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Diet Quality in Mid-Adulthood Predicts Visceral Adiposity and Liver Fatness in Older Ages: The Multiethnic Cohort Study

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Abstract

Objective—We prospectively examined the relationship of diet quality assessed by established indices (HEI-2010, AHEI-2010. aMED, DASH) with adiposity measures, especially visceral adipose tissue (VAT) and nonalcoholic fatty liver (NAFL).

Methods—Close to 2,000 participants of the Multiethnic Cohort completed validated food frequency questionnaires at cohort entry (1993–96) and clinic visit (2013–16) when they underwent whole-body DXA and abdominal MRI scans. Using linear regression, we estimated mean values of adiposity measures by dietary index tertiles at baseline and standardized regression coefficients (β_s) after adjusting for total adiposity and other covariates. We also performed logistic regression of VAT and NAFL on dietary indices.

Results—Higher dietary quality scores at cohort entry were inversely related to all adiposity measures with the strongest associations for percent liver fat (β_s=−0.14 to −0.08) and followed by VAT (β_s=−0.11 to −0.05), BMI (β_s=−0.11 to −0.06), and total body fat (β_s=−0.09 to −0.05). Odds ratios adjusted for total adiposity ranged between 0.57–0.77 for NAFL and 0.41–0.65 for high VAT when comparing the highest vs. lowest tertiles of diet quality.

Conclusions—These longitudinal findings indicate that maintaining a high quality diet during mid-to-late adulthood may prevent adverse metabolic consequences related to VAT and NAFL.

Keywords

Diet quality; visceral fat; cohort; multiethnic; epidemiology

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Introduction

Accumulation of fat as visceral adipose tissue (VAT) and the presence of non-alcoholic fatty liver NAFL appear to contribute significantly to the adverse metabolic consequences of excess body weight, in particular inflammation and cardiometabolic conditions (1;2). A recent review suggested that non-caloric qualitative aspects of diet, such as dietary fiber, calcium, fructose, and also dietary patterns as described by diet index scores, predominantly affect VAT, whereas subcutaneous fat (SAT) may be determined more by an excess in total energy intake (3). To capture the global effects of multiple qualitative aspects of diet, two approaches are commonly distinguished: *a posteriori*-derived dietary patterns are identified through exploratory data-driven techniques (4), while *a priori* indices are constructed on the basis of dietary recommendations and existing scientific evidence relating dietary intakes to chronic diseases. Based on the hypothesis that diet quality influences VAT and NAFL, we prospectively examined the association of four *a priori*-defined dietary indices, namely the Healthy Eating Index (HEI-2010), the Alternative Healthy Eating Index (AHEI-2010), the alternate Mediterranean Diet score (aMED), and the Dietary Approaches to Stop Hypertension (DASH), with dual energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI)-derived adiposity measures in a large subgroup of Multiethnic Cohort (MEC) participants.

Methods

Study Population

Study participants were recruited from the MEC, an ongoing prospective study in Hawaii and Los Angeles, California, of diet, lifestyle, and genetic risk factors for cancer and other chronic diseases with more than 215,000 men and women aged 45–75 years at recruitment of mainly Japanese American, Native Hawaiian, white, African American and Latino ancestry. All cohort members completed a 26-page baseline questionnaire by mail in 1993–1996 (5). The current Body Imaging Study (BIS) targeted a subset of MEC members who were 60–72 years of age as of January 2013 and living in the catchment area of the study clinics. Mailed invitations were followed by screening telephone calls to exclude individuals with the following characteristics: current reported body mass index (BMI) outside the target range (18.5–40 kg/m^2), current or recent (<2 years) smoking, soft or metal implants (other than knee or hip replacement) or amputations, claustrophobia, insulin treatment, thyroid medication, or other serious health conditions. Individuals with weight change of >9 kg or undergoing treatments or procedures that were likely to affect adiposity or biomarkers of interest, e.g., antibiotics, colonoscopy, chemotherapy, radiation of abdomen/pelvis, corticosteroids, weight loss drugs, estrogen/androgen receptor blockers, were deferred for 6 months, at which time their eligibility was reconsidered.

Recruitment for BIS was conducted during 2013–2016 within 60 sex/ethnicity/BMI strata (18.5–21.9; 22–24.9; 25–26.9; 27–29.9; 30–34.9; 35–40 kg/m^2) to balance the composition of the study population. The participation rate was 15.6% out of the 13,884 contacted, excluding the 4,455 persons who were willing but ineligible. Eligible cohort members visited study clinics to complete anthropometric and imaging measurements, fasting blood sample collection, and questionnaires. In Hawaii, participants completed the protocol at the

University of Hawaii (UH) Cancer Center, except for the MRI scan, which was performed at the UH/Queen's Medical Center MR Research Center, mostly within 2 weeks of the clinic visit. In Los Angeles, participants completed the study protocol in one visit to the Southern California Clinical and Translational Science Institute (SC CTSI) at the Keck School of Medicine of University of Southern California (USC). Institutional Review Boards at UH (CHS#17200) and USC (#HS-12-00623) approved the protocol and all participants signed informed consent forms.

Anthropometry and Imaging

During the BIS clinic visit, trained technicians measured height (Heightronic model# 235A at UH; SECA #240 at USC) and weight (Scale-Tronix model#5102 at UH; Health-o-meter Professional ProPlus at USC). The DXA and MRI imaging protocols were described in detail previously (6;7). Total and regional body composition was determined by a whole-body DXA (Hologic Discovery A at UH and USC) scan, which was calibrated using daily quality control phantoms. DXA image files from both study sites were centrally analyzed at UCSF. Fat mass, overall and in the trunk, arms, and legs, was estimated in kg. BMI and the muscle mass index were computed by dividing total weight or total DXA muscle mass by the square of height in meters, respectively. Abdominal MRI scans were acquired on 3-Tesla scanners (Siemens TIM Trio, Erlangen, Germany, software version VB13 at UH; General Electric HDx, Milwaukee, WI, software release 15M4 at USC) to assess VAT and SAT areas at four cross-sectional lumbar positions (L1-L2, L2-L3, L3-L4, L4-L5) using an axial gradient-echo sequence with water-suppression and breath-hold (25 slices, 10 mm thickness, 2.5 mm gap, TR/TE=140/2.6 ms, 70° flip angle). Percent liver fat was estimated from a series of axial triple gradient-echo Dixon-type scans (10 mm slices, no gap, TE=2.4, 3.7 and 5.0 ms, TR=160 ms, 25° flip angle) by measuring and analyzing in-phase, out-of-phase, and in-phase signals in a manually placed circle in the liver selected for not including hepatic veins or biliary ducts (6). MRI measures were calibration-adjusted for minimal differences between the scanners at the two study sites based on 15 healthy volunteers (BMI 21.8–39.6 kg/m^2) who were scanned at both sites within a week and regressions of the Hawaii on the Los Angeles estimates.

Dietary and Lifestyle Assessment

The mailed self-administered survey at cohort entry and the BIS visit included a quantitative food frequency questionnaire (QFFQ) with over 180 food items, as well as questions on demographics, medical conditions, anthropometric measures, physical activity, and other lifestyle factors (5;8). The validated and calibrated QFFQ has several unique attributes (8), including ethnic-specific foods, reliance on a food composition table specific to the MEC, and use of a large recipe database (9). Questionnaire information about average time spent in sleep, sedentary, moderate, and vigorous activities on a typical day was used to compute daily Metabolic Equivalents of Tasks (METs).

Diet Quality Indices

The relative importance of food groups differed across the four *a priori* indices (Table 1), which had previously been examined in MEC in relation to mortality (10) and diabetes (11). The HEI-2010 reflects the 2010 Dietary Guidelines for Americans with higher scores indicating better adherence to federal dietary guidelines (12). The AHEI-2010 (13) and the aMED (14) include foods and nutrients shown to be predictive of chronic disease risk. The DASH includes eight components that are emphasized in the DASH diet developed for hypertension management (15). The four indices were calculated separately for the QFFQs at cohort entry and at BIS clinic visit.

Statistical Analysis

The analysis examined BMI, four DXA-derived measures (muscle mass index, DXA total and trunk fat, trunk/leg fat ratio) and five MRI-based measures (mean VAT for L1-L5, VAT/SAT ratio, percent liver fat, NAFL defined as >5.5%, high VAT defined as ≥150 cm^2) in relation to the four dietary indices at cohort entry. The indices were divided into three categories, denoted as tertiles, although the categories do not always represent thirds (14;15). To assess change in diet quality since cohort entry as assessed by the HEI-2010, the scores at cohort entry and at clinic visit were dichotomized into low and high using their respective medians and combined into a four-level variable describing status at both times (low/low, low/high, high/low, high/high). A similar analysis was not performed for the other indices because some the component scores are based on the dietary intake distribution of the population under study and, thus, are not comparable over time.

General linear models were used to estimate covariate-adjusted mean adiposity values for tertiles of dietary indices. To assess dose-response relations, we performed trend tests using the dietary index scores as continuous variables after standardizing all dependent and independent variables to a mean of zero and a variance of one. The standardized regression coefficients (β_s) and 95% confidence intervals (CI) allowed comparison of the strengths of association across dietary indices and adiposity measures. To evaluate the influence of dietary patterns across models, a chi-square test compared the standardized slope values across the eight adiposity measures for each index and four dietary indices across each adiposity measure under the assumption of normality for the slope estimates. Logistic regression was applied to estimate odds ratios (OR) and 95% CI for the presence of NAFL (>5.5%) and high VAT (>150 cm^2) and the *c*-statistic to compare the model fit across exposures. All models included sex, age at clinic visit, ethnicity, total energy intake (log-transformed to correct for heteroscedasticity) and physical activity (high vs. low using the median of METs) at cohort entry as covariates. The models for trunk fat, trunk/leg fat ratio, VAT, VAT/SAT ratio, and percent liver fat were further adjusted for DXA-based total body fat. Given the importance of alcohol exposure in defining NAFL, we also adjusted the HEI-2010 and DASH models for alcohol intake, whereas the AHEI and aMED incorporate alcohol intake as a scoring component (Table 1). To evaluate the influence of ethnicity, the logistic regression models were repeated without adjusting for ethnicity. Of the 1,861 participants available for analysis, values were missing in 57 for diet at cohort entry and 36 at clinic visit, 21 for DXA, and 60 for MRI measures. Therefore, the number of participants varied slightly across models.

Results

As a result of the stratified recruitment, approximately one third of the participants within sex and ethnic groups were in the normal weight, overweight, and obese BMI categories (Table 2). The mean ages of the 1,861 participants were 48.3±2.5 years (range: 45.0–57.0) at cohort entry and 69.2±2.7 (range: 59.9–77.4) years at clinic visit, with a mean follow-up time of 20.9±1.2 years. All body fat measures were correlated with higher BMI categories with the most pronounced differences for trunk fat (9.0, 13.1, 18.5 kg), VAT (100, 173, 227 cm^2), and percent liver fat (3.7, 5.8, 7.5%). The mean HEI-2010 at clinic visit was 2.6±9.3 points higher than at cohort entry. BMI at clinic visit showed the following Spearman's correlations with total body fat (r_s=0.83), trunk fat (r_s=0.86), VAT (r_s=0.65), and NAFL (r_s=0.46, all p<0.0001).

Higher scores for all indices at cohort entry were significantly and inversely associated with lower adiposity measures as indicated by the 95% CIs of the standardized regression coefficients (Table 3 and Figure 1). When we compared the strength of the adjusted associations using the magnitude of β_s (Table 3), the trends were similar for BMI (β_s=−0.11 to −0.06) and total body fat (β_s=−0.09 to −0.05) but weaker for trunk fat (β_s=−0.04 to −0.02). The diet quality scores were not associated with muscle mass index, except for a weak inverse association for the AHEI-2010. As to MRI-based measures, all four indices were strongly inversely related to VAT, the VAT/SAT ratio, the trunk/leg fat ratio, and percent liver fat with respective β_s values of −0.11 to −0.05, −0.11 to −0.04, −0.12 to −0.03, and −0.14 to −0.08. Although these values were higher for the DASH than the other three indices for all adiposity measures except the muscle mass index, the differences across the four dietary indices were not statistically significant. For example, the respective p-values for the χ^2-tests of VAT and NAFL across the four indices were 0.13 and 0.30. On the other hand, a χ^2-test across the eight adiposity measures for the DASH resulted in a p-value of <0.0001 indicating that diet quality predicted some measures better than others.

Examining the adherence to HEI-2010 over time (Figure 2), the current adjusted mean BMI and total body fat were lower among participants who maintained (high/high) or improved (low/high) their dietary quality, compared to those with low diet quality at clinic visit (low/low, high/low). However, for total fat-adjusted regional adiposity measures, participants who maintained a high diet quality at both times (high/high) showed the most favorable values. The difference was most pronounced again for percent liver fat with adjusted means of 6.2% (95% CI, 5.8–6.5%) in the low/low and 4.8% (95% CI, 4.5–5.2%) in the high/high group; the latter value was also significantly different from the low/high group (5.9%; 95% CI, 5.4–6.4%). The respective mean VAT values were 155 cm^2 (95% CI, 160–165 cm^2) and 176 cm^2 (95% CI, 171–181 cm^2) for low/high and high/high groups.

We examined the association of baseline dietary indices and HEI-2010 changes over time (Figure 3) with common clinical definitions for high visceral (>150 cm^2) and hepatic adiposity (>5.5%). Participants in the lowest vs. the highest tertile of all four indices were significantly less likely to have NAFL or high VAT (Figure 3A and B). The ORs for participants with the highest vs. lowest diet quality ranged between 0.57–0.77 for NAFL and 0.41–0.65 for high VAT. The strongest associations were seen for the DASH and the HEI, where both the ORs of the intermediate tertiles were also significantly lower than the reference tertile. When considering change in HEI-2010 from cohort entry to clinic visit (Figure 3C and D), the risk estimates were significantly lower for only those who scored high at both times (OR=0.55; 95% CI, 0.41–0.74 for NAFL and OR=0.52; 95% CI, 0.38–0.71 for high VAT).

Removing ethnicity from the NAFL models lowered the *c*-statistics for all four indices: from 0.762 to 0.684 (HEI-2010), 0.758 to 0.682 (AHEI-2010), 0.753 to 0.670 (aMED), and 0.763 to 0.693 (DASH). However, in models with whites only, the respective values for the *c*-statistics increased to 0.809, 0.802, 0.802, and 0.808.

Discussion

In this study with DXA and MRI-based measures, better diet quality, as assessed by four commonly used indices based on dietary recommendations made to the general public, predicted lower adiposity. The strongest relations were seen for NAFL followed by VAT, the VAT/SAT ratio, the trunk/leg fat ratio, and BMI. Even after adjustment for total body fat, individuals in the upper tertile of diet quality had only half the risk of high VAT and NAFL than participants in the lower tertile of diet quality (Figure 3). Despite modest differences across indices, performance of the four dietary quality measures did not differ significantly. An analysis of HEI-2010 scores at the beginning and at the end of the 20-year study period indicated that the long-term quality of the diet is important for VAT and NAFL although the low/high group also experienced some benefit indicating that a change in diet can be beneficial.

These findings are remarkable and novel for several reasons. The standardized comparison of DXA and MRI-based adiposity measures suggested a strong association of diet quality with NAFL and VAT after adjustment for total body fatness. As previous reports on diet quality and obesity were mostly cross-sectional (16–18), the current results from a prospective cohort indicate the importance of consuming a high quality diet over many years to maintain low VAT and NAFL independent of total adiposity, whereas the influence on other adiposity measures was less clear. Without MRI measures, VAT is difficult to assess although waist and hip measurements provide some indication of abdominal adiposity (19) and investigations are underway to estimate VAT from circulating biomarkers (7).

The Mediterranean diet is the most commonly investigated *a priori* pattern. As in our study, it has been inversely associated with different measures of adiposity, e.g., excess body weight in several interventions (20) and waist circumference (21;22) and VAT (16) in cross-sectional reports. Similarly, NAFL as assessed by MRI was lower for consumers of a Mediterranean diet in an observational study among Greeks (23) and in a dietary trial (24). Results related to other *a priori* scores also agree with our findings. For example, adherence to the 2005 US Dietary Guidelines among Framingham Study participants was negatively associated with VAT measured by computed tomography (CT) in a cross-sectional design (17); lower scores of the Dietary Quality Index predicted higher MRI-derived NAFL in a Chinese population (18); and a modified diet pattern score was related to lower VAT and hepatic steatosis in the Multi-Ethnic Study of Atherosclerosis (25).

Reports based on *a posteriori* patterns also support an association of higher diet quality with lower VAT and NAFL. For example, dietary patterns from principal components analysis (PCA) predicted VAT regain in Japanese women (26) and variation in VAT in a German population (27). High “southern” and “fast food” pattern scores were associated with higher VAT in African Americans (28) and Western dietary patterns were associated with NAFL using ultrasound (29–32) or MRI (33). In cross-sectional studies of specific foods/nutrients, high energy intake (34), sugar-sweetened beverages (17;35;36), refined grains (37), potatoes (27), fat (17), meat (17;27), and alcohol (34) have been related to low diet quality and high VAT, while dietary fiber (27), vegetables, and nuts (17) have shown inverse associations.

Strengths of the current analysis include the prospective study design with 20 years of follow-up, the repeated dietary assessment, the ethnic diversity of the study population, and the state-of-art assessment of adiposity using DXA and MRI, which, along with CT, is a gold standard to assess VAT and NAFL (38). Limitations include the multiple testing and the possibility of false positive results, the small number of participants by sex and ethnicity that did not allow for stratification, and the limited age range of the study sample. Our findings restricted to whites and previous analyses within the MEC (10;11) indicate that dietary indices may not capture diet quality as well in Native Hawaiians, Japanese Americans, and Latinos because the indices were developed in primarily white and African American populations, but further ethnic-specific analyses are warranted.

Conclusions

This analysis within a multiethnic population demonstrates for the first time with a longitudinal study design that diet quality as assessed by four established indices have a strong inverse association with measures of abdominal and liver fatness after taking into account total body fatness. This finding has important implications for the management of excess body weight suggesting that body fat distribution beyond BMI is a critical feature to consider when advising individuals with overweight about the health effects of their regular diets as the metabolic consequences of visceral adiposity may lead to chronic conditions, such as type 2 diabetes (39;40). Nutritional counseling that incorporates diet quality based on one of the scientifically-based guidelines in addition to total energy intake may prevent the adverse health effects related to NAFL and VAT.

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Study Importance

1. What is already known about this subject?

- The relative size of body fat depots, especially visceral adipose tissue with or without nonalcoholic fatty liver, may be a more important risk factor for cardiometabolic diseases than total body fatness.
- Diet is an important determinant of body weight but little is known about how it affects body fat distribution, in particular visceral adipose tissue.

2. What does this study add?

- Four science-based diet quality scores predicted lower visceral adipose tissue and non-alcoholic fatty liver measured by magnetic resonance imaging 20 years after diet assessment.
- Individuals with the best (highest) diet quality scores were 35–59% less likely to have high visceral adipose tissue and 23–43% less likely to have nonalcoholic fatty liver than those with the lowest scores after accounting for total body fat.
- This study suggests that older adults will benefit from adherence to current dietary recommendations not only to maintain a healthy body weight but also to achieve a favorable distribution of body fat, which may lower the risk of cardiometabolic diseases.

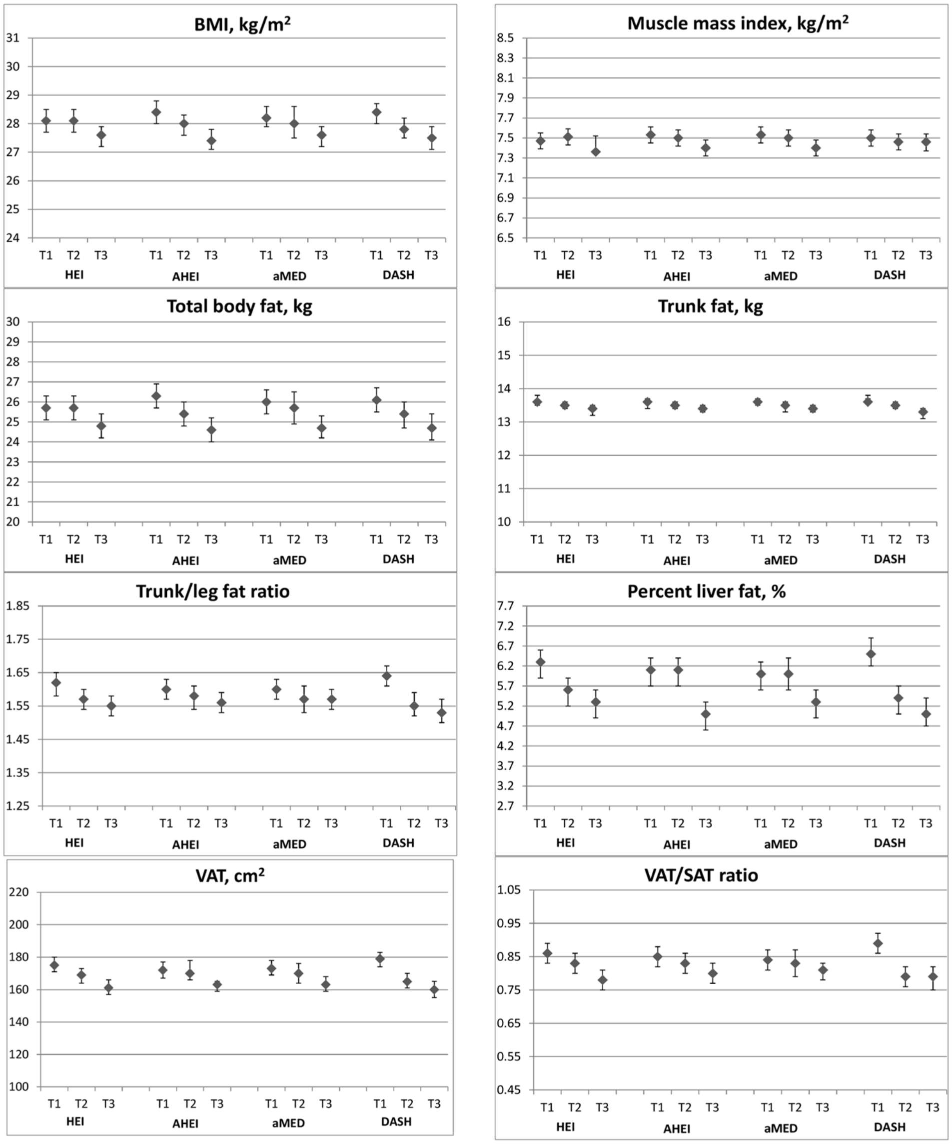

Figure 1. Means (and 95% Confidence Limits) for Current Adiposity Measures (2013–16) by Tertiles of Dietary Indexes at Cohort Entry (1993–96)[a]

[a]General linear models were used to obtain adjusted means including sex, age (continuous), ethnicity, total energy intake (log-transformed) at cohort entry, and physical activity (high vs. low) at cohort entry; HEI-2010 and DASH also adjusted for alcohol intake (categories) at cohort entry; trunk fat, trunk/leg fat ratio, and MRI measures also adjusted for total body fat at clinic visit; y-axes range from the 25th to 75th percentile; for p-values see Table 3.

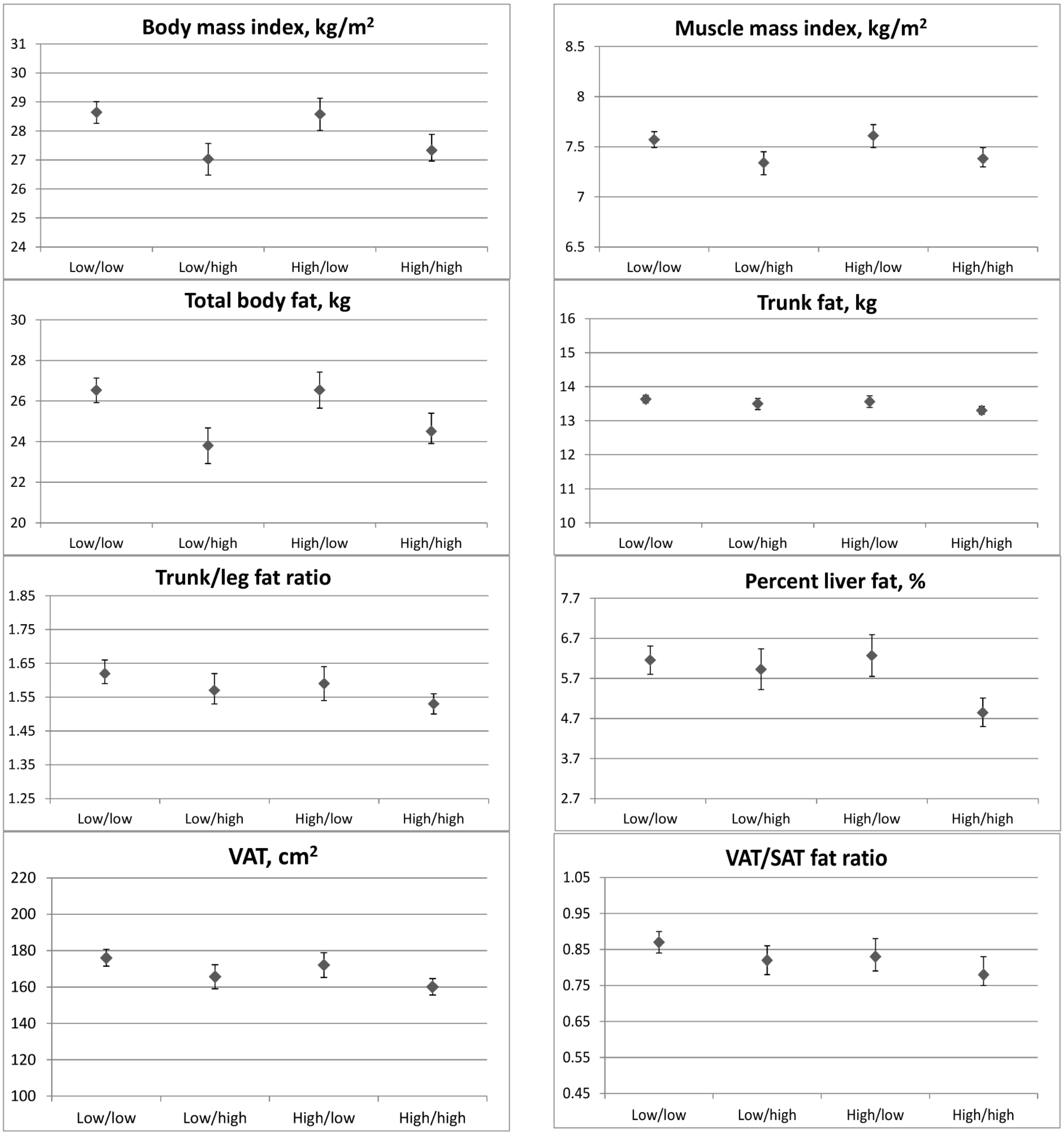

Figure 2. Mean (and 95% Confidence Limits) for Current Adiposity Measures (2013–2016) by the Change in HEI-2010 since Cohort Entry (1993–96)[a,b]

[a]General linear models were used to obtain adjusted means including sex, age (continuous), ethnicity, total energy intake (log-transformed) at cohort entry, physical activity (high vs. low) at cohort entry, alcohol intake (categories) at cohort entry; trunk fat, trunk/leg fat ratio, and MRI measures also adjusted for total body fat at clinic visit; y-axes range from the 25th to 75th percentile.

[b]The HEI-2010 scores at cohort entry and at clinic visit were dichotomized into low and high using their respective medians and combined into a 4-level variable (low/low, low/high, high/low, high/high).

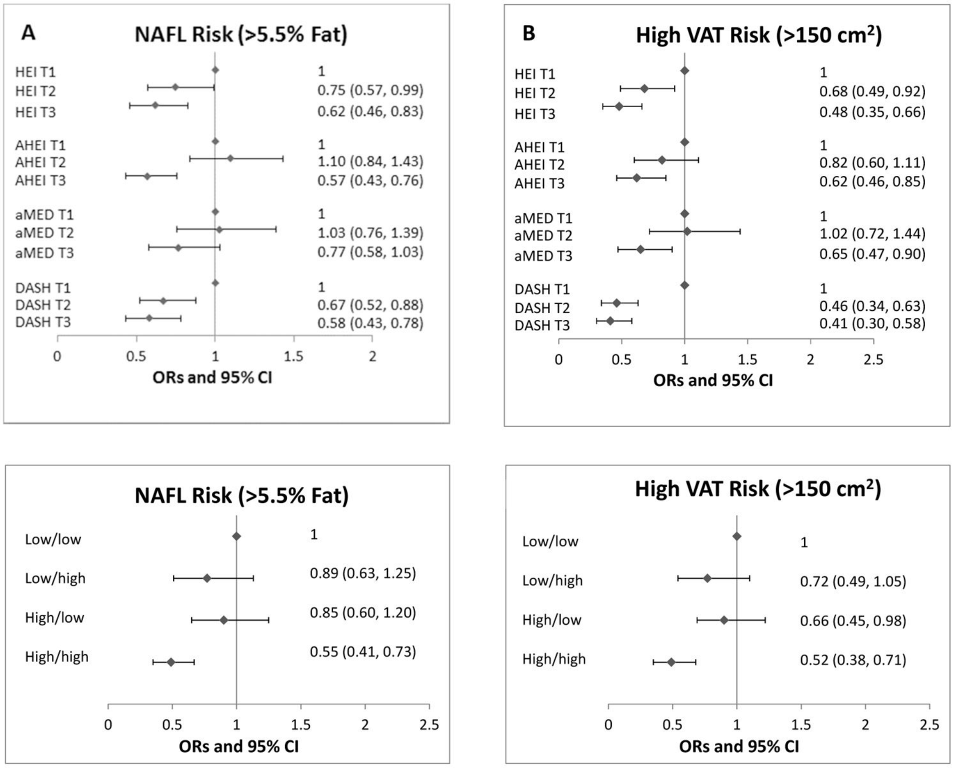

Figure 3. Risk of Current NAFL (≥5.5%) and High VAT (≥150 cm^2) (2013–16) According to Tertiles of Dietary Indexes at Cohort Entry (A, B) and Changes of HEI-2010 since Cohort Entry (1993–96) (C, D)[a]

[a] Logistic regression models were used to obtain odds ratios (OR) and 95% confidence intervals (CI) including sex, age (continuous), ethnicity, total energy intake (log-transformed) at cohort entry, and physical activity (high vs. low) at cohort entry; HEI-2010 and DASH also adjusted for alcohol intake (categories) at cohort entry; trunk fat, trunk/leg fat ratio, and MRI measures also adjusted for total body fat at clinic visit.

[b] Change from baseline to clinic visit for the HEI-2010 was assessed using a four-level variable combining diet quality at both points in time: low=HEI-2010 below the median, high=above the median.

Table 1

Components of the HEI-2010, AHEI-2010, aMED and DASH Scores

	HEI-2010	AHEI-2010	aMED	DASH
Maximum Score	100	110	9	40
Components				
Total vegetables	↑			
Vegetables excluding potatoes		↑	↑	↑
Total fruits	↑		↑	↑
Whole fruits	↑	↑		
Nuts, seeds and legumes				↑
Nuts and legumes		↑		
Nuts			↑	
Legumes			↑	
Fish			↑	
Seafood and plant protein	↑			
Total protein foods	↑			
Red & processed meat		↓	↓	↓
Dairy	↑			↑
Oils/fats	↑	↑	↑	
Alcohol		↑	↑	
Whole grains	↑	↑	↑	↑
Refined grains	↓			
Empty calories[a]	↓			
SSB[b] & fruit juice		↓		↓
Sodium	↓	↓		↓

↑ Components were positively scored such that a higher intake is associated with a higher score

↓ Components were inversely scored such that a higher intake is associated with a lower score

[a] Empty calories: energy from solid fat, added sugars and alcohol

[b] Sugar sweetened beverages (SSB)

Table 2

Characteristics of the Study Population by BMI Status at Cohort Entry and Clinic Visit[a]

Characteristic		All[c]	Normal weight[b]	Overweight	Obese
N		1861	542	750	569
Sex	Men	923	242	420	261
	Women	938	300	330	308
Ethnicity	White	411	147	164	100
	African American	317	70	117	130
	Native Hawaiian	307	74	115	118
	Japanese American	434	178	183	73
	Latino	392	73	171	148
Age, yrs	Cohort entry	48.3±2.5	48.4±2.5	48.3±2.6	48.2±2.5
	Clinic visit	69.2±2.7	69.1±2.8	69.2±2.7	69.4±2.7
BMI, kg/m^2	Cohort entry	26.1±4.2	22.6±2.2	25.8±2.5	29.8±4.4
	Clinic visit	28.0±4.8	22.6±1.6	27.4±1.4	33.8±3.1
Physical activity, METs	Cohort entry	1.6±0.3	1.6±0.3	1.6±0.3	1.6±0.3
	Clinic visit	1.6±0.3	1.7±0.3	1.7±0.3	1.6±0.3
Alcohol intake, drinks/day	Cohort entry	0.7±1.4	0.6±1.1	0.7±1.5	0.7±1.6
	Clinic visit	0.7±1.6	0.8±1.6	0.7±1.4	0.6±1.6
Total energy, Kcal	Cohort entry	2224±1028	2094±941	2216±966	2360±1161
	Clinic visit	1883±946	1784±757	1844±825	2027±1207
HEI-2010	Cohort entry	70.1±9.5	71.0±9.6	69.9±9.5	69.5±9.5
	Clinic Visit	72.7±9.6	74.6±9.9	72.6±9.3	70.8±9.5
	Change	2.6±9.3	3.7±9.2	2.7±9.7	1.4±8.6
AHEI-2010	Cohort entry	63.8±9.5	64.9±9.7	63.6±9.8	63.0±8.8
aMED	Cohort entry	4.1±1.8	4.1±1.8	4.0±1.8	4.1±1.8
DASH	Cohort entry	23.3±4.4	23.7±4.6	23.2±4.3	23.1±4.1

Characteristic	All[c]	Normal weight[b]	Overweight	Obese
Muscle mass index, kg/m^2	7.5±1.4	6.4±1.0	7.5±1.1	8.4±1.3
Total body fat, kg	25.5±8.7	17.8±4.4	24.2±4.8	34.5±7.7
Trunk fat, kg	13.5±4.8	9.0±2.6	13.1±2.5	18.5±3.9
Trunk/leg fat ratio	1.6±0.4	1.4±0.4	1.7±0.4	1.7±0.5
VAT area (L1-L5 mean), cm^2	168±84	100±49	173±63	227±87
VAT/SAT ratio	0.8±0.5	0.7±0.4	0.9±0.5	0.8±0.5
Percent liver fat, %	5.7±4.6	3.7±3.2	5.8±4.5	7.5±5.0
Non-alcoholic fatty liver (>5·5%), %[b]	33.4	12.1	34.4	52.9
High VAT (≥150 cm^2), %	52.9	15.4	59.9	80.7

[a] Means ± standard deviations are shown except for sex and ethnicity where participant numbers are given

[b] BMI at baseline categorized as normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2) or obese (30+ kg/m^2)

[c] Missing values: 57 for diet at cohort entry, 36 for diet at clinic visit, 21 for DXA, 60 for MRI

Table 3

Current Mean (95% Confidence Limits) Adiposity Measures (2013–16) by Tertiles of Dietary Indices at Cohort Entry (1993–96)[a]

Adiposity measure at clinic visit	T	N[b]	HEI-2010[c]		AHEI-2010		aMED		DASH[c]	
			Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL
Body mass index, kg/m^2	T1	601	28.1	27.7, 28.5	28.4	28.0, 28.8	28.2	27.9, 28.6	28.4	28.0, 28.7
	T2	602	28.1	27.7, 28.5	28.0	27.6, 28.3	28.0	27.5, 28.6	27.8	27.5, 28.2
	T3	601	27.6	27.2, 27.9	27.4	27.1, 27.8	27.6	27.2, 27.9	27.5	27.1, 27.9
	β_s (95%CI)[d]		−0.06 (−0.11, −0.01)		−0.09 (−0.13, −0.04)		−0.08 (−0.13, −0.03)		−0.11 (−0.16, −0.06)	
Muscle mass index, kg/m^2	T1	591	7.47	7.39, 7.55	7.53	7.45, 7.61	7.51	7.43, 7.59	7.50	7.42, 7.58
	T2	601	7.51	7.43, 7.59	7.50	7.42, 7.58	7.48	7.38, 7.58	7.46	7.38, 7.54
	T3	599	7.44	7.36, 7.52	7.40	7.32, 7.48	7.44	7.36, 7.52	7.46	7.37, 7.54
	β_s (95%CI)[d]		−0.02 (−0.06, 0.01)		−0.04 (−0.07, −0.01)		−0.04 (−0.08, 0.001)		−0.03 (−0.07, 0.003)	
Total body fat, kg	T1	592	25.7	25.1, 26.3	26.3	25.7, 26.9	26.0	25.4, 26.6	26.1	25.5, 26.7
	T2	598	25.7	25.1, 26.3	25.4	24.8, 26.0	25.7	24.9, 26.5	25.4	24.8, 26.0
	T3	595	24.8	24.2, 25.5	24.6	24.0, 25.2	24.7	24.2, 25.3	24.7	24.1, 25.4
	β_s (95%CI)[d]		−0.05 (−0.09, −0.01)		−0.08 (−0.12, −0.04)		−0.07 (−0.12, −0.02)		−0.09 (−0.14, −0.05)	
Trunk fat[e], kg	T1	581	13.6	13.5, 13.8	13.6	13.4, 13.7	13.6	13.5, 13.7	13.6	13·7, 13.8
	T2	580	13.5	13.4, 13.6	13.5	13.4, 13.6	13.5	13.3, 13.6	13.5	13.4, 13.6
	T3	577	13.4	13.3, 13.5	13.4	13.3, 13.5	13.4	13.3, 13.5	13.3	13.1, 13.4
	β_s (95%CI)[d]		−0.02 (−0.04, −0.01)		−0.02 (−0.03, −0.01)		−0.02 (−0.04, −0.01)		−0.04 (−0.06, −0.03)	
Trunk/leg fat ratio[e]	T1	546	1.62	1.58, 1.65	1.60	1.57, 1.63	1.60	1.57, 1.63	1.64	1.61, 1.67
	T2	547	1.57	1.54, 1.60	1.58	1.54, 1.61	1.57	1.53, 1.61	1.55	1.52, 1.59
	T3	547	1.55	1.52, 1.58	1.56	1.53, 1.59	1.57	1.54, 1.60	1.53	1.50, 1.57
	β_s (95%CI)[d]		−0.05 (−0.10, −0.01)		−0.05 (−0.09, −0.01)		−0.03 (−0.08, −0.01)		−0.12 (−0.17, −0.07)	
VAT area (L1-L5 mean)[e], m^2	T1	582	175	171, 180	172	167, 177	173	169, 178	179	174, 183
	T2	583	169	164, 173	170	166, 178	170	164, 176	165	161, 170
	T3	554	161	157, 166	163	159, 165	163	159, 168	160	155, 165

Adiposity measure at clinic visit	T	N[b]	HEI-2010[c]		AHEI-2010		aMED		DASH[c]	
			Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL
	β_s (95%CI)[d]		−0.06 (−0.09, −0.03)		−0.07 (−0.10, −0.03)		−0.05 (−0.08, −0.01)		−0.11 (−0.14, −0.07)	
VAT/SAT ratio[e]	T1	582	0.86	0.83, 0.89	0.85	0.82, 0.88	0.84	0.81, 0.87	0.89	0.86, 0.92
	T2	583	0.83	0.80, 0.86	0.83	0.80, 0.86	0.83	0.79, 0.87	0.79	0.76, 0.82
	T3	584	0.78	0.75, 0.81	0.80	0.77, 0.83	0.81	0.78, 0.83	0.79	0.75, 0.82
	β_s (95%CI)[d]		−0.05 (−0.09, −0.01)		−0.06 (−0.10, −0.03)		−0.04 (−0.08, −0.01)		−0.11 (−0.15, −0.07)	
Percent liver fat[e], %	T1	578	6.3	5.9, 6.6	6.1	5.7, 6.4	6.0	5.6, 6.3	6.5	6.2, 6.9
	T2	582	5.6	5.2, 5.9	6.1	5.7, 6.4	6.0	5.6, 6.4	5.4	5.0, 5.7
	T3	578	5.3	4.9, 5.6	5.0	4.6, 5.3	5.3	4.9, 5.6	5.0	4.7, 5.4
	β_s (95%CI)[d]		−0.10 (−0.15, −0.05)		−0.11 (−0.16, −0.07)		−0.08 (−0.13, −0.02)		−0.14 (−0.19, −0.09)	

[a] General linear models were used to obtain adjusted means including sex, age (continuous), ethnicity, total energy intake (log-transformed) at cohort entry, and physical activity (high vs· low) at cohort entry

[b] Missing values: 57 for diet at cohort entry, 36 for diet at clinic visit, 21 for DXA, 60 for MRI

[c] Adjusted for alcohol intake (categories) at cohort entry

[d] β_S=standardized regression parameters (95% CIs) from trend tests with dietary index scores as continuous variables

[e] Adjusted for total body fat at clinic visit