Original Paper

Dietary Diversity and Subsequent Cause-Specific Mortality in the NHANES I Epidemiologic Follow-up Study

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Objectives: Human diets tend to be complex mixtures of foods and nutrients. Therefore, we examined the relation of a measure of overall diet quality (independent of intake of individual foods or nutrients) with mortality from cardiovascular disease (CVD), cancer, and non-CVD, non-cancer (other) causes.

Methods: We used data from the NHANES I Epidemiologic follow-up study (n = 10,337; median follow-up time = 14 years; age 25–74 years at baseline), and included 988 CVD, 571 cancer, and 910 other cases. The 24-hour dietary recalls obtained at baseline were scored for quality using a dietary diversity score (DDS). The DDS (range 0–5) counts the number of major food groups—dairy, meat, grain, fruit, and vegetable consumed daily.

Results: Age-adjusted risk of mortality from all three causes (except cancer in women) was inversely related with DDS in both men and women. Adjustment for multiple covariates attenuated the relative risk estimates slightly for CVD and cancer mortality, but markedly for other mortality.

Conclusions: The results are suggestive of an increased risk of CVD and cancer mortality associated with diets characterized by omission of several major food groups.

INTRODUCTION

A large body of literature concerned with the role of specific nutrients, individual foods, and food groups in prevention/promotion of disease has been published [1–2]. Because human diets are complex mixtures of foods containing nutrients and non-nutrient components, it is also important to examine how patterns of food intake, and measures of assessment of the "total" diet relate to health. Relatively little information is available on the relation of health to qualitative or quantitative measures of overall diet quality [3–8].

Recently we reported an inverse association between overall diet quality as measured by variety among the major food groups and the risk of all-cause mortality [8]. The multiple-covariate-adjusted risk of all-cause mortality in men and women consuming two or fewer food groups relative to five was increased by 50% and 40%, respectively [8]. In this report, we extend our previous work by examining the relation of diet quality assessed as dietary diversity with cardiovascular (CVD), all-sites cancer, and other (non-CVD, non-cancer) mortality in the first National Health and Nutrition Examination Survey (NHANES I) Epidemiologic Follow-up Study (NHEFS) cohort.

METHODS

The NHANES I was conducted from 1971–75 by the National Center for Health Statistics (NCHS) [9]. The NHANES I Epidemiologic Follow-up Study (NHEFS) was initiated in 1982 by NCHS and other Public Health Service agencies, with the aim of relating mortality and morbidity at follow-up to nutritional, health, and other information collected in NHANES I [10]. Respondents who were 25–74 years of age at the time of initial survey (n = 14,407) were considered eligible for follow-up [10].

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Analytic Cohort

From the original NHEFS cohort exclusions were made for: lack of baseline 24-hour dietary recall (3059), unsatisfactory 24-hour recalls based on interviewers' judgement (205), atypical intake due to illness on the day of recall (272), recalls obtained from proxies (334), transcription errors in 24-hour recalls (45), and recalls of pregnant and lactating women (125). We also excluded cases with unknown cause of death (n = 87). Some respondents were in more than one exclusion category. The final analytic cohort included 10,337 examinees (4120 men and 6217 women), followed from 1971–75 through 1987 [10,11]. There were 988 deaths due to cardiovascular disease (International Classification of Diseases Ninth Revision (ICD9) codes 410–414 and 430–438), 571 all sites cancer (ICD9 codes 140–208, except 173) deaths, and 910 deaths due to all other causes.

Information on age, income, education, body weight, height, blood pressure, and serum cholesterol was obtained at baseline [9]. A single 24-hour dietary recall was administered to each respondent at baseline by a trained dietary interviewer using three-dimensional food models to enable estimation of amount of food consumed [9]. Estimates of nutrient intake were obtained using U.S. Department of Agriculture food composition data for the amounts of food reported consumed in each recall [12].

Dietary Diversity Measure

The measure of dietary diversity (Dietary Diversity Score) developed for this analysis counts the number of food groups, i.e., dairy, meat, grain, fruit, and vegetable consumed daily [13]. The maximum score is 5; one point is counted for each group consumed. For example, individuals who report consumption of foods from all the five food groups on the day of recall will be given a Diversity Score of 5, while those reporting no foods from the fruit or vegetable groups will be given a score of 3. A Dietary Diversity Score (DDS) was calculated for each respondent.

To create the DDS from the 24-hour dietary recalls, we assigned the 1,710 foods reported by adults in NHANES I to one or more of the five broad food groups-dairy, meat, grain, fruit, and vegetable. Foods were grouped into the different groups based on similarities in nutrient composition and uses in the diet. The dairy group was assigned all milk and milk products. The meat group included both animal and plant protein sources. The grain group included all grain products except cakes, pies, cookies and pastries. The fruit group included all fresh, canned, frozen, and dried fruits, and fruit juices, but excluded fruit drinks. The vegetable group included all raw, cooked, frozen, and canned vegetables. Food mixtures containing foods from various food groups, for example, mixed dishes with meat, grain, dairy and vegetables such as lasagna were assigned to all the relevant food groups.

In order to avoid giving credit for consumption of a food group when the amounts reported were small, we also excluded foods consumed in less than a minimum amount. For the meat, fruit, and vegetable groups, the minimum reported amount for inclusion in the diversity score was 30 g (2 tablespoons) for all solid foods with a single ingredient, and 60 g for all liquids and mixed dishes. For the dairy and grain groups, this minimum amount was 15 g (1 tablespoon) for all solids, and 30 g for all liquids and mixed dishes. The methods used for grouping foods and the rationale for decisions regarding minimum amounts have been described [13].

Analytical Methods

Due to small numbers of study subjects with diversity scores of 0, 1, and 2, the three categories were combined. Crude mortality rates for individuals scoring 0–2, 3, 4, and 5 on the DDS were calculated by dividing the number of deaths in each score category by the total number of person-years contributed by all subjects in that score category. The number of person-years contributed by an individual was calculated from baseline to the date of death or the date of follow-up interview, whichever came first. Age-adjusted death rates, standardized for age distribution of the analytic cohort, were calculated [14]. Cox's proportional-hazards regression analysis [15] was used to evaluate the association of DDS, age at baseline, and other potential risk factors for cardiovascular, cancer, and other mortality, using the PHGLM procedures available in the SAS package [16]. To test for a linear trend in the association of mortality to diversity, a categorical variable with 4 values representing diversity scores of ≤2, 3, 4, and 5 was entered into the regression model.

RESULTS

The mean age of the analytic cohort was 50 years and the median follow-up time was 14.2 years. Table 1 shows the frequency distribution of the DDS in the analytic cohort. Thirty-five percent of the analytic cohort scored 5 on the DDS; 5% of the cohort had a DDS of ≤2.

Table 2 presents the proportion of respondents within

Table 1. Frequency Distribution of the Dietary Diversity Score (DDS) in the Analytic Cohort, by Sex

DDS	All	Men	Women
N	10,337	4,120	6,217
		%	
≤2	5.2	4.6	5.6
3	20.2	19.5	20.7
4	39.3	40.3	38.6
5	35.3	35.5	35.1

DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

Table 2. Proportion of Respondents within Dietary Diversity Score (DDS) Categories who had Various Mortality Risk Factors, by Sex

Risk factor	Men				Women			
	DDS				DDS			
	≤2	3	4	5	≤2	3	4	5
	%							
Non-white	38	26	15	9	34	27	18	9
Age ≥50 years	46	45	44	44	43	43	42	43
PIR ≤1*	29	21	11	6	35	22	16	10
Education ≤12 years	86	79	73	63	91	86	82	71
Current smokers	49	45	39	30	32	30	27	22
Plasma cholesterol upper tertile	29	29	32	32	31	34	33	34
Body mass index (kg/m^2) upper tertile	33	36	35	32	44	39	33	28
Systolic blood pressure upper tertile	33	31	27	24	38	33	31	27
Vitamin/mineral supplement use								
None	87	81	73	68	76	70	65	58
Regular	9	12	17	24	15	20	23	29
Energy intake								
T1	60	41	26	19	73	49	30	20
T2	22	31	35	33	16	30	36	34
T3	18	28	39	47	11	20	34	45
Vitamin C intake								
T1	84	57	35	10	82	57	33	12
T2	12	30	41	31	13	30	39	33
T3	4	13	24	58	5	13	28	55
Percent energy from fat								
T1	41	33	30	33	41	32	31	34
T2	32	30	34	37	21	32	33	37
T3	27	36	36	29	38	36	36	29

DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

Each number represents total amount of person-time accumulated by subjects in a risk factor category as a percentage of the total amount of person-time accrued by all subjects in a DDS category. All percentages, except age, were age adjusted by the direct method based on the distribution of the age-specific person-times in the analytic cohort.

All tertile cuts were sex-specific.

* Poverty index ratio is a ratio of the reported household income to total household income necessary for maintaining a family on a nutritionally adequate food plan at the time of NHANES I. Ratios were calculated by the NCHS, and <1.0 were considered below poverty.

categories of DDS who had other risk factors of mortality. A higher proportion of respondents scoring low, as opposed to high, on the DDS were non-white, poor, less educated, current smokers, supplement non-users, and had high systolic blood pressure. The ≤2 category relative to other DDS categories had a higher proportion of women in the third tertile of body mass index (BMI). The ≤2 category, however, had a slightly higher proportion of lean men (in the first tertile of BMI). A higher proportion of respondents in the ≤2 category were also in the lowest tertiles of daily energy, percent fat energy, and vitamin C intake.

Table 3 presents the proportion of respondents omitting each of the major five food groups by DDS, for men and women in the analytic cohort. Fruit was the most frequently omitted food group, followed by dairy and vegetable groups in both men and women. Table 4 presents the mean ± standard error of sex- and age-specific recommended dietary allowance (RDA) of selected micronutrients associated with DDS. With increasing DDS, the mean % RDA increased for each of the nutrients presented.

Table 5 presents the DDS specific crude and age-adjusted mortality rates for cause specific mortality in the analytic cohort. In both men and women age-adjusted death rates from cardiovascular disease, cancer, and other causes of mortality were inversely associated with DDS.

Table 6 displays age and multiple risk factor-adjusted relative risks for various causes of mortality by DDS category. In men, age-adjusted mortality from CVD, cancer, and other causes was inversely associated with DDS. In women the age-adjusted relative risk of mortality from CVD and other causes, but not cancer, was inversely associated with DDS. Association of each cause of mortality with DDS was stronger in men relative to women.

Table 3. Proportion of the Analytic Cohort Missing Each of the Major Food Groups, by Dietary Diversity Score (DDS), by Sex

Food group	Men				Women			
	DDS				DDS			
	≤2	3	4	5	≤2	3	4	5
	%							
Dairy	88	61	22	0	81	61	24	0
Meat	21	6	2	0	35	16	6	0
Grain	17	5	1	0	24	9	4	0
Fruit	97	87	62	0	92	78	51	0
Vegetable	86	40	13	0	78	36	14	0

DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

Table 4. Percent Recommended Dietary Allowance (RDA) of Selected Micronutrients Associated with the Dietary Diversity Score (DDS)

Nutrient	DDS			
	≤2	3	4	5
Riboflavin	58 ± 1.9	82 ± 1.4	109 ± 1.0	131 ± 1.3
Thiamin	48 ± 1.5	69 ± 1.0	84 ± 0.8	100 ± 0.9
Vitamin B-6	39 ± 1.4	54 ± 0.8	70 ± 0.6	83 ± 0.7
Vitamin C	32 ± 2.9	78 ± 2.4	124 ± 1.9	203 ± 2.4
Calcium	35 ± 1.7	56 ± 1.1	85 ± 0.9	105 ± 1.0

Mean ± SE.

RDA = 1989, sex and age-specific.

DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

Table 5. Crude and Age-Adjusted Rates* of Cause-Specific Mortality, by the Dietary Diversity Score (DDS), by Sex

DDS	Men			Women		
	No. of cases	Crude rate	Age-adj rate	No. of cases	Crude rate	Age-adj rate
Cardiovascular mortality						
≤2	41	1882	1606	27	574	754
3	115	1181	1107	80	452	557
4	209	1009	975	157	482	570
5	196	1087	848	163	551	500
Cancer mortality						
≤2	20	918	828	18	383	472
3	67	688	639	45	254	303
4	114	551	538	87	267	309
5	118	654	515	102	345	328
Other (non-cardiovascular, non-cancer) mortality						
≤2	37	1699	1538	24	510	626
3	106	1088	1043	84	475	557
4	200	966	950	134	411	473
5	182	1009	787	143	483	443

* Per 100,000 person-years. Crude rates were adjusted for age by the direct method, based on age distribution of the analytic cohort.
The DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

The effect of a series of potential confounders (race, education, income, smoking status, systolic blood pressure, plasma cholesterol, alcohol use, energy intake, BMI, supplement use, fat intake, fiber intake, and vitamin C intake), one at a time, on the age-adjusted association of DDS with each cause of mortality was examined using sex-specific regression analyses. Notably, in these models, for all three categories of mortality, no single confounder altered the risk estimate associated with the lowest DDS category by more than 10%. For men, education, income, race, and smoking status attenuated the relative risk estimates for CVD, cancer and other causes of mortality somewhat. In women, in models containing age and one confounder, the trends for CVD, cancer, and other causes of mortality with decreasing DDS were present, but were no longer significant (data not shown).

After adjustment for multiple covariates, the trend for increasing mortality with decreasing dietary variety was not noted. However, significant excess risk of CVD mortality was associated with the lowest DDS category relative to the highest in men, but not in women (Table 6). For cancer, and other non-CVD, non-cancer causes of mortality, the multiple risk factor-adjusted risk associated with DDS of ≤2 relative to 5 was not significant in both men or women (Table 6).

To account for pre-clinical conditions at baseline leading to a poor DDS, all analyses were repeated after exclusion of first 2, 4, or 6 years of follow-up. Exclusion of 2 to 6 years of follow-up did not alter the relation of DDS with the 3 categories of mortality. Table 7 presents results after exclusion of first 4 years of followup (excluded were 227 CVD, 120 cancer, and 166 other-cause deaths).

Table 6. Relative Risk (RR) Estimates and 95% Confidence Intervals (CI) of Cause-Specific Mortality, by the Dietary Diversity Score (DDS), by Sex

	Dietary diversity score				X^2 for trend (p)
	≤2	3	4	5[a]	
Cardiovascular mortality					
Men (no. of cases = 561)					
Age-adjusted RR	1.9*	1.3*	1.2	1.0	14.3 (0.0002)
95% CI	1.4–2.7	1.0–1.7	1.0–1.4		
Multivariate RR	1.5*	1.1	1.0	1.0	2.6 (0.11)
95% CI	1.0–2.1	0.8–1.4	0.8–1.3		
Women (no. of cases = 427)					
Age adjusted RR	1.6*	1.1	1.2	1.0	3.6 (0.05)
95% CI	1.0–2.4	0.8–1.4	0.9–1.4		
Multivariate RR	1.3	0.9	1.1	1.0	0.1 (0.73)
95% CI	0.8–2.0	0.7–1.2	0.8–1.3		
Cancer mortality					
Men (no. of cases = 319)					
Age-adjusted RR	1.6	1.2	1.0	1.0	4.0 (0.04)
95% CI	1.0–2.5	0.9–1.7	0.8–1.3		
Multivariate RR	1.3	1.0	0.9	1.0	0.4 (0.52)
95% CI	0.8–2.1	0.8–1.4	0.7–1.2		
Women (no. of cases = 252)					
Age-adjusted RR	1.5	0.9	0.9	1.0	0.4 (0.5)
95% CI	0.9–2.5	0.7–1.3	0.7–1.3		
Multivariate RR	1.4	0.9	0.9	1.0	0.03 (0.87)
95% CI	0.8–2.3	0.6–1.3	0.7–1.2		
Other (non-cardiovascular, non-cancer) mortality					
Men (no. of cases = 525)					
Age-adjusted RR	1.9*	1.3*	1.2	1.0	12.4 (0.0004)
95% CI	1.4–2.7	1.0–1.6	1.0–1.5		
Multivariate RR	1.2	1.0	1.0	1.0	0.2 (0.65)
95% CI	0.9–1.9	0.8–1.3	0.9–1.3		
Women (no. of cases = 385)					
Age-adjusted RR	1.5	1.3	1.1	1.0	5.1 (0.02)
95% CI	1.0–2.3	1.0–1.7	0.8–1.4		
Multivariate RR	1.0	1.0	1.0	1.0	0.05 (0.82)
95% CI	0.6–1.5	0.7–1.3	0.7–1.2		

The DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.
[a] Reference category
* Significantly different from the reference category ($p < 0.05$).
Multivariate model for cardiovascular mortality included age, education, race, smoking status, systolic blood pressure, plasma cholesterol, body mass index, and energy intake as covariates.
Multivariate model for cancer mortality included age, education, race, smoking status, and energy intake as covariates.
Multivariate model for other mortality included age, education, race, body mass index, smoking status, and energy intake as covariates.

The association of DDS with each cause of mortality was examined in sex-specific regression models stratified by categories of age (<50, ≥50), education (<12, ≥12), BMI (tertiles), smoking status (never, former, and current smokers), and energy intake (tertiles). Results consistent with modification of the DDS-mortality association were not observed. The excess risk associated with the ≤2 DDS category was observed in nearly all strata; however, due to small numbers in some strata,

Table 7. Relative Risk (RR) Estimates and 95% Confidence Intervals (CI) of Cause-Specific Mortality after Exclusion of first 4 Years of Follow-up, by the Dietary Diversity Score (DDS), by Sex

	DDS ≤2	3	4	5[a]	X^2 for trend (p)
Cardiovascular mortality					
Men (no. of cases = 411)					
Age-adjusted RR	2.0*	1.2	1.1	1.0	7.8 (0.005)
95% CI	1.4–3.0	0.9–1.5	0.9–1.4		
Multivariate RR	1.7*	1.0	1.0	1.0	1.8 (0.17)
95% CI	1.1–2.5	0.7–1.3	0.8–1.2		
Women (no. of cases = 350)					
Age-adjusted RR	1.5	1.1	1.1	1.0	1.9 (0.15)
95% CI	0.9–2.3	0.8–1.5	0.8–1.4		
Multivariate RR	1.3	1.0	1.0	1.0	0.1 (0.74)
95% CI	0.8–2.1	0.7–1.3	0.8–1.3		
Cancer mortality					
Men (no. of cases = 247)					
Age-adjusted RR	2.0*	1.3	1.1	1.0	6.8 (0.009)
95% CI	1.2–3.3	0.9–1.9	0.8–1.4		
Multivariate RR	1.6	1.1	1.0	1.0	2.1 (0.14)
95% CI	0.9–2.8	0.8–1.7	0.7–1.3		
Women (no. of cases = 204)					
Age-adjusted RR	1.6	0.9	0.9	1.0	0.4 (0.51)
95% CI	0.9–2.7	0.6–1.3	0.6–1.2		
Multivariate RR	1.5	0.9	0.9	1.0	0.1 (0.58)
95% CI	0.8–2.6	0.6–1.3	0.6–1.2		
Other (non-cardiovascular, non-cancer) mortality					
Men (no. of cases = 419)					
Age-adjusted RR	2.1*	1.3	1.1	1.0	10.9 (0.001)
95% CI	1.4–3.0	1.0–1.7	0.9–1.4		
Multivariate RR	1.2	0.9	1.0	1.0	0.0 (0.85)
95% CI	0.8–1.9	0.7–1.2	0.8–1.2		
Women (no. of cases = 325)					
Age-adjusted RR	1.7*	1.3	1.1	1.0	6.2 (0.01)
95% CI	1.1–2.6	1.0–1.7	0.9–1.4		
Multivariate RR	1.1	1.0	1.0	1.0	0.0 (0.87)
95% CI	0.7–1.8	0.7–1.3	0.7–1.3		

DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable.

[a] Reference category

* Significantly different from the reference category ($p < 0.05$).

Multivariate model for cardiovascular mortality included age, education, race, smoking status, systolic blood pressure, plasma cholesterol, body mass index, and energy intake as covariates.

Multivariate model for cancer mortality included age, education, race, smoking status, and energy intake as covariates.

Multivariate model for other mortality included age, education, race, body mass index, smoking status, and energy intake as covariates.

the estimates were unstable, and did not attain statistical significance (data not shown).

DISCUSSION

The results of our study indicate an increased age-adjusted risk of mortality from CVD, cancer, and non-CVD, non-cancer causes in men reporting consumption of two or fewer food groups relative to five. Similar results were observed in women though the excess risk was somewhat smaller. After adjustment for multiple covariates the risk estimates were attenuated and the inverse trend for the association of mortality with DDS was vitiated.

As evident from Table 2, low socioeconomic status (poverty-index ratio and education) was associated with a low DDS. The observed attenuation in risk estimates after adjustment for education and other variables related to socioeconomic status (race, smoking status, BMI) indicates that not all of the association of DDS with mortality was independent of these variables. It is also plausible that a low DDS is on the causal pathway between low socioeconomic status and increased risk of mortality, which would suggest that improvement in socioeconomic status might improve diets and thereby reduce mortality.

Given that only a single 24-hour recall is available at baseline for the NHEFS cohort, we wished to avoid measures of overall diet quality based on variety within food groups and/or quantitative assessment of nutrient intake. The DDS developed here is a qualitative index of the total diet based on variety among the major food groups, and is independent of quantitative estimates of food intake beyond the minimum amount. Nevertheless, with-in subject variability in food intake is an important contributor to measurement error associated with dietary assessment methods [17,18]. Therefore, the DDS may expectedly lead to some degree of misclassification of respondents into categories of usual dietary habits. This misclassification would tend to attenuate the observed association of DDS with cause-specific mortality. There is also the possibility that some of the errors associated with dietary measurement may be differential across categories of covariates such as education.

What is the DDS in the present study measuring? As evident from Table 4, and in concurrence with previous work [19,20], respondents with low DDS had diets with marginal intakes of several micronutrients. Because the known nutrients have specific metabolic roles in humans, periodic ingestion of diets characterized by levels presently considered less than adequate may compromise health. Such diets may also lack the non-nutrient components of potential health benefit [21,22]. It is also possible that low DDS, associated with low income and education, is at least a partial surrogate for lifestyle or health care factors that increase the risk of mortality.

The somewhat weaker association of DDS with all sites cancer, and non-CVD, non-cancer mortality after adjustment for multiple confounders could partially relate to the fact that only some cancers and non-CVD, non-cancer causes of mortality have a causal relationship with dietary factors. Analyses of site-specific incident cancers and other diseases potentially related to diet might be informative. The DDS may also be of value as a screening tool when resources limit the extent of dietary data collection and nutrient analysis. Further work on other measures of total diet quality is also warranted.

In conclusion, the data presented are suggestive of an increased risk of CVD, cancer, and other causes of mortality associated with poor quality diets characterized by omission of several food groups, in the NHEFS cohort. Our results also provide preliminary data for validation of the recommendation for dietary variety for decreasing the risk of major chronic diseases [1,2]. Examination of the diet diversity-disease hypothesis in other large cohorts will be needed to further substantiate the recommendation for dietary variety.

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