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Dietary Variety Is Inversely Associated with Body Adiposity among US Adults Using a Novel Food Diversity Index[1–3]

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Abstract

Background: Consuming a variety (vs. monotony) of energy-poor, nutrient-dense foods may help individuals adhere to dietary patterns favorably associated with weight control.

Objective: The objective of this study was to examine whether greater healthful food variety quantified using the US Healthy Food Diversity (HFD) index favorably influenced body adiposity.

Methods: Men and nonpregnant, nonlactating women aged ≥20 y with two 24-h recalls from the cross-sectional NHANES 2003–2006 (n = 7470) were included in this study. Dietary recalls were merged with the MyPyramid Equivalent database to generate the US HFD index, which ranges from 0 to ~1, with higher scores indicative of diets with a higher number and proportion of healthful foods. Multiple indicators of adiposity including BMI, waist-to-height ratio, android-to-gynoid fat ratio, fat mass index (FMI), and percentage body fat were assessed across US HFD index quintiles. ORs and 95% CIs were computed with use of multivariable logistic regression (SAS v. 9.3).

Results: The US HFD index was inversely associated with most adiposity indicators in both sexes. After multivariable adjustment, the odds of obesity, android-to-gynoid ratio >1, and high FMI were 31–55% lower (P-trend < 0.01) among women in quintile 5 vs. quintile 1 of the US HFD index. Among men, the odds of obesity, waist-to-height ratio ≥0.5, and android-to-gynoid ratio >1 were 40–48% lower (P-trend ≤ 0.01) in quintile 5 vs. quintile 1 of the US HFD index.

Conclusions: Higher US HFD index values were inversely associated with indicators of body adiposity in both sexes, indicating that greater healthful food variety may protect against excess adiposity. This study explicitly recognizes the potential benefits of dietary variety in obesity management and provides the foundation to support its ongoing evaluation. *J Nutr* 2015;145:555–63.

Keywords: dietary variety, dietary diversity, healthy food diversity, healthy variety, obesity, body adiposity

Introduction

The combined effects of excess body adiposity and poor dietary habits in the United States contribute to over 500,000 deaths each year, and reducing obesity remains a formidable public health objective (1). Daily per capita energy consumption has increased by ~500 kilocalories (kcal) since the 1970s (2), making it important to consider novel strategies to combat energy imbalance. Although multiple factors are responsible for excess energy consumption (3), the variety of highly processed, energy-dense foods introduced into the marketplace over this period may have played a pivotal role (4–7). Greater food variety has been hypothesized to stimulate appetite and increase food consumption by making eating more enjoyable, thus promoting excess energy consumption and obesity in the current food environment (8).

Although excess variety in the United States may adversely contribute to energy imbalance and obesity (9–13), reducing variety may not be an effective technique to combat obesity (14–16). Strategically limiting dietary variety may adversely affect

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weight control by encouraging food cravings and contributing to high rates of attrition in weight loss programs (17–19). Although it is counterintuitive, promoting variety within healthful foods could make healthful dietary patterns more enjoyable, thus improving dietary adherence and weight outcomes. In various populations with better dietary quality, simple dietary variety measures are favorably associated with nutrient adequacy (10, 20–23), and in some cases, a limited number of adiposity markers (13, 24). Furthermore, recent evidence in children suggests that increasing the variety of healthful foods available while simultaneously reducing the number of less healthful options may be a useful intervention strategy to combat obesity because it aligns with individual preferences for variety (25).

Although it is biologically plausible that greater variety within energy-poor, nutrient-dense foods makes low-calorie diets more sustainable and favorably affects body adiposity, epidemiologic studies have not investigated this question using comprehensive variety indices able to capture the heterogeneity within varied diets that exists in US populations (26). Therefore, we previously developed and validated the US Healthy Food Diversity (HFD)[10] index (27) to simultaneously measure dietary variety, quality, and proportionality to test the hypothesis that a greater variety (vs. monotony) and proportionality of healthful foods is favorably associated with weight control. Healthfulness and proportionality were defined in accordance with the 2010 US Dietary Guidelines (28).

The objective of the current inquiry was to assess whether greater dietary variety in healthful foods quantified using the US HFD index was favorably associated with multiple, clinically relevant indicators of adiposity in a national sample of US adults.

Methods

Population description

Data from adults ≥20 y of age from 2 waves of the cross-sectional NHANES 2003–2006 were included in the present analyses. Women who were pregnant or lactating (n = 587) were excluded because of altered adiposity markers. Furthermore, adults with only 1 d of dietary recall (n = 722) or with unreliable energy intakes (<400 kcal/d or >7000 kcal/d) (n = 115) were excluded, consistent with existing NHANES studies (29, 30). The final analytic sample included 7470 adults.

Data collection

Diet was assessed with 24-h dietary recalls on 2 nonconsecutive days including 1 weekday and 1 weekend day with use of the USDA automated multiple pass method (31, 32). Nearly 90% of individuals had information deemed accurate and complete for both days of recall (31, 32). Sociodemographic information was self-reported during the household interview. Additionally, information on smoking history, minutes of leisure time, moderate and vigorous physical activity (MVPA) over the past 30 d, and hours per day of screen time (computer and television use) were also collected.

Body weight, height, and waist circumference (WC) were measured by trained personnel during the physical exam. Total body fat, android fat (i.e., trunk fat), and gynoid fat (i.e., thigh and hip fat) were measured with DXA on eligible participants (<300 pounds and <77 inches) with use of a Hologic QDR-4500A fan-beam densitometer (33, 34). The DXA software underestimated total body fat by ~5%, so a correction was made by NHANES to reflect accurate values (34).

Approximately 20% of participants had missing DXA data related to exclusion criteria and nonrandom missing data. Five imputed datasets with body fat measures for each individual were generated by NHANES to ensure that the survey-weighted estimates would be valid for the population (35). Approximately 80% of participants in the analytic sample had valid unimputed data and 90% had valid multiply imputed DXA data (34, 35). Nonimputed android and gynoid fat measurements were available in >75% of the participants. When available, multiply imputed data sets were used in these analyses.

US HFD index. US HFD index values were computed by combining the 24-h dietary recall data with the MyPyramid Equivalents database to disaggregate each reported food into its component parts. Twenty-six food groups and subgroups in the MyPyramid database were merged with the individual food files from the 24-h recalls. A detailed description of the underlying theory involved in the development and evaluation of the US HFD index is described elsewhere (27). Briefly, to incorporate a measure of dietary quality and proportionality into this index, US Dietary Guidelines for Americans were used to develop healthfulness factors or weights for each of the 26 food groups and subgroups in the 2010 Dietary Guidelines for Americans. These weights were based on the recommended proportions of each food group in the 2000-kcal USDA food pattern and sum to 1 (**Supplemental Table 1**). The US HFD index values were calculated using the following equation:

$$\text{US HFD} = \left(1 - \sum s_i^2\right) \times \text{hv} \qquad (1)$$

where s_i = share of food item or food group i based on volume in the total diet, $\text{hv} = \sum \text{hf}_i \times s_i$, and hf = healthfulness factors of food.

The range of the US HFD index is between 0 and 1–1/n. Higher values denote diets with more (vs. fewer) food shares, with consumption of food groups in 2000-kcal USDA recommended proportions (vs. equal distribution), and with greater consumption of more weighted (vs. less weighted) food groups. A dietary pattern with a single item in each of the 26 food groups in the proportions in accordance with the 2000-kcal USDA dietary pattern would score 0.49, and the index would approach 1 as an individual increased the number of food shares within more weighted food groups.

Definitions of outcome variables. Consistent with the WHO criteria, overweight was defined as a BMI ≥25 kg/m^2 and <30 kg/m^2, and obesity was defined as a BMI ≥30 kg/m^2 (36). We used a waist-to-height ratio ≥0.5 as a marker for excess adiposity because ratios ≥0.5 have been associated with greater disease risk (37). Fat mass index (FMI) values [fat mass (kg)/height^2 (m^2)] ≥9 kg/m^2 in men and ≥13 kg/m^2 in women were considered indicators of obesity, consistent with established values estimated from NHANES data (38). Men with >25% total body fat and women with >35% body fat were considered to have excess body fatness (39), and an adverse android-to-gynoid ratio was defined with use of a sex-specific median split value of 1. Although there are no specific clinical thresholds for android-to-gynoid ratio, the median split value is consistent with values observed within the NHANES (40). BMI, waist-to-height ratio, android-to-gynoid ratio, FMI, and percentage body fat were also examined continuously.

Other covariates. Race was categorized as non-Hispanic white (NHW), non-Hispanic black (NHB), Hispanic, and other races. Education was divided into "less than college" and "some college or more," and household income was dichotomized as >$75,000 or <$75,000/y. Participants who reported currently smoking cigarettes either "most days" or "some days" were considered smokers, whereas current nonsmokers who reported smoking <100 cigarettes in their lifetime were categorized as nonsmokers. Physical activity frequency, duration, and intensity (moderate or vigorous) were self-reported via questionnaire. Among participants who reported engaging in leisure MVPA over the past 30 d, minutes per month of MVPA was derived by summing the frequency and duration of each activity performed (41). Similarly, hours per day of computer and TV use was summed to determine hours of screen time per day.

Statistical analysis. P values <0.05 were considered statistically significant. Analyses were stratified by sex because of gender-related

[10] Abbreviations used: FMI, fat mass index; HFD, Healthy Food Diversity; MVPA, moderate and vigorous physical activity; NHB, non-Hispanic black; NHW, non-Hispanic white; WC, waist circumference.

differences in body composition and the significant interaction observed between the US HFD index and sex for some indicators of adiposity. First, descriptive statistics including population characteristics and anthropometric measurements were generated for the sample. Survey-weighted characteristics are presented as either means ± SEs for continuous variables or as percentages for categorical variables.

Second, age- and multivariable-adjusted logistic and linear regression analyses were conducted to generate ORs, 95% CIs, and β coefficients to examine the associations between the US HFD index and indicators of body adiposity. Analyses using multiply imputed values used the PROC MIANALYZE procedures. For logistic regressions, the continuous US HFD index was divided into sex-specific quintiles. Covariates considered and retained in the multivariable regression models included age, income, education, race, smoking status, minutes of MVPA per month, hours per day of screen time, and energy intake. All variables included in the final multivariable model were first added singly into logistic regression models. Any variable that changed the odds by >10% or that had been previously deemed important in the literature was included in the final model.

Linear associations were assessed in 2 ways. For logistic regressions, the median US HFD index value in each quintile by sex was generated and *P* for linear trend was determined by examining the overall *F* test for the median US HFD index variable. A *P* value for linear trend was determined in linear regression analyses with use of a postcontrast linear trend test with Wald's *F* tests used to determine significance.

We also tested for the presence of effect modification between the US HFD index and race/ethnicity (*P*-interaction = 0.005) in exploratory analyses. Because of limited power, the US HFD index was divided into tertiles rather than quintiles and not stratified by sex in these analyses. All analyses were conducted with SAS v. 9.3 (SAS Institute) and used cluster, strata, and survey weights per NHANES analytic guidelines to account for multistage survey design (42). Research conducted with de-identified data from the publically available NHANES does not constitute human subjects research per the University Committee on Activities Involving Human Subjects at New York University.

Results

Characteristics of the study population. Descriptive characteristics of male and female participants across quintiles of the US HFD index are presented in **Table 1**. The US HFD index ranged from 0.03 to 0.68 in both sexes, and the mean population value of 0.36 was ~30% lower than the value that would be achieved by adhering to US dietary guidelines (0.49). Participants in quintile 5 vs. quintile 1 were older and had higher educational attainment (*P*-trend < 0.0001) and household income (women only). The percentage of NHW participants increased across quintiles, whereas the number of NHB participants decreased (*P*-trend < 0.0001). Additionally, favorable lifestyle characteristics corresponded with higher US HFD index values; fewer individuals reported being current smokers in both sexes (*P*-trend < 0.0001) and women reported fewer hours per day of screen time (*P*-trend < 0.05). No differences in MVPA across US HFD index quintiles were observed in either sex (*P* = 0.39 in men and 0.30 in women).

In both sexes, energy intake increased across quintiles (*P*-trend < 0.0001), whereas BMI decreased (*P*-trend < 0.01) (**Table 2**). The proportion of obese individuals was also lower across quintiles in both sexes (*P*-trend < 0.01). Among women, WC, waist-to-height ratio, percentage body fat, android-to-gynoid ratio, and FMI decreased across quintiles (*P*-trend < 0.05), but only FMI was lower across quintiles among men.

Associations between the US HFD index and indicators of body adiposity. The age- and multivariable-adjusted odds of overweight were not reduced among women (*P*-trend = 0.28) (**Table 3**). However, the US HFD index was inversely associated with BMI (β = −5.82; 95% CI: −10.23, −1.41). Women in quintile 5 vs. quintile 1 of the US HFD index had a lower odds of obesity in both age-adjusted (OR: 0.56; 95% CI: 0.42, 0.76) and multivariable-adjusted models (OR: 0.69; 95% CI: 0.50, 0.95; *P*-trend < 0.01). After age adjustment, the odds of having an elevated waist-to-height ratio were 36% lower in the highest vs. lowest quintile (OR: 0.64; 95% CI: 0.48, 0.84). The direction of the association persisted after adjustment for other covariates, albeit nonsignificantly (OR: 0.77; 95% CI: 0.57, 1.05; *P*-trend = 0.007).

Among women who had android and gynoid fat measurements (~70%), the odds of having a high android-to-gynoid ratio in quintile 5 vs. quintile 1 in age-adjusted and multivariable-adjusted models were at least 55% lower (*P*-trend < 0.0001). The US HFD index was not associated with lower odds of excess total body fat in multivariable-adjusted analyses (*P*-trend = 0.11), but significant protective associations were observed in continuous multivariable-adjusted analyses (β = −5.03; 95% CI: −9.12, −0.94). The odds of having a high FMI was also lower in age- and multivariable-adjusted analyses (*P*-trend < 0.01).

Similar to women, no association was observed between the US HFD index and the odds of overweight among men (*P*-trend = 0.71) (**Table 4**). However, the US HFD index was inversely associated with BMI (β = −5.51; 95% CI: −8.89, −1.41), and the multivariable-adjusted odds of obesity were nearly 50% lower (OR: 0.52; 95% CI: 0.33, 0.84; *P*-trend = 0.003). Similarly, the odds of having a waist-to-height ratio ≥0.5 and android-to-gynoid ratio >1.0 were ~40% lower in quintile 5 vs. quintile 1 of the US HFD index (*P*-trend < 0.05). The age- and multivariable-adjusted associations between the US HFD index and high total body fat were not significant for the subset of men with imputed body fat measures (*P*-trend = 0.17 and 0.33, respectively). However, there was an inverse dose-response relation between the US HFD index and adverse FMI values after multivariable adjustment (*P*-trend = 0.04).

We stratified results by race to examine associations between US HFD index tertiles and indicators of body adiposity across NHW, NHB, and Hispanic adults (excluding "other" race participants for these analyses) (**Supplemental Table 2**). Although the odds of overweight were not lower in multivariable-adjusted analyses for either NHW (*P*-trend = 0.28) or NHB (*P*-trend = 0.38) adults, they were >40% lower among Hispanic adults in quintile 5 vs. quintile 1 of the US HFD index (*P*-trend = 0.006). The odds of obesity and waist-to-height ratio ≥0.5 were only lower among NHW and Hispanic adults (*P*-trend < 0.01), whereas the odds of android-to-gynoid ratio >1 were only lower among NHB and NHW adults (*P*-trend < 0.01). Lower odds of adverse FMI values were only observed among NHW adults (*P*-trend = 0.01).

Discussion

The present study used a multidimensional food diversity index with measures of dietary quality and proportionality to evaluate the associations between dietary variety and excess adiposity. Significant inverse linear associations between the US HFD index and most indicators of body adiposity among women were observed. Additionally, the odds of having an adverse android-to-gynoid ratio were 55% lower in the highest vs. lowest quintile with multivariable adjustment and the odds of clinically detrimental FMI values were nearly 40% lower (44). This is

TABLE 1 Characteristics of NHANES participants (2003–2006) by quintile of the US HFD index[1]

	Women (n = 3684)						Men (n = 3786)					
	Q1: 0.03–0.30 (n = 736)	Q2: >0.30–0.35 (n = 737)	Q3: >0.35–0.39 (n = 737)	Q4: >0.39–0.43 (n = 737)	Q5: >0.43–0.64 (n = 737)	P-trend	Q1: 0.07–0.29 (n = 757)	Q2: >0.29–0.33 (n = 757)	Q3: >0.33–0.37 (n = 758)	Q4: >0.37–0.42 (n = 757)	Q5: >0.42–0.68 (n = 757)	P-trend
Age, y	45.6 ± 0.71	46.9 ± 0.82	48.4 ± 0.91	50.1 ± 0.82	52.1 ± 0.79	<0.0001	42.6 ± 0.72	44.6 ± 0.84	46.4 ± 1.02	48.1 ± 1.10	48.5 ± 1.07	<0.0001
Race, %												
NHW	16.7	18.0	19.1	21.7	24.6	<0.0001	15.5	17.6	18.3	22.0	26.6	<0.0001
NHB	33.0	24.1	19.3	15.1	8.30	<0.0001	32.2	23.6	18.8	15.9	9.50	<0.0001
Hispanic	14.7	20.8	22.5	20.7	21.3	0.63	20.0	21.3	24.9	19.6	14.2	0.01
Some college or more, %	18.2	19.4	20.5	20.9	20.9	<0.0001	16.8	19.9	18.6	22.0	22.7	0.0006
Current smokers, %	30.8	21.1	18.2	15.9	14.0	<0.0001	30.2	21.6	18.3	15.9	14.0	<0.0001
Household income >$75,000, %	18.0	20.9	20.4	20.3	20.4	0.04	17.6	20.0	18.8	22.1	21.5	0.17
MVPA,[2] min/mo	619 ± 65.8	716 ± 65.3	883 ± 63.6	684 ± 59.1	742 ± 63.9	0.30	1110 ± 144	845 ± 73.3	932 ± 74.2	1140 ± 73.4	1140 ± 69.5	0.39
Screen time,[3] h/d	3.19 ± 0.09	3.04 ± 0.10	2.91 ± 0.10	2.94 ± 0.10	2.88 ± 0.09	0.046	3.14 ± 0.09	3.32 ± 0.11	2.92 ± 0.07	3.24 ± 0.10	3.06 ± 0.08	0.39

[1] All analyses incorporate appropriate cluster, strata, and survey weights. Categorical variables are presented as percentages and continuous variables are presented as means ± SEs. The theoretical range of the index is between 0 and nearly 1 with higher values indicative of more healthful, varied dietary patterns. HFD, Healthy Food Diversity; MVPA, moderate and vigorous physical activity; NHB, non-Hispanic black; NHW, non-Hispanic white; Q, quintile.

[2] Among participants who reported engaging in MVPA over the past 30 d, the individual activities they performed, the frequency of those activities, and their duration was queried and summed to generate the number of minutes per month engaged in moderate and vigorous activity.

[3] Hours/day of screen time equals the hours/day of TV and computer use.

TABLE 2 Energy intake and adiposity characteristics of NHANES participants (2003–2006) by quintile of the US HFD index[1]

	Women (n = 3684)						Men (n = 3786)					
	Q1: 0.03–0.30 (n = 736)	Q2: >0.30–0.35 (n = 737)	Q3: >0.35–0.39 (n = 737)	Q4: >0.39–0.43 (n = 737)	Q5: >0.43–0.64 (n = 737)	P-trend	Q1: 0.07–0.29 (n = 757)	Q2: >0.29–0.33 (n = 757)	Q3: >0.33–0.37 (n = 758)	Q4: >0.37–0.42 (n = 757)	Q5: >0.42–0.68 (n = 757)	P-trend
US HFD index	0.26 ± 0.002	0.33 ± 0.001	0.37 ± 0.001	0.41 ± 0.001	0.48 ± 0.003	<0.0001	0.25 ± 0.002	0.31 ± 0.001	0.37 ± 0.001	0.40 ± 0.001	0.47 ± 0.002	<0.0001
Energy intake, kcal/d	1710 ± 14.9	1760 ± 16.5	1815 ± 16.1	1785 ± 18.7	1830 ± 19.2	0.0003	2405 ± 30.7	2465 ± 22.3	2540 ± 24.8	2580 ± 33.7	2580 ± 16.8	<0.0001
BMI, kg/m^2	29.3 ± 0.48	28.9 ± 0.45	28.8 ± 0.45	28.0 ± 0.49	27.2 ± 0.34	0.001	28.8 ± 0.38	28.8 ± 0.25	28.2 ± 0.26	28.2 ± 0.29	27.6 ± 0.22	0.007
Overweight (BMI ≥25 to <30 kg/m^2)	17.3	20.1	19.7	21.4	20.9	0.29	19.2	18.6	20.8	21.0	20.4	0.62
Obese (BMI ≥30 kg/m^2)	23.2	22.4	20.1	18.8	15.6	0.0002	21.2	23.4	20.2	18.7	16.5	0.006
Waist circumference, cm	95.4 ± 1.18	95.7 ± 0.87	94.5 ± 0.80	93.5 ± 1.00	92.2 ± 0.83	0.004	101 ± 0.93	102 ± 0.83	100 ± 0.78	101 ± 0.83	99.8 ± 0.65	0.19
Waist-to-height ratio[2]	0.59 ± 0.01	0.59 ± 0.01	0.58 ± 0.005	0.58 ± 0.005	0.57 ± 0.005	0.002	0.58 ± 0.01	0.58 ± 0.004	0.57 ± 0.004	0.57 ± 0.01	0.57 ± 0.004	0.09
Android-to-gynoid ratio[3]	0.93 ± 0.01	0.94 ± 0.01	0.90 ± 0.01	0.90 ± 0.01	0.88 ± 0.01	<0.0001	1.15 ± 0.01	1.16 ± 0.01	1.13 ± 0.01	1.16 ± 0.01	1.13 ± 0.01	0.15
Percentage body fat,[4,5]	40.5 ± 0.50	40.6 ± 0.33	40.1 ± 0.33	39.5 ± 0.46	39.0 ± 0.40	0.002	28.2 ± 0.34	28.5 ± 0.33	28.1 ± 0.32	28.0 ± 0.30	27.9 ± 0.35	0.32
FMI,[4,6] kg/m^2	12.4 ± 0.35	12.2 ± 0.30	12.1 ± 0.29	11.6 ± 0.36	11.0 ± 0.26	0.0006	8.44 ± 0.21	8.53 ± 0.16	8.22 ± 0.15	8.23 ± 0.19	8.00 ± 0.16	0.047

[1] All analyses incorporate appropriate cluster, strata, and survey weights. Categorical variables are presented as percentages and continuous variables are presented as means ± SEs. The theoretical range of the index is between 0 and nearly 1 with higher values indicative of more healthful, varied dietary patterns. FMI, fat mass index; HFD, Healthy Food Diversity; Q, quintile.

[2] Waist-to-height ratio = 0.5 is normal in both men and women (37).

[3] Body fat measures were obtained with use of DXA and are based on unimputed data available for 2791 women and 2949 men.

[4] Body fat measures were obtained with use of DXA and are based on 5 sets of imputed data available for 3330 women and 3403 men. In 2005–2006, adults >69 y of age were not eligible for inclusion, and imputation was not applied to pregnant women or individuals with amputations.

[5] The normal range for percentage body fat is 8–24% in men and 21–35% in women (43). High body fat is >25% in men and >35% in women (39).

[6] Normal FMI is 3–6 kg/m^2 in men and 5–9 kg/m^2 in women. FMI values ≥9 kg/m^2 for men and ≥13 kg/m^2 for women at the age of 25 corresponds with an obesity prevalence defined as BMI ≥30 kg/m^2 in NHANES (38).

TABLE 3 Multivariable- and age-adjusted ORs and 95% CIs for odds of excess adiposity by quintile of the US HFD index among women from the NHANES 2003–2006[1]

	Women (n = 3684)								
	Q1: 0.03–0.30 (n = 736)	Q2: >0.30–0.35 (n = 737)	Q3: >0.35–0.39 (n = 737)	Q4: >0.39–0.43 (n = 737)	Q5: >0.43–0.64 (n = 737)	P-trend	β ± SE	95% CI	R^2
Overweight (BMI ≥25 to <30 kg/m^2)									
Age-adjusted	1.0	1.33 (0.90, 1.97)	1.11 (0.76, 1.62)	0.90 (0.61, 1.33)	0.82 (0.59, 1.14)	0.048	−8.65 ± 2.38	−13.5, −3.79	0.01
Multivariable-adjusted	1.0	1.41 (0.92, 2.15)	1.23 (0.83, 1.83)	0.97 (0.65, 1.47)	0.94 (0.63, 1.40)	0.28	−5.82 ± 2.16	−10.2, −1.41	0.07
Obese (BMI ≥30 kg/m^2)									
Age-adjusted	1.0	1.05 (0.71, 1.57)	0.90 (0.61, 1.33)	0.73 (0.51, 1.04)	0.56 (0.42, 0.76)	<0.0001	−8.65 ± 2.38	−13.5, −3.79	0.01
Multivariable-adjusted	1.0	1.13 (0.73, 1.73)	0.998 (0.66, 1.52)	0.85 (0.61, 1.19)	0.69 (0.50, 0.95)	0.003	−5.82 ± 2.16	−10.2, −1.41	0.07
Waist-to-height ratio[2] ≥0.5									
Age-adjusted	1.0	1.29 (0.94, 1.78)	1.06 (0.75, 1.48)	0.81 (0.57, 1.17)	0.64 (0.48, 0.84)	<0.0001	−0.13 ± 0.03	−0.19, −0.06	0.05
Multivariable-adjusted	1.0	1.41 (1.00, 1.98)	1.24 (0.87, 1.76)	0.92 (0.63, 1.33)	0.77 (0.57, 1.05)	0.007	−0.08 ± 0.03	−0.14, −0.02	0.12
Android-to-gynoid ratio[3] >1.0									
Age-adjusted	1.0	1.18 (0.80, 1.74)	0.68 (0.52, 0.90)	0.63 (0.41, 0.96)	0.44 (0.31, 0.63)	<0.0001	−0.27 ± 0.04	−0.36, −0.19	0.03
Multivariable-adjusted	1.0	1.19 (0.81, 1.75)	0.68 (0.50, 0.94)	0.63 (0.42, 0.95)	0.45 (0.30, 0.68)	<0.0001	−0.22 ± 0.05	−0.32, −0.12	0.08
High total body fat percentage[4]									
Age-adjusted	1.0	1.05 (0.71, 1.57)	0.96 (0.68, 1.35)	0.70 (0.42, 1.16)	0.60 (0.40, 0.91)	0.006	−7.60 ± 2.25	−12.0, −0.3.19	0.08
Multivariable-adjusted	1.0	1.19 (0.79, 1.78)	1.20 (0.84, 1.71)	0.84 (0.53, 1.33)	0.80 (0.53, 1.20)	0.11	−5.03 ± 2.09	−9.12, −0.94	0.14
FMI[4,5] (kg/m^2)									
Age-adjusted	1.0	1.04 (0.74, 1.46)	0.98 (0.74, 1.30)	0.75 (0.49, 1.13)	0.54 (0.39, 0.74)	0.0004	−5.85 ± 1.72	−9.22, −2.49	0.03
Multivariable-adjusted	1.0	1.06 (0.74, 1.51)	1.06 (0.79, 1.43)	0.80 (0.54, 1.20)	0.61 (0.43, 0.85)	0.003	−3.99 ± 1.58	−7.08, −0.90	0.08

[1] Adjusted for age, race (non-Hispanic white, non-Hispanic black, Hispanic, and other), education (less than college vs. some college or more), smoking, income (<$75,000 vs. >$75,000), hours of screen time per day, minutes of moderate-to-vigorous activity per month, and energy intake. All analyses incorporate appropriate cluster, strata, and survey weights. The theoretical range of the index is between 0 and nearly 1 with higher values indicative of more healthful, varied dietary patterns. FMI, fat mass index; HFD, Healthy Food Diversity; Q, quintile.

[2] Waist-to-height ratio <0.5 is normal in both men and women (37).

[3] The sample size for the android/gynoid measurements is 2791 women (893 missing) and 2949 men (837 missing).

[4] Body fat measures were obtained with use of DXA and are based on 5 sets of imputed data available for 3330 women and 3403 men. In 2005–2006, adults >69 y of age were not eligible for inclusion, and imputation was not applied to pregnant women or individuals with amputations. High body fat is considered >25% in men and >35% in women (39).

[5] Normal FMI is 3–6 kg/m^2 in men and 5–9 kg/m^2 in women. FMI values ≥9 kg/m^2 for men and ≥13 kg/m^2 for women at the age of 25 corresponds with an obesity prevalence defined as BMI ≥30 kg/m^2 in NHANES (38).

noteworthy because both indicators are established risk factors for metabolic syndrome and related chronic diseases (44, 45). In men, similar protective associations were observed between the US HFD index and all indicators of body adiposity, albeit not always statistically significant. Although energy intake increased across quintiles of the US HFD index, the protective associations observed for body adiposity indicators suggest that this population may have higher energy requirements.

Notably, the US HFD index was not associated with the odds of overweight in either sex. However, concordance between BMI and excess adiposity is greater once BMI reaches a threshold of 24 in women and 28 in men (46), suggesting that using existing cut-points may bias associations by incorrectly misclassifying more adults as normal weight. As a result, it may be more valid to examine BMI continuously because the associations with both overweight and obesity are likely attenuated (47).

Our results differ from findings from the National Weight Control Registry, which found that participants who had successfully maintained a weight loss of ≥30 pounds did so by reducing variety in all food groups (48). However, it is important to note that successful registry participants may not be representative of US adults, and increasing variety within non-energy-dense food groups may be more effective for the general population.

Our results are generally consistent with the literature evaluating dietary variety in recommended foods and body adiposity (13). Among NHANES participants, greater recommended food variety was inversely associated with BMI (49). Variety in fruit and vegetable intake has also been favorably associated with excess adiposity (50). Conversely, total food variety has been primarily protective against adiposity among populations with healthier food environments (11). Importantly, as food environments become more diverse, the associations between total variety and body adiposity are inconsistent and potentially biased (24, 51) because variety indices that use food counts are unable to capture variability in diet quality (13). In US populations with even greater heterogeneity in diet quality, the bias associated with count-based indices may be more pronounced, underscoring the need for comprehensive total variety measures.

Dietary quality measures that evaluate the total diet (vs. components) suggest that adherence to higher quality dietary patterns improves body weight regulation (52, 53). For example, both the Healthy Eating Index-90 and 2005 have been inversely associated with BMI and WC, particularly among Caucasians (54). Better adherence to the French Dietary Guidelines has also been associated with improved anthropometric outcomes (55). Although these associations were not always statistically significant (56, 57), this is potentially due to heterogeneity in dietary measurement (58) and the strong associations between socioeconomic factors, dietary quality, and adiposity (59). Given the reduction in odds for most indicators of adiposity observed in this research, it is also possible that dietary variety, quality, and proportionality function synergistically to reduce excess adiposity.

TABLE 4 Multivariable- and age-adjusted ORs and 95% CIs for odds of excess adiposity by quintile of the US HFD index among men from the NHANES 2003–2006[1]

	Men (n = 3786)								
	Q1: 0.07–0.29 (n = 757)	Q2: >0.29–0.33 (n = 757)	Q3: >0.33–0.37 (n = 758)	Q4: >0.37–0.42 (n = 757)	Q5: >0.42–0.68 (n = 757)	P-trend	β ± SE	95% CI	R^2
Overweight (BMI ≥25 to <30 kg/m^2)									
Age-adjusted	1.0	0.98 (0.65, 1.47)	0.97 (0.73, 1.28)	1.18 (0.89, 1.57)	0.90 (0.66, 1.23)	0.78	−5.05 ± 1.76	−8.65, −1.45	0.01
Multivariable-adjusted	1.0	0.99 (0.65, 1.51)	1.00 (0.72, 1.39)	1.14 (0.82, 1.58)	0.91 (0.63, 1.30)	0.71	−5.15 ± 1.83	−8.89, −1.41	0.04
Obese (BMI ≥30 kg/m^2)									
Age-adjusted	1.0	0.97 (0.71, 1.31)	0.85 (0.69, 1.20)	0.74 (0.54, 1.00)	0.57 (0.39, 0.83)	0.001	−5.05 ± 1.76	−8.65, −1.45	0.01
Multivariable-adjusted	1.0	0.86 (0.60, 1.21)	0.83 (0.55, 1.27)	0.68 (0.47, 0.98)	0.52 (0.33, 0.84)	0.003	−5.15 ± 1.83	−8.89, −1.41	0.04
Waist-to-height ratio[2] ≥0.5									
Age-adjusted	1.0	0.96 (0.65, 1.42)	0.79 (0.56, 1.11)	1.06 (0.76, 1.49)	0.62 (0.44, 0.86)	0.01	−0.08 ± 0.02	−0.13, −0.03	0.10
Multivariable-adjusted	1.0	0.89 (0.58, 1.36)	0.74 (0.48, 1.15)	1.04 (0.70, 1.57)	0.59 (0.40, 0.88)	0.01	−0.08 ± 0.03	−0.13, −0.03	0.13
Android-to-gynoid ratio[3] >1.0									
Age-adjusted	1.0	0.85 (0.60, 1.22)	0.73 (0.51, 1.05)	0.79 (0.55, 1.13)	0.67 (0.47, 0.95)	0.02	−0.14 ± 0.07	−0.27, −0.003	0.08
Multivariable-adjusted	1.0	0.75 (0.52, 1.07)	0.62 (0.41, 0.92)	0.71 (0.50, 1.01)	0.60 (0.41, 0.89)	0.01	−0.19 ± 0.07	−0.34, −0.05	0.14
High total body fat percentage[4]									
Age-adjusted	1.0	0.98 (0.74, 1.29)	0.99 (0.76, 1.29)	1.00 (0.75, 1.32)	0.77 (0.55, 1.07)	0.17	−3.96 ± 1.98	−7.85, −0.07	0.09
Multivariable-adjusted	1.0	0.93 (0.70, 1.23)	1.01 (0.73, 1.40)	1.03 (0.74, 1.43)	0.79 (0.55, 1.14)	0.33	−3.56 ± 1.93	−7.34, 0.23	0.15
FMI[4,5] (kg/m^2)									
Age-adjusted	1.0	0.85 (0.62, 1.16)	0.74 (0.48, 1.15)	0.58 (0.40, 0.82)	0.70 (0.45, 1.08)	0.03	−2.53 ± 1.08	−4.66, −0.41	0.04
Multivariable-adjusted	1.0	0.76 (0.54, 1.07)	0.71 (0.44, 1.14)	0.54 (0.37, 0.81)	0.66 (0.41, 1.07)	0.04	−2.41 ± 1.06	−4.50, −0.33	0.08

[1] Adjusted for age, race (non-Hispanic white, non-Hispanic black, Hispanic, and other), education (less than college vs. some college or more), smoking, income (<$75,000 vs. >$75,000), hours of screen time per day, minutes of moderate-to-vigorous activity per month, and energy intake. All analyses incorporate appropriate cluster, strata, and survey weights. The theoretical range of the index is between 0 and nearly 1 with higher values indicative of more healthful, varied dietary patterns. FMI, fat mass index; HFD, Healthy Food Diversity; Q, quintile.

[2] Waist-to-height ratio <0.5 is normal in both men and women (37).

[3] The sample size for the android/gynoid measurements is 2791 women (893 missing) and 2949 men (837 missing).

[4] Body fat measures were obtained with use of DXA and are based on 5 sets of imputed data available for 3330 women and 3403 men. In 2005–2006, adults >69 y of age were not eligible for inclusion, and imputation was not applied to pregnant women or individuals with amputations. High body fat is considered >25% in men and >35% in women (39).

[5] Normal FMI is 3–6 kg/m^2 in men and 5–9 kg/m^2 in women. FMI values ≥9 kg/m^2 for men and ≥13 kg/m^2 for women at the age of 25 corresponds with an obesity prevalence defined as BMI ≥30 kg/m^2 in NHANES (38).

The observed results for indicators of central adiposity (e.g., waist-to-height ratio and android-to-gynoid ratio) in both sexes suggest that healthful dietary variety has a role in regulating the metabolic environment (60), potentially by modulating hormonal pathways involved in fat deposition (61). Additionally, greater variety within energy-poor foods may enhance the novelty and enjoyment of high-quality diets, promote satiety, and displace intake of energy-dense foods associated with excess body weight (62). Studies examining fruit and vegetable variety contend that the beneficial effects of variety are mediated through the amount consumed (63, 64), underscoring the potential for greater variety to promote intake of nutrient-dense diets favorably associated with cardiometabolic health. More research is needed to determine whether greater variety within multiple nutrient-dense food categories influences adiposity through both variety and quantity. Heterogeneity introduced by race/ethnicity also indicates that differing dietary patterns and potentially genetic variation may modify associations between diet and body adiposity (64, 65).

Despite this study's innovation and potential clinical and public health applications, some limitations must be acknowledged. NHANES data are cross-sectional and reverse causality is possible, suggesting a need for future research in longitudinal and experimental study populations. Additionally, participants with greater adiposity were excluded from DXA analyses because of measurement challenges, which may have reduced the observed effect sizes. Because missingness was related to relevant participant characteristics, study power may have been reduced in stratified analyses (35). Finally, there may be biases in self-reported dietary recall data that attenuate risk estimates including within-person variation, under-reporting of episodically consumed foods, and differential under-reporting by gender (67, 68), food groups, and weight status (58). Hence, protective associations between the US HFD index and body adiposity in this study are likely conservative.

Overall, the current study provides foundational evidence that dietary variety may favorably influence adiposity patterns hypothesized to be associated with metabolic dysregulation and chronic disease. The US HFD index addresses a critical gap in the field of diet assessment because it captures dietary variety as a true "dimension" of the diet by simultaneously measuring variety, consumption quantity, and food quality (26). A notable strength of this study in a large, national sample was the availability of multiple, measured adiposity indicators such as android-to-gynoid ratio, waist-to-height ratio, and FMI. These adiposity indicators are more sensitive and specific than proxy indicators like BMI and may particularly help disaggregate body fatness from body size, as it pertains to chronic disease (44). The US HFD index was consistently associated with clinically relevant indicators of adiposity in this study, demonstrating that there was less bias in both measures, and illustrating the potential role of dietary variety in reducing body adiposity.

In conclusion, this study represents an important addition toward better characterizing the associations between dietary

variety and excess adiposity within an obesogenic food environment. Limiting variety in foods is a common tenet of many popular diet plans, yet monotony may contribute to high rates of diet attrition and unhealthful weight cycling (69, 70). Consequently, it is important to consider whether greater variety within energy-poor, nutrient-dense foods encourages dietary adherence before making clinical recommendations, particularly because behavioral strategies may be effective in promoting dietary change (71). The conclusions drawn from this study clearly underscore the importance of continued investigation into of the role of healthful dietary variety in behavioral weight management and provide an integral framework for ongoing investigation. Manipulation of dietary variety may be an innovative approach to national weight control and chronic disease prevention. Increasing variety in some food categories may be an overlooked strategy for weight control in adults.

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MV conceptualized, designed, and analyzed all the data and was the lead author of the paper; LBD critically reviewed the manuscript for important intellectual content; TM supervised and advised all the statistical analyses; BE reviewed the manuscript and organized the content; and NP designed the analyses along with MV, supervised the research at all stages, and critically reviewed the manuscript for important intellectual content. All authors read and approved the final manuscript.

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