The Journal of Nutrition
Nutritional Epidemiology

Changes in Diet Quality over 10 Years Are Associated with Baseline Sociodemographic and Lifestyle Factors in the Multiethnic Cohort Study

Song-Yi Park,[1] Yurii B Shvetsov,[1] Minji Kang,[1,2] Veronica Wendy Setiawan,[3] Lynne R Wilkens,[1] Loïc Le Marchand,[1] and Carol J Boushey[1]

[1]Cancer Epidemiology Program, University of Hawaii Cancer Center, Honolulu, HI, USA; [2]Center for Gendered Innovations in Science and Technology Research (GISTeR), Korea Federation of Women's Science & Technology Associations, Seoul, Republic of Korea; and [3]Department of Preventive Medicine, Keck School of Medicine and Norris Comprehensive Cancer Center, University of Southern California, Los Angeles, CA, USA

ABSTRACT

Background: Trends in diet quality among US adults indicate a steady improvement, but data on longitudinal individual-level changes in diet quality are still limited.

Objective: We examined changes in diet quality over 10 y and sought to determine whether baseline sociodemographic and lifestyle factors predicted the changes in a multiethnic population.

Methods: Data were from 63,255 African American, Native Hawaiian, Japanese American, Latino, and white men and women (45–75 y old at baseline) in the Multiethnic Cohort, who completed a quantitative food frequency questionnaire at baseline (1993–1996) and 10-y follow-up (2003–2007) and had no prevalent cancer or heart disease at either survey. Overall diet quality was measured by use of the Healthy Eating Index–2015 (HEI-2015), the Alternative Healthy Eating Index–2010 (AHEI-2010), the alternate Mediterranean Diet score, and the Dietary Approaches to Stop Hypertension (DASH) score. We used a general linear model with adjustment for covariates to compare diet quality changes by baseline characteristics in men and women separately.

Results: Overall diet quality improved over 10 y by 3.2 points in men and 2.9 in women assessed using the HEI-2015, although scores for some components worsened (saturated and trans fats, indicating increased intake) or remained unchanged at a low quality level (whole grains, dairy, and sodium). In multivariable models where changes in HEI-2015, AHEI-2010, and DASH were harmonized to a 100-point score, greater increases in scores in both men and women were found for Japanese American ethnicity (increase by 0.5–4.7 in the 3 scores, $P < 0.03$), higher education (by 0.5–1.5, $P \leq 0.001$), normal weight (BMI 18.5 to <25, by 0.6–2.5, $P \leq 0.01$), nonsmoking (by 1.5–2.7, $P < 0.001$), higher moderate/vigorous physical activity level (by 0.3–0.8, $P \leq 0.04$), and multivitamin use (by 0.4–0.7, $P < 0.001$) at baseline.

Conclusions: Sociodemographic and lifestyle factors, closely associated with diet quality, also predicted subsequent changes in diet quality over time in this multiethnic population. *J Nutr* 2020;150:1880–1888.

Keywords: Alternative Healthy Eating Index, alternate Mediterranean Diet score, diet quality, Dietary Approaches to Stop Hypertension index, dietary patterns, Healthy Eating Index, lifestyle factors, Multiethnic Cohort, sociodemographic factors

Introduction

A healthful, high-quality diet is critical for preventing noncommunicable diseases later in life (1–3). However, according to 1999–2010 NHANES data, the overall diet quality of many US adults, measured by a predefined index, remained poor across all age groups, despite the trend of a steady improvement in diet quality scores over the 12-y period (4). Patterns of change in diet quality over time may vary by personal characteristics. Indeed, longitudinal studies found that age, race/ethnicity, education level, and lifestyle factors, including physical activity, smoking, obesity status, and menopausal hormone therapy use in women, were associated with change in diet quality (5–8). In addition, a few US cohorts reported that improvement in diet quality was associated with a lower risk of chronic disease (9, 10) and mortality (6, 11) and with concurrent changes in body weight (12) and body composition (13) in a desirable direction. However, data on long-term changes in diet quality

Manuscript received September 27, 2019. Initial review completed January 27, 2020. Revision accepted March 24, 2020.
First published online April 27, 2020; doi: https://doi.org/10.1093/jn/nxaa102.

among adults are still limited, especially from ethnically diverse populations.

In our previous analysis in the Multiethnic Cohort (MEC) (14), we found that diet quality at baseline assessed by 4 predefined indexes was associated with sociodemographic and lifestyle factors, and that the associations with several factors varied between men and women: being widowed, being a previous smoker, and having a low BMI were related to lower dietary scores in men but not in women. In the present study, we investigated the patterns of diet quality changes from baseline, when the participants were middle to older aged, to a 10-y follow-up survey and the associations of baseline sociodemographic and lifestyle factors with diet quality changes.

Methods

Study population

The MEC was established to study diet and chronic disease in Hawaii and California, primarily Los Angeles County (15). In 1993–1996, more than 215,000 participants aged 45–75 y completed a comprehensive, 26-page self-administered questionnaire that asked questions on demographic factors, dietary habits, other lifestyle factors, medical conditions, and family history of cancer. Participants were mainly African American, Native Hawaiian, Japanese American, Latino, and white due to targeted recruitment. The institutional review boards of the University of Hawaii and the University of Southern California approved the study protocol. In 2003–2007, 98,214 participants completed a 10-y follow-up survey, a repeat of the 26-page questionnaire. For the current analyses, we excluded participants who were not members of 1 of the 5 racial/ethnic groups ($n = 5246$) or who had extreme diets based on energy and macronutrient intakes at baseline or follow-up ($n = 5930$). Specifically, we computed a robust SD based on the truncated normal distribution after excluding the top and bottom 10% tails of the log energy distribution. Then, we excluded all individuals with energy values out of the ranges of the mean ± 3 robust SDs. We applied similar approaches to exclude individuals with extreme fat, protein, or carbohydrate intakes. Based on these exclusions, we removed individuals with a large number of missing food items on their questionnaire responses. We further excluded participants who reported heart attack, angina at baseline or follow-up (n = 11,248), or cancer at baseline, and those who had invasive cancer linked to tumor registries up to the date of the follow-up questionnaire (n = 12,535). Based on these exclusion criteria, a total of 63,255 participants remained for the analysis.

Dietary data

Diet was assessed at baseline and the 10-y follow-up by using a quantitative food frequency questionnaire (QFFQ) to assess participants' usual intake for >180 food items during the past 12 mo. The baseline QFFQ was developed from 3-d measured food records (15). Daily intakes of foods and nutrients were calculated using a food composition table specific to the MEC. A calibration study showed satisfactory correlations for nutrients as densities (0.57–0.74) between the QFFQ and three 24-hour recalls for all ethnic and sex groups being studied (16). For the 10-y follow-up survey, the QFFQ was updated with changes in the design, food lists to include new food products, and examples given for each item. In a second calibration study, we found high correlations for nutrient densities (0.70–0.74) between the baseline and 10-y follow-up QFFQs. As part of the Dietary Patterns Methods Project (DPMP) (17), 4 predefined diet quality indexes (DQIs) were selected because of their particular relevance to dietary guidlines that had been commonly used in US populations: the Healthy Eating Index–2015 (HEI-2015; theoretical range of 0 to 100 points with 13 components), the Alternative Healthy Eating Index–2010 (AHEI-2010, 0 to 110 points with 11 components), the alternate Mediterranean Diet score (aMED, 0 to 9 points with 9 components), and the Dietary Approaches to Stop Hypertension (DASH) score (8 to 40 points with 8 components). The HEI-2015 evaluates conformance to the 2015–2020 Dietary Guidelines for Americans (18). This DQI replaced the HEI-2010 initially computed in the DPMP. The AHEI-2010 (19) and aMED (20) identify dietary patterns consistently associated with lower risk of chronic disease. The DASH index reflects adherence to a DASH-style diet designed to reduce blood pressure, which is high in fruits and vegetables, moderate in low-fat dairy products, and low in animal protein but high in plant protein (21). For all DQIs, higher scores reflect a higher-quality diet. Three of the DQIs use population-specific cutpoints in order to score the diet quality: the sodium component of AHEI-2010 (based on deciles) and all components of aMED (medians, except the alcohol component with fixed ranges) and DASH (quintiles). In the current analysis, to make DQIs comparable between the 2 surveys, we applied the cutpoints from the baseline diet to compute scores at 10-year follow-up for the distribution-dependent components.

Sociodemographic and lifestyle factors

Among the information collected at baseline, we considered 11 sociodemographic and lifestyle factors for men and 12 for women: age (45–54, 55–64, or 65–75 y), race/ethnicity (white, African American, Native Hawaiian, Japanese American, or Latino), education (≤high school, vocational/some college, or ≥graduated college), marital status (married, separated/divorced, widowed, or never married), BMI (underweight: <18.5; normal: 18.5 to <25; overweight: 25 to <30; obese: 30 to <35; obese: ≥35 kg/m^2), smoking status (never, past, or current), physical activity (<0.5, 0.5–1.3, or >1.3 h/d spent in moderate or vigorous activity, based on tertiles), multivitamin use (no or yes), family history of cancer (no or yes), energy intake (430–1670, 1671–2380, or 2381–8670 kcal/d, based on tertiles), alcohol intake (none, >0 to <1, 1 to <2, or ≥2 drinks/d), and menopausal hormone therapy use (never or ever) for women only. These characteristics were chosen based on the previous study in the MEC, in which all of them were associated with diet quality at baseline (14).

Statistical analysis

We computed DQI changes by subtracting values at baseline from those at 10-y follow-up. Since the scales for DQIs are varied, we presented the change per 100 points, calculated as DQI change × 100/theoretical range for index. The theoretical range is 100 points for HEI-2015, 110 for AHEI-2010, 9 for aMED, and 32 for DASH. The variability in the changes in aMED between the 2 surveys is very small, and because there is a limited discrete number of score changes (range: 0–9), diet quality changes in subgroups were only computed for the HEI-2015, AHEI-2010, and DASH.

We computed covariate-adjusted mean changes in DQIs with 95% CIs in subgroups defined by baseline characteristics using the SAS general linear models procedure with a least square means statement; adjustment was made for baseline scores (continuous) and all other subgroup categories. We computed *P* values for comparisons of mean changes within reference groups, adjusting for multiple comparison using the Tukey method and overall *P* values for the global test or *P* values for linear trends across subgroups for each covariate with 3 or

The Multiethnic Cohort Study is funded by grant U01 CA164973 from the National Cancer Institute (NCI). This study was partially supported by the NCI grants R03 CA223890, HHSN261201200423P, and P30 CA071789. MK was supported by a Support Program for Women in Science, Engineering and Technology grant from the National Research Foundation of Korea (NRF) (grant number 2019H1C3A1032224).

Author disclosures: The authors report no conflicts of interest.

Supplemental Figure 1 and Supplemental Tables 1–4 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/jn/.

Address correspondence to SYP (e-mail: spark@cc.hawaii.edu).

Abbreviations used: AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet score; DASH, Dietary Approaches to Stop Hypertension; DQI, diet quality index; HEI-2015, Healthy Eating Index–2015; MEC, Multiethnic Cohort; QFFQ, quantitative food frequency questionnaire; SES, socioeconomic status.

TABLE 1 Baseline characteristics of 63,255 men and women who completed both baseline and 10-y follow-up food frequency questionnaires in the Multiethnic Cohort Study[1]

Baseline characteristics	Men	Women
n	27,001	36,254
Age, y		
45–54	42.8	41.2
55–64	35.2	35.2
65–75	22.0	23.7
Race/ethnicity		
African American	7.7	12.7
Native Hawaiian	7.4	7.7
Japanese American	36.0	33.3
Latino	20.5	18.3
White	28.4	28.0
Education		
≤High school	29.7	36.2
Vocational/some college	30.4	31.3
≥Graduated college	39.9	32.4
Marital status		
Married	79.1	65.5
Separated/divorced	11.3	17.7
Widowed	2.4	10.8
Never married	7.3	6.0
BMI		
<18.5	0.4	2.4
18.5 to <25	37.0	50.0
25 to <30	47.5	30.3
30 to <35	12.0	11.7
≥35	3.1	5.7
Smoking status		
Never	35.3	59.4
Past	49.9	28.8
Current	14.9	11.8
Physical activity, h/d[2]	1.07 (1.46)	0.71 (1.07)
Multivitamin use	48.3	54.4
Family history of cancer	35.9	39.8
History of high blood pressure	32.1	29.1
History of diabetes	7.0	6.0
History of stroke	1.0	0.9
Ever use of menopausal hormone therapy	—	49.5
Energy intake, kcal/d	2431 ± 1036	1946 ± 869
Alcohol intake, g/d	3.6 (18.3)	0 (2.2)

[1]Values are means ± SDs or percentages, unless otherwise indicated.
[2]Hours spent in moderate or vigorous activity per day.

more levels. All analyses were performed using SAS version 9.4 (SAS Institute, Inc.). All tests were 2 sided with statistical significance set at $P < 0.05$.

Results

Sociodemographic and lifestyle characteristics at baseline are presented in Table 1 for MEC participants eligible for this analysis. The participants averaged 57.3 ± 8.3 y of age at baseline. Japanese Americans comprised the largest proportion, while African Americans and Native Hawaiians were the smallest groups. The prevalence of obesity (BMI ≥30) was 15.1% for men and 17.4% for women.

Mean DQIs and changes between baseline and 10-y follow-up surveys are presented in Table 2. Mean DQIs were higher in women than men except for those determined with the aMED ($P < 0.001$). Over 10 y, mean DQI changes were greater in men than in women except for those determined with the aMED ($P' \leq 0.001$).

TABLE 2 Dietary quality indexes at baseline and 10-y follow-up surveys in the Multiethnic Cohort Study[1]

	Baseline	10-y follow-up	Change[2]	Change per 100 points[3]
Men (*n* = 27,001)				
HEI-2015	65.6 ± 10.3	68.8 ± 10.6	3.2 ± 9.8	3.2 ± 9.8
AHEI-2010	64.5 ± 9.9	67.1 ± 10.4	2.5 ± 10.0	2.3 ± 9.1
aMED	4.3 ± 1.8	4.4 ± 1.8	0.1 ± 1.9	1.1 ± 20.6
DASH	24.0 ± 4.5	25.2 ± 4.4	1.2 ± 4.0	3.7 ± 12.6
Women (*n* = 36,254)				
HEI-2015	69.4 ± 10.3	72.3 ± 10.6	2.9 ± 9.9	2.9 ± 9.9
AHEI-2010	65.7 ± 9.3	67.9 ± 9.9	2.2 ± 9.5	2.0 ± 8.6
aMED	4.2 ± 1.8	4.3 ± 1.8	0.1 ± 1.9	1.1 ± 20.6
DASH	24.2 ± 4.4	25.3 ± 4.4	1.1 ± 4.0	3.4 ± 12.6

[1]Values are means ± SDs. All means were significantly different between men and women, $P \leq 0.001$, except for the changes in the aMED, by t-test. AEHI, Alternative Healthy Eating Index; aMED, alternate Mediterranean Diet score; DASH, Dietary Approaches to Stop Hypertension; HEI, Healthy Eating Index.
[2]Change = score at 10-y follow-up – score at baseline.
[3]Change per 100 points = (score at 10-y follow-up – score at baseline) × 100/theoretical range. The theoretical range is 100 points for HEI-2015, 110 for AHEI-2010, 9 for aMED, and 32 for DASH.

Supplemental Figure 1 displays component scores for the HEI-2015 at baseline and 10-y follow-up simultaneously as percentages of the maximum scores (5 or 10 points per component). For all components, mean scores remained similar or slightly increased (improved) over 10 y in both men and women, except for the saturated fat component (moderation component with higher score indicating lower intake), for which the scores slightly decreased (worsened). Scores for the whole-grain (men: 51.6%; women: 59.1%), dairy (men: 42.8%; women: 51.5%), and sodium (men: 42.6%; women: 43.7%) components remained low relative to the other components. In the AHEI-2010, scores for the trans fat component decreased, indicating higher consumption in both men and women, but were still >9 points. For AHEI-2010 and DASH, 2 components, sweetened beverages and sodium, contributed most to the improvements in the scores, while the refined grains component contributed most to the improvement in HEI-2015 scores. Otherwise there were no substantial changes in any of the other components (**Supplemental Table 1**), although the changes were statistically significant for most of the components mainly due to the large sample size. The component score for whole grains in the AHEI-2010 remained very low both in men (2.8 points) and women (3.3 points). Among the same age groups, in cross-sectional comparisons between baseline and 10-y follow-up results, the mean DQIs were slightly higher for most age groups in both men and women for the HEI-2015 and AHEI-2010 (**Supplemental Table 2**). For example, men aged 55–64 y at baseline and at follow-up had mean HEI-2015 scores of 66.0 and 67.9 and mean AHEI-2010 scores of 64.7 and 66.8, respectively.

Table 3 presents mean changes per 100 points in 3 of the DQIs over 10 y by baseline characteristics in men, with adjustment for all of the covariates listed in the table. Baseline DQI scores were inversely associated with changes in diet quality over time in both men and women. Therefore, all models were further adjusted for baseline DQI scores. Almost

TABLE 3 Diet quality index changes by baseline characteristics among 27,001 men in the Multiethnic Cohort Study[1]

	HEI-2015		AHEI-2010		DASH	
Baseline characteristics	Change per 100 points	P^2	Change per 100 points	P^2	Change per 100 points	P^2
Age, y						
45–54	2.5 (2.2, 2.8)	Ref.	1.6 (1.3, 1.9)	Ref.	2.0 (1.6, 2.4)	Ref.
55–64	2.6 (2.3, 2.9)	0.70	1.6 (1.3, 1.9)	0.99	2.8 (2.4, 3.2)	<0.001
65–75	1.3 (1.0, 1.7)	<0.001	1.1 (0.8, 1.4)	0.001	2.5 (2.0, 2.9)	0.045
P^3	<0.001		<0.001		0.017	
Race/ethnicity						
White	1.8 (1.4, 2.1)	Ref.	1.6 (1.3, 1.8)	Ref.	3.4 (3.0, 3.8)	Ref.
African American	2.0 (1.6, 2.5)	0.71	-0.1 (-0.5, 0.3)	<0.001	0.9 (0.3, 1.5)	<0.001
Native Hawaiian	2.3 (1.8, 2.7)	0.13	2.8 (2.4, 3.2)	<0.001	2.2 (1.6, 2.7)	<0.001
Japanese American	3.1 (2.7, 3.4)	<0.001	3.8 (3.5, 4.1)	<0.001	3.0 (2.6, 3.4)	0.21
Latino	1.6 (1.2, 1.9)	0.81	-0.9 (-1.2, -0.6)	<0.001	2.6 (2.2, 3.1)	0.003
P^3	<0.001		<0.001		<0.001	
Education						
≤High school	1.8 (1.4, 2.1)	Ref.	0.8 (0.5, 1.1)	Ref.	2.2 (1.8, 2.6)	Ref.
Vocational/some college	2.1 (1.8, 2.4)	0.08	1.5 (1.2, 1.8)	<0.001	2.3 (1.9, 2.7)	0.90
≥Graduated college	2.6 (2.3, 2.9)	<0.001	2.0 (1.7, 2.3)	<0.001	2.8 (2.4, 3.3)	0.001
P^3	<0.001		<0.001		<0.001	
Marital status						
Married	2.5 (2.3, 2.8)	Ref.	1.7 (1.5, 1.9)	Ref.	2.7 (2.4, 3.0)	Ref.
Separated/divorced	1.9 (1.6, 2.3)	0.002	1.5 (1.1, 1.8)	0.38	2.3 (1.9, 2.8)	0.41
Widowed	1.8 (1.1, 2.5)	0.15	1.1 (0.4, 1.7)	0.19	1.7 (0.8, 2.6)	0.15
Never married	2.4 (1.9, 2.8)	0.83	1.5 (1.1, 1.9)	0.73	3.0 (2.4, 3.5)	0.75
P^3	<0.001		0.08		0.045	
Body mass index, kg/m^2						
18.5–<25	2.6 (2.3, 2.9)	Ref.	1.5 (1.3, 1.8)	Ref.	3.0 (2.7, 3.4)	Ref.
25–<30	2.5 (2.2, 2.7)	0.52	1.4 (1.2, 1.7)	0.73	2.8 (2.4, 3.1)	0.30
30–<35	1.9 (1.5, 2.2)	<0.001	1.3 (1.0, 1.7)	0.61	2.2 (1.7, 2.7)	0.003
≥35	1.6 (1.0, 2.3)	0.014	1.4 (0.9, 2.0)	0.99	1.7 (0.9, 2.5)	0.008
P^3	<0.001		0.68		<0.001	
Smoking status						
Never	3.0 (2.7, 3.3)	Ref.	2.0 (1.7, 2.3)	Ref.	3.5 (3.1, 3.9)	Ref.
Past	2.5 (2.2, 2.8)	<0.001	1.9 (1.7, 2.2)	0.85	2.9 (2.5, 3.3)	<0.001
Current	0.9 (0.5, 1.3)	<0.001	0.4 (0.0, 0.7)	<0.001	0.8 (0.4, 1.3)	<0.001
P^3	<0.001		<0.001		<0.001	
Physical activity, h/d						
<0.5	1.7 (1.4, 2.1)	Ref.	1.0 (0.7, 1.3)	Ref.	2.1 (1.6, 2.5)	Ref.
0.5–1.3	2.3 (2.0, 2.6)	<0.001	1.6 (1.3, 1.8)	<0.001	2.5 (2.1, 2.9)	0.038
>1.3	2.4 (2.1, 2.7)	<0.001	1.7 (1.4, 2.0)	<0.001	2.7 (2.3, 3.1)	<0.001
P^3	<0.001		<0.001		<0.001	
Multivitamin use						
No	1.8 (1.5, 2.1)	Ref.	1.2 (0.9, 1.5)	Ref.	2.1 (1.7, 2.4)	Ref.
Yes	2.5 (2.2, 2.8)	<0.001	1.6 (1.4, 1.9)	<0.001	2.8 (2.4, 3.2)	<0.001
P^3	<0.001		<0.001		<0.001	
Family history of cancer						
No	2.1 (1.8, 2.4)	Ref.	1.4 (1.2, 1.7)	Ref.	2.3 (2.0, 2.7)	Ref.
Yes	2.2 (1.9, 2.5)	0.20	1.4 (1.1, 1.7)	0.90	2.5 (2.1, 2.9)	0.23
P^3	0.20		0.90		0.23	
Energy intake, kcal/d						
430–1670	2.2 (1.8, 2.5)	Ref.	1.4 (1.1, 1.7)	Ref.	2.4 (1.9, 2.8)	Ref.
1671–2380	2.3 (2.0, 2.6)	0.76	1.5 (1.2, 1.8)	0.71	2.6 (2.2, 3.0)	0.47
2381–8670	2.0 (1.7, 2.3)	0.38	1.5 (1.2, 1.7)	0.80	2.3 (2.0, 2.7)	0.99
P^3	0.18		0.52		0.98	
Alcohol intake, drink/d						
None	1.7 (1.4, 2.1)	Ref.	0.4 (0.2, 0.7)	Ref.	2.0 (1.6, 2.4)	Ref.
>0–<1	2.3 (2.0, 2.6)	<0.001	1.2 (0.9, 1.5)	<0.001	2.5 (2.2, 2.9)	0.007

(*Continued*)

TABLE 3 (*Continued*)

Baseline characteristics	HEI-2015 Change per 100 points	P[2]	AHEI-2010 Change per 100 points	P[2]	DASH Change per 100 points	P[2]
1–<2	2.3 (1.9, 2.7)	0.006	1.3 (0.9, 1.6)	<0.001	2.6 (2.1, 3.1)	0.06
≥2	2.2 (1.8, 2.6)	0.029	2.8 (2.5, 3.2)	<0.001	2.6 (2.1, 3.0)	0.048
P[3]	<0.001		<0.001		0.014	

[1]Values are means (95% CIs), adjusted for baseline DQI score and all covariates in the table. Change per 100 points = (score at 10-y follow-up – score at baseline) × 100/theoretical range. AEHI, Alternative Healthy Eating Index; DASH, Dietary Approaches to Stop Hypertension; HEI, Healthy Eating Index; Ref., reference.
[2]Comparison between categories with adjustment for multiple comparison.
[3]Overall comparison for race/ethnicity and marital status, and linear trend across subgroups for age, education, BMI, physical activity, energy intake, and alcohol intake.

all subgroups for the 11 characteristics showed an increase in all DQIs, except for African American (no significant change) and Latino (0.9-point decrease) men in the AHEI-2010. Overall, Japanese American men had greater increases across the DQIs than white men (by 1.3 points for HEI-2015 and 2.2 points for AHEI-2015, $P < 0.001$), while white men showed a greater increase in the DASH score only (by 0.8–2.5, compared with African American, Native Hawaiian, and Latino men, $P \leq 0.003$). Mean increases in the scores were greater in the participants in younger age groups (45–64 compared with 65–75 y) by 0.5–1.3 point ($P \leq 0.001$), except for DASH scores, in which older age groups (55–75 compared with 45–54 y) showed greater increases by 0.5–0.8 point ($P \leq 0.045$). Overall, DQI increases were greater in more educated groups (compared with ≤high school by 0.7–1.2, $P \leq 0.001$), the normal or overweight group (except for AHEI-2010, by 0.7–1.3, $P \leq 0.014$), never smokers (never and past smokers for AHEI-2010 compared with current smokers by 1.5–2.7, $P < 0.001$), more physically active men (>1.3 compared with < 0.5 h/d by 0.7, $P < 0.001$), and multivitamin users (by 0.4–0.7, $P < 0.001$). Alcoholic beverage drinkers at baseline showed greater increases in the scores compared with nondrinkers (by 0.5–2.4, $P \leq 0.048$). The overall tendency for HEI-2015 changes by baseline characteristics was generally observed in African American, Japanese American, Latino, and white men, but less consistently observed in Native Hawaiian men (**Supplemental Table 3**). Mean changes in the HEI-2015 among Native Hawaiians only differed by smoking status (current compared with never and past smokers) and physical activity level (the highest and middle compared with the lowest groups). Similarly, most subgroups in women showed increases in the 3 DQIs, except for African American (no change in the AHEI-2010 and DASH) and Latina (1 point decrease in the AHEI-2010) women and current smokers (no change in all DQIs, Table 4). In women, DQI increases over 10 y were greater in younger age groups (45–64 compared with 65–75 y by 0.5–1.5 points, $P \leq 0.009$), more educated groups (compared with ≤high school by 0.5–1.5, $P < 0.001$), the normal-weight group (by 0.6–2.5, $P < 0.001$), never smokers (never and past smokers for AHEI-2010 compared with current smokers by 1.7–2.5, $P < 0.001$), more physically active groups (>1.3 compared with <0.5 h/d by 0.5–0.8, $P < 0.001$), and multivitamin users (by 0.6–0.7, $P < 0.001$). Marital status, family history of cancer, and menopausal hormone therapy use were not significantly associated with DQI changes in women. Unlike in men, women who had 2 or more drinks of alcoholic beverages at baseline showed smaller increases in the HEI-2015 (by 0.9, $P = 0.001$). In racial/ethnic-specific analyses for HEI-2015 changes in women (**Supplemental Table 4**), Native Hawaiians showed less consistent trends than the other groups. For example, mean HEI-2015 changes did not vary by BMI group in Native Hawaiians, while normal-weight women at baseline in the other racial/ethnic groups showed greater increases than overweight or obese women.

Discussion

In this multiethnic population, overall diet quality, assessed by commonly used DQIs, slightly improved over 10 y, although the scores for some components of the DQIs decreased or remained low. Change patterns in the DQIs varied by sociodemographic and lifestyle characteristics at baseline. Japanese American ethnicity, higher education, normal BMI, nonsmoking, higher physical activity level, and multivitamin use at baseline were associated with a greater increase in the DQIs both in men and women. A similar tendency was observed in African Americans, Japanese Americans, Latinos, and whites in general, but less consistent in Native Hawaiians, when examining HEI-2015 changes. There were also sex- and/or DQI-specific changes. Widowed men tended to have a smaller increase in the DQIs than married men, while marital status was not associated with DQI change in women. Younger age groups both in men and women had a greater increase for all DQIs, except for the DASH in men showing an opposite trend. For the AHEI-2010, Latinos showed a slight decrease over time, and African Americans showed no change, whereas whites, Native Hawaiians, and Japanese Americans had increases. For the DASH, African Americans had no (women) or the smallest (men) increases.

Overall diet quality in US adults (aged 20–85 y) improved across the 12-y period in the NHANES, where cross-sectional assessment of diet quality was determined using the AHEI-2010 (4). The mean AHEI-2010 score increased from 39.9 in 1999–2000 to 46.8 in 2009–2010, but still remained low considering the maximum possible points of 110. Across the 12 y in the NHANES cross-sectional surveys, the non-Hispanic white group showed an improvement in the AHEI-2010 (without the trans fat component, P-trend < 0.001), while non-Hispanic black and Mexican American groups did not (P-trend ≥ 0.06) (4). Similarly in the MEC, whites had increased AHEI-2010 scores between the first (1993–1996) and follow-up (2003–2007) surveys, whereas African Americans and Latinos did not show an increase in both men and women. The improvement in diet quality over 10 y observed in the MEC may also reflect the general trend toward better diet in the United States, in addition to aging. Indeed, we found a slight improvement in the AHEI-2010 for most age groups using cross-sectional comparisons among the same age groups between baseline and the 10-y follow-up.

TABLE 4 DQI changes by baseline characteristics among 36,254 women in the Multiethnic Cohort Study[1]

Baseline characteristics	HEI-2015		AHEI-2010		DASH	
	Change per 100 points	P[2]	Change per 100 points	P[2]	Change per 100 points	P[2]
Age, y						
45–54	2.0 (1.8, 2.3)	Ref.	1.8 (1.6, 2.0)	Ref.	2.1 (1.7, 2.4)	Ref.
55–64	1.8 (1.5, 2.0)	0.06	1.3 (1.1, 1.5)	<0.001	1.8 (1.5, 2.1)	0.18
65–75	0.5 (0.2, 0.8)	<0.001	0.7 (0.4, 1.0)	<0.001	1.3 (0.9, 1.7)	<0.001
P[3]	<0.001		<0.001		<0.001	
Race/ethnicity						
White	0.9 (0.6, 1.1)	Ref.	1.6 (1.4, 1.8)	Ref.	2.9 (2.6, 3.2)	Ref.
African American	1.6 (1.3, 1.9)	<0.001	0.0 (-0.3, 0.3)	<0.001	0.1 (-0.3, 0.5)	<0.001
Native Hawaiian	1.3 (0.9, 1.7)	0.25	2.5 (2.2, 2.9)	<0.001	1.3 (0.8, 1.8)	<0.001
Japanese American	2.1 (1.8, 2.4)	<0.001	3.3 (3.1, 3.6)	<0.001	1.8 (1.5, 2.2)	<0.001
Latino	1.3 (1.0, 1.6)	0.08	-1.0 (-1.3, -0.7)	<0.001	2.4 (2.0, 2.8)	0.12
P[3]	<0.001		<0.001		<0.001	
Education						
≤High school	0.9 (0.6, 1.1)	Ref.	0.5 (0.3, 0.8)	Ref.	0.9 (0.6, 1.3)	Ref.
Vocational/some college	1.4 (1.1, 1.7)	<0.001	1.3 (1.1, 1.5)	<0.001	1.7 (1.4, 2.1)	<0.001
≥Graduated college	2.0 (1.7, 2.3)	<0.001	2.0 (1.8, 2.3)	<0.001	2.5 (2.1, 2.8)	<0.001
P[3]	<0.001		<0.001		<0.001	
Marital status						
Married	1.4 (1.2, 1.7)	Ref.	1.4 (1.2, 1.6)	Ref.	1.6 (1.3, 1.9)	Ref.
Separated/divorced	1.5 (1.2, 1.8)	0.96	1.4 (1.2, 1.6)	0.99	1.8 (1.4, 2.2)	0.61
Widowed	1.6 (1.2, 1.9)	0.86	1.3 (1.0, 1.6)	0.99	1.7 (1.3, 2.2)	0.87
Never married	1.2 (0.8, 1.7)	0.82	1.0 (0.7, 1.4)	0.17	1.7 (1.2, 2.3)	0.97
P[3]	0.62		0.22		0.6	
BMI						
18.5 to <25	2.5 (2.2, 2.7)	Ref.	2.0 (1.8, 2.2)	Ref.	3.2 (2.9, 3.5)	Ref.
25 to <30	1.6 (1.3, 1.8)	<0.001	1.4 (1.2, 1.6)	<0.001	2.0 (1.7, 2.3)	<0.001
30 to <35	1.2 (0.9, 1.5)	<0.001	1.0 (0.7, 1.3)	<0.001	1.0 (0.6, 1.5)	<0.001
≥35	0.4 (0.0, 0.9)	<0.001	0.8 (0.4, 1.2)	<0.001	0.7 (0.1, 1.2)	<0.001
P[3]	<0.001		<0.001		<0.001	
Smoking status						
Never	2.4 (2.2, 2.7)	Ref.	1.8 (1.6, 2.0)	Ref.	2.6 (2.3, 3.0)	Ref.
Past	1.9 (1.6, 2.1)	<0.001	1.9 (1.6, 2.1)	0.95	2.3 (2.0, 2.6)	0.051
Current	-0.0 (-0.3, 0.3)	<0.001	0.2 (-0.1, 0.4)	<0.001	0.2 (-0.3, 0.6)	<0.001
P[3]	<0.001		<0.001		<0.001	
Physical activity, h/d						
<0.5	1.2 (0.9, 1.4)	Ref.	0.9 (0.7, 1.1)	Ref.	1.4 (1.1, 1.7)	Ref.
0.5–1.3	1.5 (1.2, 1.7)	0.037	1.3 (1.1, 1.5)	<0.001	1.6 (1.2, 1.9)	0.49
>1.3	1.7 (1.4, 1.9)	<0.001	1.7 (1.5, 1.9)	<0.001	2.2 (1.8, 2.5)	<0.001
P[3]	<0.001		<0.001		<0.001	
Multivitamin use						
No	1.1 (0.9, 1.4)	Ref.	1.0 (0.8, 1.2)	Ref.	1.3 (1.0, 1.6)	Ref.
Yes	1.7 (1.5, 2.0)	<0.001	1.6 (1.4, 1.8)	<0.001	2.1 (1.8, 2.4)	<0.001
P[3]	<0.001		<0.001		<0.001	
Family history of cancer						
No	1.4 (1.1, 1.6)	Ref.	1.2 (1.0, 1.4)	Ref.	1.7 (1.4, 2.0)	Ref.
Yes	1.5 (1.2, 1.7)	0.35	1.3 (1.1, 1.6)	0.23	1.7 (1.4, 2.1)	0.54
P[3]	0.35		0.23		0.54	
Menopausal hormone therapy use						
Never	1.4 (1.1, 1.6)	Ref.	1.3 (1.1, 1.5)	Ref.	1.7 (1.4, 2.0)	Ref.
Ever	1.5 (1.2, 1.7)	0.26	1.2 (1.0, 1.5)	0.30	1.7 (1.4, 2.0)	0.90
P[3]	0.26		0.30		0.90	
Energy intake, kcal/d						
430–1670	1.5 (1.3, 1.8)	Ref.	1.0 (0.8, 1.2)	Ref.	1.7 (1.4, 2.1)	Ref.
1671–2380	1.5 (1.3, 1.8)	0.95	1.4 (1.2, 1.6)	<0.001	1.8 (1.5, 2.2)	0.73
2381–8670	1.2 (1.0, 1.5)	0.06	1.4 (1.2, 1.7)	<0.001	1.5 (1.2, 1.9)	0.49
P[3]	0.024		<0.001		0.26	

(*Continued*)

TABLE 4 (*Continued*)

Baseline characteristics	HEI-2015 Change per 100 points	HEI-2015 P^2	AHEI-2010 Change per 100 points	AHEI-2010 P^2	DASH Change per 100 points	DASH P^2
Alcohol intake, drink/d						
None	1.7 (1.5, 1.9)	Ref.	0.7 (0.6, 0.9)	Ref.	2.0 (1.7, 2.3)	Ref.
>0 to <1	1.7 (1.4, 1.9)	0.99	1.3 (1.1, 1.5)	<0.001	1.9 (1.6, 2.2)	0.96
1 to <2	1.6 (1.1, 2.0)	0.98	1.0 (0.6, 1.4)	0.48	1.6 (1.1, 2.2)	0.55
≥2	0.8 (0.3, 1.3)	0.001	2.1 (1.7, 2.6)	<0.001	1.3 (0.6, 1.9)	0.09
P^3	0.003		<0.001		0.011	

[1] Values are means (95% CIs), adjusted for baseline DQI score and all covariates in the table. Change per 100 points = (score at 10-y follow-up – score at baseline) × 100/theoretical range. AHEI, Alternative Healthy Eating Index; DASH, Dietary Approaches to Stop Hypertension; DQI, diet quality index; HEI, Healthy Eating Index.
[2] Comparison between categories with adjustment for multiple comparison.
[3] Overall comparison for race/ethnicity and marital status, and linear trend across subgroups for age, education, BMI, physical activity, energy intake, and alcohol intake.

A main contributor to the improvement in the AHEI-2010 in the NHANES was the reduction in trans fat consumption (4). On the contrary, trans fat consumption in the MEC participants increased slightly over 10 y. Thus the component score for trans fat was reduced (from 9.9 to 9.1) but was still high. Saturated fat intake (as density) in the MEC participants slightly increased over time as assessed by the HEI-2015 (mean component score: 7.9 to 7.3), while the total HEI-2015 score improved from 67.8 to 70.8. In the NHANES 2011–2012 (≥2 y), the mean score was 6.1 for the saturated fat component and 56.6 for the total HEI-2015 score, but trends in diet quality over time were not reported (18). In the MEC, the scores for the whole-grain, dairy, and sodium components in the HEI-2015 remained relatively low. The component score for whole grains in the AHEI-2010 also remained very low in the MEC, while whole-grain consumption in US adults increased from 0.56 serving/d in 1999–2000 to 1.00 serving/d in 2011–2012 (22).

A few longitudinal studies have examined changes in diet quality over time among adults. In the Nurses' Health Study, the middle quintile (relatively no change) group of the AHEI-2010 changes showed a mean increase of 2.2 points over 12 y (6). The corresponding number in the Health Professionals Follow-up Study was a 3.4 point increase (6). In the Women's Health Initiative Observational Study, 12% of women had a ≥11-point increase in their AHEI-2010 scores over 3 y, while 8.8% had a ≥11 point or more decrease (13). The studies in these large US cohorts found an overall increase in diet quality over time, although detailed patterns have not been reported. In a cohort of young American adults (18–30 y at baseline), the diet quality score associated with cardiovascular disease risk increased from 61.4 to 71.1 (maximum possible score: 132) over 20 y with a greater increase among the black than in the white participants (23). A study in an Australian cohort (25–75 y at baseline) also reported an overall improvement in diet quality over 15 y (the Dietary Guideline Index: 71.9 to 76.2 in men and 80.6 to 83.8 in women; theoretical maximum score: 130) (5). The study found that younger age, higher occupational level in men, and physical activity and menopausal hormone therapy in women were independently associated with a greater increase in the score (5). In the MEC, we also observed a sex-specific association for marital status, by which DQI changes varied in men but not in women. An Australian cohort (aged ≥55 y) found that diet quality (the revised Dietary Guideline Index, DGI-2013) improved only in men over the 4 y of the study, but smoking was associated with a decrease in DGI-2013 both for men and women (8). Another Australian cohort of middle-aged women reported no substantial change in diet quality over time (the Australian Recommended Food Score: 32.6 in 2001 to 33.1 in 2013; theoretical maximum score: 74) (24). The sociodemographic and lifestyle factors related to changes in diet quality over time have been also found to predict diet quality in older adults (25) and various populations (26–28).

In the present study, some of the change patterns varied across the DQIs, likely due to the different scoring schemes of each DQI. The HEI-2015 is density-based (intake per 1000 kcal), while the AHEI-2010, aMED, and DASH are based on absolute intakes. For the HEI-2015 and AHEI-2010, component scores are continuous proportionally to intake levels once they are above the minimal levels (adequacy components) or below the maximum levels (moderation components). However, the DASH has 5 levels (1 to 5) and the aMED has only 2 (0 or 1) for each component, based on distributions of intakes. In addition, the HEI-2015 (0 to 100 points) and AHEI-2010 (0 to 110) have wider ranges of total scores compared with the DASH (8 to 40) and aMED (0 to 9), although we presented changes per 100 points to compare across the scores. Thus, the HEI-2015 and AHEI-2010 are more likely to be sensitive to small changes in dietary intakes over time, compared with the DASH and aMED. Particularly, aMED is too granular to reflect small changes in diet quality. Indeed, aMED scores for 22.5% of the participants remained the same, while their mean HEI-2015, AHEI-2010, and DASH scores improved by 2.7, 2.0, and 1.0 points over 10 y.

This study has a number of important strengths including a population-based prospective design, a large sample size, and participants with various racial/ethnic backgrounds. The comprehensive questionnaires collected a wide range of sociodemographic and lifestyle information, and eating habits using a validated QFFQ. The DQIs used in the current study were calculated using standardized methods with consensus in 3 large US cohorts, and demonstrated their predictability for health outcomes across (17) and within the cohorts (29–37).

In addition to measurement error inherent in FFQs, several limitations should be considered in interpreting the study findings. Although we excluded participants who had prevalent cancer or heart disease at either survey, we could not rule out dietary changes due to underlying illness or developing medical conditions during the 10-y follow-up. When we further adjusted for prevalent (33.8% at baseline) and incident (23.8% during follow-up) medical conditions, including high blood pressure, diabetes, and stroke, the patterns of changes in the DQIs remained similar. However, we were not able to consider other medical conditions, such as oral health and gastrointestinal problems, or other factors, such as cognitive ability in youth and over the life course (38, 39), that might affect diet quality. In addition, food compositions might change over time for certain foods, but we used the same food composition database for the baseline and 10-y follow-up questionnaires. The MEC participants are largely representative of the target population in Hawaii and Southern California as evidenced by the similarity in marital status and education as the 1990 census for those regions. However, selection bias due to the volunteerism may limit generalizability of our findings. In addition, participants who completed the follow-up QFFQ tended to be younger, Japanese American, white, never smokers, more educated, and less obese than with nonrespondents. Compared with general US adults, overall diet quality in the MEC participants appears to be higher, while changes in diet quality over time seem to be smaller, although direct comparison was not possible. Compared to the other 2 US cohorts, with which a standard method was developed for the DQI computation, the MEC participants had an approximately 10-point higher AHEI-2010 score at baseline, while the other 3 DQIs (HEI-2010, aMED, and DASH) were similar across the cohorts (17). Although socioeconomic status (SES) affects diet quality, income could not be considered in the analysis due to lack of information. Instead, education level served as a proxy for individual-level SES in the current analyses. When neighborhood SES was further adjusted for by linkage to census and geospatial data (40) in addition to education levels, the results for the DQI changes remained similar.

In conclusion, overall diet quality improved over 10 y in this multiethnic population. However, among the components in the dietary indexes examined, scores for saturated and trans fats worsened, indicating increased consumption, and those for whole grains, dairy, and sodium remained unchanged at a low quality level. Sociodemographic and lifestyle factors closely associated with diet quality, including race/ethnicity, education, body weight, smoking, physical activity, and multivitamin use, also predict subsequent changes in diet quality over time.

Acknowledgments

The authors' responsibilities were as follows—SYP, LRW, LLM, CJB: formulated the research questions and designed the study; SYP, YBS, LRW: analyzed the data; SYP, YBS, MK: drafted the manuscript; VWS, LRW, LLM, CJB: provided critical feedback; SYP: had primary responsibility for final contents; and all authors: read and approved the final manuscript.

References

1. Mokdad AH, Ballestros K, Echko M, Glenn S, Olsen HE, Mullany E, Lee A, Khan AR, Ahmadi A, Ferrari AJ, et al. The state of US health, 1990–2016: burden of diseases, injuries, and risk factors among US states. JAMA 2018;319:1444–72.
2. Willett WC, Stampfer MJ. Current evidence on healthy eating. Annu Rev Public Health 2013;34:77–95.
3. Milte CM, McNaughton SA. Dietary patterns and successful ageing: a systematic review. Eur J Nutr 2016;55:423–50.
4. Wang DD, Leung CW, Li Y, Ding EL, Chiuve SE, Hu FB, Willett WC. Trends in dietary quality among adults in the United States, 1999 through 2010. JAMA Intern Med 2014;174:1587–95.
5. Arabshahi S, Lahmann PH, Williams GM, Marks GC, van der Pols JC. Longitudinal change in diet quality in Australian adults varies by demographic, socio-economic, and lifestyle characteristics. J Nutr 2011;141:1871–9.
6. Sotos-Prieto M, Bhupathiraju SN, Mattei J, Fung TT, Li Y, Pan A, Willett WC, Rimm EB, Hu FB. Association of changes in diet quality with total and cause-specific mortality. N Engl J Med 2017;377:143–53.
7. Lipsky LM, Nansel TR, Haynie DL, Liu D, Li K, Pratt CA, Iannotti RJ, Dempster KW, Simons-Morton B. Diet quality of US adolescents during the transition to adulthood: changes and predictors. Am J Clin Nutr 2017;105:1424–32.
8. Thorpe MG, Milte CM, Crawford D, McNaughton SA. Education and lifestyle predict change in dietary patterns and diet quality of adults 55 years and over. Nutr J 2019;18:67.
9. Sotos-Prieto M, Bhupathiraju SN, Mattei J, Fung TT, Li Y, Pan A, Willett WC, Rimm EB, Hu FB. Changes in diet quality scores and risk of cardiovascular disease among US men and women. Circulation 2015;132:2212–9.
10. Ley SH, Pan A, Li Y, Manson JE, Willett WC, Sun Q, Hu FB. Changes in overall diet quality and subsequent type 2 diabetes risk: three U.S. prospective cohorts. Diabetes Care 2016;39:2011–18.
11. Sun Y, Bao W, Liu B, Caan BJ, Lane DS, Millen AE, Simon MS, Thomson CA, Tinker LF, Van Horn LV, et al. Changes in overall diet quality in relation to survival in postmenopausal women with breast cancer: results from the Women's Health Initiative. J Acad Nutr Diet 2018;118:1855–63 e6.
12. Fung TT, Pan A, Hou T, Chiuve SE, Tobias DK, Mozaffarian D, Willett WC, Hu FB. Long-term change in diet quality is associated with body weight change in men and women. J Nutr 2015;145:1850–6.
13. Cespedes Feliciano EM, Tinker L, Manson JE, Allison M, Rohan T, Zaslavsky O, Waring ME, Asao K, Garcia L, Rosal M, et al. Change in dietary patterns and change in waist circumference and DXA trunk fat among postmenopausal women. Obesity 2016;24:2176–84.
14. Kang M, Park SY, Shvetsov YB, Wilkens LR, Marchand LL, Boushey CJ, Paik HY. Gender differences in sociodemographic and lifestyle factors associated with diet quality in a multiethnic population. Nutrition 2019;66:147–52.
15. Kolonel LN, Henderson BE, Hankin JH, Nomura AM, Wilkens LR, Pike MC, Stram DO, Monroe KR, Earle ME, Nagamine FS. A multiethnic cohort in Hawaii and Los Angeles: baseline characteristics. Am J Epidemiol 2000;151:346–57.
16. Stram DO, Hankin JH, Wilkens LR, Pike MC, Monroe KR, Park S, Henderson BE, Nomura AM, Earle ME, Nagamine FS, et al. Calibration of the dietary questionnaire for a multiethnic cohort in Hawaii and Los Angeles. Am J Epidemiol 2000;151:358–70.
17. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, Boushey CJ, Schap TE, Reedy J. The dietary patterns methods project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr 2015;145:393–402.
18. Reedy J, Lerman JL, Krebs-Smith SM, Kirkpatrick SI, Pannucci TE, Wilson MM, Subar AF, Kahle LL, Tooze JA. Evaluation of the Healthy Eating Index-2015. J Acad Nutr Diet 2018;118:1622–33.
19. Chiuve SE, Fung TT, Rimm EB, Hu FB, McCullough ML, Wang M, Stampfer MJ, Willett WC. Alternative dietary indices both strongly predict risk of chronic disease. J Nutr 2012;142:1009–18.
20. Fung TT, McCullough ML, Newby PK, Manson JE, Meigs JB, Rifai N, Willett WC, Hu FB. Diet-quality scores and plasma concentrations of markers of inflammation and endothelial dysfunction. Am J Clin Nutr 2005;82:163–73.
21. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med 2008;168:713–20.
22. Rehm CD, Penalvo JL, Afshin A, Mozaffarian D. Dietary intake among US adults, 1999–2012. JAMA 2016;315:2542–53.
23. Sijtsma FP, Meyer KA, Steffen LM, Shikany JM, Van Horn L, Harnack L, Kromhout D, Jacobs DR, Jr. Longitudinal trends in diet and effects of sex, race, and education on dietary quality score change: the Coronary Artery Risk Development in Young Adults study. Am J Clin Nutr 2012;95:580–6.
24. Lai JS, Oldmeadow C, Hure AJ, McEvoy M, Byles J, Attia J. Longitudinal diet quality is not associated with depressive symptoms in a cohort of middle-aged Australian women. Br J Nutr 2016;115:842–50.
25. Freisling H, Knaze V, Slimani N. A systematic review of peer-reviewed studies on diet quality indexes applied to old age: a multitude of predictors of diet quality. In: Diet Quality. Edited by Preedy VR, Hunter L-A, Patel VB . London, UK: Humana Press; 2013.
26. Chong SP, Appannah G, Sulaiman N. Predictors of diet quality as measured by Malaysian healthy eating index among aboriginal women (Mah Meri) in Malaysia. Nutrients 2019;11:135
27. Mayen AL, Marques-Vidal P, Paccaud F, Bovet P, Stringhini S. Socioeconomic determinants of dietary patterns in low- and

middle-income countries: a systematic review. Am J Clin Nutr 2014;100:1520–31.

28. Huang F, Wang Z, Wang L, Wang H, Zhang J, Du W, Su C, Jia X, Ouyang Y, Wang Y, et al. Evaluating adherence to recommended diets in adults 1991–2015: revised China dietary guidelines index. Nutr J 2019;18:70.
29. Harmon BE, Boushey CJ, Shvetsov YB, Ettienne R, Reedy J, Wilkens LR, Le Marchand L, Henderson BE, Kolonel LN. Associations of key diet-quality indexes with mortality in the Multiethnic Cohort: the Dietary Patterns Methods Project. Am J Clin Nutr 2015;101:587–97.
30. Park SY, Boushey CJ, Wilkens LR, Haiman CA, Le Marchand L. High-quality diets associate with reduced risk of colorectal cancer: analyses of diet quality indexes in the Multiethnic Cohort. Gastroenterology 2017;153:386–94.
31. George SM, Ballard-Barbash R, Manson JE, Reedy J, Shikany JM, Subar AF, Tinker LF, Vitolins M, Neuhouser ML. Comparing indices of diet quality with chronic disease mortality risk in postmenopausal women in the Women's Health Initiative Observational Study: evidence to inform national dietary guidance. Am J Epidemiol 2014;180: 616–25.
32. Reedy J, Krebs-Smith SM, Miller PE, Liese AD, Kahle LL, Park Y, Subar AF. Higher diet quality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults. J Nutr 2014;144:881–9.
33. Jacobs S, Harmon BE, Boushey CJ, Morimoto Y, Wilkens LR, Le Marchand L, Kroger J, Schulze MB, Kolonel LN, Maskarinec G. A priori-defined diet quality indexes and risk of type 2 diabetes: the Multiethnic Cohort. Diabetologia 2015;58:98–112.
34. Jacobs S, Boushey CJ, Franke AA, Shvetsov YB, Monroe KR, Haiman CA, Kolonel LN, Le Marchand L, Maskarinec G. A priori-defined diet quality indices, biomarkers and risk for type 2 diabetes in five ethnic groups: the Multiethnic Cohort. Br J Nutr 2017;118:312–20.
35. Maskarinec G, Lim U, Jacobs S, Monroe KR, Ernst T, Buchthal SD, Shepherd JA, Wilkens LR, Le Marchand L, Boushey CJ. Diet quality in midadulthood predicts visceral adiposity and liver fatness in older ages: the Multiethnic Cohort Study. Obesity 2017;25:1442–50.
36. Haring B, Crandall CJ, Wu C, LeBlanc ES, Shikany JM, Carbone L, Orchard T, Thomas F, Wactawaski-Wende J, Li W, et al. Dietary patterns and fractures in postmenopausal women: results from the women's health initiative. JAMA Intern Med 2016;176:645–52.
37. Anic GM, Park Y, Subar AF, Schap TE, Reedy J. Index-based dietary patterns and risk of lung cancer in the NIH-AARP diet and health study. Eur J Clin Nutr 2016;70:123–9.
38. Batty GD, Deary IJ, Schoon I, Gale CR. Mental ability across childhood in relation to risk factors for premature mortality in adult life: the 1970 British Cohort Study. J Epidemiol Community Health 2007;61:997–1003.
39. Crichton GE, Elias MF, Davey A, Alkerwi A, Dore GA. Higher cognitive performance is prospectively associated with healthy dietary choices: the Maine Syracuse longitudinal study. J Prev Alzheimers Dis 2015;2:24–32.
40. Conroy SM, Clarke CA, Yang J, Shariff-Marco S, Shvetsov YB, Park SY, Albright CL, Hertz A, Monroe KR, Kolonel LN, et al. Contextual impact of neighborhood obesogenic factors on postmenopausal breast cancer: the multiethnic cohort. Cancer Epidemiol Biomarkers Prev 2017;26:480–89.