Caloric Intake and Dietary Patterns Are Associated with Onset of Physical Disability and Mortality in a Representative Sample of Older U.S. Adults

ABSTRACT

Given the growing number of older adults living with physical disability and the difficulty of reversing disablement, the identification of potentially modifiable risk factors linked to the onset of disability are required to support the functional independence and survival of older adults. Our goal was to investigate the association between caloric intake, dietary patterns, and risk of activities of daily living (ADL) disability onset or mortality in a representative sample of older adults. An analytic sample of 3,335 adults age 65 and older were drawn from the 2012-2014 Health and Retirement Study and linked 2013 Health Care and Nutrition Study. Exploratory factor analysis was used to identify food groups that were commonly consumed together and multinomial logistic regression was used to assess the risk of ADL limitation onset or mortality over the two year follow-up period. Two dietary factors were identified, representing common consumption of healthy foods such as vegetables, fruit, and whole grain, or Western foods including processed meats, red meat, and refined carbohydrates. Greater caloric intake was associated with an increased risk of ADL limitation onset but was not associated with risk of mortality. Regular consumption of healthy foods reduced the risk of both ADL limitation onset and mortality, and unexpectedly, greater intake of Western foods was associated with a lower risk of developing an ADL limitation. These preliminary results suggest a complex relationship between energy intake, dietary patterns, and onset of ADL limitations or mortality among older adults, and warrant more thorough examination.

Aging is accompanied by an increased risk of decline in physical function, disability, and mortality. In 2016, 35.2% of adults age 65 and older reported at least one disability (Erickson et al. 2017). Though the declining prevalence of disability among older adults has been well documented (Freedman et al. 2004), the increased longevity of those living with disability (Crimmins et al. 2009) coupled with population aging will increase the overall costs associated with age-related disability. Once older adults become disabled, it is difficult to reverse the limitations through intervention (Cesari et al. 2014); therefore, there is a pressing need to identify modifiable lifestyle factors to support the functional independence of older adults. As older adults come to represent a greater proportion of our population, the ability to identify the risk of disability onset associated with simple indicators of dietary intake could prove a valuable means of reducing disablement among aging societies.

A growing body of evidence from animal studies suggests caloric restriction may promote functioning and longevity (Anton and Leeuwenburgh 2013; Marzetti et al. 2009). Potential mechanisms through which reduced caloric intake may be associated with physical capacity and longevity are improved mitochondrial function, reduced oxidative damage to tissues, and improved glucose tolerance (Marzetti et al. 2009; Roth et al. 2002). However, research on the effect of total energy intake on disability and mortality in older adults is conflicting. Higher energy intake has been associated with a significantly increased risk for onset or worsening of activities of daily living (ADL) disability in older adults (Balzi et al. 2010), though the authors note that the observed relationship between caloric intake and disability is likely confounded by obesity among those with excessive caloric intake. In contrast, several observational studies have demonstrated that higher energy intake may be beneficial, associated with reductions in disease specific and all-cause mortality (Franco et al. 2007; Lee and Chan

2016; Willcox et al. 2004). Sufficient caloric intake may be especially important for older adults to protect against age-related physical impairments that predict the onset of disability such as sarcopenia and bone-loss.

Independent of caloric intake, adequate nutrition is crucial for healthy aging and may prevent poor health and loss of independence (An et al. 2015; Inzitari et al. 2011). While inadequate macronutrient consumption is associated with impaired muscle strength, physical performance, and disability in older individuals, changes in overall diet quality may have a greater impact on the prevention and onset of disabilities than focusing on individual nutrients (Milaneschi et al. 2010). Indeed, healthier dietary patterns characterized by higher consumption of fruits, vegetables, fiber, and lower intakes of fat and animal products have been associated with reduced self-report of disability in lower extremity mobility (Xu et al. 2012), prevention or delay of mobility limitations (Féart et al. 2011; Houston et al. 2005; Parsons et al. 2018; Tomata et al. 2016), and reduced risk of all-cause mortality (Atkins et al. 2016).

Optimal energy intake and improved diet quality may serve as a means of preventing physical disability; however, longitudinal studies that assess the relationship between dietary intake and physical disability in older adults are limited. The Health and Retirement Study (HRS) provides an ideal data source for testing the association between dietary intake and disability onset given the longitudinal assessment of ADL limitations as well as the recent collection of dietary intake data among a sub-sample of HRS respondents in the Health Care and Nutrition Study (HCNS). Our primary goal was to investigate the association between energy intake and indicators of diet quality with onset of ADL limitation, with the secondary goal of identifying whether summary indicators of dietary intake were related to the competing risk of all-cause mortality over the two year observational period

METHODS

Observations were drawn from the HRS, a biennial national panel survey of older Americans funded by the National Institute on Aging (NIA) and the Social Security Administration (grant number: NIA U01AG009740) (Hauser and Weir 2010). The 2013 HCNS, an off-year mail-out HRS supplement conducted by the Survey Research Center at the Institute for Social Research at the University of Michigan, collected information about food consumption using a modified Harvard food frequency questionnaire developed by Willett and colleagues (University of Michigan 2014; Willett et al. 1985) with calculated energy and nutrient totals based on Harvard School of Public Health nutrient tables. The University of Michigan's institutional review board approved the HRS protocol and participants were read a confidentiality statement and provided oral or implied consent when first contacted and signed a written informed consent form at each interview (University of Michigan 2017). All measures were collected through participant self-report and proxy response to the HRS survey was allowed when the respondent was unable to complete the interview. The HRS sample is a multi-stage, area-clustered, and stratified sampling design representative of all age-eligible non-institutionalized adults in the U.S. population (Ofstedal et al. 2011).

The original HCNS contained 8,073 observations with complete information on consumption of 164 food items. Individuals under the age of 65 at time of completing the 2012 HRS (n = 3,867), those who had implausible daily energy intakes of less than 500 kilocalories or greater than 5,000 kilocalories (n = 114), who reported at least one ADL limitation in 2012 (n = 655), or who had missing values on the 2014 ADL questions not attributable to mortality between 2012 and 2014 (n = 102) were excluded, resulting in an analytic sample of 3,335. Indicators of ADL limitation onset, mortality, and covariates were primarily drawn from the

RAND HRS data file (Version P) (Chien et al. 2015), with indicators of cognitive status taken from the core HRS files. The simple response rates for the HRS and HCNS were 89.1% and 65.0%, respectively (University of Michigan 2014, 2016).

Measures

ADL limitation onset: Limitations in activities of daily living represent relatively severe disablement. If respondents reported some difficulty with any of the following activities, they were identified as having an ADL limitation: walking across a room, dressing, bathing, eating, getting in and out of bed, using the toilet (1 = any ADL limitation, 0 = no ADL limitation).

Mortality: An indicator of vital status at the 2014 HRS interview was taken from the RAND HRS dataset. Based on reports from someone capable of reporting a death, individuals were identified as alive in 2014, presumed alive in 2014, deceased between prior and current wave, and known deceased as of prior wave. Those identified as deceased between prior and current wave were identified as deceased and those identified as presumed to be alive but unavailable for response in 2014 were coded as missing.

Energy intake and dietary quality: In models predicting onset of disability and mortality, estimated daily energy intake (kcal) was included as an indicator of average daily caloric intake. In models predicting ADL limitation onset, the original metric of daily kcals was divided by 100 to facilitate interpretation of statistical estimates (kcal/100).

Respondents were asked to indicate average total consumption of 164 possible food items and average serving size over the past 12 months. Responses were converted to reflect average number of servings per day. Five food items were excluded from analysis based on recommendations provided by the Food Patterns Equivalence Database by the U.S. Department of Agriculture (Bowman et al. 2017). The remaining 159 food items were grouped based on nutritional similarity then summed to represent daily intake of 35 distinct food groups. Supplementary Table 1 describes the 35 food groups and lists excluded food items. For clarity, we use the term “food groups” to describe the 35 separate foods and food groups used to identify dietary intake factors. Due to severe non-normality in certain food groups, scores for individuals with daily food group intakes greater than four standard deviations above the mean were replaced with the food group mean plus four standard deviations above the mean. Finally, scores were log-transformed with an offset of .01 to improve normality and allow inclusion of individuals reporting non-intake of a given food group.

Covariates: All covariates were measured in 2012. Demographic measures included respondents’ age, gender (1 = female, 0 = male), race/ethnicity (White, Black, Hispanic, Other), marital status (1 = partnered or married, 0 = single, divorced, or widowed), and retirement status (1 = retired, 0 = not retired). Education (< 12 years of education, 12 years of education, > 12 years of education), longest occupational tenure (white-collar, blue-collar, female homemaker, other occupational tenure), and log-transformed household income and assets were included as indicators of socioeconomic status (SES). Health behaviors included body mass index (BMI; underweight (BMI < 18.5 kg/m^2), normal weight (18.5 kg/m^2 ≤ BMI < 25 kg/m^2), overweight (25 kg/m^2 ≤ BMI < 30 kg/m^2), obese (BMI ≥ 30 kg/m^2)), vigorous physical activity (participation in activities such as sports, heavy housework, or a job that involves physical labor; no vigorous physical activity, vigorous physical activity less than 1 time per week, vigorous physical activity more than one time per week), current smoking status (1 = current smoker, 0 = not current smoker), and alcohol consumption (non-drinkers, moderate drinkers (men drinking between 1 and 14 drinks per week and females drinking between 1 and 7 drinks per week), and heavy drinkers (men drinking more than 14 drinks per week and females drinking more than 7 drinks per week)). Health status was measured using self-rated health status (1 = poor, 5 = excellent) and a sum of doctor-diagnosed chronic conditions (high blood pressure, cancer, diabetes, lung disease, heart problems, stroke, psychiatric problems, and arthritis). An indicator of proxy response in 2012 was also included to adjust statistical models.

Methods

Exploratory factor analysis (EFA) was used to identify food groups that were commonly consumed together. The 35 food groups were entered into a factor analysis using the iterated principal factor analysis procedure with Varimax rotation in SAS version 7.3 (SAS Institute Inc. 2017). The EFA identified 2 dietary factors with eigenvalues greater than one, and items loading on each factor at .40 or greater were retained. Greater factor scores represent greater daily consumption of the food groups identified as being commonly consumed together.

Once common factors were identified, multinomial logistic regression was used to examine the association between energy intake, dietary intake, and likelihood of developing an ADL limitation or experiencing morality over the two-year observational window. Individuals who did not report developing an ADL limitation or who were not identified as deceased were used as the reference category. Mplus version 8.1 (Muthén and Muthén 2017) was used estimate the multinomial logistic regression using maximum likelihood estimation with standard errors robust to non-normality, allowing us to account for missing data on covariates measured in 2012 and to adjust estimates for the complex survey design of the HRS and HCNS.

RESULTS

Descriptive statistics for characteristics of the analytic sample are presented in Table 1. Respondents were on average around 75 years old, had a household income around $66,000 and accumulated household assets of around $558,800. On average, respondents reported around two doctor-diagnosed chronic conditions. The sample was predominantly female, tended to be of White race/ethnicity, and were typically both married and retired. Only 16.6% of older adults reported earning less than a high school degree and around 47% reported having completed at least some post-secondary education. Around 56% of respondents reported working in white-collar occupations for the majority of their careers and about 32% reported blue-collar occupational tenure. Nearly 67% of the sample was either overweight or obese, and more than half of respondents reported no vigorous physical activity. The majority of respondents were non-smokers and did not consume alcohol. Proxy response was reported for 3% of the sample.

Table 2 contains descriptive statistics for energy intake and dietary intake factors, as well as counts and weighted percentages of ADL limitation onset and mortality. The average daily kcal intake in the analytic sample was 1,767 (SD = 744.50). Factor scores for the healthy foods and Western foods factors reflect computed factor scores that attempt to represent true factor scores with a mean of zero and variance of one. Around 89% of the sample (n = 2,951) did not report onset of an ADL limitation, though close to 10% did develop an ADL limitation over the observational period (n = 338, % = 9.84). Mortality over the follow-up period was rare with only 1.2% (n = 46) of the initial sample experiencing mortality over the two years of observation.

Table 3 presents descriptive statistics for the food groups associated with the common food intake factors, both for the overall sample as well as by quartiles identified separately for each factor. The first common factor, labeled the healthy foods factor, contained nine food groups consisting of various types of vegetables, fruits, legumes, whole grain, and fish/seafood. Those in the lowest quartile of the healthy foods factor consumed few vegetables and reported consuming less than one serving of fruit and whole grains per day, where older adults in the highest healthy foods factor quartile reported regular consumption of vegetables, more than 2 servings of fruit per day, and more than one serving of whole grain each day. The Western foods factor contained 10 food groups including processed meat and red meat, French fries, refined grains, sweets, potatoes, pizza, snacks, butter/margarine, and high energy drinks. Consumption of Western foods in the lowest quartile was rare, with less than one serving per day reported for any of the food items. Older adults identified in the highest Western foods quartile reported consuming an average of at least one serving of refined grains, more than two servings of sweets, and more than one serving of butter/margarine each day. The proportion of total variance explained was 54.4% for the healthy foods factor and 31.2% for the Western foods factor.

Results from the multinomial logistic regression models estimating the odds of developing an ADL limitation or experiencing mortality over the two-year observational window are reported in Table 4. Average daily energy intake and scores on both the healthy foods and Western foods factors were associated with odds of developing an ADL limitation over the observational period. For each additional 100 calories consumed, the odds of developing an ADL limitation increased by 4% (OR = 1.04, 95% CI = 1.01, 1.06; $p = .001$). Interestingly, higher scores on both the healthy foods factor and Western foods factor were negatively associated with the odds of ADL limitation onset. With each unit increase in healthy foods factor scores, there was an 18% decrease in the odds of reporting ADL limitation onset (OR = 0.82, 95% CI = 0.69, 0.98; $p = .029$). Similarly there was an 18% decrease in the odds of ADL limitation onset with a one-unit increase in Western foods factor scores (OR = 0.82, 95% CI = 0.68, 0.98; $p = .042$). Regarding covariates in models predicting odds of ADL limitation onset, adults who were older, retired, current smokers, had a proxy response in 2012, or reported more chronic conditions had increased odds of ADL limitation onset. Compared to their respective reference groups, those reporting an unclassified occupational tenure, who were either underweight or obese, or reported no vigorous physical activity were at greater risk of developing an ADL limitation.

When estimating the odds of mortality compared to the healthiest older adults who did not report an ADL limitation and were alive at follow-up, the healthy foods factor was the only nutritional indicator related to mortality. Specifically, each unit increase in scores on the healthy foods factor decreased the odds of experiencing mortality by 38% (OR = .62, 95% CI = 0.41, 0.94; $p = .025$). Being older, retired, and proxy response were associated with increased likelihood of mortality, as was being Black or “other” race/ethnicity as compared to White.

DISCUSSION

In our examination of dietary influences on disability onset, both caloric intake and summary measures of dietary intake were associated with likelihood of ADL limitation onset in a sample of community-dwelling adults age 65 and older. Greater caloric intake appeared to increase the risk of ADL limitation onset, with greater scores on both the healthy foods and Western foods factors being negatively associated with onset of ADL limitation. Of the dietary intake measures examined, only scores on the healthy foods factor were associated with risk of mortality, with greater intake of healthy foods associated with a decreased risk of mortality. These preliminary results suggest a meaningful yet complex association between disability, energy intake, and dietary indices. Limitations and future elaboration of our work are discussed.

When adjusting for indicators of dietary quality and other covariates, greater caloric intake was associated with a greater risk of ADL limitation onset over the two year observational window. That caloric intake remained a significant predictor of ADL limitation onset when adjusting for indices of dietary quality suggests that energy intake may play a role in the progression of disability over and above that explained by nutrient intake. Excessive caloric intake may be associated with a greater risk of ADL limitation onset through the increased likelihood of obesity, though identification of excessive caloric intake would require physiological testing of basal metabolic rate and energy expended through daily activities. Our statistical models adjusted for BMI and vigorous physical activity, both of which were significantly associated with ADL limitation onset. It appears that higher caloric intake may be associated with ADL limitation onset independent of obesity and activity, which appears to support caloric restriction as a means of reducing disablement onset risk among older adults, though numerous alternative explanations for this association are plausible and need to be tested. It is likely that after adjusting models for caloric intake, dietary indicators, and relevant covariates, residual confounding remains due to unmeasured predictors of ADL onset.

Interestingly, greater scores on both the healthy foods and Western foods factors were negatively associated with the likelihood of ADL limitation onset. That greater consumption of vegetables, fruits, and whole grains represented by the healthy foods factor was protective against the onset of ADL limitation was expected, yet greater consumption of processed, low-nutrient foods was also associated with decreased risk of disability onset. We hypothesized that greater intake of Western foods would increase the rate of ADL limitation onset due to associations between Western dietary patterns and chronic disease and disablement (Heidemann et al. 2008; Hu 2002; Prentice 2004), though the processed meats and red meat food groups included in the Western dietary factor are good sources of protein; a macronutrient known to protect against sarcopenia and subsequent frailty in older adults (Paddon-Jones and Rasmussen 2009). In the population of older adults, increased intake of Western foods may actually protect against the onset of physical disability, though cautious study is needed to identify the secondary effects of high Western food consumption on other chronic health outcomes.

Our analyses also identified intake of healthful foods to be related to the likelihood of mortality over the two year follow-up period. For each unit increase in the healthy foods factor score, the odds of mortality decreased by around 38 percent. Consumption of healthy foods may increase the intake of nutrients that promote overall health and longevity, or regular consumption of healthful foods may be indicative of other health behaviors that protect older adults from disability onset. Having high scores on the healthy foods factor may also be a proxy for greater SES which would enable both consumption of healthier food as well as a host of other social and environmental advantages supportive of health and protective against disablement and mortality. Our models adjusted for a range of socioeconomic measures, but whether SES moderates the association between dietary patterns and disability onset needs to be assessed.

Limitations and Future Directions

As a preliminary analysis of the association between caloric intake, dietary patterns, and ADL disability onset, our work has a number of limitations we plan to address prior to presentation and publication. First, the presence of non-linear associations between the caloric and dietary measures and risk of ADL limitation onset is likely given that inadequate and excessive consumption of energy and nutrients are both related to numerous poor health outcomes. Also, the relationship between caloric intake and ADL limitation onset may depend on diet quality, thus potential interactions between caloric intake and dietary factors need to be examined. The role caloric and dietary intake play in the progression of disability may also depend on age and sex, both characteristics associated with dietary intake and disability. We plan on conducting multiple-group analyses to test whether dietary intake influences ADL disability onset differently for older men and women at different points of the age continuum. Additionally, we intend to investigate whether socioeconomic measures moderate the influence of dietary intake on ADL limitation onset. We believe socioeconomic context likely plays a central role in the development of, and relationship between, dietary habits and disablement.

Limitations outside of those related to the preliminary stage of our investigation include the self-report nature of dietary intake, the population being observed, and the short duration of observation used to identify ADL onset and mortality. The use of a FFQ to estimate dietary intake relies on the respondent to accurately report dietary intake, introducing measurement error into assessment of dietary intake through incorrect recall. Being representative of only community-dwelling older Americans, the HRS and HCNS do not reflect the experiences of institutionalized older adults who are at the greatest risk of nutritional deficiencies and poor health. By excluding older adults at the greatest risk of poor nutrition and disability, our findings are likely a cautious estimate of the association between dietary intake and onset of disablement, and not representative of older adults who could benefit the most from nutritional interventions. Also by relying on the RAND HRS dataset to provide indicators of ADL limitations, our follow-up period is reduced to a relatively short span of two years. Though the 2016 HRS is available as an early release, we believe it is prudent to wait for the final 2016 HRS release before examining the impact of dietary intake on disablement over longer follow-up periods.

In summary, this preliminary work suggests that caloric intake and the types of foods consumed may be a risk factor in the disablement process. Further decomposition of this association will allow us to more accurately describe how daily energy intake and consumption of different types of foods influence the course of disablement for aging adults. We hope this work is of interest to those working at the intersection of population health, gerontology, and nutritional epidemiology.

REFERENCES

An, R., Chiu, C. Y., Zhang, Z., & Burd, N. A. (2015). Nutrient intake among US adults with disabilities. *Journal of Human Nutrition and Dietetics*, *28*(5), 465–475.

Anton, S., & Leeuwenburgh, C. (2013). Fasting or caloric restriction for healthy aging. *Experimental gerontology*, *48*(10), 1003–1005.

Atkins, J. L., Whincup, P. H., Morris, R. W., Lennon, L. T., Papacosta, O., & Wannamethee, S. G. (2016). Dietary patterns and the risk of CVD and all-cause mortality in older British men. *British Journal of Nutrition*, *116*(7), 1246–1255.

Balzi, D., Lauretani, F., Barchielli, A., Ferrucci, L., Bandinelli, S., Buiatti, E., et al. (2010). Risk factors for disability in older persons over 3-year follow-up. *Age and Ageing*, *39*(1), 92–98.

Bowman, S. A., Clemens, J. C., Friday, J. E., Lynch, K. L., & Moshfegh, A. J. (2017). *Food Patterns Equivalents Database 2013-14: Methodology and User Guide: Methodology and User Guide*. http://www.ars.usda.gov/nea/bhnrc/fsrg. Accessed 29 May 2018.

Cesari, M., Demougeot, L., Boccalon, H., Guyonnet, S., Vellas, B., & Andrieu, S. (2014). The multidomain intervention to prevent disability in elders (MINDED) project: Rationale and study design of a pilot study. *Contemporary Clinical Trials*, *38*(1), 145–154.

Chien, S., Campbell, N., Chan, C., Hayden, O., Hurd, M., Main, R., et al. (2015). RAND HRS Data Documentation, Version P, (October), 1093. http://hrsonline.isr.umich.edu/modules/meta/rand/randhrso/randhrs_O.pdf Accessed 14 September 2018.

Crimmins, E. M., Hayward, M. D., Hagedorn, A., Saito, Y., & Brouard, N. (2009). Change in disability-free life expectancy for Americans 70 years old and older. *Demography*, *46*(3), 627–646.

Erickson, W., Lee, C., & Schrader, S. von. (2017). Disability Statistics from the American Community Survey (ACS). Ithaca NY: Cornell University Yang-Tan Institute (YTI).

Féart, C., Pérès, K., Samieri, C., Letenneur, L., Dartigues, J.-F., & Barberger-Gateau, P. (2011). Adherence to a Mediterranean diet and onset of disability in older persons. *European Journal of Epidemiology*, *26*(9), 747–756.

Franco, M., Ordunez, P., Caballero, B., Tapia Granados, J. A., Lazo, M., Bernal, J. L., et al. (2007). Impact of energy intake, physical activity, and population-wide weight loss on cardiovascular disease and diabetes mortality in Cuba, 1980-2005. *American Journal of Epidemiology*, *166*(12).

Freedman, V. A., Crimmins, E. M., Schoeni, R. F., Spillman, B. C., Aykan, H., Kramarow, E., et al. (2004). Resolving inconsistencies in trends in old-age disability: report from a technical working group. *Demography*, *41*(3), 417–441.

Hauser, R. M., & Weir, D. (2010). Recent developments in longitudinal studies of aging in the United States. *Demography*, *47*(1), s111–s131.

Heidemann, C., Schulze, M. B., Franco, O. H., Van Dam, R. M., Mantzoros, C. S., & Hu, F. B. (2008). Dietary patterns and risk of mortality from cardiovascular disease, cancer, and all causes in a prospective cohort of women. *Circulation*, *118*(3), 230-237.

Houston, D. K., Stevens, J., Cai, J., & Haines, P. S. (2005). Dairy, fruit, and vegetable intakes and functional limitations and disability in a biracial cohort: the Atherosclerosis Risk in Communities Study. *The American Journal of Clinical Nutrition*, *81*(2), 515–22.

Hu, F. B. (2002). Dietary pattern analysis: a new direction in nutritional epidemiology. *Current Opinion in Lipidology*, *13*(1), 3–9.

Inzitari, M., Doets, E., Bartali, B., Benetou, V., Bari, M. D. I., & Visser, M. (2011). Nutrition in the age-related disablement process, *The Journal of Nutrition, Health & Aging 15*(8), 599-604.

Lee, P. H., & Chan, C.-W. (2016). Energy intake, energy required and mortality in an older population. *Public Health Nutrition*, *19*(17), 3178–3184.

Marzetti, E., Anne Lees, H., Eva Wohlgemuth, S., & Leeuwenburgh, C. (2009). Sarcopenia of aging: Underlying cellular mechanisms and protection by calorie restriction. *BioFactors*, *35*(1), 28–35.

Milaneschi, Y., Tanaka, T., & Ferrucci, L. (2010). Nutritional determinants of mobility. *Current Opinion in Clinical Nutrition and Metabolic Care*, *13*(6), 625–629.

Muthén, L. K., & Muthén, B. O. (2017). Mplus User's Guide, Eight Edition. Los Angeles: Muthén & Muthén.

Ofstedal, M. B., Weir, D., Chen, K.-T., & Wagner, J. (2011). *HRS Documentation Report Updates to HRS Sample Weights*. https://hrs.isr.umich.edu/sites/default/files/biblio/dr-013.pdf. Accessed 6 June 2018

Paddon-Jones, D., & Rasmussen, B. B. (2009). Dietary protein recommendations and the prevention of sarcopenia. *Current Opinion in Clinical Nnutrition and Metabolic Care*, *12*(1), 86–90.

Parsons, T. J., Papachristou, E., Atkins, J. L., Papacosta, O., Ash, S., Lennon, L. T., et al. (2018). Healthier diet quality and dietary patterns are associated with lower risk of mobility limitation in older men. *European Journal of Nutrition*. doi:10.1007/s00394-018-1786-y.

Prentice, A. (2004). Diet, nutrition and the prevention of osteoporosis. *Public Health Nutirtion*, *7*(1A), 227–243.

Roth, G. S., Lane, M. A., Ingram, D. K., Mattison, J. A., Elahi, D., Tobin, J. D., et al. (2002).

Biomarkers of caloric restriction may predict longevity in humans. *Science*, *297*(5582), 811.

SAS Institute Inc. (2017) SAS STAT, Cary, NC: SAS Institute Inc.

Tomata, Y., Sugiyama, K., Kaiho, Y., Honkura, K., Watanabe, T., Zhang, S., et al. (2016). Dietary patterns and incident functional disability in elderly Japanese: the Ohsaki Cohort 2006 Study. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *71*(10), 1322–1328.

University of Michigan Survey Research Center (2014). *2013 Health Care and Nutirtion Study: Nutrient Totals Data Description*. http://hrsonline.isr.umich.edu/modules/meta/2013/hcns/desc/2013HCNS_data_description_nt.pdf. Accessed 14 September 2018.

Weir, D. R., Langa, K. M., Ofstedal, M. B., Hurd, M. D., Sharon, R., Kardia, L. R., et al. (n.d.). *Health and Retirement Study Institutional Review Board Information*. http://hrsonline.isr.umich.edu/sitedocs/irb/HRS_IRB_Information.pdf. Accessed 30 August 2017. Accessed 18 September 2018.

Willcox, B. J., Yano, K., Chen, R., Willcox, D. C., Rodriguez, B. L., Masaki, K. H., et al. (2004). How much should we eat? The association between energy intake and mortality in a 36-year follow-up study of Japanese-American men. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *59*(8), 789–95.

Willett, W. C., Sampson, L., Stampfer, M. J., Rosner, B., Bain, C., Witschi, J., et al. (1985). Reproducibility and validity of a semiquantitative food frequency questionnaire. *American Journal of Epidemiology*, *122*(1), 51–65.

Xu, B., Houston, D., Locher, J. L., & Zizza, C. (2012). The association between Healthy Eating Index-2005 scores and disability among older Americans. *Age and Ageing*, *41*(3), 365–371.

Table 1. Descriptive statistics for covariates, 2012-2014 HRS/2013 HCNS.

Continuous covariates	n	mean	SD	SEM
Age	3,976	74.51	6.62	0.16
Household income ($)	3,335	66196.00	89491.08	2616.10
Household assets ($)	3,335	558806.00	1000952.1	29452.00
Sum Chronic Conditions	3,093	2.32	1.32	0.03
Categorical covariates	n	%		
Gender				
Male	1,398	44.66		
Female	1,937	55.34		
Race/ethnicity				
White	2,678	83.92		
Black	362	7.61		
Hispanic	230	6.14		
Other	64	2.32		
Marital status				
Not Married	1,189	37.38		
Married/partnered	2,146	62.62		
Retirement status				
Not Retired	972	32.45		
Retired	2,318	67.55		
Education				
< HS degree	589	16.64		
HS degree	1,219	36.04		
> HS degree	1,527	47.32		
Occupational tenure				
White-collar	1,866	55.92		
Blue-collar	1,060	32.24		
Homemaker	86	2.55		
Other	323	9.28		
BMI				
underweight	53	1.86		
normal weight	1,017	31.49		
overweight	1,289	38.39		
obese	949	28.26		
Vigorous physical activity				
None	1,739	52.94		
Some	682	20.45		
Regular	903	26.62		
Smoking status				
Non-Smoker	3,060	90.39		
Current smoker	254	9.61		
Alcohol consumption				
None	2,094	61.93		
Moderate	1,061	32.75		
Heavy	165	5.32		

Proxy response		
Primary respondent	3,245	96.97
Proxy respondent	90	3.03

Notes: Means, standard error of mean, and percentages adjusted for complex survey design

Table 2. Descriptive statistics for caloric intake, dietary intake factors, disability onset, and mortality, 2012-2014 HRS/2013 HCNS.

	n	mean	SD	SEM
Continuous measures				
Estimated daily energy (kcal)	3,335	1766.84	744.50	15.13
Healthy foods factor	3,335	-0.03	0.93	0.02
Western foods factor	3,335	0.01	0.90	0.02
Categorical measures	n	%		
No ADL limitation onset	2,951	89.01		
ADL limitation onset	338	9.84		
Mortality	46	1.15		

Notes: Means, standard error of mean, and percentages adjusted for complex survey design.

Table 3. Daily intake of food groups used to identify dietary intake factors, 2012-2014 HRS/2013 HCNS.

				Healthy foods factor quartiles											
	Overall			Quartile 1			Quartile 2			Quartile 3			Quartile 4		
Food groups	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
Other vegetables	1.01	0.79	0.02	0.43	0.31	0.01	0.71	0.41	0.02	1.11	0.57	0.03	1.87	0.86	0.04
Dark yellow vegetables	0.33	0.37	0.01	0.11	0.12	0.00	0.21	0.16	0.01	0.33	0.23	0.01	0.70	0.49	0.02
Leafy vegetables	0.45	0.47	0.01	0.15	0.16	0.01	0.29	0.31	0.01	0.48	0.34	0.01	0.90	0.56	0.02
Cruciferous vegetables	0.33	0.35	0.01	0.12	0.12	0.00	0.23	0.17	0.01	0.34	0.23	0.01	0.66	0.49	0.02
Fruit	1.57	1.27	0.03	0.78	0.70	0.02	1.27	0.87	0.04	1.71	1.11	0.04	2.60	1.46	0.06
Tomatoes	0.54	0.47	0.01	0.29	0.32	0.02	0.45	0.39	0.02	0.58	0.42	0.02	0.88	0.52	0.02
Legumes	0.20	0.23	0.00	0.11	0.14	0.01	0.15	0.13	0.01	0.21	0.19	0.01	0.36	0.32	0.01
Whole grain	0.92	0.98	0.02	0.47	0.69	0.03	0.75	0.79	0.03	1.07	1.00	0.04	1.43	1.12	0.04
Fish/seafood	0.21	0.21	0.00	0.12	0.14	0.01	0.17	0.14	0.01	0.23	0.16	0.01	0.34	0.29	0.01
				Western foods factor quartiles											
	Overall			Quartile 1			Quartile 2			Quartile 3			Quartile 4		
	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
Processed meat	0.34	0.39	0.01	0.14	0.21	0.01	0.24	0.34	0.01	0.35	0.29	0.01	0.60	0.47	0.02
Red meat	0.45	0.37	0.01	0.21	0.19	0.01	0.35	0.23	0.01	0.45	0.28	0.01	0.77	0.45	0.02
French fries	0.07	0.09	0.00	0.02	0.04	0.00	0.04	0.06	0.00	0.07	0.07	0.00	0.14	0.14	0.01
Refined grains	1.07	1.02	0.02	0.56	0.62	0.03	0.78	0.73	0.03	1.11	0.92	0.04	1.80	1.25	0.05
Sweets	1.40	1.57	0.03	0.68	0.80	0.03	1.02	1.18	0.04	1.46	1.49	0.06	2.39	1.99	0.08
Potatoes	0.20	0.21	0.00	0.11	0.15	0.01	0.17	0.18	0.01	0.20	0.19	0.01	0.34	0.24	0.01
Pizza	0.06	0.06	0.00	0.03	0.04	0.00	0.05	0.04	0.00	0.06	0.06	0.00	0.09	0.08	0.00
Snacks	0.60	0.60	0.01	0.36	0.43	0.02	0.49	0.55	0.02	0.61	0.50	0.02	0.94	0.73	0.03
Butter/margarine	1.00	1.13	0.02	0.50	0.76	0.03	0.80	0.94	0.03	1.09	1.05	0.05	1.57	1.40	0.06
High energy drinks	0.32	0.61	0.01	0.11	0.31	0.02	0.19	0.51	0.02	0.32	0.57	0.02	0.63	0.83	0.04

Notes: Mean and standard error of mean adjusted for complex survey design.

Table 4. Odds ratios and 95% confidence intervals from multinomial regression predicting ADL limitation onset or mortality, 2012-2014 HRS/2013 HCNS.

	ADL limitation onset			Mortality		
	OR	95% CI	*p*	OR	95% CI	*p*
Estimated daily energy (kcal/100)	1.04	[1.01, 1.06]	0.001	1.03	[0.98, 1.09]	0.243
Healthy foods factor	0.82	[0.69, 0.98]	0.029	0.62	[0.41, 0.94]	0.025
Western foods factor	0.82	[0.68, 0.99]	0.042	1.04	[0.66, 1.64]	0.875
Age	1.08	[1.06, 1.11]	<.001	1.10	[1.04, 1.15]	<.001
Household income (log)	0.98	[0.86, 1.12]	0.746	1.05	[0.77, 1.44]	0.753
Household assets (log)	0.98	[0.95, 1.00]	0.069	1.03	[0.95, 1.12]	0.47
Sum of chronic conditions	1.20	[1.08, 1.34]	0.001	1.18	[0.87, 1.61]	0.279
Female	1.11	[0.80, 1.55]	0.542	0.51	[0.22, 1.15]	0.103
Black	1.21	[0.75, 1.96]	0.433	2.73	[1.02, 7.35]	0.047
Hispanic	1.22	[0.72, 2.06]	0.459	0.45	[0.06, 3.4]	0.441
Other race/ethnicity	1.39	[0.56, 3.43]	0.476	0.00	[0.00, 0.00]	<.001
Marital status	1.32	[0.96, 1.81]	0.092	1.57	[0.58, 4.24]	0.375
Retirement status	1.79	[1.22, 2.62]	0.003	3.34	[1.04, 10.73]	0.043
< HS degree	1.35	[0.94, 1.94]	0.104	0.98	[0.40, 2.41]	0.973
> HS degree	0.91	[0.66, 1.28]	0.596	1.45	[0.65, 3.24]	0.361
Blue-collar occupational tenure	1.00	[0.70, 1.41]	0.977	0.77	[0.38, 1.54]	0.452
Homemaker occupational tenure	1.61	[0.75, 3.45]	0.224	1.04	[0.13, 8.35]	0.97
Other occupational tenure	1.78	[1.15, 2.76]	0.009	1.59	[0.58, 4.39]	0.372
BMI underweight	2.66	[1.27, 5.57]	0.01	1.03	[0.1, 10.94]	0.979
BMI overweight	0.90	[0.64, 1.26]	0.528	0.84	[0.38, 1.88]	0.676
BMI obese	1.66	[1.15, 2.39]	0.007	0.61	[0.22, 1.75]	0.362
No vigorous physical activity	1.89	[1.32, 2.69]	<.001	1.81	[0.71, 4.61]	0.213
Some vigorous physical activity	0.98	[0.59, 1.60]	0.921	1.05	[0.33, 3.29]	0.937
Current smoker	2.18	[1.37, 3.45]	0.001	1.41	[0.32, 6.18]	0.649
Moderate alcohol consumption	0.85	[0.61, 1.19]	0.346	1.43	[0.66, 3.11]	0.365
Heavy alcohol consumption	1.40	[0.78, 2.50]	0.257	1.06	[0.25, 4.59]	0.937
Proxy response (2012)	2.19	[1.18, 4.07]	0.014	4.54	[1.4, 14.71]	0.012

Notes: Reference category for multinomial regression: no ADL limitation in 2014, no mortality. All estimates adjust for complex survey design of HRS and HCNS.

Supplementary Table 1. Food groupings used in the dietary profile analysis, 2012 HRS/2013 HCNS[1,2]

Food Groups	Food Items
Red meat	Lean hamburger, regular hamburger, beef/pork/lamb - mix, pork main dish, beef/lamb main
Processed meats	Bacon, beef/pork hot dogs, chicken/turkey hot dogs, processed meat, processed meat other
Refined grains	White bread, bagels, muffins/biscuits, rice white, pasta
Sweets	Milk chocolate, dark chocolate, candy bars, candy without chocolate, reduced fat cookies
Potatoes	Potatoes
Snacks	Potato chips, crackers, crackers whole grain, crackers other, popcorn light
Pizza	Pizza
French fries	French fries
Other vegetables	Onions raw, onions cooked, corn, mixed vegetables, summer squash
Dark yellow vegetables	Carrots raw, carrots cooked, winter squash, yams/sweet potatoes
Leafy vegetables	Spinach cooked, spinach raw, head lettuce, leaf lettuce,
Cruciferous vegetables	Broccoli, cabbage, cauliflower, Brussels sprouts, kale/mustard/chard greens
Fruit	Raisins or grapes, prunes/dried plums, applesauce, apples/pears, apricots
Tomatoes	Tomatoes, tomato or v8 juice, tomato sauce, salsa
Legumes	Beans or lentils, tofu soy protein, peas or lima beans,
Alcohol	Beer regular, beer light, red wine, white wine, liquor
Butter and margarine	Butter, spreadable butter, margarine
Cream Soup	Cream soup
Coffee	Coffee w caffeine, decaf coffee, dairy coffee drink
Cold cereal	Cold cereal
Condiments	Non-dairy cream, jams/preserves/ honey, ketchup/red chili sauce, salt added, number tsps. sugar
Eggs	Eggs regular, egg whites, eggs fortified,
Fish and seafood	Tuna canned, fish sticks, seafood main dish, fish dark, fish other
Fruit juice	Prune juice, apple juice, orange juice fortified, orange juice regular, grapefruit juice
High-fat dairy	Whole milk, cream, regular ice cream, cottage/ricotta cheese, cream cheese
High energy drinks	Carbonated with caffeine and sugar, carbonated with sugar other, sugar beverage other
Low-fat dairy	Skim milk, 1 or 2 percent milk, soy milk, frozen yogurt/low fat ice cream, flavored yogurt
Low energy drink	Low calorie carbonated with caffeine, low calorie carbonated without caffeine
Mayonnaise and creamy dressing	Mayonnaise regular, salad dressing
Nuts	Peanut butter, peanuts, walnuts, nuts other

Olive oil	Olive oil
Organ meat	Liver beef/pork, liver chicken/turkey
Poultry	Chicken/turkey, chicken/turkey with skin, chicken/turkey without skin
Tea	Tea w caffeine, decaffeinated tea
Whole grain	Whole grain bread, rice brown, oatmeal, rye bread, cooked cereal other

[1] Food items excluded from analysis: Splenda, artificial sweetener, garlic, low-carbohydrate bars, plain water.

[2] Some individual food items were not collapsed into groups due to the combination of multiple food items used to produce the food (i.e. pizza) or having varying preparation techniques (i.e. potatoes).