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Adherence to the Overall Nutritional Quality Index and Risk of Total Chronic Disease

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Abstract

Background: The Overall Nutritional Quality Index (ONQI) algorithm is a nutrient profiling scheme that incorporates over 30 dietary components, and aims to rank foods by relative healthfulness.

Purpose: To assess whether diets with a higher ONQI score predict lower risk of major chronic disease risk.

Methods: A total of 62,284 healthy women from the Nurses' Health Study and 42,382 healthy men from Health Professionals Follow-Up Study were followed from 1986 to 2006. Dietary data were collected from questionnaires at baseline. Each food was scored by the ONQI algorithm and the average ONQI score for the diet consumed by each participant was computed. Total chronic disease was defined as cardiovascular disease (CVD), cancer, diabetes and nontrauma death. Data analysis was conducted in 2010.

Results: A total of 20,004 and 13,520 chronic disease events were documented in women and men, respectively. The ONQI score was inversely associated with risk of total chronic disease, CVD, diabetes and all-cause mortality (p-trend≤0.01), but not cancer, in both cohorts. Women in the highest compared to lowest quintile of the ONQI score had a relative risk (95% CI) of 0.91 (0.87, 0.95) for chronic disease, 0.79 (0.71, 0.88) for CVD, 0.86 (0.78, 0.96) for diabetes and 0.90 (0.84, 0.97) for all-cause mortality. Men in the highest compared to lowest quintile of the ONQI score had a relative risk of 0.88 (0.83, 0.93) for chronic disease, 0.77 (0.70, 0.85) for CVD, 0.84 (0.73, 0.96) for diabetes and 0.89 (0.83, 0.97) for all-cause mortality.

Conclusions: The ONQI scoring system was associated with modestly lower risk of chronic disease and all-cause mortality.

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WCW served on the advisory panel in the development of the original ONQI scoring system, but he has not had any formal or financial relationship to NuVal, LLC or the ONQI system since the system became a commercial product. No other authors reported financial disclosures.

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Background

Nutrient profiling is an effort to rank or classify foods based on nutrient composition.[1] Dozens of nutrient profiling schemes have been developed,[2, 3] and the potential applications of these profiles include consumer education and dietary guidance, regulation of health claims and evaluation of the nutritional quality of food products. A rapidly growing application for these profiles is front-of-package food product labeling. Front-of-package labeling has emerged recently from many sources,[4] including manufacturers,[5] food sellers,[6] health organizations,[7] other non-industry companies[8] and government sponsored programs.[9] These symbols, logos and scores aim to communicate the nutritional quality of a food and to facilitate comparisons between food products. Although these labels intend to provide consumers simplified nutrition information, the numerous labeling schemes on supermarket shelves often are conflicting, and may foster confusion among consumers.

The validity of these systems to provide sound guidance is not well established. A few algorithms have been validated using qualitative research methods,[10] including comparison with rankings by an expert panel.[11-13] Because the intent of the front-of-package symbols is to rank foods on their basis of health effects,[14] a better validation would include an independent measure of performance, ideally the ability of the scoring system to predict risk of disease.

The NuVal™ Nutritional Scoring System, which has been endorsed by the American College of Preventive Medicine, is currently used in six supermarket chains across the U.S. totaling more than 550 individual stores, and is expected to be in 10 chains by the end of 2010. This system uses the Overall Nutritional Quality Index (ONQI) algorithm, which incorporates more than 30 nutrients and food properties. The NuVal™ score summarizes comprehensive nutritional information into a single number ranging from 1 to 100, and is designed to rank foods in order of relative nutrition and healthfulness. In this analysis, the authors evaluated whether the ONQI algorithm predicted lower risk of chronic disease over 20 years within two large cohort studies of health professionals.

Methods

Study Population

The Nurses' Health Study was established in 1976, when 121,700 female registered nurses aged 30–55 years were enrolled.[15] The Health Professionals Follow-up Study (HPFS) is a prospective cohort of 51,529 U.S. men, aged 40–75 years, who returned a mailed questionnaire about diet and medical history in 1986.[16] In both cohorts, detailed information on lifestyle habits, medical history and newly diagnosed disease is updated biennially. Dietary data were collected with a 138- and 135-item FFQ administered to the women and men respectively in 1986.

Participants with previously diagnosed chronic disease (cardiovascular disease [CVD], diabetes, and cancer) and participants with invalid dietary data at baseline in 1986 (>70 items left blank on the FFQ or reported implausible energy intake) were excluded, leaving 62,284 women and 42,382 men for this analysis. The IRBs at the Harvard School of Public Health and Brigham and Women's Hospital approved the study protocol.

Dietary assessment

The ONQI algorithm was created by a multidisciplinary panel of nutrition and public health experts and has been described in detail previously.[13, 17] The study investigators were given the ONQI algorithm in its entirety to review and use for this analysis, and all data analysis and interpretation was conducted independent from employees of NuVal, LLC. Briefly, the

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algorithm is based on data from multiple sources, including the Dietary Reference Intakes of the IOM, the Nutrition Facts Panel regulations of the FDA, the Dietary Guidelines for Americans, 2005, the USDA National Nutrient Database, the WHO dietary guidance materials and published literature on nutrients and health outcomes. Nutrients were considered for inclusion if there was an established relationship with one or more health outcomes, if they were of established public health importance, if changes in intake on a population level would be of public health benefit, if the nutrient was available in nutrient databases and if inclusion of the nutrient in the algorithm enhanced performance in developmental validation testing.

The basic nutrients in the algorithm are listed in Table 1. Nutrients with generally favorable effects on health contribute to the numerator of the ONQI score, where higher values increase the score. Nutrients with generally unfavorable effects on health are placed in the denominator, where higher values decrease the score. The micronutrients included in the ONQI algorithm were each given a trajectory score, which addresses how the nutrient value of a food compares to the recommended daily intake of that nutrient, and how the consumption of the food influences the trajectory of total daily intake of the nutrient.

For most nutrients, the target for the trajectory score is the recommended daily intake of that nutrient, as determined by the Estimated Average Requirements of the Dietary Reference Intakes or the Dietary Guidelines for Americans, 2005. The trajectory score is calculated as the ratio of the concentration of the nutrient in a food to the recommended concentration of that nutrient in the overall diet. The trajectory score is weighted further by coefficients based on the prevalence, severity, and strength of association of the nutrient with risk of chronic disease (including cardiovascular disease, cancer and diabetes), as determined through a review of the literature and expert panel consensus.[13]

The ONQI algorithm also incorporates measures of energy density and macronutrient quality. Protein quality of a food was determined based on the distribution of essential amino acids, fat quality was calculated as the percentage of total fat that is unsaturated and the glycemic load serves as a proxy for carbohydrate quality. The raw scores for foods and beverages range from ≤1 to >8000 and are converted to a more easily interpretable 1 to 100 scale for consumer use. This compression of the NuVal™ Nutritional Scoring System, which is the version found on supermarket shelf, retains the rank order of foods created from the algorithm but simplifies the presentation for consumers. Further details and a full list of references can be found in the ONQI reference manual.[18]

In previous validation studies,[13, 17] the ONQI score was strongly correlated with expert panel rankings ($r = 0.92$) and the ONQI score for the more-healthful DASH (Dietary Approaches to Stop Hypertension) diet (mean score: 46) was higher than the typical American diet based on the National Health and Nutrition Examination Survey (NHANES) 2003–2006 (mean score: 26.5; $P < 0.01$). The ONQI score was positively associated with the Healthy Eating Index 2005. In linear regression models, the NuVal system significantly predicted the HEI-2005 score (beta coefficient = 1.12, $p<0.001$). Finally, in consumer testing, focus group participants reported that the NuVal system ™ would help them make decisions about which foods to purchase in the grocery store.[13, 17]

The ONQI algorithm was applied to each food item on the FFQ in the same fashion. For each food item, a commonly used portion size was specified (e.g., 8 oz of milk) and participants were asked how often, on average, he or she had consumed that quantity over the past year. Nine responses were possible, ranging from “never” to “>6 times per day.” The ONQI score for the FFQ (ONQI-f) was estimated by multiplying the frequency of intake for each food by its ONQI score (on a 1 to 100 scale) and summing across all food items. A simple summation of the scores would lead to a greater score with greater food intake, regardless of the quality of food. Thus, the ONQI-f score was divided by total servings of food, to obtain the average ONQI-f of an individual's diet. In a secondary analysis, a score that used the energy value of foods, rather than servings, to weight the ONQI-f score was not associated with risk of chronic disease (data not shown). The reproducibility and validity of the FFQ are high when compared with multiple 1-week diet records and biochemical markers.[19-21]

Outcome definition

The primary endpoint for this study, major chronic disease, was defined as the initial occurrence of CVD, diabetes, cancer or nontrauma death. When participants reported incident CVD or cancer on a follow-up questionnaire, permission to obtain the medical records was obtained. Study physicians who were blinded to exposure data reviewed the records.

CVD was defined as nonfatal myocardial infarction, fatal CHD, fatal or nonfatal stroke, or angina. For myocardial infarction, the WHO criteria was used, along with cardiac-specific troponin levels, when available.[22] Stroke was defined according to the National Survey of Stroke criteria, requiring neurologic deficit of rapid or sudden onset, lasting ≥24 hours or until death.[23]. Angina was confirmed when a participant reported "angina pectoris" on the questionnaire plus one of the following criteria: ≥70% occlusion; coronary artery bypass graft (CABG); percutaneous transluminal coronary angioplasty (PTCA); or coronary stenting.

All cancers except nonmelanoma skin cancer, low-grade, organ-confined prostate cancer (stage A or B and Gleason grade < 7) and in situ breast cancer were included, due to relatively low mortality from these common diagnoses. Cardiovascular disease or cancers that were verified by letter or telephone interview but for which medical records or pathology reports were unavailable were defined as "probable" cases and included in the analysis.

A supplementary questionnaire was mailed to each participant confirm the self-report of diabetes diagnosis on any biennial questionnaire. A previous validation study showed a high level of confirmation (98%) of self-reported type 2 diabetes.[24] The criteria used were proposed by the National Diabetes Data Group[25] for cases diagnosed before 1998 and the American Diabetes Association criteria (reported fasting plasma glucose ≥7 mmol/l [126 mg/dl]) for cases diagnosed after 1998.

Deaths were reported by next of kin, coworkers, or postal authorities or through the National Death Index[26] and cause of death was confirmed by reviewing medical records or autopsy reports. All causes of deaths, except those resulting from external causes (e.g., injuries and suicides) were included.

Statistical Analysis

Each participant contributed follow-up time from the return of the baseline questionnaire until the date of diagnosis of the first event (CVD, diabetes or cancer), date of death or end of follow-up (June 2006 in women, February 2006 in men).

The association between quintiles of the ONQI-f score and risk of chronic disease was assessed using multivariate Cox proportional hazard models, adjusting for age (in months), calories (continuous), smoking status (never, past, current <15, current 15–24 and current 25+ cigarettes/day]), aspirin (0, 1–6, 7+ /week), moderate or vigorous activity (quintiles of total hours/week), alcohol (0, 5–15, 15+ g/day), vitamin E supplementation, family history of MI, family history of cancer, history of hypertension and history of hypercholesterolemia and in women only, menopausal status and use of hormone therapy. Because BMI may mediate the association between diet and chronic disease risk, models with and without BMI (8 categories) are presented. A trend test was computed by using the median values for quintiles modeled as a continuous variable.[27]

Results

The median (10^{th}–90^{th} percentile) of the ONQI-f score was 32.2 (23.1, 42.4) in the women and 30.1 (21.4, 40.9) in the men. The baseline characteristics and mean values for the nutrients included in the ONQI algorithm are presented by quintiles of ONQI-f score in Table 2. As expected, the intake of nutrients in the numerator was higher, and nutrients in the denominator were lower, with greater ONQI-f scores. Women and men who consumed a diet with a higher average ONQI-f score were less likely to smoke and to use aspirin regularly and were more likely to have prevalent hypercholesterolemia and a lower BMI. Individuals with higher ONQI-f scores consumed fewer calories, more alcohol and exercised more.

Over 20 years of follow-up, there were 20,004 cases of major chronic disease, including 3,699 cases of CVD, 4,351 cases of diabetes and 9,422 cases of cancer among women and 13,520 cases of major chronic disease, including 4,194 cases of CVD, 2,407 cases of diabetes and 4,937 cases of cancer among men. The ONQI-f score was inversely associated with risk of major chronic disease among women (Table 3). After adjustment for confounders, women in the highest compared to lowest quintile of the ONQI-f score had a relative risk of chronic disease of 0.88 (95%CI: 0.84, 0.93). After further adjustment for BMI this association was attenuated, but remained significant (RR: 0.91; 95%CI: 0.87, 0.95), which suggests that the association is explained only partially by effects on adiposity. The relative risk of chronic disease among men, comparing the highest to lowest quintile of the ONQI-f score, was 0.85 (95%CI: 0.80, 0.90). Again, this association was attenuated slightly, but remained significant, after adjustment for BMI (RR: 0.88; 95%CI: 0.83, 0.93).

The ONQI-f score was strongly inversely associated with risk of CVD and diabetes (Table 3). Compared to the lowest quintile, the risk of CVD in the highest quintile was 21% lower in women and 25% lower in men, and this association was not appreciably attenuated after adjustment for BMI. The risk of diabetes in the highest quintile was 22% lower in women and 30% lower in men in the lowest quintile. The association with diabetes was attenuated, but remained significant, after adjustment for BMI. The ONQI-f score was not associated with risk of cancer (p-trend in women: 0.47; p-trend in men: 0.18). The ONQI-f score was significantly associated with lower risk of total mortality among both women and men (p-trend= 0.01).

Discussion

In these two prospective cohorts, consumption of foods with higher ratings based on the ONQI algorithm was associated with lower risk of chronic disease and total mortality over 20 years of follow-up. Higher ONQI-f scores were associated with a 9%–12% lower risk of chronic disease and a 10%–11% lower risk of all-cause mortality. These associations were driven by strong associations with risk of CVD and diabetes. The ONQI-f score was not significantly associated with risk of cancer. The ONQI score is one of many nutrient profiles and the NuVal™ Nutritional Scoring System is one of the many front-of-package labeling schemes currently used in the marketplace; to our knowledge this is the first system to be evaluated against health outcomes

The attention surrounding front-of–package labeling grew rapidly after the launch of the now defunct Smart Choices Program, which was developed by the Keystone Center and aimed to identify smarter choices within 19 specific product categories on the basis of nutrient profiles and food group content.[28] The appearance of the Smart Choice symbol on food products such as sugar-sweetened cereals and high–saturated fat foods sparked a flurry of criticism from Congress,[29] as well as the attorney general of Connecticut.[30] This has prompted the FDA to address the issues and challenges of nutrition labeling, including plans to work with the food industry to develop a uniform and optimal approach to communicate nutrition-related information on food products.[31, 32] The FDA recognizes the potential benefits of front-of-package labels[33], however, a large number of existing rating systems could overwhelm consumers, and minimize consumer confidence in any food product labels.

The FDA is currently conducting consumer research to evaluate the effectiveness of front-of-package labels.[30] However, if the FDA opts to adopt or create a standardized front-of-package labeling system, it is imperative that the system is based on the best available scientific evidence. The goal of the front-of-package label is to communicate the healthfulness of the food, thus it is essential that the scoring system predicts lower risk of chronic disease. Second, the system should apply the same nutritional criteria to all food products, to allow for equal comparisons across all foods, rather than only selected foods that meet specified nutritional criteria or different food groups. Finally, the label should provide consumers with a quick and clear way to distinguish foods that are less healthy and should be consumed less frequently and foods that are healthy and should be consumed often.

Whether the FDA should develop or regulate front-of-package labels is controversial. Some critics argue that current labels are misleading, due to the lack of verification of the health claims and the selective presentation of healthy nutrients while ignoring harmful nutrients within the same food.[34] However, if based on strong scientific evidence, a front-of-package label could provide consumers with a simple method to make point of purchase choices. Furthermore, a comprehensive front-of-package label would account for the levels of beneficial and unhealthful components of a food item.

Beyond consumer education, front-of-package labeling may also lead to overall improvement in the healthfulness of the food supply, as manufacturers may reformulate food products to earn higher scores.[4, 13, 35] However, this may lead to the manipulation of the nutrient content of unhealthy food products, to increase a food's rating score without meaningful improvement in nutritional quality.[34] It may be useful to place a cap on the contribution of a micronutrient in any FOP scoring system, as done with the ONQI score, to avoid artificially inflated levels of nutrients from fortification or processing.

This analysis of the ONQI algorithm has several limitations. First, the food items on the FFQ do not distinguish between brand names and processing methods, such as canned, fresh and frozen forms of many produce items. These differences may be a large source of variation in nutrient composition in food products. For example, canned green beans have an ONQI score of 59, but canned without salt and fresh-frozen green beans have a score of 100. In the commercial application of the NuVal™ Nutritional Scoring System, the ONQI algorithm is used to generate a unique score for each branded product, matched to the unique product code (UPC). Second, in this analysis, the ONQI score of the diet was measured only once at baseline. A single measure of diet is prone to measurement error, and does not account for changes in diet, or in the food supply, over the course of follow-up. Additionally, self-reported diet assessed by the FFQ used in this cohort has had good validity when compared with weighed dietary records or biomarkers of intake[19-21], but is nevertheless imperfect. These sources of misclassification should be random with respect to disease risk and will usually lead to underestimation of associations.

Finally. the ONQI algorithm and NuVal™ Nutritional Scoring System were designed to measure nutritional quality at a food level, and not for an overall diet evaluation, which accounts for total energy balance, distribution of food intake and variety of foods. Even foods with a high ONQI score, relative to other foods, should not be consumed in unlimited amounts, thus quantity of total food must be accounted for. The ONQI-f score was adjusted for the total number of servings of food to account for this, and to evaluate the average ONQI score across the diet.

The ONQI score and several existing front-of-package labels portray a food's overall nutritional value in the form of a single number, number of checkmarks or stars, or a single symbol, thus consumers must accept these scores and symbols at face value. Therefore, it is necessary to provide consumers with a rigorous validation of these labels to truly distinguish between healthful and less-healthful foods, which potentially could enhance consumer confidence of these labels. For this analysis, incidence of disease was considered as a measure of nutritional quality and healthfulness. In other words, a food that is identified as having a high "nutritional quality" should be associated with lower risk of disease and foods identified as "low quality" should be associated with higher risk of disease.

In conclusion, the ONQI algorithm which incorporates over 30 nutrients, food properties and magnitude of association with disease, was associated with lower risk of chronic disease and total mortality. Front-of-package labeling has the potential to help consumers select foods that contribute to a healthy diet and lower risk of disease. Future research on nutrient profiles and front-of-package labeling should use similar techniques to evaluate the ability of the scoring scheme to distinguish between more- and less-healthful foods as they relate to risk of future disease.

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Table 1

Components of the ONQI algorithm

Numerator Nutrients	Denominator Nutrients	Macronutrient Factors[a]
Fiber	Saturated Fat	Fat quality[e]
Folate	*Trans* Fat	Protein quality[e]
Vitamin A	Sodium	Energy density[f,g]
Vitamin C	Added Sugar	Glycemic load[f,h]
Vitamin D	Cholesterol	
Vitamin E[b]		
Vitamin B6		
Vitamin B12		
Potassium		
Calcium		
Zinc		
Omega-3 fatty acids		
Total Flavonoids[c]		
Total Carotenoids[d]		
Magnesium		
Iron		

ONQI, Overall Nutritional Quality Index

[a] Macronutrient factors enter the algorithm as multipliers

[b] Vitamin E in the form of α-tocopherol

[c] Total flavonoids is the sum of flavones, flavonones, flavonols, flavan-3-ols, anthocyanidins, polymeric flavonoids, proanthocyanidins, theaflavins and thearubigins

[d] Total carotenoids is the sum of α-carotene, β-carotene, β-cryptoxanthin, lycopene and lutein/zeaxanthin

[e] Applied to the numerator

[f] Applied to the denominator

[g] Discounted for cooking oils

[h] Applied selectively to grain and grain-containing products to differentiate between whole- and refined-grain products

Table 2

Baseline characteristics and nutrients in the ONQI algorithm across quintiles of the ONQI-f score[a]

	Nurses' Health			Health Professionals Follow-up Study		
	Q1	**Q3**	**Q5**	**Q1**	**Q3**	**Q5**
Range of ONQI-f score	7.4–26.1	30.3–34.2	38.8–78.0	5.8–24.2	28.2–32.1	37.0–74.6
Median of ONQI-f score	23.1	32.2	42.4	21.4	30.1	40.9
Age, years	52	52	52	53	53	53
Current smoking, %	33	19	13	18	9	4
BMI	25.5	25.2	24.5	25.8	25.6	24.9
Exercise, hours/week	1.2	1.9	3.0	1.6	2.0	2.3
Alcohol intake, g/day	5.9	6.3	7.0	10.8	11.8	11.9
Regular aspirin use, % ≥7 week	20	18	16	29	27	22
Postmenopausal hormone use, %	12	15	15	N/A	N/A	N/A
History of high cholesterol, %	5	6	8	9	10	12
History of hypertension, %	13	14	15	17	20	21
Family history of MI, %	19	19	19	11	12	13
Family history of cancer, %[b]	9	10	10	2	2	2
Total energy intake (kcal/ day)	*1766*	*1789*	*1722*	*2025*	*2017*	*1930*
ONQI algorithm components [c]						
Numerator						
Fiber, g/day	13.5	17.3	22.2	15.7	20.2	27.5
Folate, μg/day	321	403	487	374	471	603
Vitamin A, μg /day[d]	1373	1684	2079	1653	2069	2727
Vitamin C, mg/day	254	335	453	301	412	598
Vitamin D, IU/day	282	341	394	329	398	489
Vitamin E, mg/day[e]	57	73	106	69	89	132
Vitamin B12, μg/day	9.2	10.3	11.5	11.6	12.7	13.6
Vitamin B6, mg/day	6.0	8.7	11.8	5.8	8.3	13.0
Potassium, mg/day	2581	3031	3536	2873	3373	4030
Calcium, mg/day	925	1090	1216	795	891	1002
Zinc, mg/day	14.3	15.6	17.2	18.6	20.7	23.9

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	Nurses' Health			Health Professionals Follow-up Study		
	Q1	**Q3**	**Q5**	**Q1**	**Q3**	**Q5**
Marine n-3 fatty acids, mg/day	148	215	306	197	291	432
Total flavonoids, mg/day[f]	309	337	377	263	323	393
Total carotenoids, μg/day[g]	10,458	14,157	19,764	11,258	15,857	23,926
Magnesium, mg/day	256	299	341	298	349	413
Iron, mg/day	16.4	18.4	19.8	17.3	19.4	22.4
Denominator						
Saturated fat, % energy	13.1	11.8	10.1	12.7	11.2	8.8
Trans fat, % energy	2.0	1.7	1.3	1.6	1.3	0.9
Sodium, mg/day	3197	2864	2471	3695	3246	2825
Added sugar, % energy	11.6	8.9	7.3	12.7	9.2	7.1
Cholesterol, mg/day	246	245	231	323	310	272
Energy density	*4.2*	*4.2*	*4.1*	*4.8*	*4.7*	*4.5*
Glycemic load	*98*	*98*	*101*	*121*	*122*	*133*

ONQI, Overall Nutritional Quality Index

[a]All nutrients and characteristics are age standardized, with the exception of age

[b]Family history of cancer includes colon cancer and breast cancer (women only)

[c]All nutrients are energy-adjusted

[d]Vitamin A measured in retinol activity equivalents

[e]Vitamin E in the form of α-tocopherol

[f]Total flavonoids is the sum of flavones, flavonones, flavonols, falvan-3-ols, anthocyanidins, polymeric flavonoids, proanthocyanidins, theaflavins and thearubigins

[g]Total carotenoids is the sum of α-carotene, β-carotene, β-cryptoxanthin, lycopene and lutein/zeaxanthin

Table 3

Relative risk (95% CI) of chronic disease by the ONQI-f scores in the Nurses' Health Study and Health Professionals Follow-up Study[a]

	Quintiles of ONQI-f score					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**P-trend**
Nurses' Health Study						
Total chronic disease [b]						
Median ONQI-f score	23.1	28.3	32.2	36.3	42.4	
Cases	4232	3937	3961	3959	3915	
Age-adjusted model	1.0 (ref)	0.86 (0.82, 0.90)	0.83 (0.79, 0.87)	0.79 (0.76, 0.83)	0.74 (0.71, 0.78)	<0.001
Multivariate model[c]	1.0 (ref)	0.93 (0.89, 0.97)	0.94 (0.90, 0.98)	0.92 (0.88, 0.96)	0.88 (0.84, 0.93)	<0.001
Multivariate model + BMI	1.0 (ref)	0.93 (0.89, 0.98)	0.94 (0.90, 0.98)	0.93 (0.89, 0.98)	0.91 (0.87, 0.95)	<0.001
Cardiovascular disease						
Cases	820	713	712	738	716	
Multivariate model	1.0 (ref)	0.86 (0.78, 0.95)	0.86 (0.77, 0.95)	0.85 (0.77, 0.94)	0.79 (0.71, 0.88)	<0.001
Multivariate model + BMI	1.0 (ref)	0.86 (0.78, 0.95)	0.85 (0.77, 0.95)	0.85 (0.77, 0.94)	0.79 (0.71, 0.88)	<0.001
Diabetes						
Cases	1013	960	879	807	692	
Multivariate model	1.0 (ref)	0.99 (0.90, 1.08)	0.94 (0.86, 1.03)	0.88 (0.80, 0.97)	0.78 (0.70, 0.86)	<0.001
Multivariate model + BMI	1.0 (ref)	0.98 (0.90, 1.08)	0.95 (0.87, 1.04)	0.93 (0.84, 1.02)	0.86 (0.78, 0.96)	0.003
Cancer						
Cases	1814	1772	1934	1908	1994	
Multivariate model	1.0 (ref)	0.96 (0.90, 1.03)	1.03 (0.97, 1.10)	0.99 (0.93, 1.06)	1.01 (0.95, 1.08)	0.47
Multivariate model + BMI	1.0 (ref)	0.96 (0.90, 1.03)	1.03 (0.97, 1.10)	1.00 (0.93, 1.06)	1.02 (0.95, 1.09)	0.37
Total mortality						
Cases	1657	1493	1422	1459	1535	
Multivariate model	1.0 (ref)	0.92 (0.86, 0.99)	0.87 (0.81, 0.93)	0.87 (0.81, 0.94)	0.89 (0.82, 0.95)	<0.001
Multivariate model + BMI	1.0 (ref)	0.93 (0.87, 1.00)	0.88 (0.82, 0.95)	0.89 (0.83, 0.96)	0.90 (0.84, 0.97)	0.01
Health Professionals Follow-up Study						
Total chronic disease[†]						
Median ONQI-f score	21.4	26.3	30.1	34.3	40.9	
Cases	2899	2712	2673	2653	2583	

	Quintiles of ONQI-f score					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**P-trend**
age-adjusted model	1.0 (ref)	0.88 (0.83, 0.93)	0.84 (0.80, 0.89)	0.81 (0.76, 0.85)	0.73 (0.69, 0.77)	<0.001
multivariate model	1.0 (ref)	0.94 (0.88, 0.99)	0.93 (0.88, 0.98)	0.91 (0.86, 0.96)	0.85 (0.80, 0.90)	<0.001
multivariate model + BMI	1.0 (ref)	0.94 (0.89, 0.99)	0.94 (0.89, 0.99)	0.93 (0.88, 0.98)	0.88 (0.83, 0.93)	<0.001
Cardiovascular disease						
Cases	930	861	849	803	751	
Multivariate model	1.0 (ref)	0.91 (0.83, 1.00)	0.90 (0.82, 0.99)	0.84 (0.76, 0.92)	0.75 (0.67, 0.83)	<0.001
Multivariate model + BMI	1.0 (ref)	0.91 (0.83, 1.00)	0.91 (0.82, 1.00)	0.85 (0.77, 0.93)	0.77 (0.70, 0.85)	<0.001
Diabetes						
Cases	594	502	501	439	371	
Multivariate model	1.0 (ref)	0.88 (0.78, 1.00)	0.91 (0.80, 1.03)	0.80 (0.70, 0.90)	0.70 (0.61, 0.80)	<0.001
Multivariate model + BMI	1.0 (ref)	0.91 (0.81, 1.03)	0.93 (0.82, 1.05)	0.87 (0.77, 0.99)	0.84 (0.73, 0.96)	0.01
Cancer						
Cases	965	954	942	1004	1072	
Multivariate model	1.0 (ref)	0.98 (0.89, 1.07)	0.97 (0.89, 1.07)	1.02 (0.93, 1.12)	1.05 (0.95, 1.15)	0.18
Multivariate model + BMI	1.0 (ref)	0.98 (0.90, 1.07)	0.97 (0.89, 1.07)	1.02 (0.93, 1.12)	1.06 (0.96, 1.16)	0.13
Total mortality						
Cases	1397	1323	1299	1314	1353	
Multivariate model	1.0 (ref)	0.93 (0.86, 1.00)	0.91 (0.84, 0.98)	0.91 (0.84, 0.99)	0.89 (0.82, 0.96)	0.01
Multivariate model + BMI	1.0 (ref)	0.93 (0.86, 1.01)	0.91 (0.84, 0.99)	0.92 (0.85, 1.00)	0.89 (0.83, 0.97)	0.01

ONQI, Overall Nutritional Quality Index

[a]Nurses' Health Study was composed of all women; the Health Professionals Follow-up Study was composed of all men

[b]Total chronic disease included incident nonfatal MI, fatal CHD, nonfatal and fatal stroke, angina, diabetes, cancer and nontrauma-related deaths.

[c]Multivariate model adjusted for age, energy intake, alcohol intake, smoking, aspirin, exercise, family history of MI, family history of cancer, history of hypertension and history of high cholesterol. In women, models were also adjusted for menopausal status and menopausal hormone use.