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The relation of midlife diet to healthy aging: a cohort study

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Abstract

Background—Understanding how to maintain health and well-being in aging populations is critical.

Objective—To examine the relation of dietary patterns in midlife to the prevalence of healthy aging.

Design—Cross-sectional observational study.

Setting—Nurses' Health Study.

Participants—10,670 women with dietary data and no major chronic diseases in 1984–1986, when they were in their late 50's and early 60s (median age = 59 years); all women provided information on multiple aspects of aging an average 15 years later.

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Conflicts of interest
The authors report no conflict of interest.

Author's contributions
C. Samieri helped to design the study, performed statistical analyses and wrote the manuscript.
Q. Sun helped to design the study and edit the manuscript.
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S.E Chiuve helped to edit the manuscript and assisted with statistical analyses.
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W.C Willett contributed to experimental design, data collection, obtaining funding, and editing the manuscript.
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All the authors read the draft critically.

Measurements—Diet quality in midlife was ascertained using the Alternative Healthy Eating Index-2010 (AHEI-2010) and Alternate Mediterranean diet (A-MeDi) scores, averaged from two food frequency questionnaires (1984–1986). We defined "healthy" *vs* "usual" aging as of age 70 years; healthy aging was based on survival to 70+ years with maintenance of four health domains - no major chronic diseases, or major impairments in cognitive or physical function or mental health.

Results—After multivariable adjustment, greater adherence to the AHEI-2010 (upper vs. lower quintile) in midlife was related to 34% (95% CI=9% to 66%, *P-trend*<0.001) greater odds of healthy versus usual aging. Greater adherence to A-MeDi was related to 46% (95% CI=17% to 83%, *P-trend*=0.002) greater odds of healthy aging. When the 4 components of healthy aging were analyzed separately, AHEI-2010 and A-MeDi were significantly associated with higher likelihood of no major limitations in physical function and mental health.

Limitations—Possibility of residual confounding, although we controlled for many confounding factors; bias due to complex patterns of measurement error within diet scores cannot be excluded.

Conclusions—Better diet quality at midlife appears strongly linked to greater health and well-being among those surviving to older ages.

Premature mortality has substantially reduced over the past two decades. With the resulting increase in life expectancy, the number of healthy years lost to disability has generally increased (1); maintaining health and well-being in aging populations now represents a major challenge (2).

Midlife factors likely underlie development of many chronic health conditions, which evolve over years or decades before emergence of clinical disease. While extensive literature has explored ways to reduce mortality, limited research has addressed promotion of overall health and well-being in aging. The Healthy Eating Index, which reflects adherence to the Dietary Guidelines for Americans, and an Alternative-Healthy Eating Index, which further incorporates research on specific foods and nutrients predictive of chronic disease risk, have been strongly related to lower mortality (3–7), lower incidence of major chronic diseases (8–11) and better physical functioning in older Americans (12, 13). Likewise, adherence to the Mediterranean diet has been related to less cardiovascular and cancer-related mortality (14), lower incidence of stroke, cognitive impairment and depression (15), and to better physical functioning (16–18). Therefore, the role of dietary patterns in overall healthy aging is potentially considerable, although inadequately studied.

We investigated the associations of dietary patterns at midlife with the prevalence of healthy aging an average 15 years later among women in the Nurses' Health Study, simultaneously considering survival, chronic diseases, cognitive function, physical function, and mental health.

METHODS

The Nurses' Health Study began in 1976 when 121,700 female nurses aged 30 to 55 years, in 11 US states, completed a mailed questionnaire. Follow-up questionnaires are sent every 2 years; follow-up remains complete for > 90% of all possible person-years. In 1980,

participants completed a semi-quantitative food frequency questionnaire (FFQ) (19), which was repeated in 1984, 1986 and every 4 years thereafter. In 1992, 1996 and 2000, the Medical Outcomes Study Short-Form-36 (SF-36) was administered, a 36 item-questionnaire which evaluates eight health concepts, including mental health and physical functioning. Its validity and reproducibility have been extensively examined, and it is commonly used to measure quality of life (20). From 1995 to 2001, a cognitive study was initiated in the 21,202 participants who were 70 years or older at that time (the overall cohort ranged from 55–80 years as of 2001), and free of stroke; participation in the cognitive assessments was >90% of eligible women. The study was approved by the Institutional Review Board of Brigham and Women's hospital.

Ascertainment of Dietary Patterns

To assess diet quality at midlife, we averaged information from the 1984 and 1986 FFQs. On each FFQ, participants were asked how often, on average, they consumed a standard portion size of each food. Food intake was converted into nutrient intakes by multiplying the consumption of each food by its nutrient content, using the US Department of Agriculture database. The reliability and validity of the FFQ has been described elsewhere (21).

Using the 1984 and 1986 FFQs, we calculated the Alternative-Healthy Eating Index-2010 (AHEI-2010) and Alternate Mediterranean diet (A-MeDi) scores. Similar in concept to the original Healthy Eating Index, which was based on the Dietary Guidelines for Americans (22), the AHEI-2010 further incorporates recent knowledge on foods/nutrients predictive of chronic disease risk (11). The AHEI-2010 includes 11 components: greater intakes of vegetables (excluding potatoes); fruits (excluding juices); whole grains; nuts, legumes and vegetable proteins; long-chain omega-3 polyunsaturated fatty acids (n-3 PUFA), PUFA (excluding long-chain n-3 PUFA), and lower intakes of: sugar-sweetened beverages/fruit juice; red/processed meats; trans fat; and sodium. In addition, moderate alcohol intake of 1/2 to 1.5 drinks per day is assigned the "best" score, with lower scores for excess (≥2.5 drinks per day in women) or non-drinking. Each AHEI-2010 component is scored from 0 (worst) to 10 (best) according to component-specific criteria reflecting either the current dietary guidelines or associations reported in the literature. Total AHEI-2010 scores range from 0 (non-adherence) to 110 (perfect adherence). The rationale for component selection and methodology to derive the AHEI-2010 have been described previously (11), and are summarized in Appendix Table 1.

The A-MeDi score was developed to assess adherence to the traditional Mediterranean diet (23, 24), with slight adaptations since then. The A-MeDi includes 9 components: vegetables (excluding potatoes); fruits; nuts; whole grains; legumes; fish; red/processed meats; moderate alcohol; and monounsaturated (MUFA)-to-saturated fat (SFA) ratio. For each component hypothesized to benefit health, 1 point is given if intake is above the median, 0 otherwise; for alcohol, 1point is given if intake is between 5–15g/day. For items hypothesized to be detrimental to health, 1 point is given if intake is below the median, 0 otherwise (see Appendix Table 2 for the details on the A-MeDi scoring system). Total A-MeDi scores range from 0 (non-adherence) to 9 (perfect adherence).

Ascertainment of Covariates

Socio-demographic, lifestyle and health-related covariates (age, nurse's education, husband's education, marital status, father's and mother's occupations when the nurse was 16 years, family histories of diabetes, cancer and myocardial infarction, physical activity, smoking, multivitamin and aspirin use, body mass index, history of high blood pressure and hypercholesterolemia) were obtained from the biennial questionnaires; since the covariates of husband's education, and father's and mother's occupations did not influence primary relations of diet to healthy aging in multivariable models, those are not controlled in results presented here. Median annual household income and home value were estimated from the census tract of participant's residence, geocoded to the 2000 US Census. We averaged BMI and energy intakes across the 1984 and 1986 questionnaires to represent mean exposure at baseline. Physical activity and histories of smoking, hypercholesterolemia and hypertension were ascertained in 1986. All other covariates were determined at the time of first dietary assessment (ie, in 1984), when these data were available.

Ascertainment of Healthy Aging

We separated "healthy" from "usual" aging based on four health domains as of 2000, the only time-point when simultaneous assessment of mental, physical, and cognitive function was completed. We considered as healthy agers those free of 11 chronic diseases, with no impairment in cognition, no physical disabilities and intact mental health, as described previously (25–27); remaining women were usual agers.

Incidence of the 11 chronic diseases was reported on the biennial questionnaires (28–31). This list combined primary causes of death in the US (i.e., cancer other than non-melanoma skin cancer, myocardial infarction, coronary artery bypass surgery or percutaneous transluminal coronary angioplasty, congestive heart failure, stroke) and diseases commonly found in the literature on healthy aging (ie, type 2 diabetes, kidney failure, chronic obstructive pulmonary disease, Parkinson's disease, multiple sclerosis, amyotrophic lateral sclerosis). To avoid redundancy, we did not include diseases which were reflected by other components of our healthy aging outcome (eg, dementia was not one of the chronic diseases considered since cognitive function was a separate health domain).

To evaluate cognitive health, we used scores from the Telephone Interview of Cognitive Status (TICS (32), range 0–41 points), a telephone adaptation of the Mini-Mental State Examination (MMSE) (33). We considered a score≥31 as the absence of cognitive impairment, according to standard criteria (34). Brandt et al. reported a correlation of 0.94 between the TICS and MMSE, and high test-retest reliability for the TICS (r=0.97) (32). In our own validation study, our telephone-based cognitive battery performed very well compared with in-person interviews (r=0.81 comparing the 2 modes of assessment).

We identified impairment of physical function as any of the following: (1) limited at least "a little" on moderate activities as assessed by the SF36 (such as moving a table, bowling, or pushing a vacuum cleaner, climbing one flight of stairs, walking more than 1 mile or walking several blocks; bathing or dressing); or (2) limited "a lot" on more difficult items

(such as running, lifting heavy objects, lifting or carrying groceries, climbing several flights of stairs; bending, kneeling, or stooping).

In addition, based on answers to the SF36 mental health index (MHI-5 (35), range 0–100 points), we defined good mental health as MHI-5>84 (the median value in the cohort).

Population for Analysis

Among the 19,415 nurses in the cognitive function sub-study, we excluded 2,585 with history of the 11 chronic diseases above as of 1986, and 2,621 with no dietary data in 1984 and 1986. We excluded 44 nurses who did not complete the SF36, 289 women who skipped >2 items on the mental health index or >5 items on the physical function scale, and 637 women missing data for education, 1,665 missing BMI and 904 missing physical activity, leaving 10,670 participants available for analyses.

Statistical analyses

Analyses focus on women's dietary reports in their late 50's and very early 60s (median age = 59 years; upper and lower quartiles = 57 years and 61 years, respectively) because most chronic diseases and health conditions develop over many years, so midlife risk factors are likely a key determinant of health in older ages. In addition, imposing a lag period between ascertainment of dietary patterns and determination of healthy aging (average follow-up 15.2 years) helps reduce the possibility of reverse causation (i.e, an effect of disease or its treatment on diet).

Baseline characteristics were standardized based upon the age distribution of the population at study entry (ie, computing weighted averages of the age-specific crude rates, where the weights are the proportions of persons in the corresponding age groups), and are presented among healthy and usual agers, as well as across quintiles of AHEI-2010 and A-MeDi scores.

Using logistic regression models, we estimated the odds of healthy versus usual aging, according to AHEI-2010 and A-MeDi scores in 1984–86.

Secondary Analyses

We conducted several secondary analyses. First, to identify whether associations might be attributable to specific healthy aging domains, we studied separately relationships between AHEI-2010 and A-MeDi scores and each of the four healthy aging components. Since there was a high prevalence of many of the individual domains, we did not use odds ratios for these analyses but rather used log binomial models to estimate prevalence ratios (and their confidence intervals) of a given domain, according to AHEI-2010 and A-MeDi scores in 1984–86 (36, 37).

Moreover, we assessed whether relations of AHEI-2010 or A-MeDi might be due to individual dietary components, by examining the primary, individual components of the AHEI-2010 and A-MeDi in relation to healthy aging.

In another set of analyses, we examined the robustness of our findings. Since there is no standard definition of healthy aging, we investigated alternative classifications. Specifically, we tried a more stringent definition for mental health limitations, as those with MHI-5 score<60 (a standard cut-off for major depression in older populations (38)). Furthermore, to exclude the possibility that associations of AHEI-2010 and A-MeDi scores might be entirely due to alcohol (a strong predictor of healthy aging in our cohort (27)), we conducted analyses excluding alcohol from AHEI-2010 and A-MeDi scores.

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RESULTS

Of 10,670 participants, 9,599 (90.0%) had no cognitive impairment; 7,234 (67.8%) had none of the 11 chronic diseases in our definition of healthy aging; 4,606 (43.2%) had no mental health limitations; and 2,905 (27.2%) had no impairment of physical function. Overall, 1,171 (11.0%) were considered healthy agers, while the remaining 9,499 (89.0%) were considered usual agers (Table 1).

Among usual agers, multiple health domains were usually impaired. For example, 32.8% had both chronic diseases and limitations in cognitive, physical, or mental health; 63.8% had limitations in cognitive, physical, or mental health only; while 3.4% had one or more chronic diseases only (Table 1). The most common chronic diseases/conditions were myocardial infarction/coronary artery bypass surgery (12%), diabetes (8.2%), and breast cancer (6.0%).

Compared to usual agers, healthy agers had lower prevalence of obesity and smoking, and exercised more at midlife (Table 2). They also had lower prevalence of hypertension and hypercholesterolemia than usual agers.

Healthy agers had higher baseline AHEI-2010 and A-MeDi scores (age-standardized average scores = 53.2 and 4.5 points, respectively, at midlife), compared to usual agers (50.6 and 4.3, respectively) (Table 3). Intake of multiple components of the dietary patterns (e.g., fruit, vegetables, whole grains, alcohol) were higher in healthy agers, compared to usual agers. Intakes of PUFA, red/processed meats and sodium were lower in healthy, than usual agers. Additional information on the relation of diet patterns to health and lifestyle factors is in Appendix Tables 3 and 4.

Dietary patterns at midlife and odds of healthy aging

In multivariate analyses of healthy *vs* usual aging, higher adherence at midlife to AHEI-2010 and A-MeDi were both strongly associated with greater odds of healthy aging (*P trend*< 0.001 and =0.002, respectively, Table 4). For example, compared to women in the worst quintile of diet score, women in the highest quintile of the AHEI-2010 and A-MeDi scores had, respectively, 34% (95% CI=9%, 66%) and 46% (95% CI=17%, 83%) greater odds of healthy aging.

In secondary analyses of each component of healthy aging, both the AHEI-2010 and A-MeDi scores were significantly associated with multiple domains in our definition of healthy aging (*i.e.*, mental health limitations, impairment of physical function, all P-trend ≤0.005, Table 5), although associations were weaker than for overall healthy aging. For example, compared to women in the lowest quintile of scores, those in the highest quintile of AHEI-2010 and A-MeDi had, respectively, 13% (95% CI 5%, 22%) and 12% (95% CI 4%, 20%) higher likelihood of no mental health limitations; and 23% (95% CI 11%, 36%) and 14% (95% CI 3%, 26%) higher likelihood of no physical function limitations.

In secondary analyses using a more stringent cut-off for the definition of mental health limitations, or excluding alcohol from diet scores, results were not materially different (data not shown in tables), suggesting that findings were robust to variations in cutpoints, and were not entirely explained by a higher proportion of moderate alcohol drinkers among adherents to healthier diets.

Dietary pattern components at midlife and odds of healthy aging

When analyzed individually, most components of the AHEI-2010 and A-MeDi were associated with healthy aging, although relations were generally weaker than the overall diet patterns and few individual findings achieved statistical significance. In multivariate models, we found statistically significant relations of greater intakes of fruit (OR for upper vs lower quintile=1.46, 95% CI=1.15,1.85) and alcohol (OR=1.28, 95% CI=1.04,1.56), and lower intakes of sugar sweetened beverages (OR=1.28, 95% CI=1.03,1.58) and PUFA (OR=1.38, 95% CI=1.10,1.73)) to healthy aging (all P trend ≤0.04, results not shown in tables).

DISCUSSION

In this large cohort of women, greater adherence in midlife to healthy diet patterns was related to approximately 40% greater odds of healthy aging. Our consistent findings of better odds of both the AHEI-2010 and the A-MeDi scores and healthy aging, and associations of the two diet scores with several individual components of healthy aging, support the robustness of a “healthy diet – healthy aging” association. Indeed, in our study, both diet scores were correlated (r=0.60, P<0.001), and were comparably related to healthy aging, suggesting that these diets capture a common healthful dimension. Both diets generally focus on greater intakes of plant foods, whole grains and fish/long-chain n-3 PUFA, moderate intake of alcohol, and lower intakes of red and processed meats, which may thus be of primary importance for healthy aging.

Our results are supported by extensive literature on the role of diet in specific health conditions, although there are limited data on diet and overall health and well-being and on some of these components (eg, physical function, mental health). Epidemiological studies have reported associations between various indices of diet quality and lower risk of type 2 diabetes (11), major coronary disease (39, 40), and cancers (41). In a pooled analysis including more than 2 million subjects, each 2 point-increase in Mediterranean diet score was related to a 10% reduction in cardiovascular disease, 6% reduction in cancers, and 13% lower risk of neurodegenerative diseases (14). Likewise, the Healthy Eating Index, or the Alternate-Healthy Eating Index, were associated, in independent studies, with a lower risk of

insulin-resistance and metabolic syndrome (42, 43), slower atherosclerosis progression in women with cardiovascular disease (44), and 19% lower risk of major chronic disease (11). In addition, although evidence is much more limited, both the Healthy Eating Index and Mediterranean diet have been associated with less depression, better cognitive performance and physical functioning (13, 15, 17, 45–47). Hence, previous data support a pleiotropic role of diet quality in health and well-being.

Our study has important strengths. These include the large sample size, high follow-up, and a multi-domain evaluation of healthy aging with validated methods. Moreover, we evaluated dietary habits using repeated, validated FFQs in midlife, likely the most relevant period of exposure for preventing chronic conditions of aging, which develop over many years. Importantly, we tried to reduce possible bias due to reverse causation by excluding participants with chronic diseases at baseline (most likely to change their diets because they were diagnosed with a major health condition), and imposing a lag between dietary assessment and healthy aging.

Yet, we were not able to exclude participants with impairments in cognition, mental health, and physical function in midlife (since we did not have those data at midlife), and although there were probably few women with severe impairments at baseline, reverse causation in these individuals might still be possible. Other potential limitations of our study should be considered. We followed participants until age 70 years, rather than through death or onset of a condition that would classify them as no longer healthy, so we were not able to prospectively estimate risks of transitioning from healthy to usual aging. There might also be measurement error in the assessment of dietary patterns. It remains unknown exactly how such potentially complex patterns of measurement error in the assessment of dietary patterns influence ranking of individuals within diet scores, and how such bias might influence relations of diet patterns to health outcomes, so our results should be interpreted with caution. Although we adjusted for multiple potential confounders, residual confounding might be another concern in this observational study. In our models, the three primary confounding variables were BMI, physical activity, and smoking. We have established that BMI is very well-reported in this cohort (48) and smoking is very well-reported in our cohort and others (49, 50); similarly, physical activity is reasonably well-reported in our cohort (51), thus a large amount of residual confounding is unlikely. Finally, our sample included female, mostly Caucasian healthcare professionals. This is useful to decrease extraneous variability and to enhance validity of health information, but results may not be generalizable to populations with different demographic features.

In summary, we found that higher diet quality at midlife was strongly associated with increased odds of good health and well-being among those surviving to older ages. These data may have an especially important role in promoting a healthy diet -- maintaining physical, cognitive, and mental health with aging may provide more powerful incentive for dietary change than simply prolonging life or avoiding any single chronic disease.

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Table 1

Proportion of healthy and usual agers and distribution of the components of healthy aging in the Nurses' Health study

	N	%
Healthy agers	1,171	11.0
Usual agers	9,499	89.0
Number of chronic diseases [a]		
1	2,570	27.1
2	656	6.9
3 or more	210	2.2
Number of limitations in cognitive, physical, or mental health domains [a]		
1 domain only	4,016	42.3
2 domains	4,593	48.4
3 domains	566	6.0
Having one or more chronic diseases and no limitations in cognitive, physical, or mental health domains [a]	324	3.4
Having limitations in cognitive, physical, or mental health domains only and no chronic diseases [a]	6,063	63.8
Having both chronic disease(s) and limitation(s) in cognitive, physical, or mental health domains [a]	3,112	32.8

[a] Proportionamong usual agers only

Abbreviations: MHI-5: Medical Outcomes Study Short-Form-36 (SF-36) Mental Health Index;

TICS: Telephone Interview of Cognitive Status.

Table 2

Age-standardized baseline characteristics (in 1984–1986) of healthy agers and usual agers in the Nurses' Health Study

	Healthy agers (n=1,171)	Usual agers (n=9,499)
Mean age at baseline, years [a]	58.6 (2.5)	59.1 (2.5)
Education		
Associate's degree	74	78
Bachelor's degree	17	15
Graduate degree	9	6
Husband's education		
High school degree or less	46	52
College degree	29	28
Graduate school	24	21
Marital status		
Married	92	93
Widowed	5	5
Separated/divorced	3	3
BMI, kg/m^2		
<22	35	22
22–24	38	33
25–29	23	32
≥30	3	13
Smoking		
Never	54	47
Former	35	36
Current	12	17
Mean physical activity, met-hours/week	19.4 (21.7)	14.1 (19.8)
Mean energy intake, kcal/day	1,692 (472)	1,743 (477)
Regular aspirin use		
<1/week	36	31
1–2/week	39	32
>2/week	24	37
Multivitamin use	52	57
History of high blood pressure	20	32
History of hypercholesterolemia	12	17
Family history of diabetes	26	30
Family history of cancer	17	19
Family history of myocardial infarction	15	18

Abbreviations: BMI: body mass index; met: metabolic-equivalent.

Values are means (SD) or percentages and are standardized to the age distribution of the study population at baseline. Percentages are of non-missing values.

[a] Value is not age-standardized.

Table 3

Age-standardized baseline dietary patterns (in 1984–1986) of healthy agers and usual agers in the Nurses' Health Study

	Healthy agers (n=1,171) Mean (SD)	Usual agers (n=9,499) Mean (SD)
AHEI-2010 score	53.2 (10.3)	50.6 (10.1)
A-MeDi score	4.5 (1.6)	4.3 (1.7)
Fruit, servings/day	1.9 (1.1)	1.7 (1.1)
Vegetables, servings/day	3.5 (1.6)	3.3 (1.6)
Whole grains, g/day	18.4 (15.6)	16.3 (12.7)
Red/processed meats, servings/day	0.9 (0.6)	1.0 (0.6)
Alcohol, drinks/day	0.6 (0.8)	0.5 (0.8)
Long-chain n-3 fats, mg/day	221 (148)	221 (165)
PUFA, % of energy	6.1 (1.5)	6.3 (1.5)
***Trans* fat**, % of energy	1.6 (0.5)	1.6 (0.5)
Sugar-sweetened beverages and fruit juice, servings/day	1.0 (0.9)	1.0 (0.8)
Low Sodium intake score [a]	5.5 (2.8)	5.1 (2.8)
Nuts, beans and soy products, servings/day	0.3 (0.4)	0.3 (0.3)
Nuts, servings/day	0.3 (0.2)	0.3 (0.2)
Legumes, servings/day	0.4 (0.3)	0.4 (0.3)
Fish, servings/day	0.3 (0.2)	0.3 (0.3)
MUFA:SFA ratio	1.0 (0.1)	1.0 (0.1)

Abbreviations: AHEI-2010: Alternative-Healthy Eating Index-2010; A-MeDi: Alternate Mediterranean diet; MUFA: monounsaturated fats; n-3: omega-3; PUFA: polyunsaturated fats; SFA: saturated fats. Values are means (SD) and are standardized to the age distribution of the study population at baseline.

[a] 10 point-score based on deciles of the distribution of intake (lowest decile = higher score).

Table 4

Odds Ratios (95% confidence intervals) of healthy aging, according to Alternative Healthy Eating Index-2010 and Alternate Mediterranean diet scores at midlife (Odds Ratios >1 denote greater odds of healthy aging)

	Quintile 1		Quintile 2		Quintile 3		Quintile 4		Quintile 5		*Ptrend*
AHEI-2010											
Median AHEI-2010 score (interq. Range)	38.1	(34.9,40.3)	45.1	(43.7,46.5)	50.4	(49.2,51.9)	56.2	(54.6,57.7)	64.3	(61.6,68.3)	
Healthy ager (n)		181		169		233		290		298	
Age-adjusted OR		Ref	0.94	0.75,1.17	1.34	1.10,1.65	1.74	1.43,2.12	1.80	1.48,2.19	*<0.001*
Multivariable-adjusted[a] OR		Ref	0.87	0.70,1.09	1.20	0.97,1.48	1.37	1.12,1.69	1.34	1.09,1.66	*<0.001*
A-MeDi score											
Median A-MeDi score (interq. Range)	2.0	(1.5,2.5)	3.0	(3.0,3.5)	4.0	(4.0,4.5)	5.0	(5.0,5.5)	6.5	(6.0,7.0)	
Healthy ager (n)		176		218		248		240		289	
Age-adjusted OR		Ref	1.30	1.05,1.60	1.30	1.06,1.59	1.35	1.10,1.66	1.61	1.32,1.97	*<0.001*
Multivariable-adjusted [a] OR		Ref	1.25	1.01,1.55	1.24	1.00,1.53	1.28	1.03,1.60	1.46	1.17,1.83	*0.002*

Abbreviations: AHEI-2010: Alternative-Healthy Eating Index-2010; A-MeDi: Alternate Mediterranean diet; OR: Odds Ratio.

[a]Models were adjusted for age (years), education (associate's degree, bachelor's degree, graduate degree), marriage status (married, widowed, separated/divorced), median income (quintiles), median house value (quintiles), family histories of diabetes, cancer and myocardial infarction (yes/no), physical activity (quintiles of metabolic-equivalent hours), energy intake (quintiles of Kcal), smoking (never smoker, past smoker of: 1–14, 15–24, 25+ cigarettes/day, current smoker of: 1–14, 15–24, 25+ cigarettes/day), multivitamins use (yes/no), aspirin use (<1, 1–2, >2 tablets/week), body mass index (<22, 23–24, 25–29, ≥30 kg/m^2), history of high blood pressure (yes/no) and history of hypercholesterolemia (yes/no).

Table 5

Multivariable-adjusted [a] Prevalence Ratios (95% confidence intervals) of each component of healthy aging, according to Alternative Healthy Eating Index-2010 and Alternate Mediterranean diet scores at midlife (Prevalence Ratios >1 denote greater risk of healthy aging component)

	Quintile 1	Quintile 2		Quintile 3		Quintile 4		Quintile 5		*P-trend*
AHEI-2010										
No chronic disease [a]	Ref	0.99	0.95,1.03	0.99	0.95,1.03	1.03	0.99,1.07	1.01	0.97,1.05	*0.26*
No cognitive impairment (TICS ≥31)	Ref	1.00	0.99,1.02	0.99	0.97,1.01	0.98	0.96,1.00	0.99	0.97,1.01	*0.09*
No impairment of physical function	Ref	0.97	0.87,1.08	1.11	1.00,1.23	1.22	1.10,1.34	1.23	1.11,1.36	*<0.001*
No limitation of mental health (MHI-5 <84)	Ref	1.02	0.95,1.10	1.06	0.99,1.14	1.11	1.03,1.19	1.13	1.05,1.22	*<0.001*
A-MeDi score										
No chronic disease [a]	Ref	1.03	0.99,1.08	1.03	0.99,1.07	1.03	0.99,1.08	1.04	1.00,1.09	*0.13*
No cognitive impairment (TICS≥31)	Ref	0.99	0.97,1.01	0.99	0.97,1.01	0.98	0.96,1.00	0.97	0.95,1.00	*0.02*
No impairment of physical function	Ref	1.04	0.94,1.15	1.08	0.98,1.19	1.12	1.01,1.24	1.14	1.03,1.26	*0.005*
No limitation of mental health (MHI-5 <84)	Ref	0.99	0.92,1.06	1.03	0.96,1.11	1.06	0.98,1.14	1.12	1.04,1.20	*<0.001*

Abbreviations: AHEI-2010: Alternative-Healthy Eating Index-2010; A-MeDi: Alternate Mediterranean diet; MHI-5: Medical Outcomes Study Short-Form-36 (SF-36) Mental Health Index; PR: Prevalence Ratio; TICS: Telephone Interview of Cognitive Status.

[a]Models were adjusted for age (years), education (associate's degree, bachelor's degree, graduate degree), marriage status (married, widowed, separated/divorced), median income (quintiles), median house value (quintiles), family histories of diabetes, cancer and myocardial infarction (yes/no), physical activity (quintiles of metabolic-equivalent hours), energy intake (quintiles of Kcal), smoking (never smoker, past smoker of: 1–14, 15–24, 25+ cigarettes/day, current smoker of: 1–14, 15–24, 25+ cigarettes/day), multivitamins use (yes/no), aspirin use (<1, 1–2, >2 tablets/week), body mass index (<22, 23–24, 25–29, ≥30 kg/m^2), history of high blood pressure (yes/no) and history of hypercholesterolemia (yes/no).

Appendix Table 1

The Alternative Healthy Eating Index-2010 scoring system

Component	Criteria for minimum score (0)	Criteria for maximum score (10)
Fruit[a], servings/day	0	≥ 4
Vegetables[b], servings/day	0	≥ 5
Whole grains[c], g/day	0	75
Red/processed meats[d], servings/day	≥ 1.5	0
Alcohol[e], drinks/day	≥ 2.5	0.5–1.5
Long-chain n-3 fats[f], mg/day	0	250
PUFA[g], % of energy	≤ 2	≥ 10
***Trans* fat**, % of energy	≥ 4	≤ 0.5
Sugar-sweetened beverages and fruit juice[h], servings/day	≥ 1	0
Sodium[k], mg/day	Highest decile	Lowest decile
Nuts, beans and soy products[l], servings/day	0	≥ 1

Abbreviations: n-3: omega-3; PUFA: polyunsaturated fats.

The cut-offs were based on previous knowledge on food and nutrients and disease risk (11). The AHEI-2010 used sex-specific cut-offs for whole grains and alcohol; values are presented for women only.

[a] Includes only whole fruit. One serving is 1 medium piece of fruit or 0.5 cup of berries (1 cup=236.59g).

[b] Includes all vegetables except potatoes (including French fries). One serving is 0.5 cup of vegetables or 1 cup of green leafy vegetables.

[c] Grams of whole grains account for the variability of the percentage of whole grains in various “whole grain” products. One serving of a 100% whole grain product (i.e., 0.5 cup of oatmeal or brown rice) contains ~ 15–20g of whole grains per dry weight.

[d] One serving is 4 oz of unprocessed meat or 1.5 oz of processed meat (1 oz=28.35g).

[e] Nondrinkers received a score of 2.5. One drink is 4 oz of wine, 12 oz of beer, or 1.5 oz of liquor.

[f] Includes eicosapentaenoic acid and docosahexaenoic acid. The cut-offfor optimal intake (250 mg/day) is ~ 2–4 oz servings of fish/week.

[g] PUFA do not include EPA or DHA intake.

[h] One serving is 8 oz.

[k] Values in lower decile were ≤ 1,112 mg/day, and in highest decile were ≥ 3,337 mg/d in 1984 in the Nurses’ Health Study.

[l] One serving is 1 oz of nuts or 1 tablespoon (15 mL) of peanut butter or 3–4 oz of tofu or soybeans.

Appendix Table 2

The Alternate Mediterranean diet scoring system in the Nurses' Health Study

Component	Criteria for minimum score (0)	Criteria for maximum score (1)
Fruit[a], servings/day	≤ 2.2	> 2.2
Vegetables[b], servings/day	≤ 2.8	> 2.8
Whole grains[c], g/day	≤ 1.0	> 1.0
Red/processed meats[d], servings/day	≥ 0.7	< 0.7
Alcohol[e], g/day	<5 or >15	5–15
Nuts[f], servings/day	≤ 0.1	> 0.1
Legumes[g], servings/day	≤ 0.3	> 0.3
Fish[h], servings/day	≤ 0.2	> 0.2
MUFA:SFA ratio	≤ 1.0	> 1.0

Abbreviations: MUFA: monounsaturated fats; SFA: saturated fats.

The cut-offs were based on the medians of intake for all components except alcohol; for alcohol, 1point was given for moderate intake, e.g., between 5–15g/day in women (23). Values presented are those estimated from the 1984 food frequency questionnaire.

[a] Includes whole fruit and fruit juice. One serving is 1 medium piece of fruit or 0.5 cup of berries (1 cup=236.59g) or a small glass of fruit juice.

[b] Includes all vegetables except potatoes (including French fries). One serving is 0.5 cup of vegetables or 1 cup of green leafy vegetables.

[c] One serving is 1 cup of cooked oatmeal or brown rice or 1 slice of dark bread.

[d] One serving is 4 oz of unprocessed meat or 1.5 oz of processed meat (1 oz=28.35g).

[e] One standard drink contains 4 oz of wine, 12 oz of beer, or 1.5 oz of liquor. Total alcohol intake was calculated in grams by adding the intake from each alcoholic-beverage unit: beer: 13.2g; wine, 10.8g; and liquor, 15.1g.

[f] One serving is 1 oz of nuts or 1 tablespoon (15 mL) of peanut butter.

[g] One serving is 0.5 cup.

[h] One serving is 2–5 oz.

Appendix Table 3

Age-standardized baseline characteristics (in 1984–1986) across quintiles of the Alternative Healthy Eating Index-2010

	Quintile 1 (n=2,134)	Quintile 2 (n=2,134)	Quintile 3 (n=2,134)	Quintile 4 (n=2,134)	Quintile 5 (n=2,134)
Mean age at baseline, years[a]	58.8 (2.5)	59.0 (2.5)	59.0 (2.4)	59.1 (2.5)	59.1 (2.5)
Education					
Associate's degree	83	80	79	76	70
Bachelor's degree	12	15	16	16	20
Graduate degree	5	5	5	8	10
Husband's education					
High school degree or less	62	55	53	47	39
College degree	24	27	26	28	34
Graduate school	14	18	21	25	27
Marital status					
Married	93	93	93	93	92
Widowed	5	4	5	5	5
Separated/divorced	2	3	3	2	3
BMI, kg/m^2					
<22	23	23	20	24	27
22–24	31	32	35	35	37
25–29	32	31	32	31	28
≥30	15	14	13	10	8
Smoking					
Never	49	49	49	47	44
Former	28	32	35	41	45
Current	23	20	15	13	11
Mean physical activity, met-hours/week	10.0 (13.7)	12.0 (15.8)	14.5 (19.3)	16.9 (19.4)	20.0 (27.9)
Mean energy intake, kcal/day	1,833 (470)	1,770 (484)	1,731 (476)	1,705 (476)	1,644 (458)
Regular aspirin use					
<1/week	30	30	31	33	34
1–2/week	32	34	34	33	33
>2/week	38	36	36	35	32

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	Quintile 1 (n=2,134)	Quintile 2 (n=2,134)	Quintile 3 (n=2,134)	Quintile 4 (n=2,134)	Quintile 5 (n=2,134)
Multivitamin use	51	55	56	56	64
History of high blood pressure	31	31	31	31	30
History of hypercholesterolemia	13	15	16	16	21
Family history of diabetes	32	30	29	28	29
Family history of cancer	18	18	18	20	19
Family history of myocardial infarction	16	17	17	18	19
Fruit, servings/day	1.1 (0.7)	1.4 (0.8)	1.7 (0.9)	2.0 (1.1)	2.4 (1.2)
Vegetables, servings/day	2.4 (1.0)	2.9 (1.3)	3.3 (1.5)	3.7 (1.6)	4.4 (1.9)
Whole grains, g/day	10.3 (8.8)	13.4 (9.8)	15.7 (11.0)	18.5 (12.8)	24.7 (16.8)
Red/processed meats, servings/day	1.4 (0.7)	1.1 (0.6)	1.0 (0.6)	0.8 (0.5)	0.5 (0.4)
Alcohol, drinks/day	0.6 (1.2)	0.5 (0.9)	0.5 (0.8)	0.5 (0.6)	0.5 (0.6)
Long-chain n-3 fats, mg/day	124 (96)	182 (137)	216 (141)	260 (164)	325 (189)
PUFA, % of energy	5.9 (1.4)	6.1 (1.4)	6.2 (1.4)	6.4 (1.5)	6.5 (1.6)
***Trans* fat**, % of energy	1.9 (0.6)	1.8 (0.5)	1.6 (0.5)	1.5 (0.4)	1.3 (0.4)
Sugar-sweetened beverages and fruit juice, servings/day	1.3 (0.9)	1.2 (0.8)	1.0 (0.8)	0.9 (0.8)	0.7 (0.8)
Low Sodium intake score	4.2 (2.7)	4.8 (2.8)	5.1 (2.7)	5.4 (2.7)	6.1 (2.6)
Nuts, beans and soy products, servings/day	0.2 (0.2)	0.2 (0.2)	0.3 (0.3)	0.4 (0.4)	0.5 (0.5)

Abbreviations: BMI: body mass index; met: metabolic-equivalent; n-3: omega-3; PUFA: polyunsaturated fats. Values are means (SD) or percentages and are standardized to the age distribution of the study population at baseline. Percentages are of non-missing values.

[a]Value is not age-standardized.

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Appendix Table 4

Age-standardized baseline characteristics (in 1984–1986) across quintiles of the Alternate Mediterranean diet score

	Quintile 1 (n=2,022)	Quintile 2 (n=1,987)	Quintile 3 (n=2,289)	Quintile 4 (n=2,139)	Quintile 5 (n=2,233)
Mean age at baseline, years [a]	58.8 (2.5)	58.9 (2.4)	59.1 (2.5)	59.0 (2.5)	59.2 (2.5)
Education					
Associate's degree	83	80	79	75	73
Bachelor's degree	11	15	15	18	19
Graduate degree	5	5	7	7	8
Husband's education					
High school degree or less	63	53	52	47	42
College degree	23	27	26	31	32
Graduate school	14	20	21	23	26
Marital status					
Married	92	92	92	93	94
Widowed	5	5	5	5	4
Separated/divorced	3	3	3	2	2
BMI, kg/m^2					
<22	24	24	22	22	25
22–24	30	33	35	35	36
25–29	31	30	32	31	30
≥30	15	13	11	12	10
Smoking					
Never	46	46	47	48	50
Former	29	35	36	39	40
Current	24	19	16	12	10
Mean physical activity, met-hours/week	9.3 (13.1)	12.8 (17.5)	13.9 (16.7)	16.3 (23.3)	20.5 (25.5)
Mean energy intake, kcal/day	1,509 (425)	1,625 (433)	1,723 (455)	1,833 (452)	1,965 (480)
Regular aspirin use					
<1/week	33	31	30	31	33
1–2/week	32	34	33	34	33
>2/week	35	36	36	36	34

	Quintile 1 (n=2,022)	Quintile 2 (n=1,987)	Quintile 3 (n=2,289)	Quintile 4 (n=2,139)	Quintile 5 (n=2,233)
Multivitamin use	50	54	55	57	65
History of high blood pressure	31	30	30	31	31
History of hypercholesterolemia	12	15	16	18	20
Family history of diabetes	33	29	29	29	28
Family history of cancer	18	17	19	20	20
Family history of myocardial infarction	15	17	18	18	18
Fruit, servings/day	1.0 (0.6)	1.4 (0.7)	1.7 (0.8)	1.9 (0.8)	2.3 (0.7)
Vegetables, servings/day	2.0 (0.9)	2.7 (1.2)	3.3 (1.5)	4.0 (1.7)	4.7 (1.9)
Whole grains, servings/day	0.7 (0.7)	1.0 (0.9)	1.2 (0.9)	1.5 (1.0)	1.9 (1.1)
Red/processed meats, servings/day	0.9 (0.5)	0.9 (0.5)	0.9 (0.5)	0.8 (0.5)	0.7 (0.5)
Alcohol, g/day	6.6 (12.9)	6.7 (11.1)	6.7 (10.4)	6.9 (9.7)	7.0 (8.8)
Nuts, servings/day	0.2 (0.2)	0.2 (0.2)	0.3 (0.2)	0.3 (0.2)	0.5 (0.2)
Legumes, servings/day	0.3 (0.2)	0.3 (0.2)	0.4 (0.3)	0.5 (0.3)	0.6 (0.3)
Fish, servings/day	0.2 (0.1)	0.3 (0.2)	0.3 (0.2)	0.4 (0.2)	0.5 (0.3)
MUFA:SFA ratio	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.1 (0.1)	1.1 (0.1)

Abbreviations: BMI: body mass index; met: metabolic-equivalent; MUFA: monounsaturated fats; SFA: saturated fats.

Values are means (SD) or percentages and are standardized to the age distribution of the study population at baseline. Percentages are of non-missing values.

[a] Value is not age-standardized.