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Diet and Adipose Tissue Distributions: The Multi-Ethnic Study of Atherosclerosis

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Abstract

Background and Aims—Dietary quality affects cardiometabolic risk, yet its pathways of influence on regional adipose tissue depots involved in metabolic and diabetes risk are not well established. We aimed to investigate the relationship between dietary quality and regional adiposity.

Methods and Results—We investigated 5,079 individuals in the Multi-Ethnic Study of Atherosclerosis (MESA) who had food-frequency questionnaires and measurement of pericardial fat and hepatic attenuation at the baseline study visit in MESA, as well as a subgroup with imaging for visceral and subcutaneous fat (N=1,390). A dietary quality score (DietQuality) was constructed to include established food group constituents of a Mediterranean-type diet. Linear models estimated associations of dietary score as well as its constituents with regional adiposity. Baseline mean age was 61 (± 10) years, and approximately half of the participants (47%) were male. Those with a higher DietQuality score were generally older, female, with a lower body mass index, C-reactive protein, and markers of insulin resistance. After adjustment, a higher DietQuality score was associated with lower visceral fat (lowest vs. highest dietary score quartile: 523.6 vs. 460.5 cm²/m; P<0.01 for trend), pericardial fat (47.5 vs. 41.3 cm³/m; P<0.01 for trend), lesser hepatic steatosis (by hepatic attenuation; 58.6 vs. 60.7 Hounsfield units; P<0.01 for trend), but not subcutaneous fat (P=0.39). Greater fruits, vegetables, whole grains, seeds/nuts and yogurt intake were associated with decreased adiposity, while red/processed meats were associated with greater regional adiposity.

Conclusion—A higher quality diet pattern is associated with less regional adiposity, suggesting a potential mechanism of beneficial dietary effects on diabetes, metabolic, and cardiovascular risk.

Introduction

The role of optimal nutrition in cardiovascular health is increasingly recognized, with recent evidence linking diet and cardiovascular risk¹. In response, the American Heart Association (AHA) has established major dietary goals as part of its “Life's Simple 7” guidelines, emphasizing a healthful diet pattern resembling a Mediterranean- or Dietary Approaches to Stop Hypertension (DASH)-style diet as one of the cornerstones of “ideal cardiovascular health”². While clinical and policy interventions often target generalized obesity, it is increasingly clear that specific regional adiposity (i.e. higher levels of pericardial, hepatic, and visceral fat) may significantly contribute to insulin resistance, inflammation, arrhythmia burden³, subclinical myocardial remodeling⁴, and cardiometabolic events⁵. Indeed, both obese and lean individuals with increased fat in these regions experience higher cardiovascular and metabolic risk not explained by weight alone⁶⁻⁸. As such, dietary interventions that influence these regional fat depots may more effectively target the cardiovascular and metabolic consequences of obesity.

Investigations into the relationship between dietary quality and adiposity have largely relied on waist circumference⁸⁻¹¹. Adherence to a Mediterranean-style diet appears to mitigate insulin resistance^{12, 13}, systemic inflammation¹⁴, and oxidative stress¹⁵, features linked to alterations in metabolically relevant regional fat depots. In a seminal study of dietary associations with precise imaging-defined measures of regional adiposity in Framingham,

Molenaar and colleagues demonstrated that higher dietary quality (by the 2005 Dietary Guidelines Adherence Index) was associated with lower subcutaneous and visceral fat¹⁶, though specific food groups were not explored^{17, 18}. Nevertheless, racial differences in dietary composition and adiposity distribution suggest that racial heterogeneity in food intake may impact fat distribution and downstream cardiometabolic risk. Elucidating links between dietary quality and directly quantified regional adiposity depots in diverse individuals would provide important evidence to further substantiate the importance of diet on adiposity in different anatomic locations.

To address these gaps in knowledge, we performed a cross-sectional analysis of individuals enrolled in the Multi-Ethnic Study of Atherosclerosis (MESA), defining a healthy diet pattern that is based on prior Mediterranean-style diet pattern established in MESA¹⁹, with specific addition of sugar-sweetened beverages as harmful, inclusion of yogurt intake as beneficial, and removal of dairy products as harmful, given their proven impact on cardiometabolic health^{2, 20-22}; Table 1). This expanded score encompassed We hypothesized that a healthier diet would be associated with decreased regional adiposity independent of major demographics and cardiometabolic risk factors. Using specific, quantitative phenotypes of ectopic fat relevant to cardiometabolic health, our ultimate goal was to provide evidence to support the role of a healthy dietary pattern on different adiposity phenotypes.

Methods

Participant population

The original MESA cohort consisted of 6,814 men and women of 4 ethnicities (non-Hispanic White, African American, Chinese American, and Hispanic) from 6 centers in the United States and enrolled between July 2000 and August 2002. These individuals were free of clinical cardiovascular disease (history of myocardial infarction, angina pectoris, prior revascularization, heart failure, atrial fibrillation, stroke, or peripheral arterial disease) at enrollment²³. Protocols were approved by the Institutional Review Board at each participating institution. All participants provided written informed consent.

The final analytic cohort for this investigation included 5,079 participants with directly measured liver attenuation (a marker of hepatic steatosis) and pericardial fat volume (our primary outcomes) at baseline (Figure 1). As with prior dietary studies in MESA¹⁹, we excluded individuals with unrealistic energy consumption (>5,000 kcal/day or <500 kcal/day), incomplete dietary questionnaires, significant alcohol consumption (>14 drinks/week in men or >7 drinks/week in women), history of end-organ disease (including self-reported cirrhosis, renal disease or cancer), or missing data on body mass index and prevalent diabetes. Relative to those individuals in the overall MESA study but not included in the primary analysis (N=1,735), the final primary analytic cohort (N=5,079) was well-matched by sex, waist circumference, systolic blood pressure, dysglycemia and triglyceride; there were slight differences in age (median 62 vs. 63 years; P=0.0005), with a slightly higher BMI (27.7 vs. 27.2 kg/m²; P=0.002), and lower high-density lipoprotein (48 vs. 50 mg/dl; P<0.0001) in the primary analytic cohort.

In a separate secondary analysis, we examined visceral and subcutaneous fat obtained by computed tomography, starting with a subset of MESA participants at the second and third study visit (between 2002-2005) studied in our prior work in MESA⁸ (N=1,511); from this initial cohort, we excluded individuals without completed dietary questionnaires, unrealistic energy consumption (as defined above), leaving 1,390 MESA participants for this secondary analysis. Of note, imputation methods were required in 292 subjects (3 for visceral fat and 292 for subcutaneous fat) to account for image truncation using previously described methods⁸. Methods for pericardial fat²⁴, hepatic attenuation²⁵, and abdominal fat imaging⁸ have been previously described. A higher hepatic attenuation is evidence for lower hepatic fat content, as in prior published work in MESA²⁵.

Dietary quality score

Usual dietary habits were assessed at baseline using a semi-quantitative, 127-item food frequency questionnaire adapted from a questionnaire used in the multi-ethnic Insulin Resistance Atherosclerosis study to capture the dietary habits of self-identified Chinese individuals²⁶. Recognizing several different approaches to defining healthy diet patterns, we created a 11-component dietary metric that closely followed the AHA's Simple 7 goals² to maximize simplicity and applicability, while also consistent with a Mediterranean-style diet pattern established in prior published work within MESA (Table 1)¹⁹. These components included fruits, vegetables (excluding potatoes), whole grains, nuts, legumes, fish, ratio of unsaturated (poly- and monounsaturated) to total saturated fat, red and processed meat, sugar-sweetened beverages, alcohol, and yogurt intake. For each food group, servings per day were calculated as the product of frequency of consumption and serving size (small, 0.5; medium, 1.0; or large, 1.5) for each contributing food item, and summed over all foods contributing to a particular food group.

For approximately 25% of the participants in MESA, a coding error led to data being unavailable on the intake of 14 foods (fruit juice, dark/white grains, fruit, salty snacks, other vegetables, leafy green vegetables, yogurt, potato, red meat, high fat and processed meat, high-fat dairy, desserts, cottage cheese and legumes). As the majority of these participants were from one of two MESA field centers, the data are not missing completely at random (MCAR) and may not be missing at random (MAR). To avoid bias in the sample, for these 14 intakes (servings per day and serving size) for this portion of the MESA population only, imputation was conducted using sequential chained regression implemented in Stata 12 using the MI program specifying multinomial or ordinal regression, with one model for all 14 items. In all cases, the imputation model accounted for basic demographics. Other auxiliary variables were selected on the basis of having a high correlation with the FFQ or serving size items. The subsequent imputed dataset was used for this analysis, and has been approved by the MESA Steering Committee.

The contribution of each food group to the overall dietary score (termed "DietQuality" hereafter) was calculated by dividing the intake of each food group into quartiles, with a score from 1-4 points. Higher scores corresponded to greater intake of each food item. Alcohol consumption was given +4 points for moderate intake (5-15 grams/day) and 0 for alcohol intake outside these bounds. The final score was obtained by summing all salutatory

food items (fruit, vegetables, whole grains, nuts, legumes, fish, unsaturated fat ratio, alcohol and yogurt), and subtracting scores from potentially harmful items (red and processed meat, sugar-sweetened beverages). Of note, for most food items (except yogurt and sugar-sweetened beverages), stratification by quartile of intake led to approximately equal number of MESA participants in each quartile; deviations from this pattern (in yogurt and sugar-sweetened beverages) were due to large numbers of individuals with zero intake (for yogurt, 2533 participants; for sugar-sweetened beverages, 2381 participants of our study cohort). For yogurt, +1 point was assigned for the lower two quartiles, and +3 and +4 points for the third and fourth quartile, respectively. Standard scoring was applied to sugar-sweetened beverages.

Statistical analysis

Baseline characteristics across quartiles of DietQuality score were tabulated and compared using Wilcoxon rank-sum testing (for continuous covariates) or chi-square tests (for categorical covariates). Given that hepatic attenuation and pericardial fat volume were measured concurrently with dietary assessment, we treated the association of DietQuality score and pericardial fat volume (indexed to height, in meters) or hepatic attenuation measured in >5,000 MESA participants at the baseline study visit as our primary outcome. Our secondary outcome was the association of DietQuality score with visceral and subcutaneous fat area (indexed to height, in meters) in a subgroup with these indices measured at the second and third MESA study visit.

We tested the form of the relationship between each regional fat depot and DietQuality score (treated as a continuous variable) using general additive models to assess linearity. Using covariates obtained contemporaneously with CT scans for regional adipose tissue measures, we constructed linear models to measure association between each regional fat depot and DietQuality (treated both as a continuous variable and in quartiles), adjusted for age, race/ethnicity, sex, weight, cigarette use, systolic blood pressure, fasting blood glucose, total cholesterol, total intentional exercise, and energy consumption (in kilocalories/day). Energy consumption was included in models to adjust for the underreporting of intake associated with food frequency questionnaire data, and to ensure that analyses were independent of caloric intake. A least squares means approach with Tukey's test was performed to test multiple comparisons of adiposity across quartiles of DietQuality score. Pericardial, visceral, and subcutaneous fat depots were log-transformed to establish linearity in these regressions (liver attenuation has negative values and was not log-transformed). Continuous variables used in adjustments in regression models (e.g., age, cholesterol, etc.) were standardized to a mean of 0 and standard deviation of 1 for inclusion in regression. In addition, we performed multiplicative interaction terms with sex and race to evaluate for effect modification.

Finally, to estimate which food groups were most strongly related to regional ectopic fat distributions, we estimated adjusted associations between each component of diet (treated as servings per day, except for alcohol intake, which was coded as beneficial or non-beneficial, as described above) and regional adiposity (with adjustments for identical covariates as in the linear models above). For the dietary component regression models, adiposity measures (including liver attenuation) were standardized (but not log-transformed) to improve

interpretability. SAS 9.3 (SAS, Cary, NC) was used for analyses. Given that 11 different food groups were tested for association with each specific fat depot, we performed a Bonferroni adjustment for 11 tests ($0.05/11 \approx 0.0045$) to minimize the chance of a type 1 error.

Results

Clinical and biochemical indices of cardiometabolic risk by quartiles of modified MedDiet score

Baseline clinical and demographic characteristics for the study population are shown in Table 2. The median DietQuality score was 15 (interquartile range IQR 12-19). In crude (unadjusted) analyses, individuals with a higher quality diet were more likely to be older and female with a lower body mass index (all $P < 0.01$). In addition, a greater DietQuality score was associated with a more favorable lipid profile (lower LDL-C and triglycerides, higher HDL-C), lower biomarkers of inflammation (C-reactive protein, interleukin-6) and greater insulin sensitivity (lower HOMA-IR). We further explored DietQuality score and food group constituents across race (Supplemental Table 1). Dietary score was slightly higher in Chinese-Americans (consistent with Table 1) with a more salutatory dietary profile, lower weight, and inflammatory markers relative to other races in MESA, including greater fish intake, more unsaturated fat, vegetables, legumes, and less sugar-sweetened beverage consumption.

Association between greater dietary quality and pericardial, visceral, subcutaneous and liver fat

After adjustment for major demographic and cardiometabolic risk factors (as specified in Methods), a higher DietQuality score was associated with lesser hepatic fat content, and lower pericardial, subcutaneous and visceral fat content (Table 3). When DietQuality score was treated as a continuous variable, a higher DietQuality score was associated with lower hepatic fat content, greater visceral and pericardial fat, but was not associated with subcutaneous fat (Table 3). Least squares means for hepatic fat content and height-indexed pericardial fat volume (primary outcomes), as well as height-indexed subcutaneous fat and visceral fat area (secondary outcomes) as a function of DietQuality quartile (fully adjusted for covariates specified in Methods) are shown in Figure 2. We observed significantly lower hepatic fat content in individuals with a healthier diet pattern, as well as lower pericardial and visceral fat with higher diet quality score. There was no significant difference in subcutaneous fat area.

We next sought to understand whether there was a difference in relationship between DietQuality and regional adiposity measures by sex or race. We used multiplicative interaction terms between DietQuality and sex or race (included in the same model for adiposity measures). There was no evidence of effect modification in the association between dietary quality (in quartiles) and regional fat quantity by sex or race (non-significant interaction term P values for each adiposity depot; visualized graphically in Supplementary Figure 1). Nevertheless, given the differences in adherence to a salutatory dietary pattern by race and potential differences in adherence to a Mediterranean-style diet

by culture (see Supplemental Table 1), we performed a sensitivity analysis by excluding Chinese-Americans (who had the greatest adherence to the salutatory dietary pattern). When we considered non-Hispanic White, African American, and Hispanic Americans, a higher DietQuality score (treated in quartiles) was associated with lower hepatic fat content ($P<0.01$), lower pericardial fat ($P<0.01$), lower visceral fat ($P<0.01$), but no difference in subcutaneous fat ($P=0.18$), after full adjustment.

Dietary components and regional adiposity

After adjustment for multiple comparisons (as specified in Methods), we found that greater intake of vegetables, whole grains, and fish was associated with less hepatic fat and greater red/processed meat intake associated with greater hepatic fat (Table 4; all $P<0.05$ after adjustment). Similarly, greater fruit, vegetable, whole grain, seeds/nuts and yogurt intake were associated with decreased pericardial fat, while increased red/processed meat and sugar-sweetened beverage intake was associated with greater pericardial fat. In terms of our secondary outcomes (visceral and subcutaneous fat), greater sugar-sweetened beverage intake was associated with greater subcutaneous fat. Greater whole grain intake and consuming a greater proportion of fat as unsaturated was associated with less visceral fat, while red/processed meat intake was associated with greater visceral fat.

Discussion

In this large multi-racial/ethnic cohort of adult Americans, we demonstrated associations between dietary quality (composed of features consistent with AHA goals and a Mediterranean-style diet) and specific regional adiposity phenotypes. Specifically, individuals who had a higher quality diet had higher hepatic attenuation (lower hepatic fat content), and lower pericardial and visceral (but not subcutaneous) fat. These associations were independent of age, race, sex, weight, and markers of cardiometabolic risk. These results provide a large-scale, imaging-based assessment of the relationship between regional adiposity and diet quality across multiple ethnicities.

Mechanisms by which improved dietary quality may impact cardiometabolic risk factors and outcomes have been the focus of intense investigation. A variety of potential pathways that may mediate the relationship between diet and cardiometabolic risk have been identified, including decreased oxidative stress¹⁵, epigenetic alterations^{27, 28}, and gut microbial diversity²⁹. Given an increasing recognition that specific fat depots (i.e., pericardial, hepatic, and visceral) may promote metabolic dysfunction⁵, establishing a link between diet quality and adipocyte quantity/function is imperative to clarify mechanisms that bridge diet and cardiometabolic disease. Indeed, both regional fat accumulation and diet influence a common set of cardiometabolic physiologies, including hypertension, dyslipidemia, endothelial function, oxidative stress, and epigenetics⁵. On a molecular level, diet may influence fat accumulation and function: for example, fructose may promote *de novo* lipogenesis and alter global transcriptional profiles within adipose tissue, leading to hepatic steatosis³⁰, and high-fat Western diets promote adipose tissue inflammation and dysfunction in mice³¹. In addition, dietary poly-unsaturated fats (PUFAs; e.g., *n*-3 PUFAs) may favorably influence adipocyte hypertrophy and inflammation^{32, 33}, key features of

dysfunctional adipose tissue structure. While these findings suggest an intimate connection between diet quality, adiposity, and downstream cardiometabolic risk, evidence from large, multi-racial populations on dietary patterns, constituents, and regional adipose tissue quantity have not been reported.

In a seminal investigation of 2,926 mainly Caucasian participants in the Framingham Heart Study, Molenaar and colleagues demonstrated an association between a composite dietary quality metric (the 2005 Dietary Guidelines Adherence Index) and decreased subcutaneous and visceral adiposity, providing important initial evidence that dietary quality may impact regional adiposity¹⁶. In this report, the authors called for studies in multi-racial groups and with specific dietary food groups to further investigate these relationships. In response, several recent reports have addressed the role for sugar-sweetened beverages on directly measured adiposity depots^{17, 18, 34} using CT methods similar to those employed in MESA. Our study directly addresses these important areas in nutritional research by examining quantitative CT adiposity phenotypes in a multi-racial/multi-ethnic cohort, focusing on both guideline-recommended diet patterns as well as dietary constituents. In addition to identifying a direct relationship between a more salutatory diet pattern and regional adiposity, we identified fruits, vegetables, legumes, fish (among others) as associated with a beneficial adiposity profile, while red and processed meats and sugar-sweetened beverages were associated with poorer adiposity profiles. These conclusions are consistent with reduction in abdominal fat mass with a Mediterranean diet (relative to a carbohydrate-rich alternative), alongside improvements in insulin resistance³⁵, and the landmark, randomized PREDIMED trial that demonstrated long-term reduction in waist circumference with traditional Mediterranean-type diets rich in extra virgin olive oil or nuts³⁶.

The strengths of our study lie in the diverse adult population comprised of multi-racial and multi-ethnic individuals, and detailed CT-based phenotyping of regional adiposity. Certainly, the use of dietary scores (as opposed to single dietary components) is critical to limit nutritional confounding, to provide an integrated landscape of dietary habits across multiple nutrients, and to closely reflect the actual consumption patterns of individuals³⁷⁻³⁹. Nevertheless, the results of our study should be viewed in the context of its design. While our study is cross-sectional, with imaging performed at three different MESA study visits, the associations we observed are based on a large sample size, precise imaging quantification, and multivariable adjustment, which may limit the effects of residual confounding. Nevertheless, it is still possible that adherence to a higher quality diet may be associated with unmeasured, salutatory health behaviors that promote reduced generalized and regional adiposity. Furthermore, hepatic attenuation is only one marker of liver triglyceride content, and future work employing more specific methods (e.g., MRI spectroscopy) and CT or MRI imaging of visceral or subcutaneous fat at the time of the dietary assessment may be useful to further elucidate these relationships. We recognize that the expanded DietQuality score has several modifications over a traditional Mediterranean diet (including inclusion of yogurt and sugar-sweetened beverages and exclusion of dairy), and has not been directly externally validated; however, yogurt has proven benefits on cardiometabolic health^{20, 21}, and reduced sugar-sweetened beverages are part of the American Heart Association Simple 7 dietary guidelines². In addition, we did not have access to glycemic indices of different foods in this study, though previous investigations in

MESA have noted relationships between a Mediterranean diet and insulin resistance¹⁹. Finally, future studies involving both serial imaging and serial questionnaire and molecular assessment of nutrition (e.g., metabolite profiling) specifically across different races/ethnicities may be warranted to further explore these associations.

In conclusion, using computed tomography, we observed an association between diet quality and regional adiposity. Specifically, a higher quality diet was associated with lower hepatic fat content and lower visceral and pericardial fat. In addition, specific foods had an impact on regional adiposity phenotypes independent of weight, energy consumption, or favorable behaviors (e.g., physical activity), suggesting that dietary quality may have an independent impact on regional adipose tissue stores. Collectively, these data demonstrate a link between adiposity in specific anatomic locations and dietary patterns in a large population of multi-ethnic Americans. These findings provide the basis for future prospective studies that investigate the effect of diet on metabolic and molecular consequences of regional adiposity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Dietary quality is a major focus of cardiometabolic disease prevention worldwide
- A dietary score consisting of constituents of a Mediterranean-style diet was associated with decreased adiposity by computed tomography
- This association was independent of age, sex, or race
- Specific food groups had beneficial (and deleterious) association with regional adiposity
- Dietary composition may be critical to determining adipose tissue distributions relevant to cardiometabolic risk

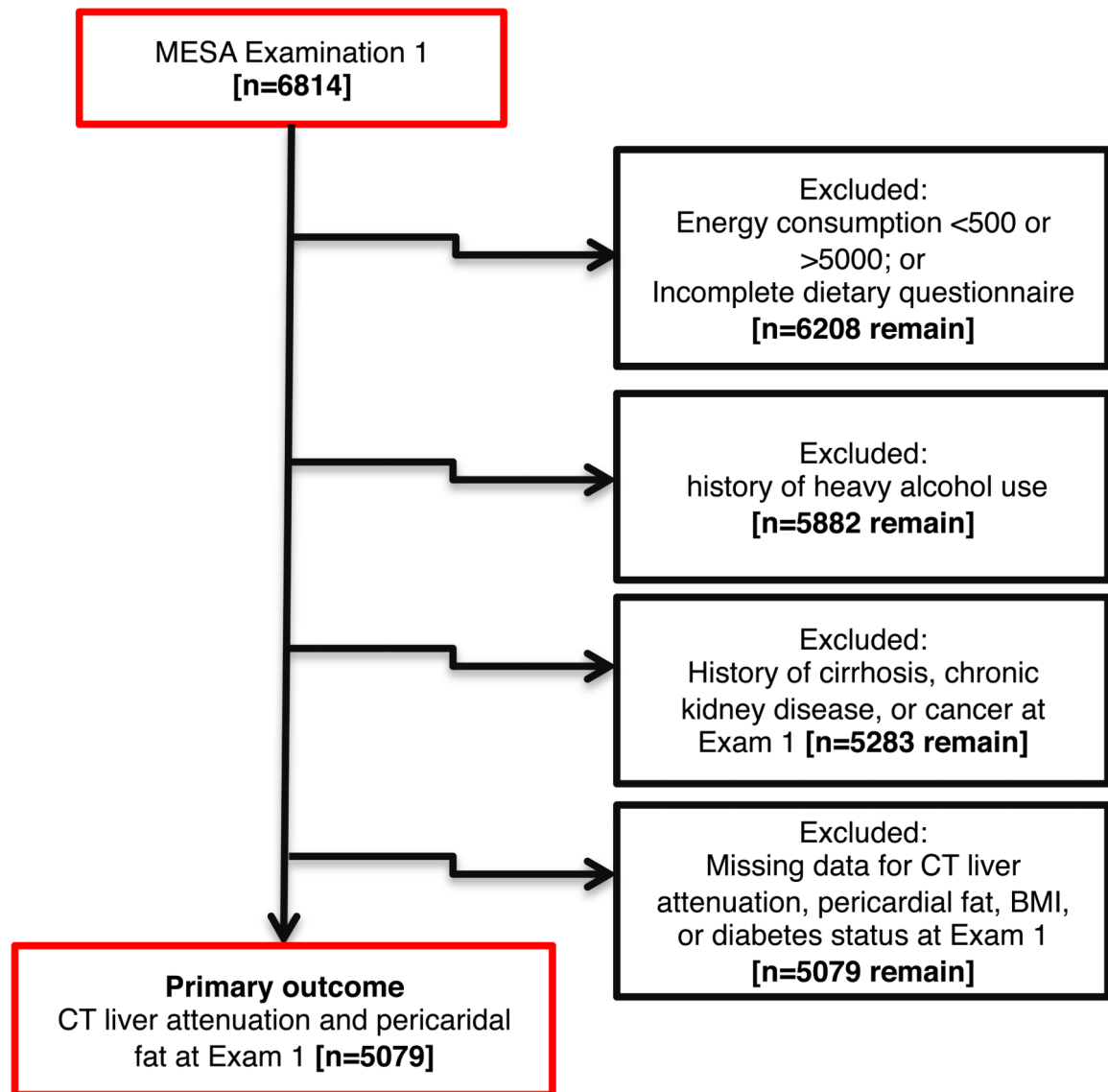


Figure 1.

Construction of the study cohort. MESA participants from the baseline examination underwent successive exclusions (as detailed in text) to arrive at a final study population ($N=5,102$) for the primary measures of liver attenuation and pericardial fat. In addition, a subgroup of individuals at the second and third MESA study visits underwent abdominal CT imaging for visceral and subcutaneous fat, of which 1,390 were included in this analysis.

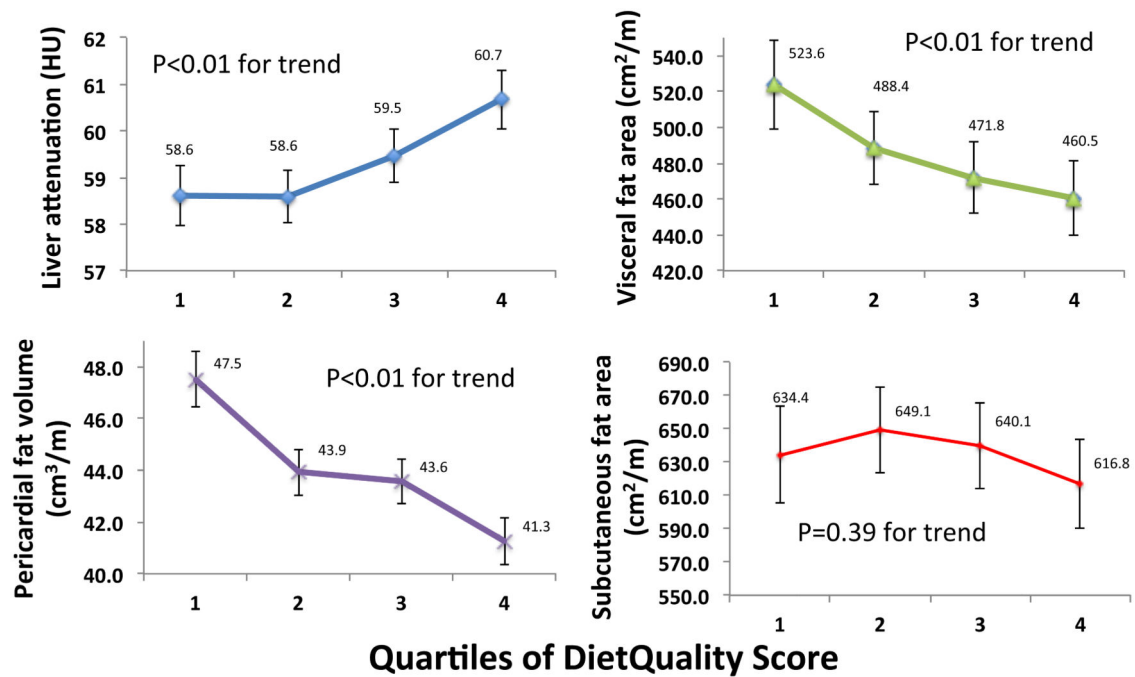


Figure 2.

Adjusted regional adiposity measures (mean with 95% confidence limits) across quartiles of DietQuality score. Means listed are least-squares means from general linear regression models, adjusted for age, race/ethnicity, sex, weight, cigarette use, systolic blood pressure, fasting blood glucose, total cholesterol, total intentional exercise, and energy consumption (in kilocalories/day).

Table 1

Modified diet pattern score construction.

Food Group	Constituent Foods	Weighting in Optimal Diet Score
Vegetables	All vegetables (cruciferous, dark yellow, green leafy, other vegetables; not potatoes)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Whole grains	All whole grain or containing products (oatmeal, dark bread, bran muffin, brown rice, selected cereals)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Seeds and nuts	Nuts (including peanuts, sunflower seeds, etc.)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Legumes (including soy)	Legume and legume-containing products (e.g., pea soup, beans, burritos, enchiladas, meat chile, fried beans) and soy products (e.g., soy milk, miso soup, stirfried tofu, tofu desserts)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Yogurt	Plain and flavored yogurt	Quartiles (+4 points for greatest intake; +1 point for least intake [*])
Fish	Fish-containing foods (e.g., boiled fish, tuna fish, shrimp, fried fish)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Alcohol	Total alcohol intake (beer, wine, other)	+4 for 5-15 grams/day consumption, otherwise 0
Unsaturated to saturated fat ratio	Mono- and polyunsaturated fat to total saturated fat ratio	Quartiles (+4 points for highest ratio; +1 point for lowest ratio)
Red and processed meats	All red meat containing products (e.g., sausage, steak, beef, etc.)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Fruits	All fruit and fruit-containing products (e.g., fruit juice, avocado, tomato, apple, etc.)	Quartiles (+4 points for greatest intake; +1 point for least intake)
Sugar-sweetened beverages	Regular soft drinks, soda, sweetened mineral water (not diet), non-alcoholic beer	Quartiles (+4 points for greatest intake; +1 point for least intake [*])

* For yogurt and sugar-sweetened beverage consumption, at least 25% of study participants reported zero consumption. See text for details.

Table 2

Baseline clinical, demographic, biochemical and imaging indices, stratified by DietQuality score in quartiles (where available). A higher quartile signifies a more salutatory diet. Values represent median (interquartile range) or number (percentage). Abbreviations: lbs, pounds; LDL, low-density lipoprotein; HDL, high-density lipoprotein; HOMA-IR, homeostatic model of insulin resistance; HU, Hounsfield units.

Variable	Dietary Quality Score (quartiles)				P
	Q1 (N=1180)	Q2 (N=1378)	Q3 (N=1335)	Q4 (N=1186)	
Age (baseline, years)	60 (52-68)	61 (53-69)	63 (54-70)	63 (54-71)	<0.01
Race (%)					<0.01
Caucasian	375 (32%)	471 (34%)	465 (35%)	502 (42%)	
Chinese-American	75 (6%)	179 (13%)	248 (19%)	145 (12%)	
African-American	394 (33%)	370 (27%)	335 (25%)	342 (29%)	
Hispanic	336 (28%)	358 (26%)	287 (22%)	197 (17%)	
Male sex (%)	615 (52%)	643 (47%)	602 (45%)	516 (44%)	<0.01
Income					<0.01
\$0-\$100,000/year	1016 (91%)	1192 (90%)	1106 (86%)	946 (82%)	
>\$100,000/year	105 (9%)	129 (10%)	178 (14%)	207 (18%)	
Educational attainment					<0.01
High school	547 (47%)	570 (41%)	463 (35%)	295 (25%)	
Some college	342 (29%)	404 (29%)	361 (27%)	320 (27%)	
4 years college	287 (24%)	402 (29%)	511 (38%)	569 (48%)	
Body mass index (kg/m ²)	28.7 (25.7-32.3)	27.8 (24.7-31.2)	27.4 (24.6-30.9)	26.9 (24.2-30.3)	<0.01
Weight (lbs)	177 (153-204)	169 (145-196)	168 (145-195)	166 (144-192)	<0.01
Waist circumference (cm)	99.8 (90.8-109.5)	97.0 (88.7-106.5)	97.0 (88.0-105.5)	95.7 (86.5-104.0)	<0.01
Systolic blood pressure (mmHg)	124 (112-140)	125 (113-141)	124 (112-139)	124 (111-139)	0.41
Never smoker (%)	563 (48%)	737 (54%)	733 (55%)	625 (53%)	<0.01

Variable	Dietary Quality Score (quartiles)				P
	Q1 (N=1180)	Q2 (N=1378)	Q3 (N=1335)	Q4 (N=1186)	
Diabetes (%)	152 (13%)	204 (15%)	170 (13%)	127 (11%)	0.02
Hypertension (%)	516 (44%)	631 (46%)	587 (44%)	530 (45%)	0.71
Biomarkers (median, IQR)					
LDL cholesterol (mg/dl)	118 (98-138)	118 (98-138)	116 (96-136)	114 (95-134)	<0.01
HDL cholesterol (mg/dl)	46 (39-56)	48 (40-58)	48 (40-58)	50 (42-60)	<0.01
Triglycerides (mg/dl)	117 (83-163)	112 (79-166)	114 (79-165)	104 (73-153)	<0.01
Fasting glucose (mg/dl)	91 (84-101)	91 (83-100)	89 (83-100)	88 (82-97)	<0.01
C-reactive protein (mg/l)	2.23 (1.02-4.46)	1.91 (0.86-4.55)	1.93 (0.86-4.24)	1.59 (0.70-3.82)	<0.01
Interleukin-6 (pg/ml)	1.27 (0.84-1.97)	1.22 (0.78-1.92)	1.20 (0.78-1.84)	1.07 (0.69-1.73)	<0.01
HOMA-IR	2.18 (1.39-3.40)	1.98 (1.35-3.08)	1.93 (1.31-2.92)	1.66 (1.18-2.59)	<0.01

* P values represent chi-square or Wilcoxon tests, where appropriate.

Table 3

Regional adipose tissue quantity as a function of DietQuality score. As noted in Methods, all adipose tissue depots (except for liver attenuation) were log-transformed for regression analyses. Values presented are least squares means of each regional fat depot at each quartile of DietQuality score, fully adjusted for demographic and cardiometabolic covariates specified in Methods. P values for quartile analyses correspond to P values for DietQuality score in multivariable linear regression. In addition, DietQuality score was treated as a continuous variable (in columns marked “Multivariable Adjusted Regression”), and beta coefficients and P values for DietQuality score (per an increment of +1 in score) are shown. Abbreviations: HU, Hounsfield units; GLM, general linear model.

Regional adiposity	Dietary Quality Score (in quartiles)				Multivariable Adjusted Regression		
	Q1	Q2	Q3	Q4	P (from GLM)	β	P
Liver attenuation (HU)	58.6 (58.0-59.2)	58.6 (58.0-59.2)	59.5 (58.9-60.0)	60.7 (60.0-61.3)	<0.01	0.15	<0.01
Visceral fat area (cm ² /m)	523.6 (498.6-549.8)	488.4 (468.2-509.5)	471.8 (451.8-492.7)	460.5 (439.8-482.2)	<0.01	-0.009	<0.01
Subcutaneous fat area (cm ² /m)	634.4 (605.5-664.7)	649.1 (623.4-675.8)	640.1 (614.2-667.2)	616.8 (590.3-644.5)	0.39	-0.003	0.17
Pericardial fat volume (cm ³ /m)	47.5 (46.4-48.6)	43.9 (43.0-44.8)	43.6 (42.7-44.5)	41.3 (40.4-42.2)	<0.01	-0.009	<0.01

Table 4

Linear models for the association between each food group with regional adiposity. Each model was adjusted for age, race/ethnicity, sex, weight, cigarette use, systolic blood pressure, fasting blood glucose, total cholesterol, total intentional exercise, and energy consumption. Fat depots (except for liver attenuation) were normalized to height (as described in Methods). Each food item was treated in servings per day, except for alcohol (treated as moderate vs. non-moderate intake) and fat ratio (a ratio of unsaturated to saturated fat).

Food group	Liver attenuation		Pericardial fat		Subcutaneous fat		Visceral fat	
	Beta	p	Beta	p	Beta	p	Beta	p
Fruit	0.001	0.87	-0.028	<0.01*	-0.008	0.42	-0.023	0.03
Vegetable	0.054	<0.01*	-0.028	<0.01*	0.007	0.68	-0.026	0.12
Whole grains	0.072	<0.01*	-0.118	<0.01*	-0.057	0.06	-0.114	<0.01*
Fish	0.123	<0.01*	-0.056	0.11	0.015	0.82	-0.037	0.58
Unsaturated/Saturated Fat								
Ratio	0.065	0.01	-0.068	<0.01*	-0.040	0.3	-0.113	<0.01*
Legumes	-0.001	0.97	0.028	0.15	-0.054	0.12	0.042	0.26
Seeds/Nuts	0.020	0.54	-0.117	<0.01*	0.071	0.15	-0.058	0.26
Yogurt	0.143	0.02	-0.164	<0.01*	-0.047	0.57	0.025	0.77
Alcohol (moderate intake)	0.087	0.02	-0.066	0.04	-0.056	0.29	0.016	0.78
Red and processed meats	-0.092	<0.01*	0.118	<0.01*	0.022	0.62	0.171	<0.01*
Sugar-sweetened beverages	-0.039	0.01	0.045	<0.01*	0.074	<0.01*	0.027	0.30

* Indicates that the corresponding p-value was significant after Bonferroni correction (as specified in Methods). "Beta" refers to beta coefficient in regression.