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Differences in the Association of Diet Quality with Body Fat Distribution between Men and Women

Gertraud Maskarinec, MD[1], **Lisa A. Namatame**[1], **Minji Kang, PhD**[1], **Steven D. Buchthal, PhD**[2], **Thomas Ernst, PhD**[3], **Kristine R. Monroe, PhD**[4], **John A. Shepherd, PhD**[1], **Lynne R. Wilkens, DrPH**[1], **Carol J. Boushey, PhD**[1], **Loïc Le Marchand, MD**[1], **Unhee Lim, PhD**[1]

[1]University of Hawaii Cancer Center, Honolulu, HI

[2]Queens Medical Center, Honolulu, HI

[3]University of Maryland, Baltimore, MD

[4]University of Southern California, Los Angeles, CA

Abstract

Background/Objective: As dietary intake and endocrine metabolism are vastly different by sex, we evaluated differences in the association of diet quality with body composition between men and women.

Subjects/Methods: Close to 2,000 participants from the Multiethnic Cohort completed calibrated quantitative food frequency questionnaires at cohort entry (1993–96) and clinic visit (2013–16), from which the Healthy Eating Index (HEI-2010) was computed. Adiposity measures were obtained through DXA and MRI at clinic visit. Multivariable-adjusted mean adiposity measures were estimated by tertiles of HEI-2010 scores using general linear regression. The associations of diet quality with high visceral fat (VAT) and non-alcoholic fatty liver disease (NAFLD) were examined by logistic regression. To assess sex differences, cross-product terms with HEI-2010 were added to the models.

Results: Mean HEI-2010 scores were higher for women than men at cohort entry (67.4 vs. 64.0) and clinic visit (73.6 vs. 71.0). Past and current diet quality was inversely associated with adiposity measures in men and women. Although interaction terms were not significant, the magnitude of the slopes and differences in adjusted means across tertiles suggested a stronger association for women than men. When comparing individuals who maintained a high vs. poor quality diet over 20 years, women but not men showed significantly lower risks for high VAT, whereas high HEI-2010 scores predicted a lower risk of NAFLD in both sexes.

Corresponding author: Gertraud Maskarinec, MD, PhD, University of Hawaii Cancer Center, 701 Ilalo Street, Honolulu, HI 96813, Phone: (808) 586-3078, gertraud@cc.hawaii.edu.

Author Contributions

LL, UL, and LRW designed the overall research project; CJB developed nutritional support and the diet scores; SDB, TE, and JAS provided essential services in imaging and adiposity measures; LAN, MK, and GM analyzed the data and drafted the paper; LRW provided statistical advice; all authors contributed to data interpretation and critical revisions. GM had primary responsibility for the final content.

Disclosure None of the authors has a conflict of interest to declare

Conclusions: The inverse association of diet quality with adiposity was similar in both sexes, but diet quality appeared to have a stronger influence on VAT in women than men.

Keywords

Diet quality; sex; visceral fat; cohort; multiethnic; epidemiology

INTRODUCTION

The importance of considering sex as a biological variable in animal and human studies has been highlighted in recent years as it becomes clear that disease etiology and treatment effects may differ between men and women [1]. In nutritional studies, the assessment of long-term dietary intake as a risk factor for chronic diseases poses an additional problem. If sex differences in portion sizes and other aspects of food consumption are not accurately captured, the validity of the findings by sex are challenged [2]. A comparison of eating patterns between men and women has indicated that, in general but not for all foods, portions consumed by men were larger than those by women [3–5]. For food choices, differences between men and women have been reported, e.g., women eat more fruits, vegetables, cereals, milk and dairy products than men do, while men consume more meat products, eggs, alcohol, and various starchy foods than women [6, 7]. We previously observed in the Multiethnic Cohort (MEC) that women tended to have better diet quality as assessed by the HEI-2010 [8], a measure of adherence to U.S. Dietary Guidelines for Americans, which are updated every 5 years but the principles in scoring essential food groups remain the same [9], than men [10].

Obesity, a risk factor for many types of chronic diseases including cancer, is rising at alarming rates worldwide [11]. The adverse consequences of excess body fat depend on its properties: visceral adipose tissue (VAT) and liver fat are more likely to be associated with the metabolic syndrome [12] and other serious consequences than subcutaneous adipose tissue (SAT) [13, 14]. In the Adiposity Phenotype Study (APS), conducted among a subset of the MEC, we demonstrated that maintaining a high quality diet during mid-to-late adulthood might prevent the accumulation of VAT and liver fat [15]. As it is not known whether the association between the HEI-2010 and adiposity measures differs by sex, the objective of the current analysis is to compare the association of diet quality as assessed by the HEI-2010 with different adiposity measures between men and women in the APS.

Methods

Study Population.

The APS participants were recruited from the MEC, a continuing prospective study in Hawaii and Los Angeles, California, which examines diet, lifestyle, and genetic risk factors for cancer. The MEC consisted of more than 215,000 men and women from five ethnic groups aged 45–75 years at the time of enrollment in 1993–1996. All participants completed a 26-page baseline questionnaire by mail [16]. Participants aged 60–72 years as of January 2013 and of good general health were targeted for stratified recruitment by sex, ethnicity and six BMI categories during 2013–16 [15]. Mailed invitations and screening telephone calls

identified eligible participants among 13,884 participants [17]. Due to the strict eligibility criteria and the requirement to travel to a clinic for imaging, the response rate was only 15.6%, resulting in a sample size of 1,861. Eligible cohort members visited study clinics to take part in anthropometric measurements, DXA and MRI imaging, fasting blood sample collection, and questionnaires. The protocols were approved by the Institutional Review Boards at UH (CHS# 17200) and USC (#HS-12–00623); all participants provided informed signed consent.

Dietary Assessment.

In addition to questions about demographics, medical conditions, physical activity, and other lifestyle factors, all participants completed a quantitative food frequency questionnaire (QFFQ) containing over 180 food items at cohort entry and clinic visit [16]. With the help of images, they reported the frequency and serving size of the items they consumed in their usual diet during the previous year. Although no true validation study was performed, a calibration sub-study found acceptable correlations between the QFFQ and three 24-hour dietary recalls among 1,606 cohort members; mean correlations ranged from 0.57–0.74 for nutrient densities [18]. Although the essence of the QFFQ remained the same to allow comparison of broad lists of food groups that remain constant over 20 years, the original QFFQ was updated in 2003 for use in the MEC-APS to change the food lists, amounts, and examples or names given for the food items. To assess regular intake, food composition tables and a large recipe database were created specifically for the MEC [19]. Scores (0–100) were computed from the QFFQ data at cohort entry and clinic visit according to the Healthy Eating Index-2010 (HEI-2010) and were categorized into tertiles based on the total study population at each point in time [9, 20]. As a result, tertile boundaries were different at cohort entry and clinic visit. To incorporate diet quality at both points in time, the HEI-2010 scores at cohort entry and at clinic visit were dichotomized into low and high levels using the median of the respective distributions. The categories for the two time points were combined into a four-level variable (low/low, low/high, high/low, high/high) describing each participant's diet quality at cohort entry and clinic visit, e.g., low/high designates a score below the median at cohort entry and a score above the median at clinic visit. In addition, change in HEI-2010 from cohort entry to clinic visit was calculated as a continuous variable. Daily Metabolic Equivalent of Tasks (METs) were calculated from sleep duration and physical activity levels.

Imaging.

As described previously [17], a whole-body DXA scan (Hologic Discovery A at UH and USC) was used to measure total and regional body composition at clinic visit. To assess localized VAT and SAT areas at the four cross-sectional lumbar sites (L1-L2, L2-L3, L3-L4, L4-L5), abdominal MRI scans were obtained on 3-Tesla scanners (Siemens TIM Trio, Erlangen, Germany, software version VB13 at UH; General Electric HDx, Milwaukee, WI, software release 15M4 at USC) using an axial gradient-echo sequence with water-suppression and breath-holds (25 slices, 10 mm thickness, 2.5 mm gap, TR/TE=140/2.6 ms, 70° flip angle). Non-alcoholic fatty liver disease (NAFLD) as assessed from the MRI images was defined as >5.5% among men consuming <30 g/day ethanol and women with <20 g/day ethanol and visceral obesity as ≥150 cm^2 mean visceral fat area (high VAT). 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 that did not include hepatic veins or biliary ducts [15].

Statistical Analysis.

In addition to BMI, two DXA-derived measures (DXA total and trunk fat) and several MRI-based measures (mean VAT area for L1-L5, VAT/SAT ratio, percent liver fat, NAFLD, and high VAT) were analyzed in relation to the HEI-2010. Covariate-adjusted mean adiposity measures by tertiles of the HEI-2010 were estimated using general linear models separately for men and women. Trend tests were performed to evaluate dose-response relations with dietary index scores as continuous variables. In addition to ethnicity and age, total energy intake (log-transformed to meet model assumptions), physical activity (high vs. low using the median of METs), and alcohol intake at the time of dietary assessment were included as covariates in all models. In the models for trunk fat, VAT, VAT/SAT ratio, and percent liver fat, DXA total body fat was also included. To assess the relation of change in diet quality from cohort entry to clinic visit, we modelled change of HEI-2010 (continuous per 10 units) as predictor of high VAT and NAFLD while adjusting for diet quality at cohort entry. To estimate odds ratios (OR) and 95% CI for the presence of NAFLD and high VAT based on diet quality at cohort entry and clinic visit using the four-level variable, logistic regression was applied using the same covariates as above, first for the entire study population and then stratified by ethnicity. To assess effect modification by sex, a main effect for sex and an interaction term of sex with the HEI-2010 were added to the models combining men and women. Differences across ethnic groups were explored through interaction terms. Due to missing values and excluding all high-alcohol drinkers for NAFLD analysis (N=57 diet at cohort entry and N=36 at clinic visit, N=21 for DXA and N=60 for MRI), the different models varied slightly in number of participants.

RESULTS

This study included 923 men and 938 women from 5 ethnic backgrounds: white, African American, Native Hawaiian, Japanese American, and Latino (Table 1). The mean ages at cohort entry were 48.5 ± 2.6 (range: 45.0–57.0) years for men and 48.2 ± 2.5 (range: 45.0–56.0) years for women, while the respective values at clinic entry were 69.3±2.8 (range: 61.4–77.4) years for men and 69.1 ± 2.7 (range: 59.9–77.0) years for women with respective follow-up times of 20.8 ± 1.2 and 21.0 ± 1.2 years.

Mean HEI-2010 scores were approximately 3 points higher for women than men at cohort entry (67.4 vs. 64.0) and at clinic visit (73.6 vs. 71.0). Therefore, men were more likely to be in the lowest and women more likely to be in the highest tertile. However, for both groups the scores increased over time: by 7.2 ± 10.9 and 6.1 ± 10.1 points for men and women, respectively. There was little difference in physical activity, but men reported higher intakes of total energy and alcohol than women.

BMI increased from cohort entry to clinic visit from 26.4 ± 3.7 kg/m^2 to 27.9 ± 4.4 kg/m^2 in men with a difference of 1.4 ± 3.0 kg/m^2. In women, BMI was 25.7 ± 4.6 kg/m^2 at cohort

entry and 28.1 ± 5.2 kg/m^2 at clinic entry with a difference of 2.3 ± 3.7 kg/m^2. Women, compared to men, had higher amounts of total body fat (27.8 ± 8.9 kg vs. 23.1 ± 7.7 kg) and trunk fat (14.1 ± 4.8 vs. 13.5 ± 4.8 kg). However, VAT (201.6±89.5 cm^2) and the VAT/SAT ratio (1.1±0.5) were greater in men than in women (134.6 ± 61.6 cm^2 and 0.5±0.2). Percent liver fat (5.7 ± 4.8% vs 5.6 ± 4.4%) differed little by sex.

As indicated by the significant p-values of the regression coefficients, all adiposity measures were inversely associated with diet quality showing lower values among participants with HEI-2010 scores in the highest vs. the lowest tertile (Table 2). Although none of interactions between sex and the HEI-2010 except for BMI at clinic visit were statistically significant, the magnitude of the regression coefficients and the greater differences across extreme tertiles suggested that women experienced stronger associations of the HEI-2010 with several adiposity measures than men. In particular, the respective VAT/SAT ratios for men and women at clinic visit was 8% and 23% lower in the top vs. bottom tertile; the corresponding values for NAFLD were 27% and 44%. In general, the results at cohort entry were quite similar to those at clinic visit.

In logistic regression models that considered the combination diet quality at cohort entry and clinic visit (Figure 1), the global interaction terms of sex with diet quality were p=0.12 for high VAT and p=0.95 for NAFLD. The risk estimates for high VAT were statistically significantly lower for women who had high HEI-2010 scores at both times (high/high); the respective ORs for low/high, high/low, and high/high status as compared to low/low (Figure 1B) were 0.53 (95% Cl, 0.31–0.92), 0.52 (95% Cl, 0.32–0.87), and 0.39 (95% Cl, 0.26–0.59). On the other hand, no significant associations between the combined HEI-2010 status and high VAT were seen among men (Figure 1A). For NAFLD (Figures 1C and 1D), the associations in men and women were similar. Only participants with a high quality diet at both assessment times were significantly less likely to have NAFLD with similar risk estimated in men (OR=0.49; 95% Cl, 0.32–0.75) and women (OR=0.52; 95% Cl, 0.35–0.78). In models with change in HEI-2010 from cohort entry to clinic visit, the stronger influence of improvement in diet quality over time among women than men was confirmed. The respective ORs for high VAT were 0.88 (95% Cl, 0.71–1.10) and 0.77 (95% Cl, 0.63–0.95) in men and women, while the corresponding values for NAFLD were 0.86 (OR=0.86; 95% Cl, 0.72–1.03) and 0.76 (95% Cl, 0.62–0.92). The interaction terms of high VAT and NAFLD with sex were not significant in any of the five ethnic groups (data not shown).

DISCUSSION

In a cross-sectional analysis at the time of clinic visit, men and women showed statistically significant differences in diet quality scores and all adiposity measures except liver fat. In general, higher diet quality as assessed by the HEI-2010 was related to lower adiposity values for men and women. However, women generally showed stronger associations than men. For example, women in the highest tertile of diet quality had a 23% lower VAT/SAT ratio as compared to the lowest tertile while the difference for men was only 8%. In an analysis of combined HEI-2010 status at clinic visit and at cohort entry 20 years earlier, women were significantly less likely to develop high VAT if they scored above the median HEI-2010 at one or both times or improved their score over time. However, in men no

significant associations were seen with improved diet quality. Both men and women were less likely to develop NAFLD if they scored above the median HEI-2010 at both time points.

As in previous investigations, men in the APS generally consumed more total energy, reported lower diet quality [10], and had less total body fat and more VAT than women but similar NAFLD [17, 21, 22]. Although diet quality associations with different adiposity phenotypes have been reported previously [15, 23–25], few studies have addressed sex differences of these relations. A German study examined dietary components and reported effect modification by sex for *a posteriori* patterns, e.g., a negative association with VAT was seen for fiber and carbohydrates from cereals in men but not women [26]. Yet, another analysis did not detect any effect modification for the relation of 14 food groups with various adiposity tissues [27]. Men and women in the MEC have shown similar associations of high diet quality with disease outcomes, e.g., mortality [20] and type 2 diabetes [28]. Looking at biomarkers, the association between diet quality and carotenoids was also similar in men and women [29], but mortality associated with higher γ-tocopherol levels was only elevated in women and not in men [30].

Strengths of the current study include the long follow-up time of 20 years since cohort entry providing dietary information at two points in time. State-of-the-art methods were applied to assess total body composition by DXA and MRI imaging. The QFFQ was specifically designed for a multiethnic population to capture diverse foods. However, several limitations need to be considered. As the QFFQ was only calibrated and not validated using a gold standard, the dietary assessment and the HEI-2010 may not have completely captured the true diet of the participants. The relation between diet quality and adiposity at clinic visit cannot be interpreted as causal although the significant associations between diet quality at cohort entry and adiposity measures 20 years later indicate the possibility that diet quality may influence body fat distribution over a long time. As the sample sizes for ethnic-specific analyses were very limited, no ethnic specific models were presented. The limited age-range of the study sample may have affected our results, as the relation may be stronger in younger individuals before onset of chronic conditions may affect dietary habits and/or body fat distribution.

The question whether diet quality is better and associations with adiposity measures are stronger among women than men is difficult to explain. Besides being a chance finding, it is possible that women report their diet more accurately or that portion sizes in the QFFQ are closer to those consumed by women than men as suggested previously [5]. Given the similar magnitude of the associations between a high quality diet and chronic disease incidence and mortality in both sexes [20, 31], the large differences in VAT and the VAT/SAT ratio between men and women are probably due to an underlying biologic mechanism, most likely genetic variation, that leads to differential fat accumulation.

In conclusion, the associations of the HEI-2010 with adiposity were comparable by sex except for the stronger inverse association with high VAT in women. A high diet quality over a 20-year period appeared to have a stronger influence in women than among men. The question of whether these findings are due to true biologic differences or a lack of ability to

assess diet quality equally well in men as among women needs to be investigated in future studies.

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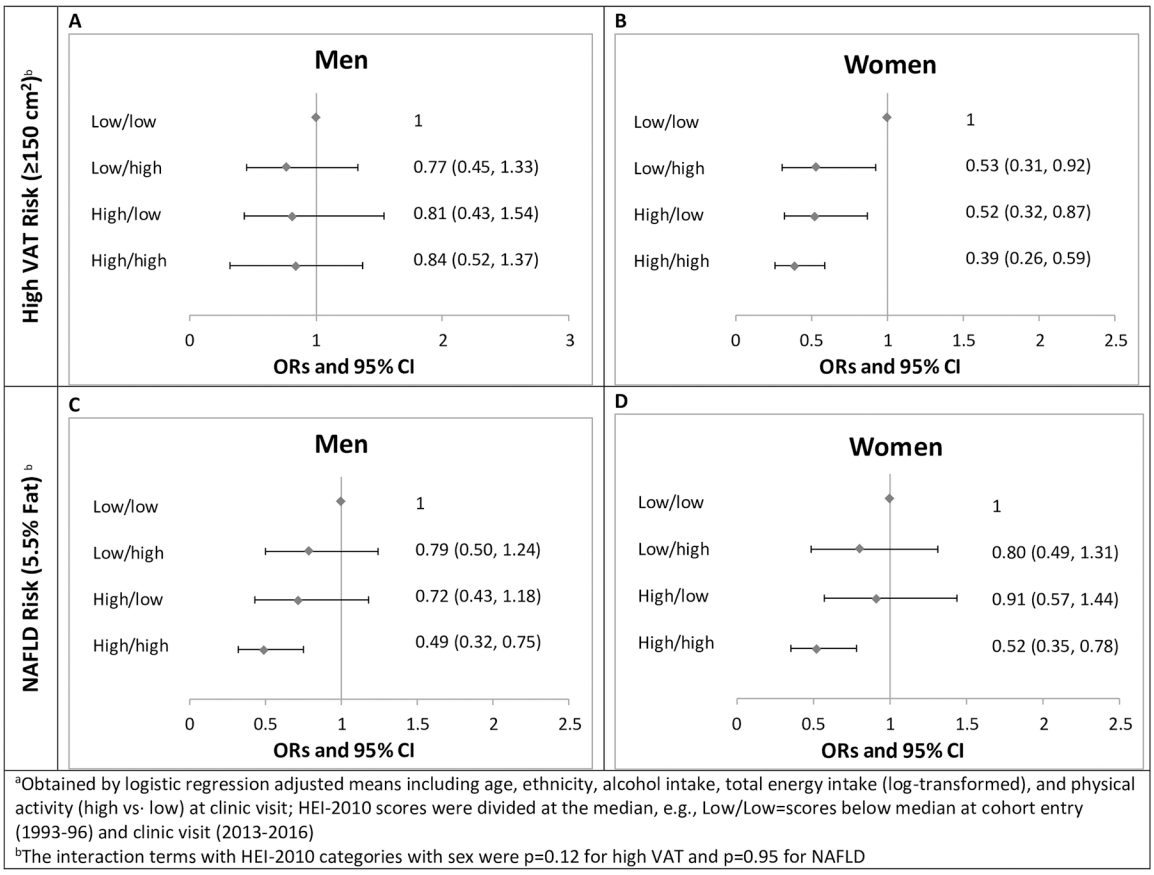

[a]Obtained by logistic regression adjusted means including age, ethnicity, alcohol intake, total energy intake (log-transformed), and physical activity (high vs· low) at clinic visit; HEI-2010 scores were divided at the median, e.g., Low/Low=scores below median at cohort entry (1993-96) and clinic visit (2013-2016)

[b]The interaction terms with HEI-2010 categories with sex were p=0.12 for high VAT and p=0.95 for NAFLD

Figure 1.

Association of Diet Quality at Cohort Entry (1993–96) and Clinic Visit (2013–2016) with High VAT and NAFLD by Sex[a]

Table 1.

Study Population by Sex at Cohort Entry (1993–96) and Clinic Visit (2013–2016)[a]

Characteristic[b]		All	Men	Women
Number		1861	923	938
Ethnicity	White	411 (22)	214 (23)	197 (21)
	African American	317 (17)	133 (14)	184 (20)
	Native Hawaiian	307 (17)	145 (16)	162 (17)
	Japanese American	434 (23)	230 (25)	204 (22)
	Latino	392 (21)	201 (22)	191 (20)
Age, yrs	Cohort entry	48.3±2.5	48.5±2.6	48.2±2.5
	Clinic visit	69.2±2.7	69.3±2.8	69.1±2.7
BMI, kg/m^2	Cohort entry	26.1±4.2	26.4±3.7	25.7±4.6
	Clinic visit	28.0±4.8	27.9±4.4	28.1±5.2
Physical activity, METs	Cohort entry	1.6±0.3	1.6±0.3	1.6±0.3
	Clinic visit	1.6±0.3	1.7±0.3	1.6±0.3
Alcohol intake, drinks/day	Cohort entry	0.7±1.4	1.0±1.8	0.4±0.8
	Clinic visit	0.7±1.6	1.0±1.9	0.4±1.0
Total energy,	Cohort entry	2224±1028	2484.8±1069	2062.2±982
Kcal	Clinic visit	1883±946	20354±968	1729.6±899
HEI-2010	Cohort entry	65.7±10.6	64.0±10.6	67.4±10.5
	Clinic Visit	72.7±9.6	71.0±11.0	73.6±10.0
	Change	6.6±10.5	7.2±10.9	6.1±10.1
HEI-2010 over time[c]	Low/Low	616	359	257
	Low/High	292	158	134
	High/Low	297	138	159
	High/High	622	253	369
Body composition	Clinic Visit (only)			
Total body fat, kg		25.5±8.7	23.1±7.7	27.8±8.9
Trunk fat, kg		13.5±4.8	12.9±4.7	14.1±4.8
VAT area (L1–L5 mean), cm^2		168±84	202±90	135±62
VAT/SAT ratio		0.8±0.5	1.1±0.5	0.5±0.2
Percent liver fat, %		5.7±4.6	5.6±4.4	5.7±4.8
High VAT (≥150 cm^2), %		52.9	70.0	36.4
Nonalcoholic liver disease (>5.5%), %		33.4	33.6	33.1

[a] Means ± standard deviations or numbers (%) are shown

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

[c] HEI-2010 scores were divided at the median, i.e., Low/Low=scores below median at cohort entry (1993–96) and clinic visit (2013–2016); Low/High=scores below median at cohort entry and above median at clinic visit; High/Low=scores above median at cohort entry and below median at clinic visit; High/High=scores above median at cohort entry and clinic visit.

Table 2.

Mean Adiposity Measures by Tertiles of Diet Quality at Cohort Entry (1993–1996) & Clinic Visit (2013–2016) Stratified by Sex[a]

	Cohort Entry								Clinic Visit							
Adiposity measure	**T**	**N[b]**	**Men**		**N[b]**	**Women**		**P[e]**	**T**	**N[b]**	**Men**		**N[b]**	**Women**		**P[e]**
			Mean	**95% CL**		**Mean**	**95% CL**				**Mean**	**95% CL**		**Mean**	**95% CL**	
Body mass index, kg/m^2	31–61	369	28.2	27.7, 28.6	251	29.0	28.4, 29.6	0.10	35–68	348	28.7	28.3, 29.2	261	29.2	28.6, 29.8	0.01
	61–71	311	27.8	27.3, 28.3	310	28.1	27.5, 28.6		68–78	290	27.7	27.2, 28.2	319	28.7	28.1, 29.2	
	71–92	243	27.4	26.9, 28.0	377	27.4	26.8, 27.9		78–99	270	26.9	26.4, 27.4	339	26.7	26.2, 27.2	
β (P-value)			−0.023 (0.11)			−0.063 (0.0001)					−0.063 (<0.0001)			−0.113 (<0.0001)		
Total body fat, kg	31–61	365	23.7	22.9, 24.4	247	28.7	27.7, 29.7	0.57	35–68	344	24.6	23.9, 25.4	257	29.4	28.5, 30.4	0.11
	61–71	309	23.1	22.3, 23.9	307	27.9	27.0, 28.8		68–78	285	22.6	21.8, 23.4	316	286	27.8, 29.4	
	71–92	237	22.3	21.4, 23.2	375	26.9	26.1, 27.7		78–99	267	21.6	20.8, 22.4	337	25.7	24.9, 26.5	
β (P-value)			−0.039 (0.09)			−0.072 (0.005)					−0.111 (<0.0001)			−0.166 (<0.0001)		
Trunk fat[c], kg	31–61	361	13.0	12.9, 13.1	239	14.3	14.1, 14.5	0.50	35–68	341	13.0	12.8, 13.1	248	14.3	14.1, 14.5	0.99
	61–71	306	12.8	12.7, 13.0	301	14.2	14.0, 14.4		68–78	282	12.8	12.7, 13.0	308	14.2	14.0, 14.4	
	71–92	224	12.7	12.5, 12.9	364	13.9	13.7, 14.1		78–99	254	12.7	12.6, 12.9	330	14.0	13.8, 14.1	
β (P-value)			−0.007 (0.07)			−0.015 (0.005)					−0.008 (0.08)			−0.020 (0.0003)		
VAT (L1–L5 mean)[c], cm^2	31–61	358	206	199, 212	245	145	139, 151	0.60	35–68	329	206	198, 212	254	144	138, 149	0.28
	61–71	297	205	197, 212	304	136	131, 141		68–78	286	206	199, 213	312	140	135, 145	
	71–92	231	192	184, 200	366	126	122, 131		78–99	256	193	186, 201	330	123	118, 128	
β (P-value)			−0.415 (0.04)			−0.654 (<0.0001)					−0.468 (0.02)			−0.889 (<0.0001)		
VAT/SAT ratio[c]	31–61	358	1.14	1.09, 1.19	245	0.59	0.57, 0.62	0.95	35–68	329	1.13	1.08, 1.18	254	0.59	0.56, 0.62	0.78
	61–71	297	1.12	1.07, 1.18	304	0.55	0.52, 0.57		68–78	286	1.15	1.10, 1.20	312	0.57	0.54, 0.59	
	71–92	231	1.05	0.98, 1.11	366	0.50	0.48, 0.53		78–99	256	1.04	0.99, 1.10	330	0.49	0.46, 0.51	
β (P-value)			−0.003 (0.09)			−0.003 (<0.0001)					−0.003 (0.03)			−0.004 (<0.0001)		
Percent liver fat[c,d], %	31–61	354	6.13	5.70, 6.56	246	6.62	6.03, 7.20	0.61	35–68	326	6.12	5.67, 6.57	256	6.70	6.14, 7.25	0.74
	61–71	296	5.46	4.99, 5.93	303	5.69	5.17, 6.20		68–78	282	5.79	5.32, 6.27	308	6.14	5.64, 6.64	
	71–92	230	5.11	4.58, 5.65	361	5.22	4.74, 5.70		78–99	257	4.88	4.38, 5.38	327	4.67	4.18, 5.17	
β (P-value)			−0.047 (0.0005)			−0.052 (0.0006)					−0.054 (<0.0001)			−0.069 (<0.0001)		

[a]General linear models were used to obtain means adjusted for age, ethnicity, alcohol intake, total energy intake (log-transformed), and physical activity at clinic visit

[b] Missing values: 57 for diet at cohort entry (1993–96), 36 for diet at clinic visit, 21 for DXA, 60 for MRI (2013–2016)

[c] Adjusted for total body fat at clinic visit

[d] Liver fat was log-transformed

[e] Obtained from interaction terms between sex and continuous HEI-2010 score.