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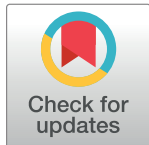
Longitudinal change in the diet's monetary value is associated with its change in quality and micronutrient adequacy among urban adults

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Data Availability Statement: Data are available upon request to researchers with valid proposals who agree to the confidentiality agreement as required by our Institutional Review Board. The policies regarding HANDLS data can be found here: <https://handls.nih.gov>. Requests for data access may be sent to the study manager, Jennifer Norbeck at norbeckje@mail.nih.gov.

Abstract

Background

Reducing diet costs may lead to the selection of energy-dense foods, such as refined grains or foods high in added sugars and/or fats, which can lower overall dietary quality. We examined the longitudinal association between the monetary value of the diet (MVD) and the overall dietary quality across sex, race and income groups.

Methods and findings

Longitudinal data from 1,466 adult urban participants from Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study were used. Healthy Eating Index–2010 (HEI–2010) and Mean Adequacy Ratio (MAR) were computed and a national food price database was used to estimate MVD. Multiple linear regression analyses were conducted linking annual rates of change (Δ) in MVD to Δ HEI–2010 and Δ MAR, stratifying by sex, race and income groups. Among key findings, Δ HEI–2010 was comparable across socio-demographic groups, while Δ MAR was higher among women and individuals above poverty. Adjusting for key covariates, Δ MVD was positively associated with both Δ HEI–2010 and Δ MAR, and with a consistently stronger association among individuals above poverty, specifically for the total proteins and empty calories components of HEI–2010 and several nutrient adequacy ratios (NARs: vitamins C, E, B-6 and Zinc). Δ MVD– Δ MAR association was stronger in women, mainly influenced by Δ MVD's positive associations with B-vitamins, copper, calcium, magnesium and phosphorus NARs. Δ MVD– Δ vitamin D NAR's positive relationship was stronger among Whites, while Δ MVD– Δ vitamin B-12 NAR's association was stronger among African-Americans.

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Abbreviations: Δ , Annual rate of change; DQ, Diet Quality; HEI-2010, Healthy Eating Index, 2010 version; FNDDS, Food and Nutrient Database for Dietary Studies; HANDLS, Healthy Aging in Neighborhood of Diversity across the Life Span; HS, High School; MAR, Mean Adequacy Ratio, MVD = Monetary value of the diet, NAR = Nutrient Adequacy Ratio, NHANES = National Health and Nutrition Examination Surveys; PIR, Poverty Income Ratio; RDA, Recommended Dietary Allowance; SE, Standard Error; USDA, US Department of Agriculture; WRAT-3, Wide Range Achievement Test, 3rd revision.

Conclusions

In sum, a potential increase in MVD may have a stronger impact on dietary quality among urban adult women and above-poverty individuals.

Introduction

Evaluating the healthfulness of dietary patterns is a key challenge when studying diet-disease relationships. The US federal government established a set of recommendations for an optimal quality of the total diet through providing Dietary Guidelines for Americans (DGA), while setting some benchmarks to would lead people closer towards these specific recommendations through the Healthy People objectives.[1] Those objectives are outlined in the Health People 2020 and the Dietary Guidelines for Americans.[2,3] The latter provides evidence-based information on healthfulness of diets.[4] Thus, the total diet quality is often measured with various indices relying on combinations of food groups and nutrients. Among those that are non-data driven, the Healthy Eating Index-2010 (HEI-2010) is an energy-adjusted food-group based index evaluating people's conformity to most recent Dietary Guidelines for Americans. [5–9] Similarly, the Mean Adequacy Ratio (MAR) aims at comparing an individual's mean micronutrient intake to its Recommended Dietary Allowance (RDA).[10] Importantly, food choice determinants, particularly those of economic nature, must be examined.

Altering food choice can modify diet quality to be consistent with recent guidelines. Those foods choices strongly depend on people's health status, preferences, cultural influences and more importantly socio-economic constraints, including income. Under financial constraints, food expenditure experiences substantial cuts relative to other portions of household expenditures, resulting in the choice of less expensive foods.[11] Reducing diet costs is often accomplished by selecting more energy-dense foods, such as refined grains or foods high in added sugars and/or fats, resulting in lower overall dietary quality.[12–16]

While current research focuses on associations between food prices at the regional, city and neighborhood levels and food consumption behaviors and patterns, [17–22] examining the monetary value of the diet (MVD) and how it is related to various dietary components and quality has gained more recent interest. [10,23–53] Most studies reported a direct relationship between MVD and diet quality (or an inverse relationship with consumption of energy-dense foods),[10,23–31,33–38,40–42,44–47,50,51,54–60], a finding not replicated in other studies. [32,39,43,48,49]

To our knowledge, this study is the first to examine the net association between annual rates of change in MVD and dietary quality, across sex, race and poverty status, using data from a large sample of low-income urban US adults, the Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS).

Methods

Database

HANDLS is a prospective cohort study that is ongoing since 2004. The study primarily focuses on disparities in cardiovascular and cognitive health of a socioeconomically diverse sample of Whites and African-Americans (30–64 years old at baseline), representing selected neighborhoods in Baltimore, Maryland. While the HANDLS sample selection methodology is described in greater detail elsewhere [61], in brief, it uses an area probability sampling strategy of thirteen

neighborhoods. Phase 1 of the baseline visit (also known as (aka) visit 1 (in our study) or Wave 1 (in HANDLS): 2004–2009) consisted of screening, recruitment, first dietary recall, and household interviews, whereas phase 2 of visit 1 consisted of the second dietary recall and examinations in mobile Medical Research Vehicles (MRV). Two 24-hr recalls were also collected at the follow-up visit [aka visit 2 (in our study) or wave 3 (in HANDLS): 2009–2013]. Longitudinal data from participants examined both during the baseline visit 1 (2004–2009) and the first follow-up visit 2 (2009–2013) were used in this study, with a mean follow-up time \pm SE of $4.62y \pm 0.95$ (range: 0.42–8.20).

Written informed consent was obtained from all participants who accessed a protocol booklet in layman's terms and a video that described all procedures and future re-contacts. HANDLS study was ethically approved by the National Institutes of Health, National Institute of Environmental Health Sciences (NIEHS/NIH) Institutional Review Board.

Study sample

Of the original HANDLS sample selected at wave 1 ($N = 3,720$), 2,177 had complete data on two 24-hour dietary recalls at baseline collected both at Phase 1 (household visit), and Phase 2 (MRV visit). Out of those, we excluded participants with incomplete dietary recalls from the first follow-up visit, resulting in a sample of $N = 1,516$. An additional 50 individuals had missing data on several covariates including literacy, education, self-rated health and body mass index. Missing data on smoking/drug use were included as a dummy variable in multivariable models. This resulted in a final sample of $N = 1,466$ (SI Fig). Compared with the sample with complete baseline dietary data ($N = 2,177$), the final selected sample with complete data on both waves and covariates ($N = 1,466$) differed from those excluded, by having a higher proportion of women, African-Americans and individuals above poverty. This sample selectivity was adjusted for using a 2-stage Heckman selection model (See statistical analysis section).

Dietary assessment

At each of two HANDLS visits (i.e. visits 1 and 2), two 24-hour dietary recalls were collected through the utilization of the US Department of Agriculture (USDA) Automated Multiple Pass Method, a well-established computerized structured interview.[62] Several measurement aids were used, including measuring cups, spoons, rulers, and an illustrated Food Model Booklet which allowed participants to report accurate food and beverage quantities that were consumed. Both recalls were administered in-person by trained interviewers, 4 to 10 days apart, during the visit 1 study period (2004–2009) while one of two recalls was administered by a telephone interview during the visit 2 study period (2009–2013). The coding process of the dietary recall was completed by trained nutrition professionals using the Survey Net statistical software,[63] which matched foods consumed with 8-digit codes identified in the Food and Nutrient Database for Dietary Studies (FNDDS) version 3.0 for baseline visit 1 and version 5 for the follow-up visit 2. [64]

Key outcome measures

Healthy Eating Index– 2010. HEI-2010's computational steps and statistical code for the 24-hr recalls can be found at the National Cancer Institute website on Applied Research.[65] Moreover, specifically for the HANDLS study, detailed description of the steps used can be found elsewhere. [66] For each recall day (days 1 and 2) and each study visit, total and component HEI-2010 scores were computed. Those estimates were subsequently averaged to obtain the mean HEI-2010 total and component scores for both days combined for each of two visits.

HEI-2010 and components were measured at both HANDLS visits (DQ_{base} and DQ_{follow}) and annual rate of change (Δ) was measured as: $(DQ_{\text{follow}} - DQ_{\text{base}}) / (Age_{\text{follow}} - Age_{\text{base}})$.

Mean Adequacy Ratio (MAR) and Nutrient Adequacy Ratio (NAR). The MAR and NAR nutrient-based diet quality were estimated using methods that were published elsewhere [67,68]. Actual dietary intakes relative to RDAs of selected vitamins and minerals (i.e. calcium, magnesium, phosphorus, Vitamins A, C, D, E, B-6, folate, B-12, iron, thiamin, riboflavin, niacin, copper, and zinc) were used to compute a second diet quality index. From the RDA and actual intake of each vitamin and mineral considered, a nutrient adequacy ratio (NAR) was estimated, as follows: NAR = Subject's actual daily nutrient intake divided by the RDA of that nutrient. Moreover, 35 mg of vitamin C was added to the RDA of participants reported as being current smokers.[69] Each NAR was then expressed as percentage and truncated at 100%. [68] The mean adequacy ratio (MAR), a nutrient-based measure of overall dietary quality, was computed using as the sum of all 16 nutrient NARs divided by 16. Annual rates of change in MAR and NAR were computed using a similar approach as for HEI-2010 and components.

Monetary value of diet estimation (MVD). Diet cost per 100 grams was estimated using the Global Food Research Program at UNC's Packaged Food Purchase and Price Database, 2004–13, which provides average national and market-specific prices of ~3,700 foods in “as-purchased” form per quarter. [70,71] Prices are derived from packaged foods including minimally processed foods, commercially prepared ready-to-eat foods and commercially formulated or prepared dishes. The database was generated by linking food and beverage purchase data from the Nielsen Homescan Consumer Panel to Nutrition Facts Panel data from various sources including the Mintel Global New Products Database. [72,73] Detailed design of the Homescan study is provided in [S1 Method](#). Using descriptions and ingredient lists, products were categorized at the barcode-level into 34 food and 8 beverage groups based on nutritional content and consumption patterns; this methodology and the UNC Homescan food groups were previously described.[74] Market-specific price per 100 g for each food group in each quarter was calculated by dividing the survey-weighted dollars spent by weighted volume of purchases for all products in a given food group by households in that market during the quarter. [70] For this study, average real prices of each food group were calculated for all households in the Baltimore market and scaled to the first quarter of 2004 to account for inflation and allow comparability over time. All 8-digit codes in the Food and Nutrient Database for Dietary Studies (FNDDS) versions 4.1, 5.0 and 2011–12 reported by National Health and Nutrition Examination Survey participants from stores or vending in 2007–08 to 2011–12 were matched to UNC Homescan food groups. This database provided food prices per 100g at the national level for about 3,700 FNDDS food codes, determined from 1,934,441 barcoded products (814,481 unique Nutrition Facts Panel records), and facilitated MVD per day estimates among HANDLS participants.

Given limited linkage between Homescan food prices with NHANES 2007–08 and 2011–12, half of the remaining FNDDS food codes reported by HANDLS participants were imputed, by matching previously computed food groups for HANDLS (60 food and beverage groups) with 42 food and beverage groups computed by UNC. When a reasonable match was not found, a nearest neighbor code matched to one of the 42 groups was used for imputation. This resulted in a harmonization algorithm by which all reported HANDLS FNDDS food codes were placed in one of 42 food groups and then linked to a singular food price, given the year and quarter in which they were reported. Taking the example of wave 1, day 1, it is shown that some food groups rank high in terms of prevalence of reporting for both the imputed and non-imputed observations, starting from individual food codes. This validates the imputation technique through the harmonization of food groups. ([S2 Method](#)).

Total cost was measured by adding food prices within individual HANDLS ID, given the amount consumed per food code per recall and individual. The MVD was then estimated per individual per wave as average MVD across recalls for each wave. Annual rate of change in MVD was estimated as follows: $\Delta\text{MVD} = (\text{MVD}_{\text{follow}} - \text{MVD}_{\text{base}}) / (\text{Age}_{\text{follow}} - \text{Age}_{\text{base}})$.

Covariates

Several baseline or fixed covariates were considered as potential confounders and/or effect modifiers. Those included age, sex, race (White vs. African American), completed years of education (<High School (HS); HS and >HS), literacy (WRAT-3 total score), poverty status, a design-based binary variable in HANDLS based on poverty income ratio (PIR<125%: below poverty; PIR≥125%: above poverty), current smoking status (0: "never or former smoker" and 1 "current smoker") and current drug use (0: "never or former drug user and 1 "current drug user"). The reading subtest of the Wide Range Achievement Test-3rd Edition (WRAT-3), a widely validated measure of literacy, assessed participants' ability to recognize and name letters and words, with a total score computed as "total correctly pronounced letters + total correctly pronounced words".[75] Other baseline covariates included employment status, body mass index (weight/squared-height, kg.m⁻²) and self-rated health (0: Poor/fair, 1: Good, 2: Very good/excellent). Finally, models were also adjusted for % energy consumed at home (food items purchased at grocery stores) to account for price inflation in away-from-home settings. In fact, since most of the MVDs were based on estimated prices of foods as sold in grocery stores and prepared at home rather than away from home food prices, it was important to adjust for the % energy consumed at home in all our models. Energy intake (kcal/d) from the total diet was adjusted for in all regression models. In both latter cases, annual rates of change (Δ) were entered rather than baseline values, given the strong association between energy intake and MVD.

Statistical analysis

Stata release 14.0 (StataCorp, College Station, TX) was used to complete all statistical analyses. [76] First, study sample characteristics were assessed by tertiles of annual rates of change in MVD (ΔMVD tertile), as was done in our previous cross-sectional analyses.[10] To test linear trend relationship between MVD tertiles and continuous characteristics, a bivariate ordinary least square (OLS) regression was used with MVD entered as an ordinal predictor of each continuous variable of interest. Associations between categorical study characteristics and MVD tertiles were evaluated with χ^2 tests. Second, means of baseline, follow-up and annual rates of change in diet quality indices (total scores on HEI-2010, MAR and individual components) were compared across sex, race and poverty status groups using independent samples *t*-tests. Finally, multiple OLS regression models were conducted to examine the net association between annual rates of change in MVD and the annual rate of change in different diet quality indices, adjusting for potentially confounding factors and stratifying by sex, race and poverty status. To test statistically the moderation by those socio-demographic factors separately, interaction terms were added to the unstratified multivariable models (i.e. $\Delta\text{MVD} \times \text{sex}$, $\Delta\text{MVD} \times \text{race}$ and $\Delta\text{MVD} \times \text{pov}$), while also including the main effects and the other covariates. Predictive margins of annual rates of change in HEI-2010 total score and MAR were plotted from those models, against MVD tertiles and across each of the three socio-demographic moderating factors.

The non-random selection of participants with complete data from the target study population can often lead to selection bias. To account for this type of bias, a 2-stage Heckman selection model was constructed,[77] using a probit model to obtain an inverse Mills ratio at the

first stage (derived from the predicted probability of being selected out of the sample with complete 24 hr recalls at baseline (N = 2,177, **S1 Fig**), conditional on the covariates in the probit model, mainly baseline age, sex, race, poverty status and education), as was done in earlier studies.[10,78–80] Specifically, participants selected into the final analytic sample compared to those excluded from the total with complete and adequate baseline dietary data (i.e. N = 1,466 vs. N = 711) were more likely to be women (59.3% vs. 51.1%, P<0.001), African-American (59.8% vs. 54.0%, P = 0.010), and to have above poverty status (58.7% vs. 53.7%, P = 0.027). When comparing the final selected sample (N = 1,466) to those excluded from the original phase I, visit 1 sample (N = 2,254 of 3,720), only sex differentials were observed whereby women were likely to be selected (59.3% vs. 51.7%). Thus, we chose to include the inverse mills ratio that adjusted for selectivity between baseline and follow-up dietary data completeness, given its ability to adjust for greater bias.

Type I error was set at 0.05 for main effects and 0.10 for interaction terms due to the latter's reduced statistical power compared to the former.[81]

Results

The distribution of selected fixed, baseline and annual rate of change (Δ) values of study characteristics by Δ MVD tertile are presented in **Table 1**. Overall, both baseline (-) and follow-up

Table 1. Study sample characteristics by tertile of longitudinal change in the monetary value of diet (Δ MVD, \$/d), HANDLS 2004–2013³.

	Δ MVD tertiles (\$/d/y) ¹			P ²
	T ₁ (N = 489)	T ₂ (N = 489)	T ₃ (N = 488)	
Range,\$/d/y:	-6.053; -0.168	-0.168; +0.223	+0.223;+2.261	
Monetary value of diet and energy intakes				
Monetary value of diet at baseline, \$/day (X ± SE)	8.1±0.1	5.6±0.1	5.0±0.1	<0.001
Monetary value of diet at follow-up, \$/day (X ± SE)	5.2±0.1	5.6±0.1	7.4±0.1	<0.001
Δ MVD, \$/d/y (X ± SE) ¹	-0.64±0.02	-0.01±0.01	+0.54±0.01	<0.001
Energy intake at baseline, kcal/d (X ± SE)	2,504±49	1,872±33	1,650±34	<0.001
Energy intake at follow-up, kcal/d (X ± SE)	1,836±37	1,918±32	2,396±41	<0.001
Δ Energy intake, kcal/d/y (X ± SE) ¹	-152.9±9.8	+10.0±5.6	+169±8	0.11
Baseline socio-demographic and SES variables				
Sex, % male	45.2	36.2	41.2	0.023
Age at baseline, yrs. (X ± SE)	48.5±0.41	48.7±0.4	48.1±0.4	0.57
Age at follow-up, yrs. (X ± SE)	53.1±0.41	53.5±0.4	52.7±0.4	0.38
Δ Age, yrs. (X ± SE)	4.60±0.04	4.80±0.03	4.60±0.04	<0.001
African-American, %	56.9	60.7	60.3	0.75
Poverty status, % (<125% PIR)	40.5	44.2	38.3	0.18
Education, yrs. completed (X ± SE)				0.81
<HS	6.1	7.6	5.9	
HS	58.1	57.5	56.4	
>HS	35.8	35.0	37.5	
Literacy, WRAT-3 score				0.31
<36, %	21.3	23.7	19.3	
37–40, %	16.4	13.3	15.2	
41–46, %	26.6	29.7	29.3	
≥47, %	35.8	33.3	36.3	
% Unemployed in last month, yes	34.0	34.4	32.6	0.51

(Continued)

Table 1. (Continued)

	ΔMVD tertiles (\$/d/y) ¹			P ²
	T ₁	T ₂	T ₃	
	(N = 489)	(N = 489)	(N = 488)	
Range,\$/d/y:	-6.053; -0.168	-0.168; +0.223	+0.223;+2.261	
% Unemployment in last month, missing	19.4	15.1	17.8	
Baseline drug and tobacco use				
Any drug, current user, %	17.6	15.5	14.6	0.22
Any drug, missing, %	5.3	5.1	8.0	
Tobacco, current user, %	45.4	41.5	39.6	0.13
Tobacco, missing, %	5.3	5.1	8.0	
Baseline body mass index, kg/m ² (X ± SE)	30.1±0.3	29.8±0.3	30.1±0.3	0.83
Baseline self-rated health				0.001
Poor/Average, %	26.4	19.4	23.4	
Good, %	44.2	40.3	38.9	
Very good/Excellent %	28.8	40.3	37.7	
Baseline energy from grocery stores	1,921±48	1,448±30	1,254±30	<0.001
Follow-up energy from grocery stores	1,424±35	1,494±30	1,779±40	<0.001
Δ % energy from grocery stores (X ± SE)	+0.53±0.34	0.08±0.27	-0.39±0.30	0.11

Abbreviations: Δ = Annual rate of change; HANDLS = Healthy Aging in Neighborhood of Diversity across the Lifespan; HS = High School; MVD = Monetary value of the diet; PIR = Poverty Income Ratio; SE = Standard Error; T = tertile; WRAT-3 = Wide Range Achievement Test, 3rd revision.

¹ The monetary value of the diet (MVD) was estimated for each HANDLS wave using the HOMESCAN database at the annual and quarterly level for each food group. This was summed across individual dietary recall and averaged across individual participant in each wave. The annual rate of change in MVD (ΔMVD) is the difference between follow-up and baseline MVD divided by the time elapsed between baseline and follow-up. A similar calculation was done for Δ Energy intake (kcal/d/y) and Δ % energy from grocery stores.

² P-value from one-way ANOVA (continuous variables) or from χ² test (categorical variables). PIR = Poverty Income Ratio; SE = Standard Error; WRAT-3 = Wide Range Achievement Test, version 3.

³ Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004–2013, for the US market Nielsen data is licensed from The Nielsen Company, 2016 The conclusions drawn from the Nielsen data are those of the Researchers and do not reflect the views of Nielsen. Nielsen is not responsible for and was not involved in analyzing and preparing the results reported herein.

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(+) energy intakes (total and from grocery stores) were linearly related to ΔMVD (P-trend < 0.001), though Δenergy intake (kcal/d/y) and Δ % energy from grocery stores were not related to ΔMVD. While ΔMVD was not associated with race, age or poverty status, percent male was over-represented in the lowest tertile of ΔMVD (45.2% (T₁) vs. 36.2% (T₂) and 41.2% (T₃)). Moreover, a higher proportion rated their health as poor/average when belonging to the lowest tertile ΔMVD, as compared to the middle and uppermost tertiles (T₁: 26.4% vs. T₂: 19.4% and T₃: 23.4%).

S1 Table presents means of baseline, follow-up and longitudinal annual rates of change in diet quality by sex, race and poverty status. Both baseline and follow-up total scores on HEI-2010 indicated better quality among women compared to men, while the reverse was true for MAR. For both diet quality indices, individuals above poverty scored higher than participants living below poverty. An additional differential was observed for MAR, whereby Whites had a better diet quality compared with African-Americans. However, when examining annual rates of change in dietary quality, ΔHEI-2010 was comparable across socio-demographic groups, while ΔMAR was higher among women and individuals above poverty. Specifically, MAR was found to be increasing at a faster pace among women compared to men in terms of intakes of vitamin A, vitamin C, niacin, iron, though a slower pace was noted for zinc NAR. In terms of

Table 2. Annual rate of change in MVD tertiles as predictors of annual rate of change in the HEI-2010 (total score and components), stratifying by sex, race and poverty status: Multiple ordinary least square regression models, HANDLS 2004–2013⁵.

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm SE^1$ (T ₂ vs. T ₁)	$\beta \pm SE^1$ (T ₃ vs. T ₁)	
Δ HEI-2010 total score			
Overall	+0.71±0.19***	+1.33±0.22***	<0.001
Men	+0.56±0.28*	+1.29±0.31***	<0.001
Women	+0.85±0.27**	+1.44±0.32***	<0.001
Whites	+0.87±0.33**	+1.70±0.37***	<0.001
AA	+0.61±0.23**	+1.08±0.28***	<0.001
Above poverty	+0.84±0.26**	+1.76±0.30*** ⁴	<0.001 ⁴
Below poverty	+0.47±0.27†	+0.56±0.34†	0.097
Δ Total vegetables			
Overall	+0.02±0.03	+0.06±0.03†	0.061
Men	+0.04±0.05	+0.07±0.05	0.14
Women	+0.02±0.04	+0.06±0.04	0.15
Whites	-0.01±0.04	+0.05±0.05	0.35
AA	+0.04±0.03	+0.07±0.04†	0.072
Above poverty	+0.01±0.04	+0.08±0.04†	0.049
Below poverty	+0.02±0.04	+0.01±0.05	0.79
Δ Greens and beans			
Overall	+0.02±0.03	+0.09±0.04**	0.008
Men	-0.03±0.04	+0.00±0.05 ³	0.97 ³
Women	+0.07±0.04	+0.17±0.05**	0.001
Whites	-0.07±0.05	+0.03±0.06	0.57
AA	+0.09±0.04*	+0.15±0.05**	0.001
Above poverty	-0.02±0.04	+0.09±0.05	0.050
Below poverty	+0.06±0.04	+0.09±0.05†	0.088
Δ Total fruit			
Overall	+0.06±0.03†	+0.09±0.03*	0.013
Men	+0.06±0.04	+0.10±0.05*	0.041
Women	+0.06±0.04	+0.09±0.05†	0.091
Whites	+0.10±0.05*	+0.14±0.05**	0.009
AA	+0.02±0.04	+0.02±0.05	0.64
Above poverty	+0.11±0.04**	+0.16±0.05**	0.001
Below poverty	-0.01±0.04	-0.03±0.05	0.58
Δ Whole fruit			
Overall	+0.09±0.03**	+0.22±0.04***	<0.001
Men	+0.11±0.04*	+0.23±0.05***	<0.001
Women	+0.08±0.04†	+0.22±0.05***	<0.001
Whites	+0.14±0.05**	+0.26±0.06***	<0.001
AA	+0.04±0.04	+0.17±0.04***	<0.001
Above poverty	+0.13±0.04**	+0.27±0.05***	<0.001
Below poverty	+0.02±0.04	+0.14±0.05**	0.005
Δ Whole grains			
Overall	+0.10±0.05*	+0.14±0.05*	0.015
Men	+0.15±0.08*	+0.06±0.08	0.45
Women	+0.07±0.07	0.20±0.09*	0.018

(Continued)

Table 2. (Continued)

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm SE$ ¹ (T ₂ vs. T ₁)	$\beta \pm SE$ ¹ (T ₃ vs. T ₁)	
Whites	+0.18±0.09†	+0.20±0.10*	0.051
AA	+0.05±0.06	+0.09±0.07	0.19
Above poverty	+0.15±0.07*	+0.17±0.08*	0.047
Below poverty	+0.05±0.07	+0.12±0.08	0.15
Δ Dairy			
Overall	+0.22±0.05***	+0.44±0.06***	< 0.001
Men	+0.25±0.08**	+0.48±0.09***	< 0.001
Women	+0.21±0.07**	+0.42±0.08***	< 0.001
Whites	+0.24±0.09*	+0.54±0.11***	< 0.001
AA	+0.19±0.06**	+0.34±0.07***	< 0.001
Above poverty	+0.17±0.07*	+0.41±0.08***	< 0.001
Below poverty	+0.31±0.07***	+0.48±0.09***	< 0.001
Δ Total protein foods			
Overall	+0.04±0.02†	+0.04±0.02†	0.087
Men	+0.05±0.03†	+0.07±0.03*	0.037
Women	+0.01±0.03	+0.00±0.03	0.91
Whites	+0.04±0.04	+0.06±0.04	0.14
AA	+0.03±0.02	+0.03±0.03	0.24
Above poverty	+0.07±0.03*	+0.09±0.03***,4	0.005 ⁴
Below poverty	-0.01±0.03	-0.04±0.04	0.28
Δ Seafood and plant proteins			
Overall	+0.09±0.03**	+0.05±0.04	0.24
Men	+0.05±0.05	+0.03±0.06	0.59
Women	+0.11±0.04*	+0.06±0.05	0.33
Whites	+0.11±0.06†	+0.05±0.06	0.42
AA	+0.09±0.04*	+0.05±0.05	0.31
Above poverty	+0.09±0.05†	+0.04±0.05	0.44
Below poverty	+0.08±0.05†	+0.06±0.06	0.30
Δ Fatty acids			
Overall	-0.11±0.06†	-0.05±0.07	0.50
Men	-0.15±0.09	-0.09±0.10	0.38
Women	-0.08±0.08	-0.02±0.09	0.85
Whites	-0.09±0.11	+0.10±0.11	0.38
AA	-0.12±0.07†	-0.15±0.08†	0.08
Above poverty	-0.07±0.08	+0.02±0.09	0.84
Below poverty	-0.18±0.08*	-0.15±0.10	0.12
Δ Sodium			
Overall	-0.08±0.06	-0.21±0.07**	0.002
Men	-0.13±0.09	-0.12±0.10	0.22
Women	-0.04±0.08	-0.27±0.10**	0.005
Whites	-0.03±0.10	-0.35±0.11**	0.002
AA	-0.09±0.07	-0.10±0.09	0.27
Above poverty	-0.15±0.08†	-0.31±0.09**	0.001
Below poverty	+0.01±0.09	-0.07±0.11	0.52
Δ Refined grains			

(Continued)

Table 2. (Continued)

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm \text{SE}^1$ (T ₂ vs. T ₁)	$\beta \pm \text{SE}^1$ (T ₃ vs. T ₁)	
Overall	+0.18±0.06**	+0.30±0.07***	<0.001
Men	+0.12±0.09	+0.13±0.10	0.20
Women	+0.28±0.08***	+0.53±0.09***	<0.001
Whites	+0.17±0.10	+0.27±0.12*	0.021
AA	+0.23±0.07***	+0.41±0.08***	<0.001
Above poverty	+0.18±0.08*	+0.32±0.09***	<0.001
Below poverty	+0.17±0.08*	+0.27±0.10**	0.007
Δ Empty calories			
Overall	+0.07±0.09	+0.16±0.15	0.15
Men	+0.03±0.15	+0.32±0.17†	0.064
Women	+0.05±0.12	-0.02±0.15	0.86
Whites	+0.08±0.16	+0.35±0.18†	0.055
AA	+0.05±0.11	-0.02±0.13	0.87
Above poverty	+0.15±0.12	+0.43±0.14***,4	0.002 ⁴
Below poverty	-0.07±0.14	-0.33±0.17*	0.049

Abbreviations: Δ = Annual rate of change; HEI-2010 = Healthy Eating Index, 2010 version; HANDLS = Healthy Aging in Neighborhood of Diversity across the Lifespan; MVD = Monetary value of the diet; SE = Standard Error.

***P<0.001

**P<0.010

*P<0.05

†P<0.10 for null hypothesis that $\beta = 0$ (i.e. T₂ vs. T₁ and/or T₃ vs. T₁).

¹ Values are regression coefficients and their standard errors ($\beta \pm \text{SE}$) from a multivariable linear regression model with Y = annual rate of change in 2010-HEI (or components) or MAR (or components) and the key predictor being tertile of annual rate of change in MVD, contrasting the middle tertile with the lowest tertile (T₂ vs. T₁) and the uppermost tertile with the lowest tertile (T₃ vs. T₁). Models were adjusted for baseline age, sex, race, poverty status, educational attainment, literacy, employment status, current smoking status, current drug use, body mass index, self-rated health, annual rates of change in total energy intake and in % energy from grocery stores.

² P-trend was derived from a similar model as in a, but with the key predictor MVD tertiles entered as a single ordinal variable rather than two dummy variables.

³ P<0.05 for null hypothesis that the term sex^{*}MVD = 0 in a separate un-stratified regression model in which this interaction term was added.

⁴ P<0.05 for null hypothesis that the term pov^{*}MVD = 0 in a separate un-stratified regression model in which this interaction term was added.

⁵ Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004–2013, for the US market Nielsen data is licensed from The Nielsen Company, 2016 The conclusions drawn from the Nielsen data are those of the Researchers and do not reflect the views of Nielsen. Nielsen is not responsible for and was not involved in analyzing and preparing the results reported herein.

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poverty status differentials, MAR was found to increase at a faster pace among adults above poverty compared to below poverty, mainly through a higher Δ NAR in vitamin A, vitamin E, vitamin B-12, riboflavin, folate, calcium and magnesium. Other socio-demographic differentials, including differences in specific Δ HEI-2010 components by race were inconsistent.

Tables 2 and 3 show adjusted associations between annual rate of change in MVD tertiles and annual rates of change in the key diet quality indices, stratifying by sex, race and poverty

Table 3. Annual rate of change in MVD tertiles as predictors of annual rate of change in MAR and NAR, stratifying by sex, race and poverty status: Multiple ordinary least square regression models, HANDLS 2004–2013⁵.

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm SE$ ¹ (T ₂ vs. T ₁)	$\beta \pm SE$ ¹ (T ₃ vs. T ₁)	
Δ MAR score			
Overall	+1.40±0.19***	+2.90±0.20***	<0.001
Men	+1.08±0.26***, ³	+2.20±0.30***, ³	<0.001 ³
Women	+1.45±0.26***	+2.93±0.32***	<0.001
Whites	+1.31±0.32***	+3.17±0.35***	<0.001
AA	+1.39±0.23***	+2.60±0.28***	<0.001
Above poverty	+1.36±0.26***	+3.29±0.29***, ⁵	<0.001 ⁵
Below poverty	+1.44±0.27***	+2.22±0.34***	<0.001
Δ Vitamin A, NAR			
Overall	+1.89±0.53***	+4.61±0.62***	<0.001
Men	+1.89±0.84*	+3.46±0.94***	<0.001
Women	+2.01±0.71**	+5.63±0.86***	<0.001
Whites	+0.16±0.91 ⁴	+3.60±1.02***	<0.001
AA	+3.09±0.65***	+5.39±0.80***	<0.001
Above poverty	+1.40±0.75†	+4.76±0.84***	<0.001
Below poverty	+2.61±0.75**	+4.32±0.93***	<0.001
Δ Vitamin C, NAR			
Overall	+0.91±0.67	+1.01±0.78	0.20
Men	+0.24±1.04	-0.44±1.16	0.72
Women	+1.87±0.90*	+2.87±1.10**	0.010
Whites	+1.00±1.09	+2.57±1.22*	0.034
AA	+0.87±0.86	-0.03±1.04	0.98
Above poverty	+1.73±0.93†	+2.69±1.04* ⁵	0.010 ⁵
Below poverty	-0.30±0.97	-1.74±1.21	0.15
Δ Vitamin D, NAR			
Overall	+2.84±0.44***	+4.09±0.51***	<0.001
Men	+1.63±0.68*	+3.04±0.76***	<0.001
Women	+3.94±0.58***	+5.23±0.71***	<0.001
Whites	+2.65±0.59***	+4.85±0.65***, ⁴	<0.001 ⁴
AA	+3.09±0.62***	+3.90±0.75***	<0.001
Above poverty	+2.15±0.54***	+3.48±0.60***	<0.001
Below poverty	+3.86±0.74***	+5.08±0.91***	<0.001
Δ Vitamin E, NAR			
Overall	+0.14±0.38	+1.32±0.44**	0.003
Men	-0.33±0.60	+1.20±0.67†	0.083
Women	+0.23±0.50	+0.92±0.61	0.13
Whites	+0.50±0.67	+2.60±0.75**	0.001
AA	-0.18±0.44	+0.30±0.54	0.58
Above poverty	+0.82±0.54	+2.64±0.61***, ⁵	<0.001 ⁵
Below poverty	-0.96±0.50†	-0.93±0.61	0.13
Δ Vitamin B-6, NAR			
Overall	+2.03±0.35***	+3.80±0.41***	<0.001
Men	+1.56±0.47***, ³	+3.40±0.52***, ³	<0.001 ³
Women	+2.11±0.51***	+3.40±0.62***	<0.001
Whites	+1.99±0.60**	+4.11±0.67***	<0.001

(Continued)

Table 3. (Continued)

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm SE$ ¹ (T ₂ vs. T ₁)	$\beta \pm SE$ ¹ (T ₃ vs. T ₁)	
AA	+1.97±0.43***	+3.50±0.53***	<0.001
Above poverty	+2.11±0.47***	+4.69±0.52***,5	<0.001 ⁵
Below poverty	+1.82±0.55**	+2.19±0.68**	0.001
Δ Vitamin B-12, NAR			
Overall	+1.13±0.35**	+2.74±0.41***	<0.001
Men	+0.52±0.48 ³	+1.89±0.53***,3	<0.001 ³
Women	+1.35±0.50**	+3.01±0.61***	<0.001
Whites	+0.58±0.53	+2.55±0.59***	<0.001 ⁴
AA	+1.42±0.47**	+2.79±0.57***	<0.001
Above poverty	+1.00±0.49*	+3.16±0.54***	<0.001
Below poverty	+1.30±0.51*	+2.04±0.63**	0.001
Δ Thiamin, NAR			
Overall	+1.16±0.32***	+2.47±0.37***	<0.001
Men	+1.29±0.46**	+2.02±0.52***, 3	<0.001 ³
Women	+0.67±0.44	+1.91±0.54***	<0.001
Whites	+1.33±0.51*	+2.52±0.57***	<0.001
AA	+0.91±0.42*	+2.15±0.51***	<0.001
Above poverty	+1.05±0.43	+2.58±0.48***	<0.001
Below poverty	+1.65±0.50**	+2.30±0.62***	<0.001
Δ Riboflavin, NAR			
Overall	+0.75±0.24**	+2.05±0.28***	<0.001
Men	+0.32±0.36	+1.41±0.41***, 3	0.001 ³
Women	+0.84±0.33*	+2.07±0.40***	<0.001
Whites	+0.51±0.34 ⁴	+1.61±0.38***, 4	<0.001
AA	+0.80±0.34*	+2.05±0.41***	<0.001
Above poverty	+0.65±0.32*	+2.26±0.36***	<0.001
Below poverty	+1.00±0.38**	+1.76±0.47***	<0.001
Δ Niacin, NAR			
Overall	+1.33±0.28***	+2.22±0.32***	<0.001
Men	+0.71±0.37† ³	+1.72±0.42***, 3	<0.001 ³
Women	+1.35±0.38***	+1.76±0.47***	<0.001
Whites	+1.33±0.48**	+2.56±0.54***	<0.001
AA	+1.27±0.33***	+1.88±0.41***	<0.001
Above poverty	+1.00±0.38**	+2.40±0.42***	<0.001
Below poverty	+1.66±0.40***	+1.80±0.50***	<0.001
Δ Folate, NAR			
Overall	+1.52±0.38***	+3.47±0.44***	<0.001
Men	+1.73±0.52**	+2.95±0.59***, 3	<0.001 ³
Women	+1.03±0.54†	+2.90±0.65***	<0.001
Whites	+1.64±0.67*	+3.88±0.74***	<0.001
AA	+1.20±0.45**	+2.69±0.55***	<0.001
Above poverty	+1.18±0.53*	+3.74±0.59***	<0.001
Below poverty	+1.98±0.54***	+2.99±0.67***	<0.001
Δ Iron, NAR			
Overall	+1.08±0.34**	+2.74±0.40***	<0.001

(Continued)

Table 3. (Continued)

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm SE$ ¹ (T ₂ vs. T ₁)	$\beta \pm SE$ ¹ (T ₃ vs. T ₁)	
Men	+0.19±0.27 ³	+0.52±0.31† ³	<0.001
Women	+1.50±0.50**	+3.04±0.61***	<0.001
Whites	+1.12±0.59†	+2.66±0.66***	<0.001
AA	+0.96±0.41*	+2.65±0.50***	<0.001
Above poverty	+0.93±0.47*	+2.72±0.53***	<0.001
Below poverty	+1.27±0.49*	+2.60±0.61***	
Δ Copper, NAR			
Overall	+1.23±0.28***	+2.86±0.33***	<0.001
Men	+1.03±0.39**	+2.10±0.43***	<0.001 ³
Women	+1.04±0.39**	+2.63±0.48***	<0.001
Whites	+0.99±0.47*	+2.83±0.52***	<0.001
AA	+1.30±0.35***	+2.80±0.42***	<0.001
Above poverty	+1.57±0.39***	+3.26±0.43***	<0.001
Below poverty	+0.73±0.40†	+2.22±0.50***	<0.001
Δ Zinc, NAR			
Overall	+1.75±0.39***	+3.94±0.45***	<0.001
Men	+2.44±0.60***	+5.11±0.68***	<0.001
Women	+0.76±0.50	+2.06±0.61**	0.001
Whites	+2.29±0.64***	+4.78±0.72***	<0.001
AA	+1.14±0.47*	+3.09±0.58***	<0.001
Above poverty	+2.66±0.53*** ⁵	4.94±0.60*** ⁵	<0.001 ⁵
Below poverty	+0.60±0.55	+2.37±0.68**	0.001
Δ Calcium, NAR			
Overall	+1.98±0.41***	+4.08±0.47***	<0.001
Men	+2.02±0.61**	+3.75±0.68***, ³	<0.001 ³
Women	+1.62±0.56**	+3.76±0.68***	<0.001
Whites	+2.40±0.65***	+4.72±0.73***	<0.001
AA	+1.64±0.52**	+3.39±0.64***	<0.001
Above poverty	+1.13±0.55* ⁵	+4.04±0.61***	<0.001
Below poverty	+3.11±0.61***	+4.06±0.75***	<0.001
Δ Magnesium, NAR			
Overall	+2.10±0.27***	+3.53±0.32***	<0.001
Men	+1.70±0.40***	+2.67±0.45***, ³	<0.001 ³
Women	+2.32±0.38***	+4.15±0.46***	<0.001
Whites	+2.19±0.48***	+3.30±0.53***	<0.001
AA	+2.02±0.33***	+3.73±0.40***	<0.001
Above poverty	+1.80±0.37***	+3.65±0.42***	<0.001
Below poverty	+2.52±0.40***	+3.36±0.50***	<0.001
Δ Phosphorus, NAR			
Overall	+0.59±0.21**	+1.47±0.24***	<0.001
Men	+0.30±0.24 ³	+0.56±0.27*, ³	0.040 ³
Women	+0.55±0.31†	+1.55±0.38***	<0.001
Whites	+0.23±0.33	+1.50±0.36***	<0.001
AA	+0.75±0.27**	+1.29±0.33***	<0.001
Above poverty	+0.59±0.29*	+1.66±0.32***	<0.001

(Continued)

Table 3. (Continued)

	Δ MVD tertiles (\$/d/y) ¹		P-trend ²
	$\beta \pm SE$ ¹ (T ₂ vs. T ₁)	$\beta \pm SE$ ¹ (T ₃ vs. T ₁)	
Below poverty	+0.55±0.31†	+1.07±0.38**	0.005

Abbreviations: Δ = Annual rate of change; HANDLS = Healthy Aging in Neighborhood of Diversity across the Lifespan; MAR = Mean Adequacy Ratio; MVD = Monetary value of the diet, NAR = Nutrient Adequacy Ratio; SE = Standard Error.

***P<0.001

**P<0.010

*P<0.05

†P<0.10 for null hypothesis that $\beta = 0$ (i.e. T₂ vs. T₁ and/or T₃ vs. T₁).

¹ Values are regression coefficients and their standard errors ($\beta \pm SE$) from a multivariable linear regression model with Y = annual rate of change in 2010-HEI (or components) or MAR (or components) and the key predictor being tertile of annual rate of change in MVD, contrasting the middle tertile with the lowest tertile (T₂ vs. T₁) and the uppermost tertile with the lowest tertile (T₃ vs. T₁). Models were adjusted for baseline age, sex, race, poverty status, educational attainment, literacy, employment status, current smoking status, current drug use, body mass index, self-rated health, annual rates of change in total energy intake and in % energy from grocery stores.

² P-trend was derived from a similar model as in a, but with the key predictor MVD tertiles entered as a single ordinal variable rather than two dummy variables.

³ P<0.05 for null hypothesis that the term sex*MVD = 0 in a separate un-stratified regression model in which this interaction term was added.

⁴ P<0.05 for null hypothesis that the term race*MVD = 0 in a separate un-stratified regression model in which this interaction term was added.

⁵ P<0.05 for null hypothesis that the term pov*MVD = 0 in a separate un-stratified regression model in which this interaction term was added.

⁶ Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004–2013, for the US market Nielsen data is licensed from The Nielsen Company, 2016 The conclusions drawn from the Nielsen data are those of the Researchers and do not reflect the views of Nielsen. Nielsen is not responsible for and was not involved in analyzing and preparing the results reported herein.

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status. Δ MVD was positively associated with both Δ HEI-2010 and Δ MAR, and with a consistently stronger association among individuals above poverty, specifically for the total proteins and empty calories components of HEI-2010 and several NARs (vitamins C, E, B-6 and Zinc). Δ MVD- Δ MAR association was stronger in women, mainly influenced by Δ MVD's positive associations with B-vitamins, copper, calcium, magnesium and phosphorus NARs. Δ MVD- Δ vitamin D NAR's positive relationship was stronger among Whites, while Δ MVD- Δ vitamin B-12 NAR's association was stronger among African-Americans. Key associations between Δ MVD tertiles and changes in the two diet quality indices are illustrated in **S2 through S4 Figs** using predictive margins from the mixed-effects regression models, stratifying by sex, race and poverty status.

Discussion

This research is the first to link annual rates of change (Δ) in MVD to its dietary quality counterpart using the HEI-2010 and MAR scores simultaneously among urban US adults, while systematically examining differential associations across sex, race and poverty status. Among key findings, Δ HEI-2010 was comparable across socio-demographic groups, while Δ MAR was higher among women and individuals above poverty. Adjusting for key covariates, Δ MVD was positively associated in both Δ HEI-2010 and Δ MAR, and with a consistently stronger association among individuals above poverty, specifically for the total proteins and empty calories components of HEI-2010 and several nutrient adequacy ratios (NARs: vitamins C, E, B-6 and Zinc). Δ MVD- Δ MAR association was stronger in women, mainly influenced by Δ MVD's positive associations with B-vitamins, copper, calcium, magnesium and phosphorus NARs. Δ MVD- Δ vitamin D NAR's positive relationship was stronger among Whites, while Δ MVD- Δ vitamin B-12 NAR's association was stronger among African-Americans.

Although this is the first study examining this research question using a longitudinal design in a US population, another very recent longitudinal study conducted among Spanish adults found that increasing the average daily dietary cost from 3.68(SD0.0.89)€/8.36 MJ to 4.97 (SD1.16)€/8.36 MJ during the study period was associated with significant improvements in diet quality, as reflected by the Mediterranean Diet Score (MDS), (Δ ED and Δ MDS-rec; $P < 0.0001$). A 1€ increase in monetary diet cost per 8.36 MJ was linked to a decrease of an estimated 0.3 kg in body weight ($P = 0.02$) and a 0.1 kg/m² in BMI ($P = 0.04$). An attenuation in those associations was observed after adjustment for changes in diet quality indicators.[59]

Another observational panel data study of UK adults concluded that a lower expenditure on food is likely a key contributor to less-healthy food choices among lower socioeconomic groups, through a series of mediation analyses. Specifically, 63% of the total socioeconomic differences in choices of less-healthy foods/beverages were explained through a pathway involving expenditure, with a similar mediation proportion estimated at 36% for fruit and vegetables. Those figures were attenuated to 53% and 31%, respectively after adjustment for supermarket choice. [58] In addition, two intervention studies mirrored those findings among French adults.[56,57] For instance, simulating subsidies among French adult women triggered improvements in nutritional quality (fruit and vegetable quantities increased, ED decreased, the MAR increased), though the improvement magnitudes were often reduced among lower income women.[57]

Previous cross-sectional studies have corroborated our findings. For instance, a large study of women enrolled in the US Nurses' Health Study ($N = 78,191$) found that energy-adjusted MVD (uppermost vs. lowest quintile) was associated with a 30 point higher Alternative Healthy Eating Index score.[37] In another large cross-sectional study that restricted its sample to adult UK women ($N = 35,000$), dietary diversity and healthful dietary patterns were linked to a higher MVD, while SES among women had a positive association with the likelihood of a healthful dietary pattern. (44) Furthermore, another study found MVD to be a key mediator in the pathway linking income to diet quality, and education a moderator in that pathway. [42] Using the same sample ($N = 1,266$), another study reported MVD to be directly associated with dietary intakes of fiber, several vitamins (A, C, D, E, and B-12, β -carotene, folate), and selected minerals (iron, calcium, potassium and magnesium); contrasted with an inverse relationship between MVD and intakes of saturated fats, trans fats, and added sugars.[46] Among French adults, belonging to the highest MAR tertile was associated with the lowest dietary energy density and the highest diet costs,[30] a finding that was replicated by another cross-sectional study.[42]

Two studies by Rehm and colleagues using NHANES 2001–2002 and 2007–2010 corroborated findings from other large cross-sectional studies regarding the direct association between MVD and dietary quality, specifically as measured by the HEI-2005 and HEI-2010 indices. In their first study (NHANES 2001–2002), they reported that higher MVD was strongly associated with consuming more servings of fruit and vegetables and fewer calories derived from solid fat, alcoholic beverages and added sugars, as well as the total HEI-2005 score.[44] Using recent waves of NHANES (2007–2010) and the HEI-2010, Rehm and colleagues found that lower dietary costs were associated with lower consumption of vegetables, fruits, whole grains, and seafood, and higher consumption of refined grains, solid fat, alcohol and added sugars. The direct relationship between MVD and the total score on HEI-2010 was stronger among women, a finding that is similar to ours. Individual studies, including our previous cross-sectional analysis of HANDLS, also indicated that MVD's positive association with dietary quality associations was stronger among US women compared to men. [33,34,44,54]

Moreover, in our study, the annual rate of change in the sodium moderation component of the HEI-2010 was inversely associated with Δ MVD, after adjustment for energy intake and other key confounders. This finding was comparable to our previous cross-sectional analysis

of HANDLS,[10] as well as another study which reported a positive association between MVD and biomarker-based estimates of protein, potassium and sodium intake in young Japanese women. In the latter study, the monetary costs of vegetables and fish were main mediators.[35]

Pooling results from 24 studies and from 10 countries, a recent meta-analysis suggested that there were marked pricing differences between food groups, which ultimately increased the cost of healthful diets. Nevertheless, price differences had a weaker effect on nutrient-based patterns.[60] In addition, a more recent review came to a similar conclusion, whereby acceptable healthier diets were uniformly associated with higher costs, with food budgets in poverty being insufficient to ensure optimum diets.[55]

Among many of our study's strengths, it is the first to utilize the HEI-2010 and MAR scores to test MVD's association with overall dietary quality, while using longitudinal measurements of dietary intakes and their estimated MVD. Specifically, annual rates of change in those diet quality indices were linked to the annual rate of change in their estimated cost, using time-varying food price indices at the quarterly levels for each year that were assigned and linked to several food groups. Furthermore, it is among the few studies to examine differential associations between diet quality and MVD across race, sex and income groups. Our findings can be extrapolated to several African American and White populations, as HANDLS is representative of 14 urban settings across the United States. An improvement over our previous cross-sectional analysis of the HANDLS study,[10] is our assignment of food prices that were specific to Baltimore City, were measured to the nearest quarter and year, and that were deflated to a specific time point (the first quarter of 2004).

Nevertheless, our study findings should be interpreted with caution, given several important limitations. First, using food prices to estimate MVD may mildly underestimate actual food expenditures. [15] Second, there is evidence that the poor, given their lower volume purchases and reduced ability to travel, had a higher MVD.[82] This suggests that our key finding of the income differential in the association between Δ MVD and change in diet quality is potentially underestimated.[83,84] In terms of MVD estimation, some FNDDS food codes used to obtain food price indices lacked specificity needed to provide an exact match to foods as purchased; for example, a "burrito with chicken" may be reported for burritos purchased frozen, refrigerated, or prepared from a meal kit. Another limitation is that foods without barcodes, such as unpackaged fresh produce or meat sold by weight, are excluded from the database; prices for corresponding food groups are generated only from packaged items, over-representing frozen and canned items while under-representing fresh products. Homescan participants do not report foods purchased from fast food eateries, restaurants, and other away-from-home sources, and prices of foods purchased from stores may differ from prices these away-from-home sources. In addition, as stated earlier, imputations were conducted in order to estimate food price indices for certain FNDDS codes that did not fit into the pre-assigned 42 food groups.

In conclusion, we found a positive overall association between rate of change in MVD and that of indices of dietary quality. For both HEI-2010 and MAR, participants above poverty had a stronger longitudinal association between MVD and overall dietary quality as opposed to participants below poverty. Our findings also indicated that diet quality based on the HEI-2010 is far from being compliant with the Dietary Guidelines at both waves, whereby compliance is defined by a cut-point of 80 or higher. While a higher income can be a driving force for the effectiveness of MVD in reaching this level of compliance, nutrition education is another force that would influence people's decision-making regarding food venues and dietary choices. Since this study is observational, future intervention studies are warranted in urban populations to examine the differential effects of MVD on dietary quality across sex, race and poverty status.

Supporting information

S1 Method. HomeScan data description.

(DOCX)

S2 Method. Food group description.

(DOCX)

S1 Table.

(DOCX)

S1 Fig.

(PPTX)

S2 Fig.

(PPTX)

S3 Fig.

(PPTX)

S4 Fig.

(PPTX)

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Supplemental methods 1: HomeScan data description

The Homescan panel is a nationwide sample of US households that record all packaged foods and beverages purchased from grocery stores, supermarkets, and other retail food stores continuously throughout the year. Households are followed prospectively and must report purchases for at least 10 months per year. The sample includes approximately 40,000-60,000 US households each year from 76 geographic markets, and Nielsen provides projection factor weights to generate nationally representative estimates.(1) Household members scan the Universal Product Code barcode on each purchased item after each shopping trip using a handheld scanner and report the quantity purchased. Methods for reporting price paid depend on the store where the purchase takes place. For most products, Nielsen imputes the price paid from store-level point-of-sales data (“ScanTrack”) as the average price paid for the product from that store for the given week and market.(2) However, for items purchased from stores not covered by ScanTrack, households must manually record the price paid; if the reported price is outside of the typical range, Nielsen replaces the reported value with the median regional price.(2)

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Supplemental methods 2: Food group description

FG UNC	UNC Description of FG	HANDLS code for closest FG
1	cheese	24,25,26
2	yogurt	
3	dairy products, other	
4	dairy-based desserts	30,31
5	meat	32,36,38,39
6	meat, breaded	33,35,37
7	processed meat	40
8	Eggs	44
9	Legumes	45
10	Nuts and nut products	57
11	Bread and bread products	1,2
12	TORTILLAS, TACO SHELLS, AND WRAPS	
13	QUICK BREADS	
14	GRAIN-BASED DESSERTS	
15	Grain-based bars	
16	Pasta and rice	4,5,6
17	Cereal	7
18	Fruit	13,14,15,16
19	Fruit dish	17
20	Vegetables	18,19,21
21	Starchy vegetables	20
22	Fried potatoes	
23	Fats and oils	54,55,56
24	Sweeteners	52
25	CANDY AND SWEET SNACKS	51,53
26	Baking products	11
27	Salt and seasoning	60
28	Soups and stews	14,41
29	Salty snacks	8,9
30	SAUCES, DIPS, AND CONDIMENTS	
31	Baby food	12
32	MIXED DISH, REFRIGERATED	
33	MIXED DISH, FROZEN	46
34	MIXED DISH, CANNED/SHELF-STABLE	
35	MIXED DISH, INSTANT/MIX	
36	Water	61 or closest neighbor
37	Coffee and tea	47
38	SSB	48,49
39	FRUIT AND VEGETABLE JUICE	

40	Milk	22,23
	COCOA AND SWEETENED MILK	
41	BEVERAGES	
42	MILK SUBSTITUTES AND MILK BEVERAGES	58

Use closest neighbor imputation instead if imputed
 Use HANDLS code if imputed; UNC code otherwise

HANDLS 61 food groups.

GRAINS

1. (1) Refined breads, (3) Multigrain breads, (5) Low sodium breads, (6) Refined Quick breads
2. (2) 100% whole wheat breads, (4) High fiber, reduced calorie breads, (7) Whole wheat quick breads, (10) Whole wheat pasta without added fat, (11) Whole wheat pasta with added fat, (12) Brown rice without fat added, (13) Brown rice with fat added
3. (18) Whole grain cooked cereals no fat added, (19) Whole grain cooked cereals with fat added, (25) Whole wheat crackers, (21) High fiber cereals
4. (8) Pastas without added fat, (9) Pastas with added fat, (154) Pasta with meat, (155) Pasta without meat
5. (14) Cereals and white rice without added fat, (15) Cereals and white rice with added fat, (156) Rice dishes with meat, (157) Rice dishes without meat
6. (16) Cooked cereals with no fat, (17) Cooked cereals with fat added
7. (20) Ready to eat cereals, (37) Breakfast bars
8. (22) Regular crackers, (26) Salty snacks (chips, pretzels, popcorn, chips)
9. (23) Reduced fat crackers, (27) Low sodium snacks (pretzels, crackers, chips, popcorn), (28) Reduced fat potato chips
10. (24) Sweet crackers (graham, animal), (29) Cakes, (31) Doughnuts, (32) Cookies, (34) Pies (excludes fruit pies), (36) Pastries
11. (30) Diet cakes and pastries, (33) Diet cookies

12. (39) Baby foods, (129) Infant formulas, (230) Baby foods

FRUITS

13. (50) Raw, canned, frozen fruit without added sugar, (62) Unsweetened fruit juices,
(51) Canned sweetened fruit, (63) Sweetened fruit juices,
14. (52) Citrus fruits without added sugar, (53) Citrus fruits with added sugar, (60) Unsweetened citrus fruit juices, (61) Sweetened citrus fruit juices,
15. (54) Berries without added sugar, (55) Berries with added sugar
16. (56) Dried fruit, dried fruit cooked without added sugar, (57) Dried fruit cooked with added sugar
17. (58) Fruit desserts, (59) Fruit with added fat, (35) Fruit pies

VEGETABLES

18. (200) Raw and cooked without fat dark green vegetables, (204) Low sodium canned dark green vegetables, (202) Canned dark green vegetables with or without added fat, (201) Cooked with added fat dark green vegetables
19. (205) Raw and cooked without fat orange vegetables, (207) Canned orange vegetables with or without added fat, (209) Low sodium canned orange vegetables, (210) Cooked orange vegetables with sugar added, (206) Cooked with added fat orange vegetables, carrot juice
20. (211) Raw and cooked without fat starchy vegetables, (213) Canned starchy vegetables without added fat, (215) Low sodium canned starchy vegetables, (224) Canned vegetable combinations cooked with or without fat, (212) Cooked with added fat starchy vegetables, (214) Canned starchy vegetables with added fat, (216) French fried potatoes
21. (217) Raw and cooked without fat other vegetables, (219) Canned other vegetables without added fat, (221) Low sodium canned other vegetables, (222) Vegetable combinations cooked without fat, (218) Cooked with added fat other vegetables, (220) Canned other vegetables with added fat, (223) Vegetable combinations cooked with fat, (229) Vegetable salads with added fat, (228) Pickled vegetables, (226) Vegetable juices, (227) Low sodium vegetable juices, (232) Low sodium veg combinations

MILK and MILK PRODUCTS

- 22. (100) Regular milk
- 23. (101) Reduced fat milk, (102) Fat free milk
- 24. (112) Natural, regular cheese, (116) Low sodium cheese
- 25. (113) Natural, reduced fat and fat free cheese
- 26. (114) Processed, regular cheese
- 27. (115) Processed, reduced fat and fat free cheese
- 28. Regular dairy products:
 (120) Regular cheese products (cottage, cream), (106) Regular cream, (108) Regular milk based beverages, (117) Regular cheese sauce, (122) Cheese based soups, (110) Regular yogurt (includes frozen)
- 29. Low fat dairy products:
 (121) Lowfat or fat free cheese products (cottage, cream), (107) Reduced fat cream, (109) Reduced fat milk based beverages, (118) Low fat cheese sauce, (111) Lowfat yogurt (includes frozen)
- 30. Dairy desserts- regular: (123) Regular ice cream, (126) Regular pudding, (103) Condensed milk
- 31. Dairy desserts – low or ff desserts: (124) Light ice cream, (125) Fat free ice cream, (127) Reduced fat pudding, (162) nondairy frozen desserts

MEATS

- 32. (300) Lean red meats no added fat, (309) Veal, (311) Game
- 33. (301) Red meats with fat, (308) Lamb
- 34. (302) Chicken/poultry no added fat
- 35. (303) Chicken/poultry with added fat
- 36. (304) Fin fish no fat
- 37. (305) Fin fish with added fat
- 38. (306) Shellfish
- 39. Sandwich: (119) Cheese sandwich, (320) Beef/pork sandwiches, (321) Poultry sandwiches, (322) Fish sandwiches, (323) Bacon/sausage hot dog sandwiches,

- (324) Submarine sandwiches and luncheon meat sandwiches, (38) Sandwiches (croissant, turnover)
40. (307) Sausage/bacon/luncheon meats, (310) Organ meats
41. (312) Meat dishes, (325) Frozen meat meals, (329) Frozen veal meals, (313) Chicken dishes, (327) Frozen chicken meals, (314) Seafood dishes, (330) Frozen fish meals, (150) Hispanic dishes with meat, (160) Dumplings and egg rolls
42. Soups: (315) Mixed meats (stews, gumbo), (316) Beef/pork soups, (317) Poultry soups, (318) Seafood soups, (161) Grain-based soups with meat, (231) Vegetable soups
43. Diet Frozen meals: (326) meat, (328) chicken, (331) fish

EGGS

44. Egg dishes: (140) Egg dishes without fat, (141) Egg dishes with added fat, (142) Egg substitutes, (143) Egg sandwiches, (144) Frozen egg meals

LEGUMES

45. (250) Legumes prepared with fat, (251) Legumes prepared without fat, (252) Canned legumes prepared with fat, (253) Canned legumes prepared without fat, (254) Low sodium canned legumes, (255) Legume prepared dishes with meat, (256) Legume prepared dishes without meat, (257) Legume based soups, (258) Low sodium legume based soups, (104) Soy milk, (151) Hispanic dishes without meat

MIXED DISHES

46. Pizza: (152) Pizza with meat, (153) Pizza without meat

BEVERAGES

47. Coffee/ Tea: (80) Coffee, (83) Coffee substitutes, (84) Tea
48. Sweetened drinks: (89) Regular soft drinks, (81) Presweetened coffee, (85) Presweetened tea, (87) Fruit drinks
49. Diet drinks: (90) Diet soft drinks, (82) Coffee with low calorie sweeteners, (86) Tea with low calorie sweetener, (88) Low calories fruit drinks
50. (91) Alcoholic beverages

SUGARS

- 51. Sugar: (400) Added sugars, (402) Regular gelatin dessert
- 52. Sugar substitute: (401) Sugar substitutes, (403) Sugar free gelatin desserts, (405) Dietetic free/low calorie candy
- 53. (404) Candy

FATS

- 54. (420) Animal fats and salad dressings, (319) Meat gravy
- 55. (421) Vegetable fats and salad dressings
- 56. (422) Reduced calorie spreads and salad dressings

NUTS

- 57. (450) Nuts and nut butters, (451) Low sodium nuts and nut butters, (452) Peanut butter sandwiches

OTHERS

- 58. (470) Protein powders and meal replacements, (128) Milk based powders, Milk substitutes, nutritional beverage.
- 59. (480) Yeast
- 60. (490) Condiments
- 61. Water

TABLE S1. Baseline, follow-up and longitudinal annual rate of change in diet quality scores (HEI-2010 and MAR/NAR scores) by sex, race and poverty status, HANDLS 2004-2013^{1,3}

	Overall	Men	Women	P _{sex} ²	Whites	AA	P _{race} ²	Above Poverty	Below Poverty	P _{pov} ²
	N=1,466	N=597	N=869		N=589	N=877		N=861	N=605	
	X ± SE	X ± SE	X ± SE		X ± SE	X ± SE		X ± SE	X ± SE	
HEI-2010 total score										
Baseline	43.2±0.3	41.9±0.4	44.0±0.4	<0.001	43.5±0.5	42.9±0.4	0.40	44.5±0.4	41.3±0.4	<0.001
Follow-up	46.5±0.3	45.3±0.4	47.4±0.4	<0.001	47.2±0.6	46.1±0.4	0.098	47.9±0.4	44.6±0.46	<0.001
Δ	+0.74±0.07	+0.73±0.11	+0.75±0.10	0.88	+0.86±0.13	+0.66±0.09	0.17	+0.78±0.10	+0.68±0.10	0.47
Total vegetables										
Baseline	2.71±0.03	2.55±0.05	2.81±0.05	<0.001	2.84±0.1	2.62±0.04	0.002	2.77±0.04	2.62±0.05	0.036
Follow-up	2.72±0.04	2.61±0.05	2.79±0.05	0.009	2.89±0.1	2.60±0.04	<0.001	2.81±0.05	2.58±0.05	0.001
Δ	+0.00±0.01	+0.01±0.02	+0.00±0.01	0.73	+0.01±0.02	-0.00±0.01	0.41	+0.01±0.01	-0.01±0.01	0.16
Greens and beans										
Baseline	0.99±0.04	0.88±0.05	1.07±0.05	0.016	0.91±0.06	1.04±0.05	0.072	1.00±0.05	0.98±0.05	0.79
Follow-up	1.27±0.04	1.12±0.06	1.37±0.05	0.002	1.32±0.07	1.24±0.05	0.35	1.32±0.05	1.19±0.06	0.12
Δ	+0.06±0.01	+0.05±0.02	+0.08±0.02	0.24	+0.10±0.02	+0.04±0.01	0.014	+0.08±0.02	+0.04±0.02	0.08
Total fruit										
Baseline	1.63±0.04	1.53±0.07	1.71±0.06	0.035	1.70±0.07	1.59±0.05	0.22	1.84±0.06	1.35±0.06	<0.001
Follow-up	1.87±0.05	1.65±0.07	2.02±0.06	<0.001	1.80±0.07	1.92±0.04	0.21	1.97±0.06	1.73±0.07	0.009
Δ	+0.04±0.01	+0.02±0.02	+0.06±0.02	0.11	+0.02±0.02	+0.06±0.01	0.074	+0.02±0.02	+0.07±0.02	0.030
Whole fruit										
Baseline	1.25±0.04	1.11±0.06	1.35±0.06	0.006	1.56±0.08	1.05±0.05	<0.001	1.45±0.06	0.97±0.06	<0.001
Follow-up	1.57±0.05	1.34±0.07	1.72±0.06	<0.001	1.80±0.08	1.41±0.06	<0.001	1.73±0.06	1.34±0.07	<0.001
Δ	+0.07±0.01	+0.05±0.02	+0.08±0.02	0.19	+0.06±0.02	+0.08±0.01	0.33	+0.07±0.02	+0.07±0.02	0.77
Whole grains										
Baseline	1.85±0.07	1.62±0.09	+2.00±0.10	0.005	2.10±0.11	1.67±0.08	0.001	2.01±0.09	1.61±0.10	0.003
Follow-up	2.23±0.07	2.02±0.10	+2.38±0.09	0.009	2.32±0.11	2.17±0.09	0.28	2.43±0.09	1.95±0.10	<0.001

Δ	+0.08±0.02	+0.09±0.03	+0.08±0.03	0.85	+0.05±0.03	+0.11±0.02	0.15	+0.09±0.03	+0.07±0.03	0.65
Dairy										
Baseline	3.57±0.07	3.50±0.10	+3.62±0.09	0.40	4.51±0.11	2.95±0.08	<0.001	3.72±0.09	3.37±0.10	0.012
Follow-up	4.20±0.07	4.04±0.10	+4.30±0.09	0.063	5.15±0.11	3.56±0.08	<0.001	4.42±0.09	3.89±0.10	<0.001
Δ	+0.14±0.02	+0.13±0.03	+0.16±0.03	0.48	+0.16±0.04	+0.14±0.02	0.55	+0.17±0.03	0.07±0.03	0.17
Total protein foods										
Baseline	4.29±0.03	4.37±0.04	4.24±0.03	0.018	4.07±0.05	4.44±0.03	<0.001	4.31±0.03	4.25±0.04	0.20
Follow-up	4.29±0.03	4.39±0.04	4.22±0.03	0.002	4.08±0.05	4.43±0.03	<0.001	4.30±0.03	4.28±0.04	0.64
Δ	+0.00±0.01	+0.00±0.01	+0.00±0.01	0.99	+0.00±0.01	+0.00±0.01	0.99	-0.00±0.01	+0.01±0.01	0.37
Seafood and plant proteins										
Baseline	1.67±0.04	1.54±0.07	1.78±0.06	0.008	1.69±0.07	1.68±0.06	0.78	1.81±0.06	1.48±0.06	<0.001
Follow-up	1.80±0.04	4.39±0.04	1.86±0.06	0.10	1.94±0.07	1.70±0.06	0.009	1.93±0.06	1.62±0.07	<0.001
Δ	+0.03±0.01	+0.05±0.02	+0.03±0.02	0.37	+0.07±0.02	+0.01±0.02	0.013	+0.03±0.02	+0.03±0.02	0.94
Fatty acids										
Baseline	5.17±0.07	5.12±0.11	5.20±0.09	0.60	4.39±0.11	5.69±0.09	<0.001	5.23±0.10	5.07±0.11	0.26
Follow-up	5.33±0.07	5.28±0.12	5.37±0.09	0.52	4.69±0.12	5.77±0.09	<0.001	5.28±0.10	5.41±0.11	0.37
Δ	+0.03±0.02	+0.03±0.03	+0.03±0.03	0.95	+0.06±0.04	+0.01±0.03	0.23	+0.01±0.03	+0.07±0.03	0.19
Sodium										
Baseline	4.95±0.08	4.93±0.12	4.97±0.10	0.76	4.39±0.11	5.01±0.10	0.36	4.90±0.10	5.03±0.12	0.38
Follow-up	4.20±0.07	4.12±0.12	4.26±0.10	0.34	4.25±0.12	4.17±0.09	0.61	4.15±0.10	4.28±0.12	0.37
Δ	-0.18±0.02	-0.19±0.04	-0.18±0.03	0.78	-0.17±0.04	-0.19±0.03	0.55	-0.19±0.03	-0.17±0.03	0.56
Refined grains										
Baseline	6.23±0.07	6.11±0.12	6.33±0.09	0.16	5.89±0.12	6.47±0.09	<0.001	6.21±0.10	6.29±0.11	0.58
Follow-up	6.61±0.07	6.61±0.11	6.61±0.09	0.94	6.31±0.11	6.82±0.09	0.0003	6.60±0.09	6.63±0.11	0.80
Δ	+0.09±0.02	+0.10±0.04	+0.08±0.03	0.59	+0.11±0.04	+0.08±0.03	0.51	+0.09±0.03	+0.08±0.03	0.73
Empty calories										
Baseline	8.83±0.14	8.61±0.22	8.97±0.18	0.20	9.00±0.23	8.73±0.17	0.37	9.21±0.19	8.28±0.21	0.001
Follow-up	10.44±0.14	10.38±0.21	10.48±0.18	0.71	10.64±0.23	10.31±0.17	0.24	10.95±0.18	9.70±0.21	<0.001
Δ	+0.35±0.04	+0.39±0.06	+0.33±0.04	0.45	0.39±0.06	+0.33±0.04	0.46	+0.40±0.05	+0.29±0.05	0.16
MAR										

Baseline	73.3±0.4	77.1±0.6	70.7±0.5	<0.001	75.7±0.6	71.6±0.5	<0.001	73.7±0.5	72.7±0.6	0.25
Follow-up	75.4±0.4	78.1±0.5	73.6±0.5	<0.001	77.3±0.6	74.1±0.5	<0.001	76.6±0.5	73.7±0.6	<0.001
Δ	0.48±0.10	+0.23±0.13	0.65±0.13	0.032	+0.36±0.16	+0.56±0.12	0.30	+0.68±0.13	+0.20±0.13	0.014
Vitamin A, NAR										
Baseline	53.2±0.8	56.3±1.2	51.2±1.0	0.001	58.3±1.2	49.9±1.0	<0.001	53.7±1.0	52.6±1.2	0.49
Follow-up	63.2±0.8	60.5±1.2	65.0±1.0	0.004	67.6±1.2	60.2±1.0	<0.001	65.6±1.0	59.7±1.2	<0.001
Δ	+2.37±0.22	+0.99±0.35	+3.33±0.28	<0.001	+2.46±0.38	+2.32±0.27	0.76	+2.96±0.30	+1.54±0.31	0.002
Vitamin C, NAR										
Baseline	53.8±0.9	55.4±1.5	52.7±1.2	0.14	52.2±1.5	54.9±1.2	0.15	56.3±1.2	50.2±1.4	0.001
Follow-up	63.0±0.9	59.1±1.5	65.7±1.2	<0.001	59.5±1.5	65.4±1.2	0.002	64.9±1.2	60.4±1.5	0.016
Δ	1.86±0.26	+0.58±0.42	+2.73±0.33	<0.001	+1.66±0.43	+2.00±0.33	0.53	+1.80±0.36	+1.94±0.38	0.79
Vitamin D, NAR										
Baseline	23.7±0.5	27.1±0.9	21.4±0.7	<0.001	25.5±0.9	22.5±0.66	0.006	23.6±0.7	23.8±0.8	0.84
Follow-up	19.0±0.5	23.5±0.9	16.0±0.6	<0.001	20.8±0.9	17.9±0.6	0.007	19.8±0.7	17.9±0.8	0.064
Δ	-0.87±0.17	-0.68±0.28	-1.00±0.22	0.37	-1.08±0.25	-0.73±0.24	0.32	-0.80±0.21	-0.97±0.29	0.63
Vitamin E, NAR										
Baseline	42.2±0.6	46.5±1.0	39.2±0.8	<0.001	44.6±1.0	40.5±0.77	0.001	42.9±0.8	41.2±0.9	0.17
Follow-up	46.8±0.6	51.5±1.0	43.5±0.8	<0.001	48.7±1.0	45.5±0.8	0.012	48.7±0.8	44.0±0.9	<0.001
Δ	+1.06±0.17	+1.14±0.27	+1.00±0.21	0.67	+1.00±0.29	+2.32±0.27	0.77	+1.40±0.24	+0.57±0.23	0.015
Vitamin B-6, NAR										
Baseline	85.9±0.5	89.3±0.8	83.6±0.7	<0.001	87.1±0.8	85.1±0.7	0.068	85.9±0.7	85.9±0.8	0.90
Follow-up	87.5±0.5	90.8±0.7	85.2±0.7	<0.001	87.0±0.9	87.8±0.6	0.47	88.3±0.7	86.3±0.8	0.062
Δ	+0.38±0.15	+0.38±0.19	+0.38±0.21	0.99	-0.01±0.25	+0.64±0.18	0.031	+0.56±0.20	+0.12±0.22	0.14
Vitamin B-12, NAR										
Baseline	91.5±0.5	94.6±0.6	89.3±0.7	<0.001	93.0±0.7	90.4±0.7	0.013	91.1±0.7	92.0±0.7	0.34
Follow-up	91.8±0.5	94.2±0.6	90.2±0.7	<0.001	93.6±0.7	90.7±0.7	0.003	92.4±0.6	91.1±0.8	0.19
Δ	+0.12±0.14	-0.08±0.19	0.27±0.20	0.22	+0.17±0.21	+0.09±0.19	0.77	+0.35±0.19	-0.21±0.20	0.048
Thiamin, NAR										
Baseline	87.8±0.5	90.1±0.7	86.2±0.7	<0.001	92.8±0.6	85.6±0.7	<0.001	88.1±0.6	87.4±0.8	0.49
Follow-up	90.5±0.5	93.1±0.6	88.6±0.6	<0.001	91.1±0.7	88.9±0.6	<0.001	91.0±0.6	89.6±0.7	0.13
Δ	+0.54±0.13	+0.71±0.19	+0.43±0.19	0.31	+0.32±0.21	0.70±0.18	0.17	+0.63±0.18	+0.42±0.21	0.45

Riboflavin, NAR										
Baseline	94.0±0.4	95.0±0.5	93.2±0.5	0.015	96.2±0.5	92.5±0.5	<0.001	93.9±0.5	94.1±0.6	0.71
Follow-up	94.1±0.4	95.1±0.5	93.4±0.5	0.017	96.7±0.4	92.4±0.5	<0.001	94.9±0.4	93.0±0.6	0.011
Δ	+0.03±0.10	+0.02±0.15	+0.04±0.14	0.92	+0.11±0.14	-0.02±0.14	0.52	+0.21±0.13	-0.22±0.15	0.035
Niacin, NAR										
Baseline	91.7±0.4	95.7±0.5	89.0±0.6	<0.001	92.6±0.6	91.1±0.6	0.076	91.9±0.5	91.4±0.7	0.56
Follow-up	95.1±0.3	96.8±0.4	93.9±0.5	<0.001	94.9±0.5	95.2±0.4	0.69	95.4±0.4	94.7±0.5	0.29
Δ	+0.72±0.11	+0.29±0.15	+1.02±0.16	0.002	+0.48±0.20	+0.89±0.14	0.08	+0.80±0.16	+0.61±0.17	0.40
Folate, NAR										
Baseline	72.8±0.7	77.8±1.0	69.3±0.9	<0.001	77.3±1.0	69.7±0.8	<0.001	73.1±0.9	72.3±1.0	0.56
Follow-up	75.7±0.6	81.3±0.9	71.7±0.8	<0.001	80.5±0.9	72.4±0.8	<0.001	77.8±0.8	72.6±1.0	<0.001
Δ	+0.65±0.17	+0.80±0.24	+0.54±0.23	0.46	+0.71±0.28	+0.60±0.21	0.75	+1.09±0.23	+0.02±0.24	0.002
Iron, NAR										
Baseline	78.5±0.7	97.5±0.4	65.4±0.8	<0.001	80.3±1.0	77.1±0.9	0.020	79.0±0.9	77.3±1.00	0.35
Follow-up	89.6±0.5	98.1±0.3	83.8±0.8	<0.001	90.2±0.8	89.3±0.7	0.35	90.3±0.6	88.7±0.83	0.14
Δ	+2.48±0.15	+0.13±0.11	+4.10±0.23	<0.001	+2.38±0.25	+2.56±0.19	0.57	+2.64±0.21	+2.27±0.22	0.23
Copper, NAR										
Baseline	90.6±0.4	93.8±0.5	88.5±0.6	0.006	91.4±0.7	90.1±0.6	0.16	91.1±0.5	90.00±0.68	0.21
Follow-up	90.2±0.4	93.2±0.5	88.1±0.6	<0.001	91.3±0.7	89.4±0.6	0.033	91.2±0.5	88.7±0.83	0.005
Δ	-0.11±0.11	-0.08±0.16	-0.12±0.17	0.86	-0.08±0.20	-0.13±0.15	0.85	+0.03±0.14	-0.31±0.17	0.17
Zinc, NAR										
Baseline	86.1±0.5	85.6±0.8	86.4±0.7	0.44	84.3±0.7	88.7±0.8	<0.001	85.5±0.7	86.9±0.8	0.18
Follow-up	64.5±0.6	68.7±1.0	61.6±0.8	<0.001	62.4±0.8	67.6±1.0	<0.001	65.7±0.8	62.8±1.0	0.021
Δ	-4.87±0.17	-3.77±0.26	-5.63±0.22	<0.001	-4.64±0.21	-5.20±0.30	0.11	-4.75±0.24	-5.04±0.24	0.42
Calcium, NAR										
Baseline	62.3±0.7	70.0±1.1	57.0±0.9	<0.001	68.6±1.1	58.1±0.9	<0.001	63.2±0.9	61.0±1.1	0.11
Follow-up	71.1±0.7	79.2±1.0	65.6±0.9	<0.001	76.6±1.0	67.5±0.9	<0.001	73.0±0.9	68.5±1.0	0.001
Δ	+2.07±0.18	+2.14±0.27	+2.02±0.24	0.73	+1.95±0.28	+2.14±0.23	0.58	+2.38±0.24	+1.62±0.26	0.035
Magnesium, NAR										
Baseline	63.2±0.6	61.1±0.9	64.6±0.8	<0.001	68.4±1.0	59.6±0.7	0.003	64.2±0.8	61.8±0.9	0.051
Follow-up	67.3±0.6	65.4±0.9	68.6±0.8	0.006	71.5±0.9	64.5±0.7	<0.001	69.5±0.8	64.2±0.9	<0.001

Δ	+0.90±0.15	+0.91±0.23	+0.90±0.19	0.98	+0.61±0.26	1.10±0.18	0.11	+1.19±0.21	+0.49±0.21	0.022
Phosphorus, NAR										
Baseline	95.4±0.3	97.6±0.4	93.9±0.5	<0.001	96.6±0.4	94.7±0.4	<0.001	95.6±0.4	95.2±0.5	0.59
Follow-up	97.0±0.3	98.6±0.3	95.9±0.4	<0.001	97.6±0.4	96.5±0.4	0.048	97.1±0.3	94.7±0.4	0.45
Δ	+0.32±0.08	+0.21±0.10	+0.40±0.13	0.29	+0.22±0.13	+0.39±0.11	0.33	+0.36±0.11	+0.27±0.12	0.60

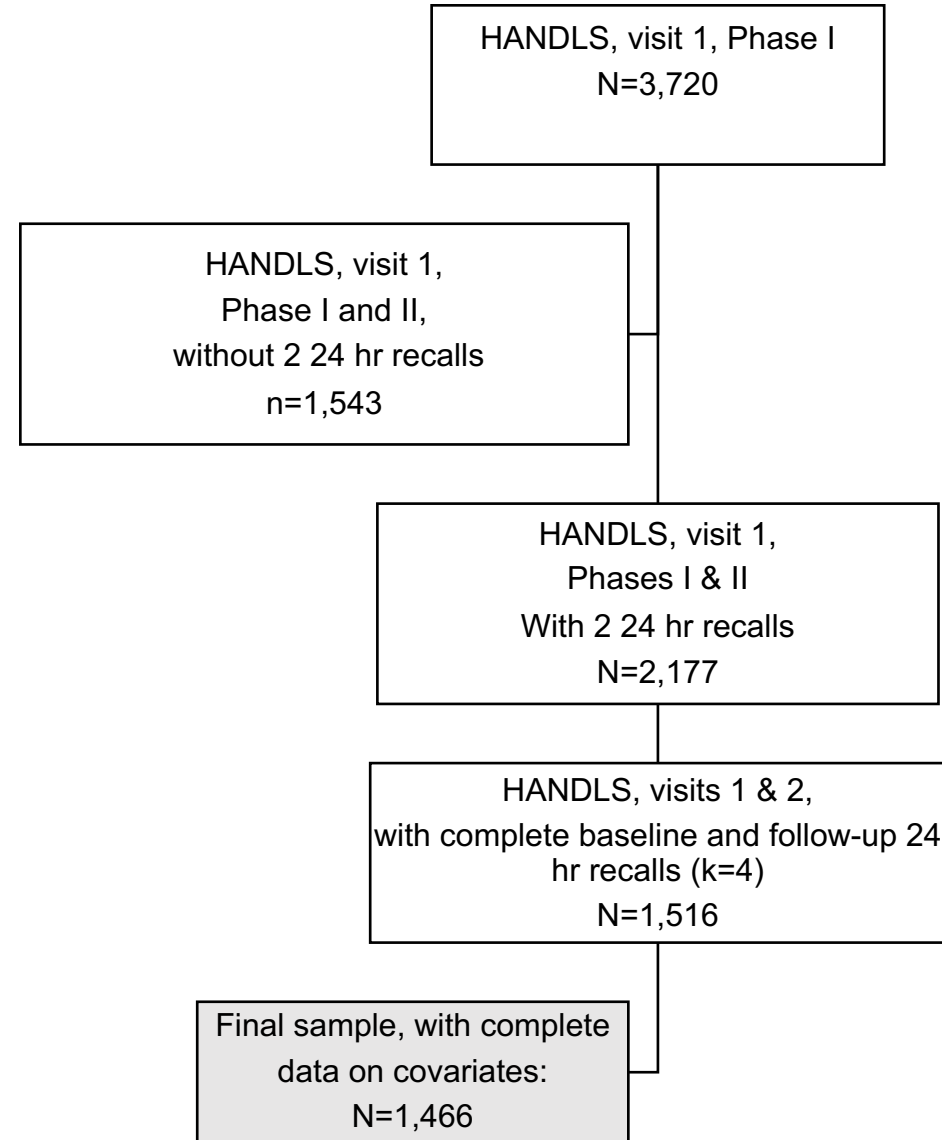
Abbreviations: Δ =Annual rate of change; HEI-2010= Healthy Eating Index, 2010 version; HANDLS=Healthy Aging in Neighborhood of Diversity across the Lifespan; MAR=Mean Adequacy Ratio, MVD=Monetary value of the diet, NAR=Nutrient Adequacy Ratio; SE=Standard Error.

¹ Values are means \pm standard errors for baseline, follow-up and annual rates of change (Δ) of diet quality indices, total scores and components. Components of the mean adequacy score (MAR) and the individual nutrient adequacy scores for each micronutrient (NAR). Both MAR and NAR can range from 0 to 100. Total score for HEI-2010 can range from 0 to 100, but component scores vary in possible ranges (e.g. 0-20 for empty calories vs. 0-5 for total fruit).

² 2-sided P-value associated with an independent samples *t*-test for comparing means across sex, race or poverty status.

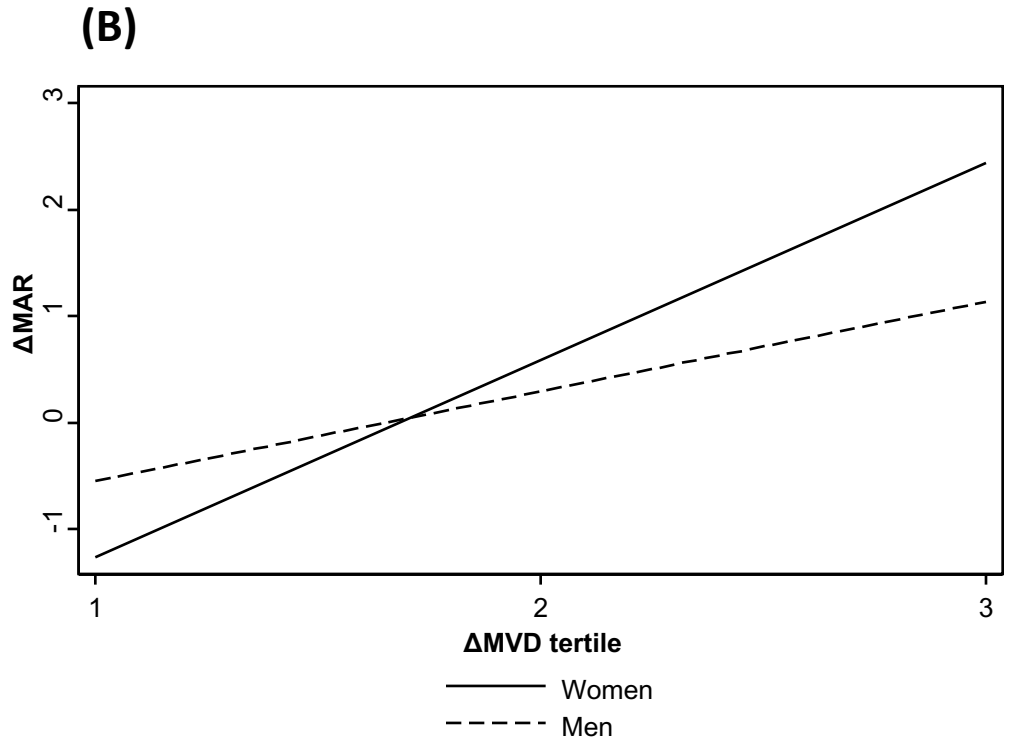
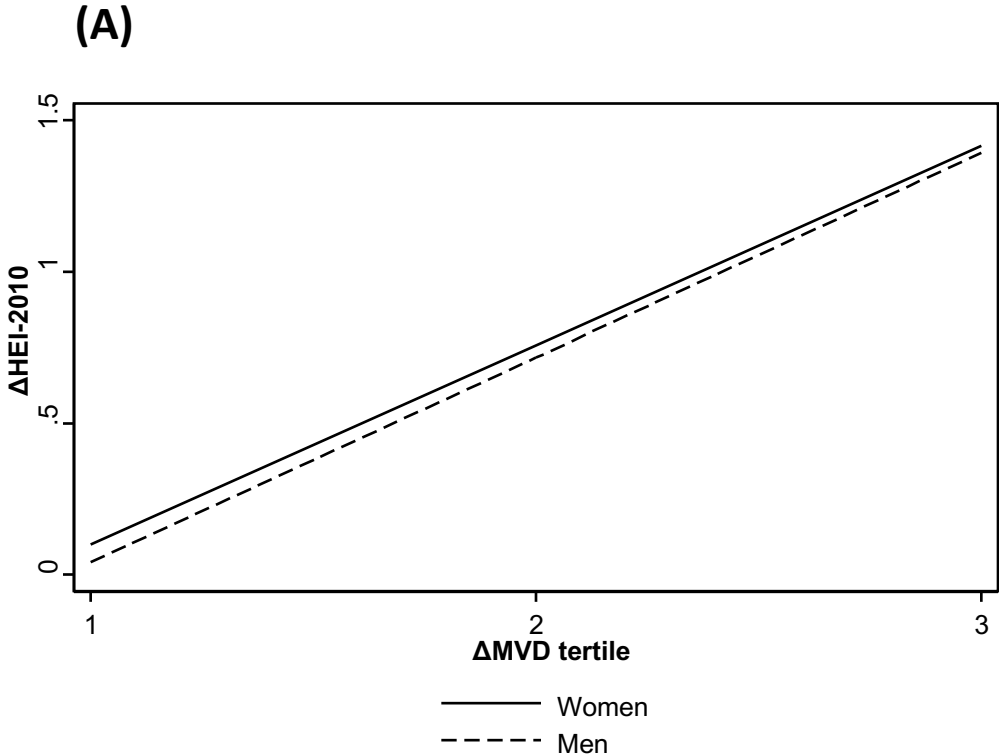
³ Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004-2013, for the US market Nielsen data is licensed from The Nielsen Company, 2016 The conclusions drawn from the Nielsen data are those of the Researchers and do not reflect the views of Nielsen. Nielsen is not responsible for and was not involved in analyzing and preparing the results reported herein.

FIGURE S1. Participant flowchart¹



¹Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004-2013, for the US market. Nielsen data is licensed from The Nielsen Company, 2016. The conclusions drawn from the Nielsen data are those of the Researchers and do not reflect the views of Nielsen. Nielsen is not responsible for and was not involved in analyzing and preparing the results reported herein.

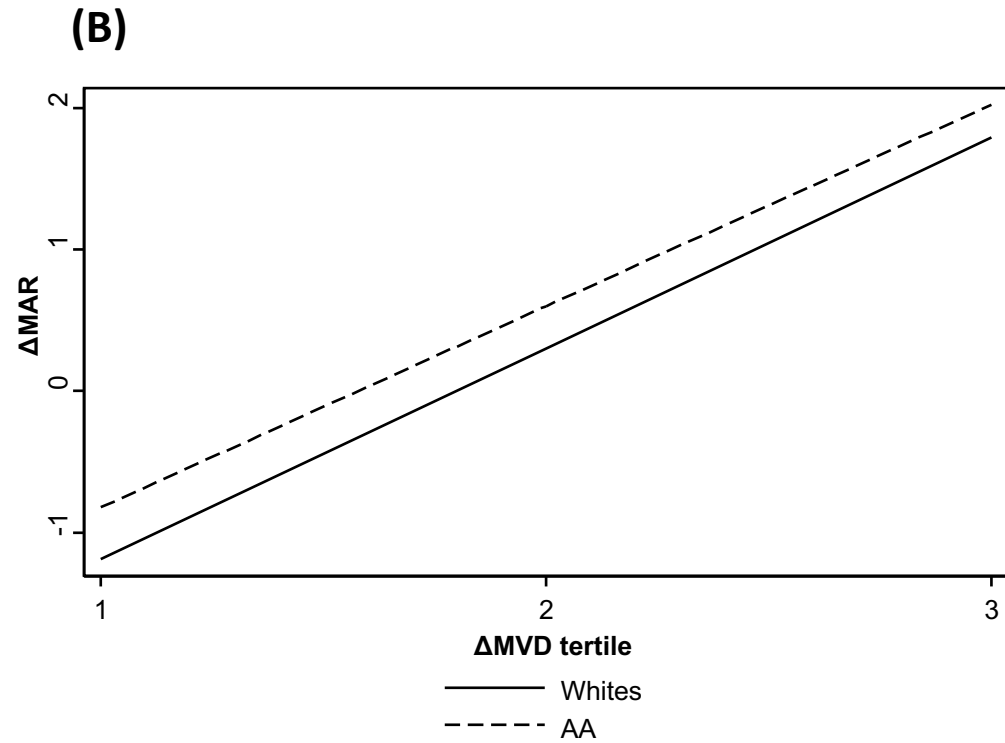
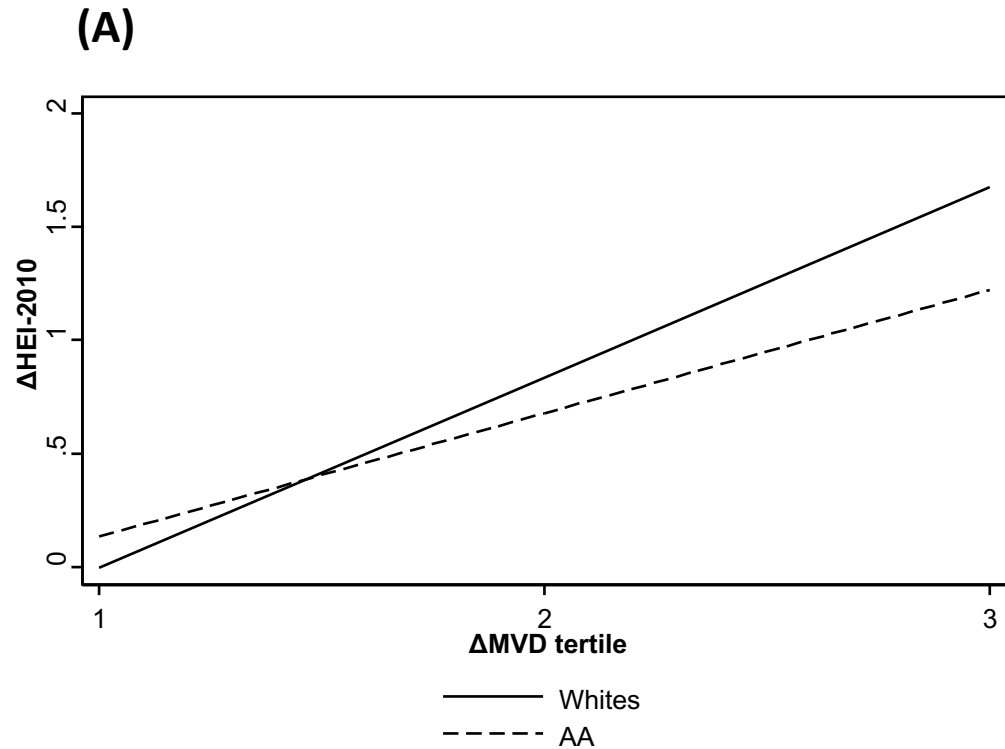
S2A and S2B Figs Predicted mean of annual rate of change (Δ) in HEI-2010 total score **(A)** and MAR **(B)** by annual rate of change in monetary value of diet (MVD, \$/day/y) tertile, stratified by sex: multiple OLS model with interaction between MVD and sex^{1,2}



¹P<0.001 for sex* Δ MVDtert interaction term

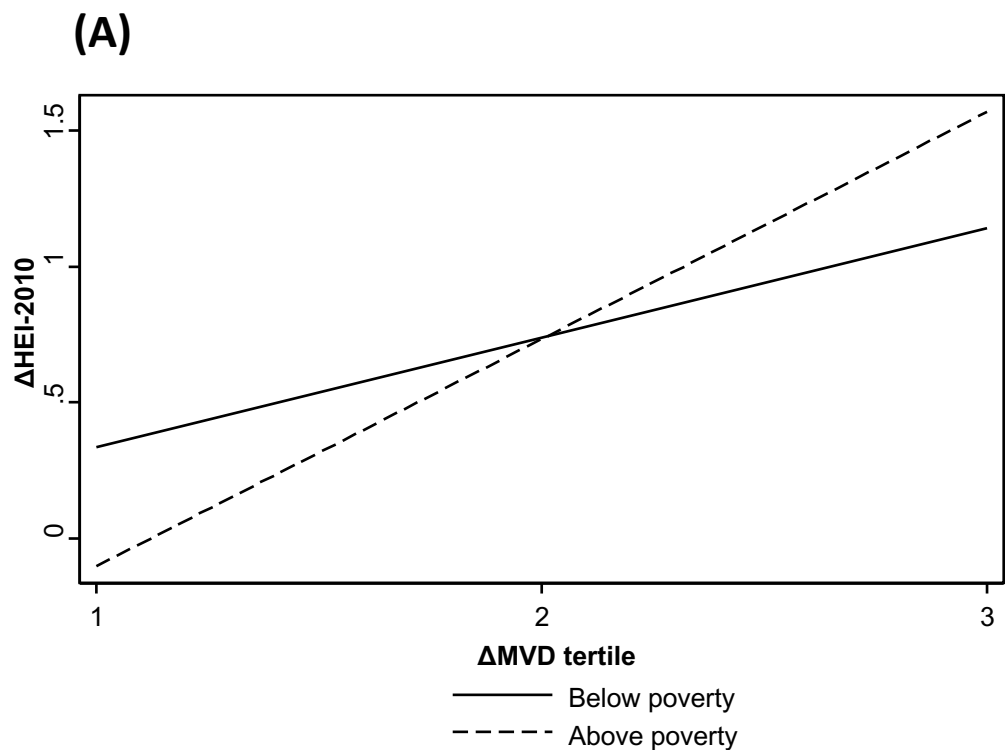
²Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004-2013, for the US market
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S3A and S3B Figs. Predicted mean of annual rate of change (Δ) in HEI-2010 total score **(A)** and MAR **(B)** by annual rate of change in monetary value of diet (MVD, \$/day/y) tertile, stratified by race: multiple OLS model with interaction between MVD and race¹

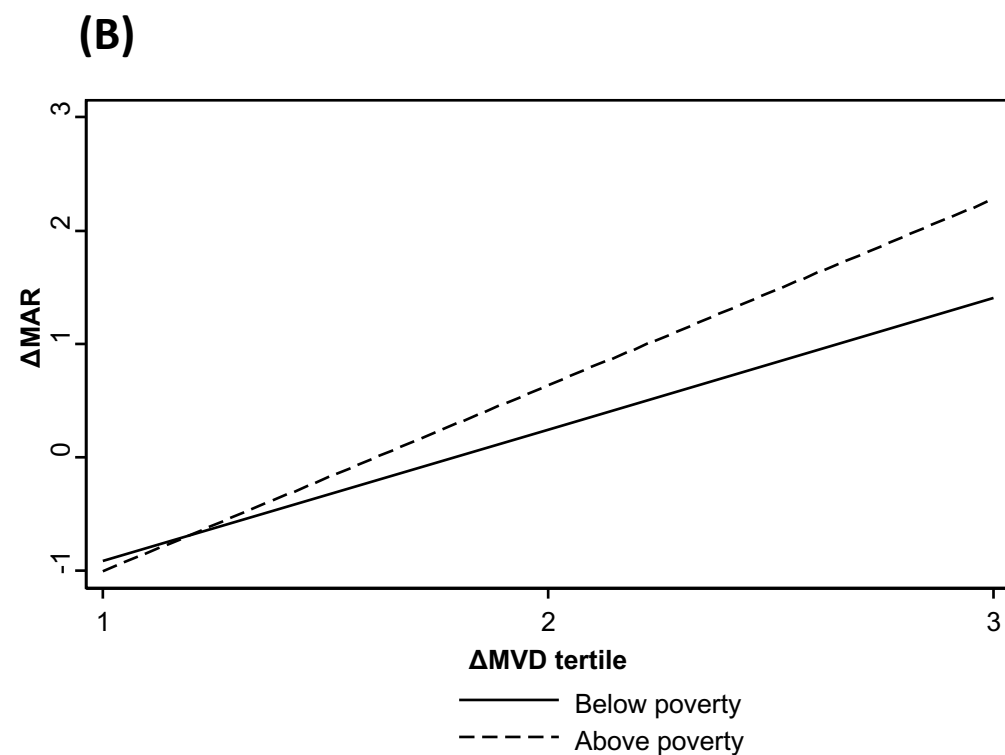


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S4A and S4B Figs. Predicted mean of annual rate of change (Δ) in HEI-2010 total score (A) and MAR (B) by annual rate of change in monetary value of diet (MVD, \$/day/y) tertile, stratified by poverty status: multiple OLS model with interaction between MVD and poverty status^{1,2,3}



¹ $P < 0.05$ for pov* Δ MVDtert interaction term



² $P < 0.001$ for pov* Δ MVDtert interaction term

¹Researchers own analyses and calculations based in part on data reported by Nielsen through its Homescan Service for the food and beverage categories for the years 2004-2013, for the US market
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