a BMI of 30-34.9 associated with decreased risk for ER visits after controlling for demographic characteristics and diet quality. Increased risk of outpatient visits with rising BMI is not surprising. The burden of chronic disease increased with increasing BMI, indicating that the outpatient visits were likely for management of co-morbid conditions. The lower risk of ER visits with class I obesity is more difficult to explain. The negative impacts of class I obesity upon requirements for urgent care may be attenuated in those who survive to old age. These findings are consistent with previous research suggesting that higher BMIs may decrease healthcare resource use in older adults with the exception of outpatient visits. While we did not find significant associations between underweight and healthcare resource use, it is likely because too few individuals in this cohort met the low BMI threshold. It is also likely that individuals living to advanced old age represent a group of survivors that are less susceptible to the negative impacts of higher BMI. Because outpatient visits make up a much smaller portion of total medical expenditures than inpatient visits, overall
contribution of BMI to medical costs in adults over 74 years of age may not be as impactful as other factors.

Due to the potential for over-adjustment we did not adjust for disease burden in the present analysis. The disease burden variable was extracted from electronic health records and consisted of the obesity-related co-morbidities diabetes mellitus, hypertension, coronary artery disease, osteoarthritis, obstructive sleep apnea, depression and liver disease. Because of the age of our cohort, the presence of these diseases was considered prevalent, and number of conditions were summed and treated as a continuous variable. This obesity-related disease burden variable potentially falls on the pathway between BMI, diet and healthcare resource utilization, and so was not considered in the analysis presented. Previous research has suggested that Medicare expenditures increase with age, and at a faster rate for overweight and obese individuals. That analysis considered all individuals over 65 and differences in expenditures were still attenuated with consideration of chronic disease. It is also likely that the increase in outpatient visits observed in the present analysis with BMI is at least in part attributable to chronic disease. It is difficult to determine contribution of these variables without longitudinal data. With advanced age, BMI may play a less significant role in inpatient healthcare resource use, and overweight and mild obesity may even reduce all-cause mortality in the oldest old. The obesity associated disease co-morbidities may partly increase overall costs through prescription medication use.

A major strength of this study is the relatively large sample size from an undersampled, rural, population of quite advanced age. The response rate (50%) is consistent with other community dwelling cohorts of older persons. We were also able to analyze
descriptive data for the non-responders. Healthcare use outcomes were extracted from electronic health records and are not subject to self-report bias. Several limitations should be noted. BMI was calculated from self-reported height and weight. However, for 2,221 participants in this sample, measured BMI from electronic health records was available and there was a strong correlation between self-reported and measured BMI (Pearson correlation = 0.91, p < 0.0001). This analysis was also based on health care use and not cost, so caution must be taken in making assumptions about increased health expenditures with increasing BMI in an aging population. Due to the nature of the data, we were unable to identify circumstances that led to inpatient and emergency room visits. Additionally, longer follow-up time for healthcare use measures would be of benefit and longitudinal data could help determine risk attributable to BMI versus disease. Dietary information was self-reported and so may be subject to recall bias. Finally, this analysis was conducted in a homogenous sample of primarily non-Hispanic white rural Pennsylvanians. Because healthcare resource use varies by race \(^{45,46}\), further analysis in more heterogeneous populations will be required to inform broad-scale recommendations.

**Conclusions**

In an aging population, concerns regarding increasing healthcare resource consumption are warranted. Though evidence suggests that obesity, and to a lesser extent poor diet, increase healthcare use and expenditures in younger adults, our current findings suggest that these relationships may be more limited in adults aged \(\geq 74\) years. In contrast, mild obesity showed some protective effects against ER visits. The increased risk of outpatient visits in overweight and obese participants may be primarily
attributable to visits associated with co-morbidities. These results indicate that BMI and diet quality at age 74 years and above may infer less risk on healthcare resource use then in younger individuals. It is perhaps likely that achievement of healthy diet, particularly high intake of fruits and vegetables, and a healthy BMI earlier in life might promote long-term positive health outcomes and attenuate healthcare costs later in life.
Table 5-1. Demographic and personal characteristics by Gender for the Geisinger Rural Aging Study (GRAS)

<table>
<thead>
<tr>
<th>Demographic and Personal Characteristics</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>1267 (42.3)</td>
<td>1728 (57.7)</td>
</tr>
<tr>
<td>Mean Age (y)</td>
<td>81.1 ± 4.2</td>
<td>81.5 ± 4.8</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1224 (98.3)</td>
<td>1687 (99.4)</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>20 (1.6)</td>
<td>9 (0.5)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (0.1)</td>
<td>2 (0.1)</td>
</tr>
<tr>
<td>Education</td>
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<td></td>
</tr>
<tr>
<td>Less than High School</td>
<td>349 (28.1)</td>
<td>437 (25.9)</td>
</tr>
<tr>
<td>≥ High School</td>
<td>894 (71.9)</td>
<td>1250 (74.1)</td>
</tr>
<tr>
<td>Eversmoke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>51 (4.1)</td>
<td>63 (3.7)</td>
</tr>
<tr>
<td>No</td>
<td>1195 (95.9)</td>
<td>1636 (96.3)</td>
</tr>
<tr>
<td>Self V. Proxy Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-Report</td>
<td>1117 (89.1)</td>
<td>1586 (93.0)</td>
</tr>
<tr>
<td>Proxy</td>
<td>137 (10.9)</td>
<td>120 (7.0)</td>
</tr>
<tr>
<td>Live With…</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spouse</td>
<td>905 (72.1)</td>
<td>687 (40.3)</td>
</tr>
<tr>
<td>Description</td>
<td>Value</td>
<td>(Percent)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>Son or Daughter</td>
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<td>4.6</td>
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<tr>
<td>Other Family</td>
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<td>1.4</td>
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<td>Other</td>
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<td>1.8</td>
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<td>Alone</td>
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<td>19-21</td>
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<td>35.1 ± 22.2</td>
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<td>0.6 ± 1.2</td>
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<tr>
<td>Inpatient Days</td>
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<td>3.0 ± 6.8</td>
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<td>1.2 ± 2.1</td>
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Table 5-2. Relative Risk for Inpatient Visits

**Model 1**

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<td>&lt;18.5</td>
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<tr>
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<td>823</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
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</tr>
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<td>DST Quintiles(^2)</td>
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1 Controlled for age, sex, education, smoking status, weight gain, weight loss and DST

2 Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI

**Model 2**

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<th>P-Value</th>
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1 Controlled for age, sex, education, smoking status, weight gain, weight loss and fruit and vegetable score

2 Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI
Table 5-3. Relative Risk for Inpatient Days

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<th>RR for Inpatient Days</th>
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<th>P-Value</th>
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<td>(0.64, 2.83)</td>
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<td>823</td>
<td>Ref</td>
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<td>0.82</td>
<td>(0.61, 1.11)</td>
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<td>223</td>
<td>0.91</td>
<td>(0.60, 1.38)</td>
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<td>1.02</td>
<td>(0.73, 1.41)</td>
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<td>568</td>
<td>1.06</td>
<td>(0.77, 1.48)</td>
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<tr>
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<td>58-64</td>
<td>663</td>
<td>1.03</td>
<td>(0.74, 1.43)</td>
<td>0.86</td>
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<tr>
<td></td>
<td>65-71</td>
<td>535</td>
<td>0.84</td>
<td>(0.60, 1.17)</td>
<td>0.30</td>
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<tr>
<td></td>
<td>≥72</td>
<td>559</td>
<td>Ref</td>
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|          | Fruit + Vegetable Quintiles² | 0-11 | 675 | 1.27 | (0.92, 1.75) | 0.15 |
|          |          | 12-15 | 568 | 1.23 | (0.89, 1.71) | 0.21 |
|          |          | 16-18 | 663 | 1.19 | (0.87, 1.65) | 0.28 |
|          |          | 19-21 | 535 | 1.17 | (0.84, 1.64) | 0.35 |

1 Controlled for age, sex, education, smoking status, weight gain, weight loss and DST
2 Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI

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<th>RR (95% CI)</th>
<th>P-Value</th>
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<td>823</td>
<td>Ref</td>
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<td>(0.62, 1.12)</td>
<td>0.23</td>
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<tr>
<td>≥35</td>
<td>223</td>
<td>0.93</td>
<td>(0.61, 1.41)</td>
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<td>Fruit + Vegetable Quintiles²</td>
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<td>675</td>
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<td>(0.92, 1.75)</td>
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<td>12-15</td>
<td>568</td>
<td>1.23</td>
<td>(0.89, 1.71)</td>
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<tr>
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<td>16-18</td>
<td>663</td>
<td>1.19</td>
<td>(0.87, 1.65)</td>
<td>0.28</td>
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<tr>
<td></td>
<td>19-21</td>
<td>535</td>
<td>1.17</td>
<td>(0.84, 1.64)</td>
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1 Controlled for age, sex, education, smoking status, weight gain, weight loss and fruit and vegetable score
2 Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI
Table 5-4. Relative Risk for Emergency Room Visits

### Model 1

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<td>(0.77, 1.04)</td>
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<td>535</td>
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<td>(0.82, 1.21)</td>
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1 Controlled for age, sex, education, smoking status, weight gain, weight loss and DST
2 Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI

### Model 2

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<th>P-Value</th>
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1 Controlled for age, sex, education, smoking status, weight gain, weight loss and fruit and vegetable score
2 Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI
Table 5-5. Relative Risk for Outpatient Visits

### Model 1

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<th>P-Value</th>
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<td>0.55</td>
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<td>(0.81, 1.12)</td>
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<td>823</td>
<td>Ref</td>
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<td>25-29.9</td>
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<tr>
<td>≥72</td>
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1. Controlled for age, sex, education, smoking status, weight gain, weight loss and DST
2. Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI

### Model 2

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<th>RR for Outpatient Visits</th>
<th>P-Value</th>
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<td>823</td>
<td>Ref</td>
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<td>1.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.08, 1.23)</td>
<td></td>
</tr>
<tr>
<td>≥35</td>
<td>223</td>
<td>1.21</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.10, 1.32)</td>
<td></td>
</tr>
<tr>
<td>Fruit + Vegetable Quintiles2</td>
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<td></td>
</tr>
<tr>
<td>0-11</td>
<td>675</td>
<td>1.02</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.95, 1.10)</td>
<td></td>
</tr>
<tr>
<td>12-15</td>
<td>568</td>
<td>1.05</td>
<td>0.21</td>
</tr>
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<td></td>
<td></td>
<td>(0.97, 1.13)</td>
<td></td>
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<tr>
<td>16-18</td>
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<td>0.16</td>
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<td></td>
<td></td>
<td>(0.98, 1.13)</td>
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<td>19-21</td>
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<td>0.09</td>
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<td>≥22</td>
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<td>-</td>
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</tbody>
</table>

1. Controlled for age, sex, education, smoking status, weight gain, weight loss and fruit and vegetable score
2. Controlled for age, sex, education, smoking status, weight gain, weight loss and BMI
References


Chapter 6

BODY MASS INDEX, POOR DIET QUALITY AND HEALTH RELATED QUALITY OF LIFE ARE ASSOCIATED WITH MORTALITY IN PERSONS ≥ 74 YEARS OF AGE

Abstract

Introduction

Subjects and Methods

Results

Discussion

Conclusions

References
Abstract

In an aging population, potentially modifiable factors impacting mortality such as diet quality, BMI and health related quality of life (HRQOL) are of interest. Surviving members of the Geisinger Rural Aging Study (GRAS) (n=5,993; aged ≥ 74 years) were contacted in the fall of 2009. Participants in the present study were the 2,995 (1,267 male, 1,728 female; mean age 81.4 ± 4.4 years) who completed dietary and demographic questionnaires and were enrolled in the Geisinger Health Plan over follow-up (mean=3.1 years). Cox proportional hazards multivariate regression models were used to examine the associations between all-cause mortality and BMI, diet quality, and HRQOL. Compared to GRAS participants with BMIs in the normal range, a BMI < 18.5 was associated with increased mortality (HR 1.85 95% CI 1.09, 3.14, p=0.02), while a BMI of 25-29.9 was associated with decreased risk of mortality (HR 0.71 95% CI 0.55, 0.91, p=.007). Poor diet quality increased risk for mortality (HR 1.53 95% CI 1.06, 2.22, p=0.02). Finally, favorable health related-quality of life was inversely associated with mortality (HR 0.09 95% CI 0.06, 0.13, p<0.0001). Higher diet quality and HALex scores, and overweight status, were associated with reduced all-cause mortality in a cohort of advanced age.
**Introduction**

The associations between body mass index (BMI) and all-cause mortality remain highly controversial in the aging population (1). Recent findings suggest that overweight (BMI 25-29.9) in older persons (≥ 65 years) may be associated with decreased risk for all-cause mortality (1, 2). While in younger and middle-aged adults overweight and obesity are associated with increased risk for all-cause mortality, this association appears to be attenuated with advanced age (2). Underweight (BMI < 18.5) is associated with increased all-cause mortality risk in younger, middle-aged, and older adults, but this relationship is especially strong among those of advanced age (3, 4). The 2010 US Census figures reveal that 5.4% of the population was aged ≥ 80 years and when contrasted with the 2000 figures, these old older persons were the fastest growing segment of the US population (5). Therefore, determining the relationship between BMI and all-cause mortality in this age group is of particular interest.

Evidence regarding the association between diet quality and mortality is mixed, and results vary based on methods that are used to assess diet quality (6). Research in adults aged 65 years and greater has shown that individuals who adhere to a Mediterranean pattern, or eat what is deemed a ‘healthy’ pattern derived through statistical methods have decreased rates of mortality (6). However, this is not a consistent finding, with some studies finding no association between diet quality and mortality outcomes in adults aged ≥ 75 years (7).

In addition to health-related factors such as BMI and diet quality, health related quality of life (HRQOL) is also of interest in the aging population. HRQOL is a broad concept that encompasses subjective assessments of overall quality of life (QOL) as well
as perceptions of physical and mental health that may impact quality of life (8). Evaluating measures for monitoring HRQOL in the United States is a goal of Healthy People 2020 (9), and improvements in the subjective HRQOL may be meaningful in altering the perceived health status of older adults. Poorer HRQOL assessed using the SF-36 Physical and Mental Component Scores has been associated with increased risk for mortality among adults aged 60 and older. The relationship between the Health and Activity Limitation Index (HALex), a specific measure of HRQOL, and mortality, does not appear to have been previously reported. The objectives of this investigation were to examine the associations of BMI, diet quality, and HRQOL with mortality in an aged cohort of rural persons.

**Subjects and Methods**

More than 20,000 adults aged greater than 65 years that were enrolled in a Medicare managed health maintenance organization were recruited for the Geisinger Rural Aging Study (GRAS) in 1994 (10). Detailed information on subject recruitment has been previously published (10). Over time, the participants have been followed as a longitudinal cohort with data repeatedly collected on height, weight, living situation, functional status, self-rated health and diet among other characteristics. All participants are community dwelling individuals in rural northeastern and central Pennsylvania, residing in an area where the population density is 14-475 individuals/mile² (5-183 individuals/km²) (11). The cohort is primarily non-Hispanic white, and high school educated.

Surviving members of the GRAS (n=5,993 aged ≥74 years) were mailed surveys in the fall of 2009 regarding demographic and health information as well as the DST. Of
the survivors, 2,995 participants returned completed surveys and were followed forward in time using electronic medical record and National Death Index data through February 25, 2013. The study protocol was approved by both the Office of Research Protections at the Pennsylvania State University and the Human Research Protection Program of the Geisinger Health Systems Institutional Review Board. Consent was implied by survey completion.

**DST, BMI, and HAlex**

The Dietary Screening Tool (DST) has been described in detail previously (10, 12). Briefly, this tool consists of 25 food-based questions which have been validated to assess diet quality in older adults (12). The questions on the DST were derived from information from multiple 24 hour recalls conducted with a subset of the GRAS population. Questions were formatted to capture usual intake and point breakdown was based on the major dietary component breakdown of the Healthy Eating Index (HEI)-2005 (13). Questions were tested to ensure understandability for the target population through cognitive interviewing, and diet quality was established through comparison with both nutrient and food group intakes (10, 12). Scores range from 0-100, with 5 “bonus” points available for multivitamin/mineral supplement use (score could not exceed 100). Based on the previously validated scoring algorithm, a score of < 60 was considered ‘unhealthy’, 60-75 ‘borderline’, and > 75 ‘healthy’(12). Good test-retest reliability of the DST has been previously demonstrated with a coefficient of 0.83 (p < 0.0001).

Individuals consuming a healthy diet (DST > 75) served as the referent group for all analyses.
BMI was calculated from self-reported height and weight as reported in the fall of 2009 and was categorized based on the National Institutes of Health (NIH) guidelines (14). A BMI < 18.5 kg/m² was considered underweight, 18.5-24.9 healthy, 25-29.9 overweight, 30-34.9 obese class I, and ≥35 combined obesity classes II and III. The healthy BMI range (18.5-24.9) was the referent for all statistical analyses of BMI as a categorical variable.

Health-related quality of life (HRQOL) was assessed using the Health and Activity Limitation Index (HALex) (15). This measure combines self-reported functional limitation and self-rated health into a single HRQOL measure scored on a continuum from 0.0 (deceased) to 1.0 (optimal health) (16). An individual with no functional limitations (i.e. no limitations in activities of daily living (ADLs) or instrumental activities of daily living (IADLs)) who self-reports excellent health would receive a score of 1.00. Placement on the score matrix is derived from five categories of self-rated health (excellent, very good, good, fair and poor) and six levels of activity limitation (not limited, limited- other, limited- major, unable- major, limited in IADL, limited in ADL) (16). The HALex was developed using the National Health Interview Survey (NHIS) data and was validated in 41,104 persons over the age of 18 years standardized to 10,000 persons by age and gender group (15). Because age was a consideration on the original tool for score placement based on functional limitation, only those categories befitting the ages of the present cohort (≥ 74 years) were used in order to model findings as closely as possible to original development (15). The range of scores in the present analysis is 0.1 to 1.0.
**Morbidity and Mortality**

A disease burden variable was created based on the sum of obesity-related co-morbidities extracted from electronic medical records including diabetes mellitus, hypertension, coronary artery disease, osteoarthritis, obstructive sleep apnea, depression and liver disease. The presence of disease at baseline was extracted from electronic medical records. Because of the age of our cohort, the presence of these diseases was considered prevalent, and number of conditions present were summed and treated as a continuous variable. This disease burden variable, based on obesity-related co-morbidities, potentially falls on the pathway between diet, BMI and mortality, and so was not considered as a covariate in the analysis presented (17).

Deaths were identified using electronic medical records and the Social Security Death Index data (18). The last date of data extraction for the present analysis was February 25, 2013. All individuals surviving beyond that point were censored at that date.

**Statistical Analysis**

All data were analyzed using the Statistical Analysis Software Package 9.3 (SAS Institute Inc., Cary, NC). Demographic and descriptive data are presented by gender as means with standard deviations for continuous variables and percentages for categorical variables. Cox proportional hazards regression models were used to estimate multivariate adjusted hazard ratios of mortality for different categories of BMI, DST and continuous HALex scores. Although tests of the proportional hazards assumption suggested the relationship varied quantitatively over time (p<0.05), the associations were qualitatively similar, thus we present results including the full follow-up period. Adjusted hazard ratios (HR) and their 95% confidence intervals (95% CI) are reported. For each participant,
follow-up time accrued from administration of the baseline survey (October 28, 2009) until date of death or end of the study period (February 25, 2013) if death did not occur. Three separate models were used to assess the hazard ratio for mortality with each predictor of interest (BMI, DST, and HALex), while controlling for the demographic covariates. A fourth model was used including BMI, DST and HALex within the same model to assess associations with mortality, while adjusting for the two predictors not being analyzed in addition to the demographic covariates. The covariates included age (continuous), sex, smoking status (ever/never), and recent weight loss or gain (greater than 5 pounds (2.3 kg) self-reported in previous 6 months yes/no). Self-vs. proxy reporting, living situation, physical activity and education were all considered as covariates but did not contribute significantly to the models and so were excluded from analysis. Results are presented as hazard ratios (HR) with 95% confidence intervals (95% CI). Interactions between predictors of interest (BMI, DST and HALex score) and each covariate (age, sex, smoking status, weight loss and gain) were assessed by including each individual factor (e.g. age) and its cross product term in separate models. Interactions between predictors of interest were also assessed. Significance was considered at p < 0.05.

**Results**

Descriptive data are presented in Table 6-1. Of the 4,009 participants who provided completed demographic and dietary questionnaires in the fall of 2009, approximately three-quarters (n=2,995; 1,267 male, 1,728 female; mean age 81.3 years) were enrolled in the Geisinger Health Plan (GHP) for at least part of the follow-up. Follow-up time ranged from 71 – 1,201 days, with a mean follow-up of 1,144 days (> 3
years). Those who did not respond, returned incomplete surveys, or were not enrolled in
the Health Plan were excluded from primary analysis, but were available for comparison
by demographic characteristics and mortality data. Compared to participants with
complete information, non-responders and those with incomplete information were
significantly older (82.8 ± 4.8 yrs, vs. 81.4 ± 4.4 yrs., p < 0.05) and more likely to be
female (OR 1.1 95% CI 1.0, 1.3, p <0.05). In the entire remaining GRAS sample of
5,993, there were 1,015 (17%) deaths during follow-up. In contrast, 360 (12%) occurred
for the subset of 2,995 respondents with complete data included in the present analyses.
Incomplete or non-responders were also more likely to be deceased at the end of follow-
up (OR 2.1 95% CI 1.8, 2.4, p < 0.05). Of those with complete information, women
reported significantly higher diet quality scores (61.6 ± 12.6 vs. 57.8 ± 12.4, p <0.05) and
had a higher BMI (27.3 ± 5.5 vs. 27.1 ± 4.1, p<0.05) than their male counterparts.

In models adjusted for age, sex, smoking status, weight gain and weight loss, low
BMI (<18.5) was associated with an increased hazard ratio for mortality (HR 1.85 95%
CI 1.09, 3.14, p=0.02). In this model, being overweight (BMI 25-29.9) was associated
with a decreased hazard ratio for mortality (HR 0.71 95% CI 0.55, 0.91, p=0.007), while
obesity was not associated with mortality (BMI 30-34.9; HR 0.82 95% CI 0.60, 1.11,
p=0.19; BMI ≥ 35; HR 0.89 95% CI 0.62, 1.51, p=0.89). We did not observe any
meaningful effect modification for any of these associations by age, sex, education,
smoking status, weight change, diet quality, living situation or self vs. proxy reporting.

In the adjusted models, individuals with an unhealthy (low) DST score had an
increased hazard ratio for mortality (HR 1.53 95% CI 1.06, 2.22, p=0.02) compared to
those with higher quality diets. Intakes classified as borderline were not associated with
mortality and again no significant interactions were observed with age, sex, education, smoking status, weight change, BMI, living situation or self vs. proxy report.

Finally, we assessed the relationship between HALex score and mortality. In the adjusted models, a higher (more favorable) HALex score was significantly associated with a decreased hazard ratio (HR 0.09 95% CI 0.06, 0.13, p<0.0001). The HALex model also contained no significant interactions with age, sex, education, smoking status, weight change, BMI, diet quality, living situation or self vs. proxy reporting.

Significant findings were somewhat attenuated when all predictors were considered within the same model (Table 6-3). Findings indicate that the unique attributable portion of risk remains significant for individuals who are classified as overweight, with overweight associated with marginally significant decreased risk of all-cause mortality (HR 0.78 95% CI 0.60, 1.00, p=0.05). Additionally, increased HALex score remains highly associated with decreased risk of all-cause mortality, even when controlling for BMI and DST score (HR 0.09 95% CI 0.06, 0.14, p<0.0001). Associations between underweight and poor quality diet with mortality were attenuated in this model, but the anticipated trends remained.

**Discussion**

We found that hazard ratios for all-cause mortality increased with lower BMI and poor diet quality, while they decreased with a BMI of 25-29.9 and with more favorable HALex scores. Our findings are in line with other research demonstrating that in older adults, a low BMI is associated with greater rates of all-cause mortality, even when controlling for weight loss and conditions that may cause weight loss (3, 4, 19). Additionally, our finding that hazard ratios for all-cause mortality decreased with
overweight in adults aged 74 years and older supports growing evidence that overweight status may confer reduced risk for all-cause mortality in persons of advanced age (2, 3, 20). These findings persisted even when controlling for dietary intake and health related quality of life. Mild obesity did not appear to increase risk of all-cause mortality in this age group, further suggesting that the excess mortality associated with obesity in older age is primarily attributable to BMI class II and III (1). The current NIH recommendations for healthy BMI may be less relevant for this age group compared to younger persons in relation to all-cause mortality. This observation does not rule out that there may remain associations between overweight and other adverse health outcomes. In addition, it is not clear that these findings may be extended to populations under 74 years of age. Those persons who make it to the advanced age of our cohort already reflect selection as survivors.

In the current analyses, we did not statistically control for co-morbidities because adjusting for intermediate variables (i.e. disease) may result in biased estimates (17). However, in preliminary models where disease burden (prevalent cases of the obesity-related chronic diseases diabetes mellitus, hypertension, coronary artery disease, osteoarthritis, obstructive sleep apnea, depression and liver disease) was adjusted for as a continuous covariate, the increased hazard ratio for mortality with low BMI remained (HR 1.89 95% CI 1.11, 3.21, p=0.02), while both overweight (HR 0.66 95% CI 0.51, 0.85, p=.002) and class I obesity (HR 0.72 95% CI 0.53, 0.98, p=.04) were associated with reduced hazard ratios. The interaction between BMI and disease burden was not significant.
The present analysis indicates that poor diet quality is associated with an increased hazard ratio for mortality. While previous work regarding this topic had been inconclusive (6, 7), our investigation is one of the first to use a diet quality tool that was developed and validated for use in the targeted age population (7). Again, in the models that we present, adjustments for disease burden were not made due to concerns for biased results. In preliminary models in which disease burden was utilized as a covariate, though moderately attenuated, the significant relationship between poor diet and mortality remained (HR 1.47 95% CI 1.01, 2.13, p=0.04). The majority of previous studies controlled for disease burden (6) when examining associations between diet quality and mortality. Poor diet quality may serve as a proxy for disease, thus significant associations may diminish when disease burden is entered into a model. When BMI is considered as a covariate, the significance of diet is diminished, but the trend toward increased mortality with poor diet remains.

Finally, we found a dramatic association between the HRQOL measure of HALex and hazard ratios for mortality. This relationship also remained the same in models controlling for disease burden (HR 0.11 95% CI 0.07, 0.17, p<0.0001), and when diet and BMI were covariates (HR 0.09 95% CI 0.06, 0.14, p<0.0001). Previous studies have shown that low baseline physical and mental component scores were associated with increased mortality over 3-years of follow-up in community dwelling adults aged ≥ 65 years in urban and rural areas of Taiwan (21). Otero-Rodriguez et. al. (22) also showed that a decline in HRQOL over time was associated with increased rates of mortality in a population-based Spanish cohort of adults at least 60 years of age. These studies, combined with the present results, suggest that poor HALex score carries strong
prognostic import for mortality outcomes. To our knowledge our investigation is one of the first studies to examine the association of the HALex as a specific measure of HRQOL to mortality.

Major strengths of this study include a robust sample representing an understudied population of aging adults (≥74 years). Healthcare data was obtained from electronic medical records. Descriptive data for non-responders was also available for comparison analysis. Some limitations must also be noted. Height, weight, dietary information, functional limitations, weight loss or gain and health rating were all self-reported, potentially allowing for recall bias. However, for 2,221 individuals measured height and weight were available from electronic medical records and the correlation between self-reported and measured BMI for these individuals was strong (Pearson correlation = 0.91, p < 0.0001). Dietary data was self-reported, but the DST measures dietary patterns and has previously been shown to correlate well with markers of nutrient adequacy in older adults (10). The DST was developed and thus far has been used in a rather homogenous sample. Further investigation with populations of greater diversity will be necessary to broaden applicability of this tool.

Conclusions

Higher diet quality, overweight status and especially higher HALex score, were associated with reduced all-cause mortality in a cohort of advanced age. The strong association between HALex and mortality subsisted even in the model fully adjusted for BMI and diet quality. These findings highlight the priority to better understand the health-related characteristics of “old older” persons in relation to mortality outcomes as they may not be appropriately extrapolated from those of younger samples.
Take Away Points

- Both low BMI and poor diet quality increased risk for all-cause mortality.
- A BMI in the overweight category (25.0-29.9) was associated with a reduced risk for all-cause mortality in older adults.
- Health-related quality of life is strongly inversely associated with risk of all-cause mortality.
Table 6-1. Demographic and personal characteristics by gender for the Geisinger Rural Aging Study (GRAS)

<table>
<thead>
<tr>
<th></th>
<th>Male (n=1267)</th>
<th>Female (n=1728)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years, mean ± SD</td>
<td>81.2 ± 4.2</td>
<td>81.5 ± 4.8</td>
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<tr>
<td>Smoking Status n (%)</td>
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<td></td>
</tr>
<tr>
<td>Ever</td>
<td>51 (4.1)</td>
<td>63 (3.7)</td>
</tr>
<tr>
<td>Never</td>
<td>1195 (95.9)</td>
<td>1636 (96.1)</td>
</tr>
<tr>
<td>Education n (%)</td>
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</tr>
<tr>
<td>&lt; High School</td>
<td>349 (28.1)</td>
<td>437 (25.9)</td>
</tr>
<tr>
<td>≥ High School</td>
<td>894 (71.9)</td>
<td>1250 (74.1)</td>
</tr>
<tr>
<td>Source n (%)</td>
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<tr>
<td>Self</td>
<td>1117 (89.1)</td>
<td>1586 (93.0)</td>
</tr>
<tr>
<td>Proxy</td>
<td>137 (10.9)</td>
<td>120 (7.0)</td>
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<td>Weight Gain n (%)</td>
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</tr>
<tr>
<td>Yes</td>
<td>143 (11.3)</td>
<td>248 (14.4)</td>
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<tr>
<td>No</td>
<td>1124 (88.7)</td>
<td>1480 (85.6)</td>
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<td>Weight Loss n (%)</td>
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<td>Yes</td>
<td>339 (26.8)</td>
<td>450 (26.0)</td>
</tr>
<tr>
<td>No</td>
<td>923 (73.2)</td>
<td>1278 (74.0)</td>
</tr>
<tr>
<td>BMI n (%)</td>
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<tr>
<td>&lt;18.5</td>
<td>12 (1.0)</td>
<td>50 (2.9)</td>
</tr>
<tr>
<td>18.5-24.9</td>
<td>315 (24.8)</td>
<td>508 (29.4)</td>
</tr>
<tr>
<td>25-29.9</td>
<td>610 (48.1)</td>
<td>638 (36.9)</td>
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<tr>
<td>30-34.9</td>
<td>271 (21.4)</td>
<td>368 (21.3)</td>
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<td>35-39.9</td>
<td>53 (4.2)</td>
<td>124 (7.2)</td>
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<tr>
<td>≥40</td>
<td>6 (0.5)</td>
<td>40 (2.3)</td>
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<tr>
<td>DST Score n (%)</td>
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<tr>
<td>Unhealthy</td>
<td>693 (54.7)</td>
<td>725 (42.0%)</td>
</tr>
<tr>
<td>Borderline</td>
<td>459 (36.2)</td>
<td>723 (41.8)</td>
</tr>
<tr>
<td>Healthy</td>
<td>115 (9.1)</td>
<td>280 (16.2)</td>
</tr>
<tr>
<td>HALex Score, mean ±SD</td>
<td>0.76 ± 0.20</td>
<td>0.73 ± 0.21</td>
</tr>
<tr>
<td>Deceased n (%)</td>
<td>185 (14.6)</td>
<td>175 (10.1)</td>
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</tbody>
</table>
Table 6-2. Associations between BMI, DST and HALex score with All-Cause Mortality in GRAS (N=2995)

*Each predictor was analyzed in a separate model, controlling for: age, sex, smoking status, weight gain and weight loss

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard Ratio (95% CI)</th>
<th>P-Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>1.85 (1.09, 3.14)</td>
<td>0.02</td>
</tr>
<tr>
<td>18.5-24.9</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>25-29.9</td>
<td>0.71 (0.55, 0.91)</td>
<td>0.007</td>
</tr>
<tr>
<td>30-34.9</td>
<td>0.82 (0.60, 1.11)</td>
<td>0.19</td>
</tr>
<tr>
<td>≥ 35</td>
<td>0.89 (0.62, 1.51)</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>DST Score</strong></td>
<td></td>
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</tr>
<tr>
<td>Unhealthy</td>
<td>1.53 (1.06, 2.22)</td>
<td>0.02</td>
</tr>
<tr>
<td>Borderline</td>
<td>1.19 (0.81, 1.74)</td>
<td>0.39</td>
</tr>
<tr>
<td>Healthy</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td><strong>HALex Score</strong></td>
<td>0.09 (0.06, 0.13)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
Table 6-3. Associations between BMI, DST and HALex score with All-Cause Mortality in GRAS; All predictors in the same model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard Ratio (95% CI)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>1.47 (0.84, 2.47)</td>
<td>0.18</td>
</tr>
<tr>
<td>18.5-24.9</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>25-29.9</td>
<td>0.78 (0.60, 1.00)</td>
<td>0.05</td>
</tr>
<tr>
<td>30-34.9</td>
<td>0.80 (0.59, 1.10)</td>
<td>0.17</td>
</tr>
<tr>
<td>≥ 35</td>
<td>0.75 (0.48, 1.17)</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>DST Score</strong></td>
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<tr>
<td>Unhealthy</td>
<td>1.34 (0.91, 1.97)</td>
<td>0.14</td>
</tr>
<tr>
<td>Borderline</td>
<td>1.13 (0.76, 1.68)</td>
<td>0.54</td>
</tr>
<tr>
<td>Healthy</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td><strong>HALex Score</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.09 (0.06, 0.14)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

* Controlling for age, sex, smoking status, weight gain, weight loss, DST score (categorical) and HALex

† Controlling for age, sex, smoking status, weight gain, weight loss, BMI (categorical) and HALex

‡ Controlling for age, sex, smoking status, weight gain, weight loss, BMI (categorical) and DST (categorical)
References

Chapter 7

CONCLUSIONS
SUMMARY OF RESEARCH FINDINGS AND IMPLICATIONS

The purpose of this research was to assess the associations of BMI and diet quality with HRQOL, HRU and mortality in a cohort of adults ≥ 74 years old. In an aging population quality of life, morbidity, and mortality are significant concerns. Rates of overweight and obesity have been rising even among older persons (1); a cohort at increased risk for nutritional deficiencies (2-4). The impact of BMI and diet quality on health outcomes in older adults warranted further investigation.

Prior work within the GRAS cohort developed and validated the DST for administration in older adults to assess nutritional risk (5, 6). Based on the previously validated scoring algorithm, a score < 60 was considered ‘unhealthy’, 60-75 ‘borderline’, and >75 ‘healthy’ (5), with comparison to nutrient and food group intakes establishing diet quality. The present work builds upon this foundation, determining the associations of diet quality assessed by the DST with HRQOL, HRU and all-cause mortality in older adults. Chapter 3 discusses the analyses aimed at determining the impact of diet-related factors on diet quality in older adults. Skipping breakfast, reporting a decline in intake over the previous six months, being food insufficient or having chewing difficulties all contributed to lower adjusted mean diet score, indicating poorer diet quality. Being underweight compared to normal weight and all combined weight categories, was also strongly associated with poorer diet quality. While these associations likely represent bi-directional relationships, they help to identify targetable and potentially modifiable diet-related practices for improvement of diet quality in older adults.

Chapter 4 addressed objective two, examining the associations of BMI and diet quality with HRQOL. HRQOL was evaluated using the Health and Activity Limitation Index (HALex), a HRQOL measure based on self-rated health and functional limitations. Compared to
participants with diets considered healthy by DST scoring, participants with both unhealthy (0.71, 95% CI 0.70, 0.72, p<0.0001) and borderline (0.72, 95% CI 0.70, 0.73, p=0.0008) diets had significantly lower HRQOL. F^2 testing confirmed that results were not only statistically significant but clinically meaningful with a moderate effect size. Evidence regarding the underlying etiology of the diet-HRQOL relationship is quite limited. Poor diet quality may result in nutrient deficiencies that adversely affect physical and mental functioning and health (7), with older adults being particularly susceptible. These findings provide a basis for continued promotion of high diet quality even in the oldest old.

The association between BMI and HRQOL was examined, with a BMI of 18.5-24.9 serving as the referent group. Participants with a low BMI (< 18.5) or a BMI in the class II (34.0-39.9) or class III (≥ 40) obesity ranges had significantly lower HRQOL than those with a BMI in the desirable range. The HRQOL scores did not differ for those who were overweight (BMI 25.0-29.9) or mildly obese (BMI 30.0-34.9) compared to those with a desirable BMI. The significant associations between poor diet quality and HRQOL persisted when controlling for BMI, and vice versa, indicating that poor diet quality, underweight and obesity independently contribute to poor HRQOL in older adults. This supports previous research showing declines in HRQOL with increasing levels of obesity (8-10). However, the present analysis demonstrates that overweight and mild obesity may not be detrimental in terms of HRQOL measures in older adults. This is an understudied association in the oldest segment of the population, but present findings support the priority for re-evaluation of desirable BMI for older adults.

Associations between BMI and diet quality with objective health measures were examined in chapters 5 and 6. Chapter 5 addressed the associations of BMI and diet quality with healthcare resource use. Data was extracted from electronic medical records for four categories
of healthcare resource use; outpatient clinic visits, inpatient hospital visits, inpatient hospital
days and emergency room visits. Because of the strong association of fruit and vegetable
consumption with chronic disease development and mortality (11-14), the relationship between a
fruit and vegetable sub-score with HRU outcomes was analyzed as well. BMI had no effect on
inpatient hospital visits or days. Class I obesity was associated with decreased risk of emergency
room visits, and overweight and all obesity classes were associated with increased risk of
outpatient clinic visits. It is not surprising that rising level of obesity was associated with
increased utilization of outpatient clinic visits. The presence of chronic diseases increased with
increasing BMI in the cohort analyzed, likely implicating use of outpatient visits for management
of co-morbid conditions. The lower risk of ER visits with class I obesity is more difficult to
explain. It is possible that there is a decreased susceptibility to the negative impacts of obesity in
those who survive to old age (15, 16). Excess body fat may also act as a metabolic reserve during
times of illness and injury, providing protection in an age group with increasing disease burden
and frailty (17). However, because overall number of ER visits increased with rising outpatient
visits in unadjusted regression analysis, we cannot attribute the decline in ER visits in class I
obesity to enhanced disease management. The association warrants more research.

Though potentially attenuated with age, associations of overall diet score and the fruit
and vegetable sub-group with HRU outcomes were found. Fruit and vegetable score in the
lowest quintile of intake compared to the highest quintile was associated with increased risk for
inpatient visits, and the three lowest fruit and vegetable quintiles increased risk for emergency
room visits. Overall diet quality was only associated with emergency room visits, with the lowest
quintile of diet quality demonstrating a significantly increased risk of emergency room visits
compared to those in the highest quintile of dietary quality. Greater diet quality, and higher fruit
and vegetable intake in particular have been associated with reduced development of chronic disease in younger cohorts (18). In the present analysis, while overall diet quality was not associated with disease burden, there was a significant inverse association between fruit and vegetable intake and disease burden in unadjusted regression models (-0.21, p=0.01). It is difficult to discern directionality, and the relationship is complex because fruit and vegetable intake in older adults is impacted by physical and oral health, ability to prepare foods, geographic location, marital status, social support and socioeconomic status (13, 19). It is possible that individuals with higher fruit and vegetable intake, and greater overall diet quality, are in better general health with greater social support. Multiple factors play a role in healthy aging, but improvements in overall diet quality, and especially consumption of fruits and vegetables, should continue to be encouraged in older adults.

Chapter 6 examined the associations of BMI, diet quality and HRQOL with all-cause mortality. Compared to older adults with a BMI in the desirable range, those who were underweight had a significantly higher risk of all-cause mortality (HR 1.85, 95% CI 1.09, 3.14, p=0.02). In contrast, overweight individuals had reduced all-cause mortality over the mean follow-up period of 37-months (HR 0.71 95% CI 0.55, 0.91, p=0.007). This protective effect of overweight remained when controlling for dietary quality and health related quality of life. No significant associations between obesity of any level and all-cause mortality were found. The protective association of overweight on mortality outcomes in older adults builds upon recent findings. Flegal et al. (20) examined all adults, and found that across age groups and specifically in those ≥ 65 years, overweight decreased risk of all-cause mortality while obesity had no association with all-cause mortality (20). It is likely that the survivors in such an aged cohort are less susceptible to the adverse co-morbidities that are associated with obesity (15), and as
previously mentioned, excess body fat may serve as an important metabolic reserve in times of illness and injury (21). Mounting evidence suggests that the current recommendations for desirable BMI in older adults warrant reconsideration.

Participants reporting consumption of an unhealthy diet as assessed by the DST compared to those with a healthy diet had an increased risk of all-cause mortality (HR 1.53 95% CI 1.06, 2.22, p=0.02). This association was attenuated when controlling for BMI and HRQOL, but trends in the expected direction remained. Many of the leading causes of death including heart disease, cancer and stroke are influenced by diet quality (22). High quality diets may help with management of chronic conditions contributing to lower rates of all-cause mortality. The associations between poor diet quality and increased rates of all-cause mortality likely reflect long-term consumption of nutrient-poor diets. Subsequent analysis determined that individuals reporting fruit and vegetable intake in the lowest quintile had a greater risk of all-cause mortality than those with consumption in the highest quintile (HR 1.43 95% CI 1.01, 2.01, p=0.04 adjusting for age, sex, smoking status, weight gain and weight loss). These findings are in line with two recent analyses examining the role of fruit and vegetable consumption in all-cause mortality. Bellavia et al. (23) demonstrated that individuals with greater consumption of fruits and vegetables had lower all-cause mortality, with levels of consumption below 5 servings per day associated with progressively shorter survival times. Leenders and colleagues (24) investigated fruit and vegetable consumption and mortality relationships in the European Prospective Investigation into Cancer and Nutrition (EPIC) and found that over 13 years of follow-up, higher combined fruit and vegetable intake was associated with decreased risk of all-cause mortality. Poor dietary quality in older adults may be partially attributed to an inability to consume (i.e. poor dentition (25)) or limited access (19) to healthy foods such as fruits and
vegetables due to environmental or socioeconomic barriers or physical limitations. These additional barriers complicate the relationship, but high quality diets continue to be associated with improved outcomes in an aging population.

Finally, the association between higher HRQOL and lower all-cause mortality was quite strong (HR 0.09 95% CI 0.06, 0.13, p<0.0001), and remained so when controlling for BMI and DST score. National data shows that 80% of adults > 65 years old have at least 1 chronic disease (26). In the present sample of adults aged ≥ 74 years, that number reached approximately 90%. With such a high prevalence of co-morbid conditions in older persons, use of biomedical outcomes to determine improvements in health status may be less meaningful than in younger cohorts that have lower prevalence of disease and biomedical outcomes that are more easily altered. HRQOL measures allow for the consideration of perception of health, and provide insight into the quality of life. The associations found herein indicate that not only are individuals with greater HRQOL living longer, but also with more quality years.

The findings from this analysis demonstrate that both diet quality and body mass index play a role in subjective and objective health outcomes among aging adults as depicted in the figure at the end of this chapter. Diet-related behaviors that impact diet quality were identified. These findings impact clinical practice, supporting continued promotion of improvements in these areas through actions such as promoting breakfast consumption. The latter also has implications for policy change for services such as Meals on Wheels. Poor diet quality was found to be associated with a BMI <18.5. The association between low BMI and detrimental outcomes is well established, particularly in the oldest old. Alternatively, high diet quality was found to be associated with greater HRQOL, lower HRU and delayed mortality. These findings suggest a priority for encouraging high diet quality throughout life. It is important to note that the
associations between diet and mortality were attenuated when controlling for HRQOL. This suggests that though diet continues to play a role in health outcomes in late life, HRQOL remains a pertinent variable for assessment in aging.

BMI is also associated with HRQOL, HRU and mortality, but the associations differ from those found in younger cohorts. While a BMI above 35 was associated with reduced HRQOL, individuals with a BMI of 25-34.9 did not differ in HRQOL outcomes than those with a BMI of 18.5-24.9. Additionally, overweight (BMI 25-29.9) was associated with reduced mortality in this cohort. Together these findings suggest that the desirable BMI for individuals over the age of 74 years may be higher than that which is recommended for younger cohorts. In order to inform recommendations, it is necessary to determine potential mechanisms through which excess weight may offer protection against such negative health outcomes. It is possible that this association represents genetic variation, or is actually a proxy for more desirable lifestyle habits or that metabolic reserves serve as protection against illness or injury. Specific implications from this research findings warrant re-evaluation of desirable BMI for older persons, and continued encouragement of a healthy diet throughout life.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Limitations pertaining to our analyses should be noted. The GRAS cohort is a rather homogenous sample of primarily non-Hispanic white rural Pennsylvanians. Demographic and dietary data were self-reported and so were subject to recall bias. Sample sizes at the extreme ends of BMI were small, making it difficult to interpret results and make conclusions regarding these categories. However, this also likely reflects limited survivorship to advanced age for those with either very high or very low BMI. Height and weight were self-reported at baseline.
However, for 2,221 of the 2,995 individuals in the sample discussed in Chapters 5 and 6, height and weight were available in electronic medical records for comparison. From this, we identified a strong correlation between self-reported and measured height and weight (Pearson correlation = 0.91, p < 0.0001). We were unable to determine the medical circumstances leading to use of healthcare resources due to the nature of the data. Follow-up time from baseline assessment to mortality and for healthcare resource use variables was approximately 37 and 27 months respectively. While there were quite ample outcome events for analysis, a follow-up of greater duration would be beneficial in better understanding the long-term effects of diet quality and BMI in an aged population.

Diet was only assessed at baseline, so changes in diet quality over time could not be ascertained. This forces us to assume that diet quality remained stable over follow-up. While dietary patterns have generally been found to remain constant, particularly in older adults (27), this does not preclude possible alterations over time. Future research should examine diet quality at multiple time points to elucidate the directionality of the relationships discussed. An additional limitation is that the DST does not provide estimates for macro and micronutrients, and does not give comprehensive estimates for a wide variety of foods and food groups. Significant results were however found regarding fruit and vegetable intake, but it is important to note that there were more points allotted for the fruit and vegetable sub-group than for any other sub-group in the DST. This may have led to insufficient variation in scoring of other sub-groups, limiting our ability to detect statistically significant results.

The use of BMI may also be somewhat problematic in old age. There are several limitations in using BMI as a measure of body fatness, especially in aging cohorts. BMI is unable to: discern fat mass from fat-free mass, account for age-related body composition changes, or
determine body fat distribution (28, 29). Central adiposity may be more predictive of health outcomes in older adults than overall body fatness (30). Though BMI is an imperfect measure of body fatness, it continues to be the primary method of routine body fat assessment in clinical practice, and for guiding treatments, due to its ease of use (31). As long as BMI remains the primary measure of adiposity in practice (21), it is prudent to identify an age-specific optimal BMI for older adults. Finally, because this is observational data we are unable to determine causation.

In conclusion, the research presented in this dissertation contributes to the body of literature regarding the role of diet quality and BMI in both objective and subjective health outcomes. Specifically, this research has furthered the understanding of these factors in an under-studied rural sample of advanced age. Ultimately it must be determined if promotion of high quality diets and desirable BMI translate into improved health outcomes for older persons. Because of the implications for improvements upon HRQOL, and the strong relationship between HRQOL and mortality, it is likely that continued promotion of high quality diets throughout life will prove beneficial. Re-evaluation of the desirable BMI guidelines for older persons is certainly indicated based upon this research. At least for all-cause mortality, it is likely that desirable BMI extends into what is presently considered the overweight BMI range.
Conclusion Summary

Diet-related behaviors

- Normal to Overweight
  - High diet quality
    - Reduced HRU
    - Reduced Mortality
    - Improved HRQOL
- Poor diet quality
  - BMI <18.5
    - Increased HRU
    - Reduced HRQOL
    - Increased Mortality
References


26. National Center for Chronic Disease Prevention and Health Promotion (U.S.), Division of Adult and Community Health. Healthy aging; helping people to live long and productive lives and enjoy a good quality of life. 2011. Atlanta, GA.
Appendix A

The Dietary Screening Tool
Dietary Screening Tool

How often do you usually eat fruit as a snack?
0   Never
2   Less than once a week
4   1 or 2 times a week
5   3 or more times a week

How often do you usually eat whole grain breads?
0   Never or less than once a week
3   1 or 2 times a week
5   3 or more times a week

How often do you usually eat whole grain cereals?
0   Never or less than once a week
3   1 or 2 times a week
5   3 or more times a week

How often do you usually eat candy or chocolate?
4   Never
3   Less than once a week
2   1 or 2 times a week
0   3 or more times a week

How often do you eat crackers, pretzels, chips, or popcorn?
4   Never
3   Less than once a week
2   1 or 2 times a week
0   3 or more times a week

How often do you eat cakes or pies?
4   Never
3   Less than once a week
2   1 or 2 times a week
0   3 or more times a week

How often do you eat cookies?
4   Never
3   Less than once a week
2   1 or 2 times a week
0   3 or more times a week
<table>
<thead>
<tr>
<th>Question</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often do you eat ice cream?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>4 Never</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3 Less than once a week</td>
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<tr>
<td>2 1 or 2 times a week</td>
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<tr>
<td>0 3 or more times a week</td>
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<tr>
<td>How often do you eat cold cuts, hot dogs, lunchmeats or deli meats?</td>
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<td>5</td>
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<tr>
<td>5 Never or less than once a week</td>
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<tr>
<td>3 1 or 2 times a week</td>
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<tr>
<td>0 3 or more times a week</td>
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<tr>
<td>How often do you eat bacon or sausage?</td>
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<td></td>
<td>5</td>
</tr>
<tr>
<td>5 Never or less than once a week</td>
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<tr>
<td>3 1 or 2 times a week</td>
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<tr>
<td>0 3 or more times a week</td>
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<tr>
<td>How often do you eat carrots, sweet potatoes, broccoli, or spinach?</td>
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<td></td>
<td></td>
<td>0</td>
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<tr>
<td>0 Never</td>
<td></td>
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</tr>
<tr>
<td>2 Less than once a week</td>
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<tr>
<td>6 1 or 2 times a week</td>
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<td>8 3 or more times a week</td>
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<tr>
<td>How often do you eat fruit (not including juice)? Please include fresh,</td>
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<td></td>
<td>0</td>
</tr>
<tr>
<td>canned or frozen fruit.</td>
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<td></td>
</tr>
<tr>
<td>0 Never or Less than once a week</td>
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<tr>
<td>2 1 or 2 times a week</td>
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<tr>
<td>4 3 to 5 times a week</td>
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<tr>
<td>5 Every day or almost every day</td>
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<tr>
<td>How often do you eat hot or cold breakfast cereal?</td>
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<td>0</td>
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<tr>
<td>0 Never</td>
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<tr>
<td>1 Less than once a week</td>
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<td>3 1 or 2 times a week</td>
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<tr>
<td>4 3 to 5 times a week</td>
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</tr>
<tr>
<td>5 Every day or almost every day</td>
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</tr>
<tr>
<td>How often do you drink some kind of juice at breakfast?</td>
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<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0 Never or Less than once a week</td>
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</tr>
<tr>
<td>2 1 or 2 times a week</td>
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<td></td>
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<tr>
<td>4 3 to 5 times a week</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5 Every day or almost every day</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often do you eat chicken or turkey?</td>
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<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0 Never or less than once a week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 1 or 2 times a week</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5 More than 3 times a week</td>
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<td></td>
</tr>
</tbody>
</table>
How often do you drink a glass of milk?
0  Never or Less than once a week
1  1 or 2 times a week
3  3 to 5 times a week
4  Every day or almost every day
5  More than once every day

Do you usually add butter or margarine to foods like bread, rolls, or biscuits?
0  Yes
1  No

Do you usually add fat (butter, margarine or oil) to potatoes and other vegetables?
0  Yes
1  No

Do you use gravy (when available) at meals?
0  Yes
1  No

Do you usually add sugar or honey to sweeten your coffee or tea?
0  Yes
1  No

Do you usually drink wine, beer or other alcoholic beverages?
0  Yes
1  No

How often do you eat fish or seafood that IS NOT fried?
0  Never
1  Less than once a week
3  Once a week
5  More than once a week

How many servings of milk, cheese, or yogurt do you usually have each DAY?
0  None
3  One
5  Two or more
How many different vegetable servings do you usually have at your main meal of the day?
0  None
1  One
5  Two
7  Three or more

Which of the following best describes your nutritional supplement use.
0  I don’t use supplements
0  I use supplements other than vitamins and mineral
5  I use a multivitamin/mineral preparation (e.g. Centrum)

¹ The bolded score values were not presented on the DST when it was completed by the participants.
Appendix B

The Health and Activity Limitation Index Scoring Matrix
<table>
<thead>
<tr>
<th>Activity Limitation</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Limited¹</td>
<td>1.00</td>
<td>0.92</td>
<td>0.84</td>
<td>0.63</td>
<td>0.47</td>
</tr>
<tr>
<td>Limited-other</td>
<td>0.87</td>
<td>0.79</td>
<td>0.72</td>
<td>0.52</td>
<td>0.38</td>
</tr>
<tr>
<td>Limited-major</td>
<td>0.81</td>
<td>0.74</td>
<td>0.67</td>
<td>0.48</td>
<td>0.34</td>
</tr>
<tr>
<td>Unable-major</td>
<td>0.68</td>
<td>0.62</td>
<td>0.55</td>
<td>0.38</td>
<td>0.25</td>
</tr>
<tr>
<td>Limited in IADL¹</td>
<td>0.57</td>
<td>0.51</td>
<td>0.45</td>
<td>0.29</td>
<td>0.17</td>
</tr>
<tr>
<td>Limited in ADL¹</td>
<td>0.47</td>
<td>0.41</td>
<td>0.36</td>
<td>0.21</td>
<td>0.10</td>
</tr>
</tbody>
</table>

¹Categories for adults aged ≥ 65 years
VITA
Dara Wheeler Ford

EDUCATION
2013 Ph.D., Nutritional Sciences, The Pennsylvania State University (PSU)
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2010 Graham Fellowship