

The Intersection of Diet Quality and Ultraprocessed Food Intake: Using Evidence-Based Categories to Characterize Differences in Cardiometabolic Profiles

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Objectives. To examine how ultraprocessed food (UPF) consumption and diet quality jointly relate to cardiometabolic health.

Methods. This serial cross-sectional study used data from 15 760 US adults (aged ≥ 20 years) in the 2009–2018 National Health and Nutrition Examination Surveys. Participants completed two 24-hour recalls and did not have a chronic disease. Diet quality was categorized using Healthy Eating Index–2020 (HEI) scores as high (70 to 100), moderate (60 to < 70), low (50 to < 60), and very low (0 to < 50). UPF consumption, determined by Nova classification, was categorized as high ($\geq 40\%$ energy intake) and low ($< 40\%$ energy intake). Joint HEI–UPF categories combined these variables. We examined unadjusted and adjusted associations between joint HEI–UPF category and anthropometric and cardiometabolic biomarkers.

Results. Among US adults, only 0.3% had high HEI–low UPF consumption, while 45.3% had very low HEI–high UPF consumption. Those with very low HEI–high UPF intake had the least favorable metabolic profiles, including the highest mean body mass index (29.6, defined as weight in kilograms divided by the square of height in meters) and fasting glucose (106.2 milligrams per deciliter).

Conclusions. Diet quality was more consistently associated with cardiometabolic health than UPF intake.

Public Health Implications. Overall diet quality is a strong predictor of cardiometabolic health, even with varying UPF consumption. (*Am J Public Health*. 2026;116(7):993–1003. <https://doi.org/10.2105/AJPH.2026.308494>)

Poor diet quality is a risk factor for chronic diseases, including obesity, diabetes, cardiovascular disease, stroke, and some cancers.^{1–3} Diet quality is often measured with nutrient and food-based indices, such as the Healthy Eating Index (HEI), which assesses how well consumption aligns

with the *Dietary Guidelines for Americans*. The average HEI–2020 score for adults is 58 out of 100, reflecting suboptimal adherence to dietary recommendations.⁴ Low-quality diets are driven by low intake of fruits, vegetables, whole grains, seafood, and plant proteins and high intake of refined grains and foods

high in saturated fat, added sugar, and sodium. This dietary pattern is associated with an increased likelihood of adiposity, insulin resistance, and adverse lipid profiles, which contribute to chronic disease risk.^{1–3}

There is growing evidence of the negative health impacts of ultraprocessed

foods (UPFs), defined as “formulations of industrial food ingredients that are created from industrial processes, including added colors, flavors, and other additives.”^{5(p937)} UPFs account for more than half of the daily energy intake of children and adults in the United States.⁶ Higher UPF consumption is associated with obesity, hypertension, dyslipidemia, and type 2 diabetes.^{7–9} Several mechanisms between UPF consumption and poor health outcomes have been proposed, including UPFs poorer nutrient profile, higher glycemic load, displacement of whole foods, and hyperpalatable taste that increases consumption, as well as the effects of processing on satiety, gut microbiota, and metabolic regulation.^{10,11}

This study used nationally representative data from the National Health and Nutrition Examination Survey (NHANES) to evaluate the combined associations of diet quality and UPF consumption with cardiometabolic health outcomes. Our objective was to examine differences in anthropometric measures, lipid profiles, and glycemic outcomes by joint HEI–2020 score and UPF consumption.

METHODS

We conducted our analyses using data from the 2009–2018 NHANES. NHANES is an ongoing multistage, nationally representative survey conducted by the National Center for Health Statistics. NHANES data were limited to 2009 to 2018 because Nova classification codes for more recent cycles were not available to the research team at the time of analysis. Adults with preexisting congestive heart failure, angina or angina pectoris, heart attack, stroke, liver

condition, diabetes, and cancer were excluded. The analytic sample included 15 760 adults aged 20 years or older with 2 valid 24-hour recalls. There were 8487 participants in the fasting sample. Data collection was approved by the National Center for Health Statistics ethics review board, and all participants provided written consent.

Dietary Assessment and Healthy Eating Index–2020

Dietary intake was assessed via two 24-hour dietary recalls administered by trained interviewers using the US Department of Agriculture Automated Multi-Pass Method.¹² One 24-hour recall is collected in person, and a second recall is completed by telephone 3 to 10 days later. Methods and validation studies for conducting 24-hour recalls have been previously published.¹³ Data from the two 24-hour recalls were converted into standard food groups and food pattern components using the Food Patterns Equivalents Database to calculate individual HEI–2020 scores.

Participants' HEI–2020 scores per day were first calculated using the simple HEI scoring algorithm method. Then, we used the National Cancer Institute (NCI) SAS Macros (version 2.1) to estimate usual intake to account for the within-person variability of dietary intake and to estimate predicted HEI scores (i.e., usual HEI).¹⁴ Specifically, we used the MIXTRAN macro to generate parameter estimates for dietary intake accounting for all sociodemographic covariates (as described subsequently), and we used the INDIVINT macro to predict individual intakes using the previously generated parameter estimates. More information about this method

can be found here: https://epi.grants.cancer.gov/diet/usualintakes/macros_single.html.

Healthy Eating Index–2020 Categories

The determination of the cut points used to define HEI–2020 categories was informed on multiple criteria. First, we considered NCI's suggested HEI cut-points and corresponding grade.¹⁵ Because less than 1% of the population had an HEI score of 80 or above, corresponding to an A or B grade, we comprehensively reviewed previous findings from prospective observational studies that examined HEI scores in relation to major chronic disease outcomes (Table A, available as a supplement to the online version of this article at <https://ajph.org>).² Most studies derived population-specific quintiles of HEI scores as the exposure, and individuals in the highest HEI quintile consistently had lower risks of cardiovascular disease, cancer, type 2 diabetes, and all-cause mortality compared with individuals in the lowest quintile.² Finally, we examined the distributions of HEI scores in NHANES to understand the extent to which US adults aligned with the cut points in the studies in Table A. Collectively, this evidence informed the following category definitions: high HEI score (70 to 100), moderate HEI score (60 to < 70), low HEI score (50 to < 60), and very low HEI score (0 to < 50). High HEI score indicates a higher adherence to the DGA and where the greatest risk reduction of morbidity and mortality from diet-related chronic diseases has been observed.^{2,16} In contrast, very low HEI score indicates lower adherence to the DGA and is associated with the highest risks of morbidity and mortality

from diet-related chronic diseases.^{2,16} Moderate and low HEI scores are intermediate risk levels.

Ultraprocessed Food Intake

The Nova classification has 4 categories: unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and ultraprocessed foods.⁵ We used an established methodology and data set to code foods by Nova category that is supported by the NCI.^{17,18} Briefly, NHANES 24-hour diet recalls were linked to the Food and Nutrient Database for Dietary Studies, where each food was mapped to its underlying food code and standard reference codes. For mixed dishes and home-made foods, Food and Nutrient Database for Dietary Studies recipe files were used to decompose items into their standard reference components, which were individually classified into the corresponding Nova category. Food codes were broken into their component standard reference codes, which were classified according to Nova and used to derive daily intake for each Nova category.¹⁷ In this analysis, we focused on Nova category 4, ultraprocessed foods, because groups 2 (culinary ingredients) and 3 (processed foods) are a much lower percentage of total energy intake, and UPFs are of greater health concern.¹⁹ Similar to the approach for HEI-2020 scores, we used the NCI MIXTRAN and INDIVINT SAS macros to estimate usual UPF intake as a percentage of total energy (% kilocalories [kcal]) from UPFs, consistent with methods used in other NHANES studies of UPF and health outcomes.^{20,21} UPF food consumption was then dichotomized as follows: high UPF consumption was defined as

40% or more of total energy intake (% kcal), and low UPF consumption as less than 40% of total energy intake (% kcal). This cut point was selected because it corresponds to the top quartile of UPF consumption that has been previously associated with poor health outcomes in this sample.^{21,22}

Joint Diet and Food Processing Categories

We combined the 4-category usual HEI-2020 variable and the 2-category usual UPF intake variable to create an 8-level categorical variable representing all combinations of usual HEI score and usual UPF consumption, where high HEI score (70 to 100), moderate HEI score (60 to < 70), low HEI score (50 to < 60), and very low HEI score (0 to < 50) and high UPF consumption was 40% or more of total energy intake and low UPF consumption was less than 40% of total energy intake. This variable is referred to as the joint HEI-UPF category. The reference group is very low HEI-high UPF.

Cardiometabolic Health Outcomes

Height, weight, and waist circumference were measured by trained personnel in the Mobile Examination Center.²³ Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Obesity was defined as a BMI greater than or equal to $30 \text{ kg}/\text{m}^2$.²⁴ High waist circumference was defined as greater than 88 centimeters for females and greater than 102 centimeters for males.²⁴

Other biomarker outcomes include blood levels of total cholesterol (milligrams per deciliter [mg/dL]), high-density

lipoprotein cholesterol (HDL; mg/dL), fasting low-density lipoprotein cholesterol (LDL; mg/dL), fasting triglycerides (mg/dL), hemoglobin A1c (HbA1c), and fasting glucose (mg/dL). Low HDL cholesterol was defined as less than 40 mg/dL and elevated LDL cholesterol was defined as greater than or equal to 100 mg/dL.²⁵ Elevated triglycerides were defined as greater than or equal to 150 mg/dL.²⁶ Elevated HbA1c was defined as greater than or equal to 5.7%, and elevated fasting glucose was defined as greater than 100 mg/dL.²⁷ Blood samples were collected by NHANES medical personnel following standardized phlebotomy protocols and analyzed at the National Center for Environmental Health laboratories.

Sociodemographic Characteristics

We included characteristics associated with diet quality and UPF consumption in previous research as covariates.^{21,22,28} Sociodemographic variables were ascertained at the NHANES interview, including self-reported age, gender, race and ethnicity, place of birth, educational attainment, employment status, marital status, family income to poverty ratio, and food security status. We derived household food security status by using the 18-item US Food Security Survey Module.

Statistical Analysis

We performed all statistical analyses with SAS version 9.4 (SAS Institute Inc, Cary, NC). Per NHANES guidelines, we recalculated complex dietary (WTDR2D) and fasting subsample (WTSF2YR) sampling weights by dividing by 5 to reflect the probability of being sampled across the 10-year period. In SAS, we

used SURVEYMEANS, SURVEYFREQ, SURVEYREG, and SURVEYLOGISTIC procedures with strata (SDMVSTRA), cluster (SDMVPSU), and weight statements to account for the complex sampling scheme and to make nationally representative inferences. We applied dietary weights to all analyses, with the exception of analyses involving LDL cholesterol, triglycerides, and fasting glucose, which used the fasting subsample weights because the fasting subsample has a smaller number of respondents than the dietary subsample.

We evaluated survey-weighted differences in sociodemographic characteristics by joint HEI–UPF categories using the Rao–Scott χ -square test. Next, we estimated unadjusted means and proportions of cardiometabolic characteristics by joint HEI–UPF categories. Then, we used survey-weighted multivariable linear and logistic regression models to examine differences in cardiometabolic outcomes by joint HEI–UPF categories, with the reference category of very low HEI–high UPF. These models adjusted for all sociodemographic characteristics and usual total energy intake (following the same approach as HEI–2020 scores and UPF intake). We report least squared

means (for continuous outcomes) and predicted probabilities (for categorical outcomes) of the 8 HEI–UPF categories. We used pairwise differences to evaluate differences within HEI category and by UPF consumption category.

RESULTS

Among US adults, 46.0% had a very low usual HEI score (< 50), 40.6% had a low usual HEI score (50 to < 60), 12.6% had a moderate usual HEI score (60 to < 70), and 0.8% had a high usual HEI score (≥ 70). High usual UPF consumption ($\geq 40\%$ kcal) was observed among 93.7% of US adults, and 6.3% had low usual UPF consumption ($< 40\%$ kcal). When examining joint HEI–high UPF categories, 45.3% of US adults had very low HEI–high UPF consumption, 37.5% had low HEI–high UPF consumption, 10.3% had moderate HEI–high UPF consumption, and 0.6% had high HEI–high UPF consumption (Figure 1). When examining joint HEI–low UPF consumption, 0.7% US adults had very low HEI–low UPF consumption, 3.1% had low HEI–low UPF, 2.3% had moderate HEI–low UPF, and 0.3% had high HEI–low UPF.

There were significant differences in joint HEI–UPF categories by all sociodemographic characteristics except employment status (Table 1, P linear trend $< .01$). Very low HEI–high UPF consumption was more prevalent among individuals who were younger, male, non-Hispanic Black, born in the United States, high-school educated or less, single, lower income, and food insecure.

Unadjusted Differences vs Reference Group

In unadjusted analyses (Table 2), there were consistent differences in anthropometric measures across joint HEI–UPF categories. The reference group, very low HEI–high UPF consumption, had the highest mean BMI (29.6 kg/m^2), percentage with obesity (41.6%), mean waist circumference (100.0 cm), and percentage with high waist circumference (55.4%) compared with the other joint HEI–UPF categories. There were inconsistent patterns for cardiometabolic biomarkers. HDL cholesterol tended to be higher among categories with higher HEI scores. Unadjusted means for total cholesterol and LDL cholesterol were higher

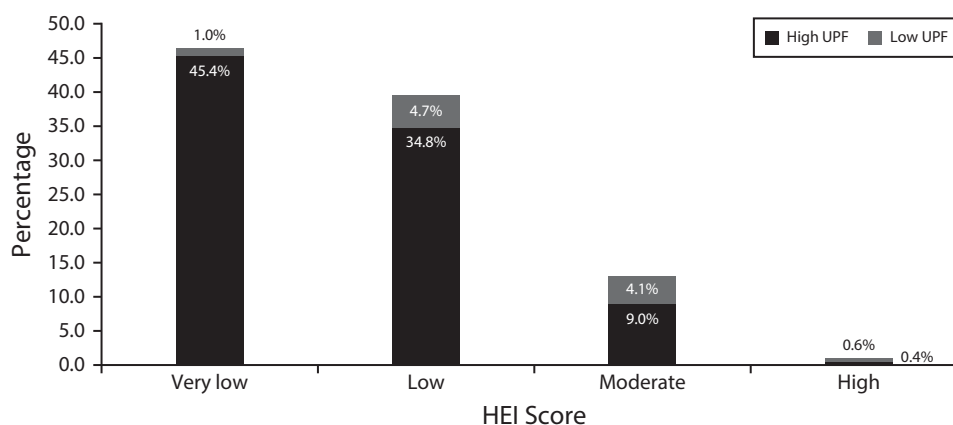


FIGURE 1— Proportion of High Versus Low Ultraprocessed Food (UPF) Consumption by Healthy Eating Index (HEI) Score Category: United States, National Health and Nutrition Examination Survey, 2009–2018

TABLE 1— Sociodemographic Characteristics of US Adults (Aged ≥20 Years) Stratified by Joint Healthy Eating Index (HEI) Score Categories and Ultraprocessed Food (UPF) Consumption Using Usual Intake: National Health and Nutrition Examination Survey, 2009–2018

	Overall	Very Low HEI (<50)		Low HEI (50 to <60)		Moderate HEI (60 to <70)		High HEI (≥70)		P
		High UPF, No. (Weighted %) (n = 7152 [45.3])	Low UPF, No. (Weighted %) (n = 165 [0.7])	High UPF, No. (Weighted %) (n = 5483 [37.5])	Low UPF, No. (Weighted %) (n = 747 [3.1])	High UPF, No. (Weighted %) (n = 1422 [10.3])	Low UPF, No. (Weighted %) (n = 639 [2.3])	High UPF, No. (Weighted %) (n = 64 [0.6])	Low UPF, No. (Weighted %) (n = 88 [0.3%])	
Age, y										<.001
≤30	3 752 (26.1)	2 337 (61.6)	42 (0.8)	1 024 (29.1)	116 (2.3)	171 (5.1)	59 (1.0)	1 (0.04)	2 (0.03)	
31–50	6 319 (40.7)	2 988 (45.9)	68 (0.8)	2 206 (38.1)	304 (3.4)	496 (9.3)	216 (2.0)	19 (0.3)	22 (0.2)	
≥51	5 689 (33.3)	1 827 (31.8)	55 (0.4)	2 253 (43.4)	327 (3.3)	755 (15.5)	364 (3.8)	44 (1.2)	64 (0.6)	
Gender										<.001
Male	7 288 (47.8)	3 831 (53.0)	104 (0.8)	2 246 (33.4)	347 (2.9)	475 (7.7)	239 (1.7)	16 (0.3)	30 (0.2)	
Female	8 472 (52.2)	3 321 (38.2)	61 (0.5)	3 237 (41.3)	400 (3.2)	947 (12.6)	400 (3.0)	48 (0.8)	58 (0.3)	
Race and ethnicity										<.001
Hispanic	3 931 (15.6)	1 613 (46.4)	38 (0.6)	1 514 (37.5)	245 (5.1)	313 (6.5)	176 (3.0)	9 (0.4)	23 (0.5)	
Non-Hispanic Black	3 459 (11.6)	2 016 (61.6)	20 (0.6)	1 056 (28.8)	85 (2.6)	205 (4.8)	56 (1.2)	10 (0.2)	11 (0.2)	
Non-Hispanic White	6 186 (63.8)	2 992 (44.4)	18 (0.2)	2 335 (40.8)	57 (1.0)	689 (12.1)	56 (0.9)	32 (0.7)	7 (0.04)	
Other ^a	2 184 (9.0)	531 (28.9)	89 (3.9)	578 (26.1)	360 (15.1)	215 (11.1)	351 (13.0)	13 (0.4)	47 (1.6)	
Birthplace										<.001
United States	11 538 (82.7)	6 303 (50.0)	30 (0.2)	4 040 (37.9)	76 (0.7)	984 (10.1)	54 (0.5)	42 (0.6)	9 (0.02)	
Outside of the United States	4 222 (17.3)	849 (22.8)	135 (2.8)	1 443 (35.6)	671 (14.5)	438 (10.9)	585 (11.3)	22 (0.6)	79 (1.5)	
Educational attainment										<.001
High school education or less	6 567 (35.3)	3 866 (62.8)	78 (0.8)	1 877 (27.7)	271 (2.7)	300 (4.5)	158 (1.4)	4 (0.1)	13 (0.1)	
Any college or college graduate	9 193 (64.7)	3 286 (35.8)	87 (0.6)	3 606 (42.9)	476 (3.3)	1 122 (13.4)	481 (2.9)	60 (0.8)	75 (0.4)	
Employment status										.61
Employed	10 054 (68.8)	4 581 (45.5)	108 (0.7)	3 499 (37.7)	488 (3.0)	906 (10.3)	386 (2.2)	34 (0.5)	52 (0.2)	
Not employed	5 706 (31.2)	2 571 (45.0)	57 (0.6)	1 984 (37.2)	259 (3.2)	516 (10.2)	253 (2.6)	30 (0.7)	36 (0.3)	
Marital status										<.001
Married or living with partner	9 460 (62.8)	3 862 (40.9)	97 (0.6)	3 411 (39.5)	557 (3.5)	937 (11.6)	477 (2.8)	47 (0.7)	72 (0.4)	
Single	6 300 (37.2)	3 290 (52.7)	68 (0.7)	2 072 (34.2)	190 (2.2)	485 (8.1)	162 (1.7)	17 (0.3)	16 (0.1)	

Continued

TABLE 1— Continued

	Very Low HEI (<50)		Low HEI (50 to <60)		Moderate HEI (60 to <70)		High HEI (≥70)		P
	High UPF, No. (Weighted %) (n = 7152 [45.3])	Low UPF, No. (Weighted %) (n = 165 [0.7])	High UPF, No. (Weighted %) (n = 5483 [37.5])	Low UPF, No. (Weighted %) (n = 747 [3.1])	High UPF, No. (Weighted %) (n = 1422 [10.3])	Low UPF, No. (Weighted %) (n = 639 [2.3])	High UPF, No. (Weighted %) (n = 64 [0.6])	Low UPF, No. (Weighted %) (n = 88 [0.3])	
Overall									<.001
Household income ^b									
≤200% federal poverty level	6740 (32.2)	84 (1.1)	2001 (29.4)	275 (3.3)	347 (5.2)	172 (1.5)	11 (0.2)	15 (0.1)	
>200% federal poverty level	9020 (67.8)	81 (0.4)	3482 (41.4)	472 (3.0)	1075 (12.7)	467 (2.8)	53 (0.7)	73 (0.3)	
Household food security ^c									NA
High or marginal food security	12488 (84.5)	121 (0.6)	4634 (39.9)	632 (3.2)	1309 (11.6)	581 (2.6)	64 (0.7)	82 (0.3)	
Low or very low food security	3272 (15.5)	44 (1.1)	849 (24.5)	115 (2.2)	113 (3.1)	58 (0.9)	0	6 (0.1)	

Note: High UPF ≥ 40% kcal; low UPF < 40% kcal; NA = not available.

^aOther included American Indian or Alaskan Native, Asian, Native Hawaiian or Pacific Islander, and other.

^bAs defined by the US Department of Health and Human Services.

^cHousehold food security assessed using the US Household Food Security Survey Module.

among categories with higher HEI scores. There were no differences in fasting glucose levels compared with the reference category.

Unadjusted Differences Within Diet Categories

Within each HEI category, there were few differences in unadjusted anthropometric and cardiometabolic markers between low and high UPF consumption. Among participants with low and very low HEI scores, those with low UPF consumption had lower mean BMI, obesity prevalence, mean waist circumference, and prevalence of high waist circumference. In the low HEI group, mean HDL cholesterol was lower in the low UPF group (54.6 mg/dL) compared with the high UPF group (56.3 mg/dL). In the moderate HEI category, fasting glucose was higher for the low UPF consumption (100.7 mg/dL vs 98.3 mg/dL), while in the high HEI category, low UPF was associated with lower HDL (57.6 mg/dL vs 74.1 mg/dL) and higher triglyceride levels (126.5 mg/dL vs 82.8 mg/dL) compared with the high UPF group.

Adjusted Differences vs Reference Group

After we adjusted for sociodemographic covariates, there were consistent differences in anthropometric measures between the very low HEI–high UPF and the other joint HEI–UPF categories (Table 3). The very low HEI–high UPF category had a mean BMI of 29.6 kg/m² compared with 23.8 kg/m² in the high HEI–high UPF category ($P < .001$). Obesity prevalence was lower in all categories compared with the reference category, where 40.9% had obesity, compared with 7.4% in the high HEI–high UPF category ($P = .004$). Only

TABLE 2— Unadjusted Anthropometric and Cardiometabolic Markers Stratified by Joint Healthy Eating Index (HEI)–Ultraprocessed Food (UPF) Category: United States, National Health and Nutrition Examination Survey, 2009–2018

	Very Low HEI (<50)		Low HEI (50 to <60)		Moderate HEI (60 to <70)		High HEI (≥70)	
	High UPF	Low UPF	High UPF	Low UPF	High UPF	Low UPF	High UPF	Low UPF
BMI								
Mean (95% CI), kg/m ²	29.6 (29.4, 29.9)	27.1 (25.3, 28.8)	28.5 (28.2, 28.8)	26.6 (26.1, 27.2)	27.0 (26.6, 27.5)	26.4 (25.8, 27.0)	24.1 (22.1, 26.1)	25.7 (24.5, 26.8)
% with obesity (95% CI)	41.6 (39.8, 43.6)	26.6 (18.3, 37.0)	34.2 (23.1, 36.4)	24.7 (20.7, 29.1)	22.4 (19.6, 25.6)	23.1 (18.8, 28.0)	8.1 (2.1, 26.8)	16.0 (8.0, 29.4)
Waist circumference								
Mean (95% CI), cm	100.0 (99.4, 100.6)	93.6 (89.6, 97.7)	97.2 (96.5, 97.9)	92.1 (90.7, 93.4)	93.7 (92.5, 95.0)	91.4 (89.9, 92.9)	85.8 (81.1, 90.5)	91.1 (88.9, 93.3)
% with high waist circumference (95% CI)	55.4 (53.4, 57.4)	34.1 (24.9, 44.7)	54.6 (51.8, 57.5)	41.1 (35.6, 46.9)	47.8 (43.5, 52.1)	39.5 (34.4, 45.0)	27.6 (14.5, 46.3)	40.9 (53.4, 57.4)
Total cholesterol								
Mean (95% CI), mg/dL	192.0 (190.5, 193.6)	198.6 (185.5, 211.7)	197.2 (195.3, 199.1)	199.3 (193.7, 204.9)	199.0 (195.9, 202.1)	196.1 (191.9, 200.3)	202.9 (184.6, 221.2)	203.2 (193.0, 213.4)
% ≥200 mg/dL (95% CI)	38.6 (37.0, 40.4)	44.8 (34.1, 56.0)	44.0 (41.8, 46.2)	44.4 (38.7, 50.2)	46.4 (42.9, 50.0)	47.1 (39.7, 54.6)	49.5 (31.4, 67.7)	56.0 (41.7, 69.3)
HDL cholesterol								
Mean (95% CI), mg/dL	50.8 (50.2, 51.3)	52.6 (47.8, 57.5)	56.3 (55.6, 57.0)	54.6 (53.0, 56.2)	60.1 (58.8, 61.4)	58.5 (56.4, 60.5)	74.1 (61.9, 86.3)	57.6 (51.7, 63.5)
% <40 mg/dL (95% CI)	22.0 (20.5, 23.5)	19.7 (12.3, 29.9)	13.3 (12.0, 14.7)	14.9 (11.5, 19.1)	9.5 (7.3, 12.3)	12.8 (9.2, 17.6)	5.2 (0.7, 29.5)	10.9 (4.8, 22.9)
LDL cholesterol								
Mean (95% CI), mg/dL	114.4 (112.9, 115.8)	120.6 (111.1, 130.1)	116.5 (114.5, 118.1)	122.2 (117.1, 127.3)	115.6 (111.7, 119.6)	120.8 (116.8, 124.8)	112.1 (95.3, 128.9)	120.7 (106.6, 134.8)
% ≥100 mg/dL (95% CI)	64.1 (61.8, 66.3)	61.7 (47.8, 73.9)	68.2 (65.8, 70.6)	68.0 (61.7, 73.7)	66.5 (61.5, 71.0)	72.8 (67.0, 77.9)	58.6 (35.0, 78.8)	72.9 (53.2, 86.5)
Triglycerides								
Mean (95% CI), mg/dL	117.6 (113.5, 121.7)	160.8 (111.1, 210.4)	114.1 (109.2, 119.1)	116.1 (106.0, 126.1)	104.7 (97.5, 112.0)	102.9 (90.6, 115.2)	82.8 (72.0, 93.6)	126.5 (102.3, 150.6)
% ≥150 mg/dL (95% CI)	21.8 (20.0, 23.7)	27.2 (17.5, 39.6)	20.2 (18.0, 22.6)	24.0 (19.0, 29.9)	16.3 (13.0, 20.3)	14.0 (9.5, 20.0)	1.9 (0.2, 13.1)	30.2 (17.9, 46.2)
Hemoglobin A1c								
Mean (95% CI), %	5.42 (5.40, 5.44)	5.44 (5.24, 5.64)	5.43 (5.40, 5.46)	5.48 (5.42, 5.54)	5.41 (5.38, 5.45)	5.59 (5.52, 5.65)	5.40 (5.26, 5.53)	5.61 (5.53, 5.69)
% ≥5.7% (95% CI)	23.8 (22.2, 25.4)	23.6 (17.2, 31.5)	23.8 (22.1, 25.7)	26.5 (21.9, 31.8)	21.9 (18.5, 25.8)	35.0 (30.0, 40.4)	26.7 (14.4, 43.7)	39.2 (27.1, 52.8)
Fasting glucose								
Mean (95% CI), mg/dL	100.5 (99.8, 101.2)	102.0 (99.8, 101.2)	100.4 (99.6, 101.2)	102.1 (100.3, 103.9)	98.3 (97.0, 99.6)	100.7 (98.9, 102.4)	95.6 (92.3, 98.8)	102.6 (95.5, 109.7)
% >100 mg/dL (95% CI)	36.8 (33.0, 40.7)	50.5 (23.4, 77.3)	35.8 (32.0, 39.7)	30.9 (23.0, 40.0)	34.7 (27.6, 42.5)	42.5 (31.2, 54.7)	37.1 (20.1, 58.0)	57.6 (24.4, 85.1)

Note. BMI = body mass index (defined as weight in kilograms divided by the square of height in meters); CI = confidence interval; high UPF ≥40% kcal; low UPF <40% kcal.

TABLE 3— Multivariable-Adjusted Anthropometrics and Cardiometabolic Markers Stratified by Joint Healthy Eating Index (HEI)–Ultraprocessed Food (UPF) Category, United States, National Health and Nutrition Examination Survey, 2009–2018

	Very Low HEI (<50)		Low HEI (50 to <60)		Moderate HEI (60 to <70)		High HEI (≥70)	
	High UPF	Low UPF	High UPF	Low UPF	High UPF	Low UPF	High UPF	Low UPF
BMI								
Mean (95% CI), kg/m ²	29.6 (29.3, 29.8)	27.6 (25.7, 29.5) ^{a,b}	28.4 (28.1, 28.7) ^a	27.1 (26.5, 27.7) ^{a,b}	26.9 (26.5, 27.4) ^a	26.8 (26.0, 27.5) ^a	23.8 (21.8, 25.8) ^a	25.9 (24.6, 27.2) ^a
% with obesity (95% CI)	40.9 (38.9, 43.0)	29.9 (20.6, 41.3)	33.3 (31.2, 35.5) ^a	27.6 (23.0, 32.6) ^{a,b}	21.6 (18.7, 24.7) ^a	25.3 (20.2, 31.2) ^a	7.4 (1.8, 25.4) ^a	17.1 (8.3, 31.6) ^a
Waist circumference								
Mean (95% CI), cm	99.2 (98.6, 99.8)	95.3 (90.9, 99.6)	96.3 (95.5, 97.0) ^a	93.4 (91.9, 94.9) ^{a,b}	92.6 (91.4, 93.8) ^a	92.6 (90.8, 94.3) ^a	83.8 (78.8, 88.8) ^a	91.3 (88.8, 93.9) ^{a,b}
% with high waist circumference (95% CI)	58.3 (56.1, 60.4)	42.5 (30.4, 55.6) ^{a,b}	50.5 (47.5, 53.4) ^a	42.5 (36.8, 48.6) ^{a,b}	39.3 (34.9, 43.9) ^a	35.1 (29.1, 41.6) ^a	15.1 (6.6, 30.8) ^a	33.9 (22.3, 47.8) ^{a,b}
Total cholesterol								
Mean (95% CI), mg/dL	193.6 (192.1, 195.1)	198.8 (187.0, 210.7)	193.1 (191.4, 194.8)	194.3 (188.6, 199.9)	191.9 (189.0, 194.8)	187.4 (183.1, 191.6) ^a	190.6 (173.3, 207.9)	189.8, (180.4, 199.2)
% ≥ 200 mg/dL (95% CI)	39.3 (37.4, 41.3)	44.7 (34.4, 55.5)	38.7 (36.6, 40.8)	38.4 (32.2, 45.0)	37.9 (34.6, 41.2)	37.1 (30.1, 44.7)	35.6 (21.2, 53.2)	40.8 (27.4, 55.7)
HDL cholesterol								
Mean (95% CI), mg/dL	51.7 (51.1, 52.3)	55.6 (51.6, 59.6)	55.0 (54.4, 55.6) ^a	55.7 (54.0, 57.4) ^a	57.3 (56.1, 58.5) ^a	57.5 (55.3, 59.6) ^a	69.1 (57.5, 80.8) ^a	56.4 (50.7, 62.2)
% < 40 mg/dL (95% CI)	17.7 (16.2, 19.3)	13.3 (7.8, 21.8)	12.6 (11.3, 14.1) ^a	11.7 (8.7, 15.6) ^a	10.5 (8.0, 13.8) ^a	12.5 (8.4, 18.3)	7.6 (1.0, 40.2)	11.1 (4.4, 25.2)
LDL cholesterol								
Mean (95% CI), mg/dL	115.6 (114.1, 117.0)	117.9 (109.1, 126.6)	114.1 (112.4, 115.8)	117.5 (112.0, 123.1)	111.5 (107.8, 115.1)	114.4 (110.2, 118.6)	105.6 (88.4, 122.7)	110.4 (96.5, 124.3)
% ≥ 100 mg/dL (95% CI)	67.1 (64.7, 69.4)	57.4 (42.6, 70.9)	66.5 (63.8, 69.0)	61.9 (54.1, 69.1)	62.0 (56.9, 66.9)	65.0 (58.4, 71.0)	50.2 (27.2, 73.1)	58.8 (37.0, 77.8) ^b
Triglycerides								
Mean (95% CI), mg/dL	115.5 (111.4, 119.6)	154.2 (103.9, 204.4)	112.0 (107.7, 116.4)	111.4 (101.0, 121.9)	103.0 (95.9, 110.1) ^a	101.4 (88.9, 114.0) ^a	81.1 (66.4, 95.8) ^a	112.5 (96.8, 148.2)
% ≥ 150 mg/dL (95% CI)	19.8 (18.0, 21.8)	23.0 (13.4, 36.5)	18.3 (16.3, 20.5)	20.9 (16.3, 26.5)	14.9 (11.7, 18.7) ^a	12.6 (8.5, 18.3) ^a	1.7 (0.2, 11.7) ^a	27.2 (14.6, 45.1) ^b
Hemoglobin A1c								
Mean (95% CI), %	5.49 (5.47, 5.51)	5.36 (5.16, 5.57) ^a	5.45 (5.43, 5.48) ^a	5.36 (5.31, 5.42) ^{a,b}	5.40 (5.37, 5.43) ^a	5.41 (5.35, 5.47) ^a	5.31 (5.19, 5.43) ^a	5.33 (5.24, 5.43) ^a
% ≥ 5.7% (95% CI)	31.9 (29.8, 34.1)	19.1 (13.8, 25.8) ^{a,b}	27.8 (26.0, 29.7) ^a	17.2 (13.7, 21.4) ^{a,b}	24.0 (21.1, 27.2) ^a	25.0 (20.4, 30.4) ^a	20.9 (12.1, 33.6)	21.2 (13.5, 31.7)
Fasting glucose								
Mean (95% CI), mg/dL	106.2 (105.2, 107.2)	101.2 (97.8, 104.5) ^{a,b}	105.1 (103.8, 106.3)	101.5 (99.1, 103.8) ^{a,b}	99.8 (98.4, 101.3) ^a	103.3 (98.7, 107.9)	98.3 (91.1, 105.5) ^a	96.4 (89.3, 103.5) ^a
% > 100 mg/dL (95% CI)	36.6 (32.5, 40.9)	43.7 (17.2, 74.4)	33.6 (29.3, 38.3)	26.3 (17.2, 38.0)	29.0 (23.1, 35.7)	37.9 (27.1, 50.1)	31.5 (13.6, 57.4)	43.8 (12.1, 81.5)

Note. BMI = body mass index (defined as weight in kilograms divided by the square of height in meters); CI = confidence interval; high UPF ≥ 40% kcal; low UPF < 40% kcal. Values adjusted for age, sex, race and ethnicity, birthplace, educational attainment, employment status, marital status, household income, household food security, and usual total energy intake (kilocalories). Fasting sample n = 8487.

^aSignificantly different from the reference group, very low HEI-high UPF.

^bSignificantly different from high UPF group within the same HEI score category.

the moderate HEI–low UPF category had lower total cholesterol (187.4 mg/dL; $P = .01$) compared with the reference category (193.6 mg/dL). Mean HDL cholesterol was 51.7 mg/dL in the very low HEI–high UPF category compared with 69.1 mg/dL in the high HEI–high UPF category ($P < .001$). LDL cholesterol did not differ between categories. Mean triglycerides were lower for the moderate HEI–high UPF (103.0 mg/dL; $P = .005$), the moderate HEI–low UPF (101.4 mg/dL; $P = .04$), and the high HEI–high UPF (81.1 mg/dL; $P < .001$) categories compared with the reference (115.5 mg/dL). Mean HbA1c was lower in every joint HEI–UPF category compared with the reference, decreasing from 5.49% to 5.31% in the high HEI–high UPF category ($P = .02$). Most categories had lower mean fasting glucose than the reference, decreasing from 106.2 mg/dL in the very low HEI–high UPF category to 96.4 mg/dL in the high HEI–low UPF category ($P = .03$).

Adjusted Differences Within Diet Category

Within each HEI score category, differences in cardiometabolic measures by UPF intake were inconsistent. Among those with very low HEI scores, low UPF intake was associated with lower mean BMI (27.6 kg/m² vs 29.6 kg/m²; $P = .04$), lower prevalence of high waist circumference (42.5% vs 58.3%; $P = .02$), lower prevalence of high HbA1c (19.1% vs 31.9%; $P < .001$), and lower mean fasting glucose (101.2 mg/dL vs 106.2 mg/dL; $P = .004$) compared with the high UPF group. Within the low HEI score category, adults with low UPF consumption had more favorable values across all anthropometric measures, mean HbA1c (5.36% vs 5.45%),

prevalence of high HbA1c (17.2% vs 27.8%; $P = .005$), and fasting glucose (101.5 mg/dL vs 105.1 mg/dL; $P = .003$) compared with those with high UPF consumption. There were no differences in anthropometric and cardiometabolic measures by UPF consumption within the moderate HEI score category. In the high HEI category, the low UPF intake group had higher waist circumference (91.3 cm vs 83.8 cm; $P = .01$), prevalence of high waist circumference (33.9% vs 15.1%; $P = .04$), and prevalence of high triglycerides (27.2% vs 1.7%; $P = .006$).

Adjusted Differences in Food Processing Category

When separated by high and low UPF consumption, lower diet quality was associated with less favorable anthropometric and cardiometabolic markers and a higher prevalence of individuals with elevated values in both high and low UPF groups. Within the high UPF group, mean BMI was 29.6 kg/m² in the very low HEI category and 23.8 kg/m² in the high HEI category ($P < .001$). For those with low UPF consumption, BMI was 27.6 kg/m² in the very low HEI category and 25.9 kg/m² in the high HEI category ($P = .14$). Lipid profiles showed similar trends. Mean total cholesterol, LDL cholesterol, and triglycerides were higher, and HDL cholesterol was lower in the very low HEI score category compared with the high HEI category within both UPF groups. This finding continued for blood glucose levels. Within the high UPF group, the mean fasting glucose was 106.2 mg/dL for the very low HEI category compared with 98.3 mg/dL for the high HEI category ($P = .03$). Within the low UPF group, the mean fasting glucose was 101.2 mg/dL for the very low HEI category compared

with 96.4 mg/dL for the high HEI category ($P = .28$).

DISCUSSION

This nationally representative, descriptive 10-year study found that higher HEI–2020 scores, indicating greater adherence to 2020–2025 Dietary Guidelines for Americans, were associated with better cardiometabolic profiles regardless of UPF intake. These results highlight that overall diet quality remains strongly associated with cardiometabolic health, even in the context of varying UPF consumption.

Previous research has found that higher UPF consumption and lower diet quality are separately associated with poorer diet quality and greater risk of obesity, dyslipidemia, type 2 diabetes, and cardiovascular disease.^{2,7,8} However, most existing studies have examined these relationships separately. One prospective cohort study reported that high adherence to the Mediterranean diet combined with low UPF consumption was associated with lower all-cause, cardiovascular, and noncardiovascular, noncancer mortality compared with low adherence and high UPF intake.²⁹ This analysis extends these findings by assessing cardiometabolic biomarkers across joint HEI scores and UPF consumption in a nationally representative sample. This study finds that diet quality, as measured with the HEI–2020, was more consistently associated with anthropometric and cardiometabolic markers associated with chronic disease than UPF.

These findings may reflect the heterogeneity within the UPF category. UPFs include both nutrient-poor foods like sugar-sweetened beverages and processed meats and nutrient-dense foods, such as whole-grain breads and

yogurt.⁹ The Nova classification has been important in highlighting the impact of food processing on public health and is the most commonly used definition of UPFs. However, there is ongoing discussion on the best way to define and operationalize UPFs within the US food system because of the different products captured within it.^{30,31} Recent prospective cohort studies that have disaggregated UPFs by food group have found that adverse health effects are most consistently associated with a subset of UPFs including sugar-sweetened beverages and red and processed meats.^{9,32,33} This analysis did not look at food groups within UPFs, which may be why fewer relationships were observed. In addition, there is currently no agreed-upon threshold that defines high UPF consumption. This analysis identified high UPF consumption as greater than or equal to 40% of total energy intake from UPFs, which is consistent with the top quartile of consumption among NHANES participants.^{21,22,34} Future studies should consider higher or lower cut points, as well as further validating methods for estimating usual intake of UPFs.

Strengths and Limitations

Strengths of this study include our use of data from a large, nationally representative sample of US adults spanning recent years. Second, we identified the cut points for HEI categories through multiple sources of health outcome evidence and used validated methods to identify UPFs. Third, we leveraged the rich data sources available from NHANES, validated dietary recalls, physical measurements, and available biomarker data to examine concurrent implications of the HEI score categories

and UPF cut points at the individual level.

However, this study is limited by its cross-sectional nature; prospective follow-up is needed to capture changes in clinical outcomes over time. The 24-hour dietary recall is a validated approach but is subject to measurement error and recall bias; however, interviewer-assisted recalls can help reduce error. Diet recalls are not designed to assess food processing level, so applying the Nova classification may involve a degree of misclassification. We were unable to use the NCI HEI-2020 cut points because too few participants had a usual HEI-2020 score of 80 or higher. Excluding participants with one 24-hour recall and the categorization of HEI-2020 scores and UPF intake may have reduced statistical power. While we restricted our study population to people without a chronic disease diagnosis, we were not able to exclude people with undiagnosed or preclinical disease, and this may have attenuated some of the associations, particularly between the high versus low UPF groups.

Public Health Implications

These findings suggest that improving the overall diet quality, as measured by the HEI-2020, should remain a focus of public health efforts to prevent cardiometabolic disease. While reductions in UPFs may support this goal, eating nutrient-dense foods appears to have a stronger association with health markers. Public health recommendations and interventions should continue to promote fruits, vegetables, whole grains, seafood, and plant proteins and recommend limited intake of refined grains and foods high in saturated fat, added sugar, and sodium.

Continued research is needed to refine approaches to UPF classification. **AJPH**

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to report.

HUMAN PARTICIPANT PROTECTION

No protocol approval was necessary because this work did not involve human participants.

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