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Socio-economic and racial/ethnic disparities in the nutritional quality of packaged food purchases in the USA, 2008–2018

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Abstract
Objective: To determine whether disparities exist in the nutritional quality of packaged foods and beverage purchases by household income, education and race/ethnicity and if they changed over time.
Design: We used Nielsen Homescan, a nationally representative household panel, from 2008 to 2018 ($n = 672\ 821$ household-year observations). Multivariate, multilevel regressions were used to model the association between sociodemographic groups and a set of nutritional outcomes of public health interest, including nutrients of concern (sugar, saturated fat and Na) and calories from specific food groups (fruits, non-starchy vegetables, processed meats, sugar-sweetened beverages and junk foods).
Setting: Household panel survey.
Participants: Approximately 60 000 households each year from the USA.
Results: Disparities were found by income and education for most outcomes and widened for purchases of fruits, vegetables and the percentage of calories from sugar between 2008 and 2018. The magnitude of disparities was largest by education. Disparities between Black and White households include the consumption of processed meats and the percentage of calories from sugar, while no disparities were found between White and Hispanic households. Disparities have been largely persistent, as any significant changes over time have been substantively small.
Conclusions: Policies to improve the healthfulness of packaged foods must be expanded beyond SSB taxes, and future research should focus on what mediates the relationship between education and diet so as not to exacerbate disparities.

Keywords
Food purchases
Diet quality
Diet disparities
Low education

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Diet disparities, or lower dietary quality among marginalised populations, have been well documented at the national level in the USA[1–5]. Although dietary quality for the average American adult has been improving, disparities in dietary quality by socio-economic status (SES) are widening[1,4–6]. Since diet is both a leading cause of poor health[7–9] and a key mediator of the association between SES and health outcomes[10], research into the association between SES and diet quality will improve our understanding of health disparities.

It is unknown whether trends in disparities in overall diet quality are also reflected in the nutritional quality of packaged food and beverage purchases (PFP). Packaged foods (or foods with a universal barcode, e.g., a bag of onions, frozen entrees, etc.) are a subset of the overall diet, which also includes unpackaged foods (e.g. loose onions, meat from a butcher) as well as food eaten away from home (e.g. from schools, restaurants). This study focuses solely on PFP for several reasons. First, packaged foods contribute significantly to overall dietary quality. Foods from stores constituted approximately 70 % of total caloric intake[11,12] and, in 2017, 52 % of total food budget[13]. While store-bought food also includes unpackaged foods, PFP constitute the majority of calories from store foods (80 % among children and 70 % among adults)[14]. Second, the average American consumes excess saturated fat, sugar and Na[15], and the types of PFP most purchased are high in these nutrients of concern[16]. Third, healthy reformulation or packaging of

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PFP can be induced through targeted interventions or policies, including taxes[17], front-of-package labels[18,19], restrictions of specific nutrients[20,21] and voluntary industry initiatives[22]. Therefore, it is necessary to characterise trends in the nutritional quality of PFP to elucidate some of the major contributors driving trends in overall dietary quality as well as inform future policy.

There is evidence that disparities exist in the quality of at-home food purchases, but further research is needed to understand whether these disparities have continued and if they have changed over time. Studies using the National Household Food Acquisition and Purchase Survey, a data set which captures the entire basket of store food purchases with and without barcodes, have found that individuals with low income[23–25] and low education[24,25] purchase unhealthier foods, although results based on race/ethnicity are mixed[23–25]. In particular, low-income households purchase fewer fruits and vegetables than households with an income above 185 % of the federal poverty level[25]. However, National Household Food Acquisition and Purchase Survey data were collected from 2012 to 2013 and are therefore unable to capture longitudinal trends in disparities. Research using Nielsen Homescan PFP data has found disparities by participation in the Supplemental Nutrition Assistance Program between 2010 and 2014[26–28], where Supplemental Nutrition Assistance Program households purchase fewer fruits and vegetables and more processed meats, junk foods and SSB. Disparities have also been observed between non-Hispanic (NH) Black and White households using data from 2000 to 2012[6,27,29,30], with Black households purchasing more Na, sugar and SSB than White households. However, additional research is needed to update these long-term trends and to understand disparities by income, rather than Supplemental Nutrition Assistance Program participation, and by education.

The objective of this study was to characterise descriptive trends in the nutritional quality of households' PFP. Specifically, we examined whether disparities exist at the national level and if they changed from 2008 to 2018. Disparities were characterised by household income and education as measures of SES, as well as by household race/ethnicity. Nutritional quality was assessed using a range of outcomes, including nutrients of concern (saturated fat, sugar and Na), unhealthy food groups (processed meats, sugar-sweetened beverages and junk foods) and healthy food groups (fruits, non-starchy (NS) vegetables).

Methods

Household packaged food purchase data

This study included data from the 2008–2018 Nielsen U.S. Homescan Consumer Panel ($n = 677\,006$ household-year observations). Households self-report demographic measures, are instructed to scan barcodes on all purchases and must participate for at least 10 months each year to be included. Nielsen uses direct mailing (targeting low-income and racial/ethnic minority groups) and the Internet to recruit households in an open cohort study design, where households may exit any time and new households are enrolled to replace dropouts based on demographic and geographic targets. Households are sampled from fifty-two metropolitan and twenty-four non-metropolitan markets across the contiguous US and are weighted to be nationally representative.

Observations were defined as household-years, where nutritional outcomes were derived for each year a household was in the panel. For example, a household participating from 2008 to 2010 would contribute three household-year observations to the data set. Household-years were included in our study sample if the household had accurate data on county of residence and the household was a 'reliable food reporter,' purchasing a minimum amount of food and beverages ($45 for a single-person household and $135 for households with two or more people in a 3-month period). About 4185 household-year observations were excluded, for a final sample size of 672 821 household-year observations from 2008 to 2018.

Outcome measures

To evaluate the nutritional quality of household PFP, our research team linked 98 % of Homescan purchases (as a function of total dollars) to Nutrition Facts Panel data, which includes information about calories, saturated fat, sugar and Na. These matches were updated annually to account for product reformulation and product availability in the market. Details of these methods have been published elsewhere[11].

We defined and chose nutritional outcomes based on their relevance to understanding population health nutrition. Nutrient measures of concern included: total sugar (calculated as % kcal purchased and as g/capita per d), saturated fat (% kcal purchased and as g/capita per d) and Na (mg/capita per d). Food group outcomes were measured in calories/capita per d. Unhealthy food groups included processed meats, mixed dishes, sugar-sweetened beverages and junk foods, while healthy food groups included fruits and NS vegetables. The public health relevance for each outcome is detailed in Table 1. Further detail on specific Nielsen food types that we combined to form our healthy and unhealthy food groups can be found in online supplementary material, Supplementary Table 1.

In order to normalise annual household purchases to daily per capita values, data from reliable reporting quarters within a calendar year were summed to calculate average daily purchases at the household level. Next, daily values were normalised by the number of people in the household in the corresponding year. The proportion of adults and children was later accounted for in analysis by adjusting for household composition as a series of covariates.

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Table 1 Public health relevance of nutritional outcomes*

Nutritional outcomes	Rationale for including outcome
% calories from sugar, % from saturated fat; grams of sugar, grams of saturated fat, mg of Na (per capita per d)	• These nutrients are overconsumed in the USA[98] and are risk factors for poor health • Diets high in sugar are associated with cancer, metabolic syndrome and obesity[99] • Replacement of saturated fat with polyunsaturated fat reduces CVD risk[100] • Salt intake associated with cancer[99] and CVD[101]
Total calories (per capita per d)	Provide context for calories from select food groups below
Calories from healthy food groups: fruit, non-starchy (NS) vegetables (kcal/capita per d)	• These food groups are underconsumed in the USA[98] and are associated with lower disease risk. • Important sources of vitamins and fibre. • High consumption associated with lower CVD risk[102].
Calories from unhealthy food groups: processed meats, mixed dishes, sugar-sweetened beverages (SSB), junk foods (kcal/capita per d)	• These food groups are large contributors of total energy, sugar, saturated fat and Na in US diet, particularly mixed dishes and junk foods which tend to be more highly processed[16]. • The consumption of processed meat is classified as "carcinogenic to humans" by the International Agency for Research on Cancer[103], possibly due to nitrates, higher salt content and other chemical preservatives[82,99]. • SSB independently linked to chronic diseases[104].

*Nielsen disclaimer: Calculations based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2008–2018 periods across the US market. The Nielsen Company, 2018. The conclusions drawn from the Nielsen data do not reflect the views of Nielsen. Nielsen is not responsible for and had no role in, and was not involved in, analysing and preparing the results reported herein.

Sociodemographic variables

Trends were characterised from three different sociodemographic domains at the household level: income, education and race/ethnicity. Income was chosen as a dimension of SES because income is directly used for food purchases[31] and the cost of food is associated with dietary quality[2,32,33]. To account for differences in the cost of living across the country, Regional Price Parities from the Bureau of Economic Analysis were used for adjusting self-reported household income[34]. Income was then recalculated as a percentage of the federal poverty level[35] and divided into tertiles. These household income tertiles were derived each year to reflect changes in household composition and income, Regional Price Parities and the federal poverty level.

We selected education as a second dimension of SES because it has been independently associated with dietary quality[36–38]. We defined household education as the highest level of self-reported educational attainment by a household head, which was then categorised as high school or less, some college, college graduate or post college graduate.

Race and ethnicity have also been associated with overall dietary quality[3,4,39] and household food purchases[27,29]. Race and Hispanic ethnicity were self-reported by only one household head. For use as a covariate, race and Hispanic ethnicity were combined into five categories: Hispanic (any race), NH White, NH Black, NH Asian and NH Other Race. Due to small sample sizes of the NH Asian and NH Other groups, they were combined when race/ethnicity was the main exposure for trends analysis.

Statistical methods

Statistical analysis was conducted using STATA version 15[40]. Multilevel generalised linear models (STATA command: meglm) were used to control for clustering of multiple years of observations at the household level and allowed for use of household survey weights that varied from year to year incorporation of survey weights to generate nationally representative estimates. Nielsen recalculates households weights each year to adjust for changes in their cohort and US demographic trends. STATA's svyset command was used with meglm to generate nationally representative estimates. While all households were retained in the model to calculate SE, only those households that met inclusion criteria were included in the final analytic sample. Household weights were rescaled to generate weights at level 1 (year) and level 2 (household) following Heeringa *et al*[41].

Generalised linear models was used with a gamma family and a log link due to the log-normal distribution of most nutritional outcomes to reduce the impact of outliers. Two exceptions were percentage of calories from sugar and percentage of calories from saturated fat, where a generalised linear models was used with Gaussian family and identity link specifications.

All models control for year and household composition. Models characterising trends by income controlled for household education and race/ethnicity and included an interaction term for income and year when it was found to be statistically significant ($P < 0{\cdot}05$). This interaction term was included to assess whether differences between sociodemographic groups changed over time. Models characterising trends by education controlled for household income and race/ethnicity and included an interaction term for

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education and year when significant. Last, models characterising trends by race/ethnicity controlled for income and education and included an interaction term for race/ethnicity and year, which was significant in all models.

Predictive margins were used to test differences in outcomes over time and between groups. For generalised linear models using a log link, STATA generates margins in the original units of each outcome (i.e. calories/capita per d). Differences were also considered disparities if two criteria were met: (1) the difference was statistically significant and (2) the more vulnerable sociodemographic group (i.e. low-income, low-education, racial/ethnic minority) also had a less healthy nutritional outcome (e.g. less calories from healthy food groups, more calories from unhealthy groups).

Results

From 2008 to 2018, 672 821 household-year observations were included in the final sample, or about 60 000 household observations per year. Survey-weighted sociodemographic characteristics for 2008, 2013 and 2018 are shown in Table 2. Adjusting household income slightly reduced the proportion of high-income households. Data for all years can be found in online supplementary material, Supplementary Table 2a.

Unadjusted nutritional outcomes for household purchases are shown in Table 3 (data available for all years in online supplementary material, Supplementary Table 2b). Overall, calories from PFP declined from 2008 to 2018. This decline is reflected in most food groups, with the exceptions of fruits, NS vegetables and processed meats. While purchases of packaged fruits and NS vegetables have remained low, purchases of junk foods have remained high. Despite a large decrease in grams of sugar from PFP, the percentage of calories from sugar declined less sharply due to the simultaneous decline in total calories. In comparison, grams of saturated fat have remained constant, resulting in an increase in the percentage of calories from saturated fat.

Disparities by income

Differences between income groups were considered disparities when low-income households had less healthy outcomes than high-income households. Model-adjusted trends in nutritional outcomes are shown in Figs 1 and 2. Disparities were observed in purchases of healthy food groups, although the purchase of fruits and NS vegetables across all households was low (Fig. 1). For fruit PFP, the disparity between low- and high-income households was 5 kcal/person per d in 2008 and 7 kcal/person per d in 2018 and the disparity in NS vegetable PFP was 4 kcal/person per d in 2008 and 6 kcal/person per d in 2018. These disparities widened slightly over time (Fig. 3). Disparities also existed in the purchases of unhealthy food groups. Low-income households purchased significantly more processed meats by 11 kcal/person per d in 2008 and 2 kcal/person per d in 2018, as well as more SSB by 23 kcal/person per d in 2008 and 19 kcal/person per d in 2018. The decrease in these disparities was only statistically significant for processed meats.

Although the sugar content of PFP decreased over time for all households, as measured both by g/capita per d and by the percentage of total calories from sugar (Fig. 2), the disparity between high- and low-income households in the percentage of calories from sugar widened over time (Fig. 3). In 2008, there was a disparity of 1 % in the proportion of calories from sugar in PFP purchases, which increased to a disparity of 2 % in 2018. Compared with sugar, saturated fat does not differ by income. Finally, Na follows purchasing trends in overall calories, with low- and high-income households purchasing more Na than middle-income households (see online supplementary material, Supplementary Fig. 1).

Disparities by education

Similar to income, differences between educational groups almost always reflected disparities, where having a high school education or less is associated with less healthy purchasing patterns compared with having a graduate degree. For healthy food groups, the disparity in fruit PFP between low- and high-education households was 4 kcal/person per d in 2008 and 7 kcal/person per d in 2018. Households with higher education started purchasing more NS vegetables than households with lower education in 2016. For unhealthy food groups, low-education households purchased more processed meats, SSB and junk foods than high-education households. Disparities decreased significantly in processed meat PFP, from 32 kcal/person per d in 2008 to 25 kcal/person per d in 2018, in SSB purchases, from 58 kcal/person per d in 2008 to 34 kcal/person per d in 2018, and in junk food purchases, from 96 kcal/person per d in 2008 to 78 kcal/person per d in 2018 (Fig. 3).

Similar trends were found for nutrients of concern by household education when compared with trends by income. Disparities in grams of sugar purchased decreased significantly. Compared with households with high education, households with low education purchased more sugar by 27 g/person per d in 2008, which decreased to 19 g/person per d in 2018. However, similar to income, the disparity in the proportion of PFP calories from sugar increased – a disparity of 1 % in 2008 increased to a disparity of 2 % in 2018. All households with less than a graduate education purchased the same percentage of calories from saturated fat (see online supplementary material, Supplementary Figs. 2–4).

Importantly, for most outcomes, disparities by household education are greater than that by income. For example, for sugar, the disparity between low- and high-income households was 3 g/person per d in 2008 and 2 g/person per d in 2018 (Fig. 2). In comparison, the disparity between

Table 2 Survey-weighted averages of sample characteristics for selected years*

	2008		2013		2018	
Demographics	Mean	SE‡	Mean	SE‡	Mean	SE‡
# Households excluded†	446		332		270	
# Households in final sample	61 091		60 750		61 102	
Education						
High school or less	30·6 %	0·3 %	29·1 %	0·3 %	27·2 %	0·3 %
Some college	32·2 %	0·3 %	32·4 %	0·3 %	31·3 %	0·3 %
College graduate	25·1 %	0·3 %	26·2 %	0·3 %	26·5 %	0·3 %
Post college graduate	12·2 %	0·2 %	12·2 %	0·2 %	15·0 %	0·2 %
Race/ethnicity						
Hispanic	11·7 %	0·3 %	13·0 %	0·3 %	14·0 %	0·2 %
NH white	71·4 %	0·3 %	69·0 %	0·3 %	66·8 %	0·3 %
NH black	11·5 %	0·2 %	11·8 %	0·2 %	11·6 %	0·2 %
NH Asian	2·8 %	0·1 %	3·4 %	0·1 %	4·4 %	0·1 %
NH other	2·5 %	0·1 %	2·8 %	0·1 %	3·2 %	0·1 %
Nominal household income						
Average ratio to FPL	3·65	0·02	3·21	0·01	3·40	0·01
<185 % FPL	25·9 %	0·3 %	31·2 %	0·3 %	25·2 %	0·3 %
185–400 % FPL	33·9 %	0·3 %	35·6 %	0·3 %	41·6 %	0·3 %
>400 % FPL	40·2 %	0·3 %	33·3 %	0·3 %	33·2 %	0·3 %
Income adjusted for the cost of living§						
Average ratio to FPL	3·63	0·02	3·20	0·01	3·39	0·01
<185 % FPL	24·9 %	0·3 %	31·2 %	0·3 %	26·6 %	0·3 %
185–400 % FPL	35·8 %	0·3 %	37·9 %	0·3 %	37·3 %	0·3 %
>400 % FPL	39·2 %	0·3 %	30·9 %	0·3 %	36·1 %	0·3 %

NH, non-hispanic; FPL, federal poverty level.
*Estimates are not adjusted for household characteristics but are adjusted using survey weights to obtain nationally representative estimates.
†Households were excluded if they were not 'reliable food reporters,' that is, did not meet a minimum threshold for food purchases for all quarters in a calendar year.
‡Since values are calculated using Nielsen's survey weights, standard errors are presented rather than SD.
§Income adjusted for the cost of living is categorised into tertiles for use in regression analysis. In this table, nominal household income and adjusted household income are presented relative to the FPL for ease of comparison.

Table 3 Survey-weighted averages of nutritional outcomes for selected years*

	2008		2013		2018	
Nutritional outcomes	Mean	SE†	Mean	SE†	Mean	SE†
Total calories‡	1374	5·8	1274	5·5	1201	4·7
Healthy groups						
Fruit (kcal)	21	0·2	18	0·2	22	0·2
NS vegetables§ (kcal)	16	0·1	17	0·1	18	0·1
Unhealthy groups						
Processed meat (kcal)	53	0·4	49	0·4	53	0·4
SSB (kcal)	72	0·7	60	0·6	49	0·5
Junk foods (kcal)	351	1·7	335	2·6	306	1·5
Nutrients of concern						
Saturated fat (g)	17	0·1	17	0·1	18	0·1
Sugar (g)	90	0·4	81	0·4	71	0·3
Na (mg)	2665	14·4	2410	12·1	2300	11·8
Saturated fat (% of kcals)	26 %	0·1 %	25 %	0·0 %	24 %	0·0 %
Sugar (% of kcals)	11 %	0·0 %	12 %	0·0 %	13 %	0·0 %

NH, non-Hispanic; NS, non-starchy; SSB, sugar-sweetened beverages.
*Estimates are not adjusted for household characteristics but are adjusted using survey weights to obtain nationally representative estimates.
†Since values are calculated using Nielsen's survey weights, SE are presented rather than SD.
‡Total calories and all food groups are expressed in units of calories purchased per capita per d. Nutrients presented in grams or milligrams are also expressed in units per capita/d. Percentages are calculated by converting grams of saturated fat (or sugar) purchased in a year to calories from saturated fat (or sugar) and dividing by total calories for the same year.
§Vegetables refer to packaged non-starchy vegetables. Mixed dishes include foods like canned soups and frozen entrees. Junk foods include salty snacks, grain and dairy-based desserts, sweeteners, toppings, candy and chocolate.

low- and high-education households was 27 g/person per d in 2008 and 19 g/person per d in 2018 (see online supplementary material, Supplementary Fig. 3). The disparity in processed meats by income was 11 and 2 calories/person per d in 2008 and 2018, respectively (Fig. 1), compared with disparities by education of 32 and 25 calories/person per d in 2008 and 2018, respectively (see online supplementary material, Supplementary Fig. 2). Significant disparities exist in the purchase of junk foods by education, but do not exist by income.

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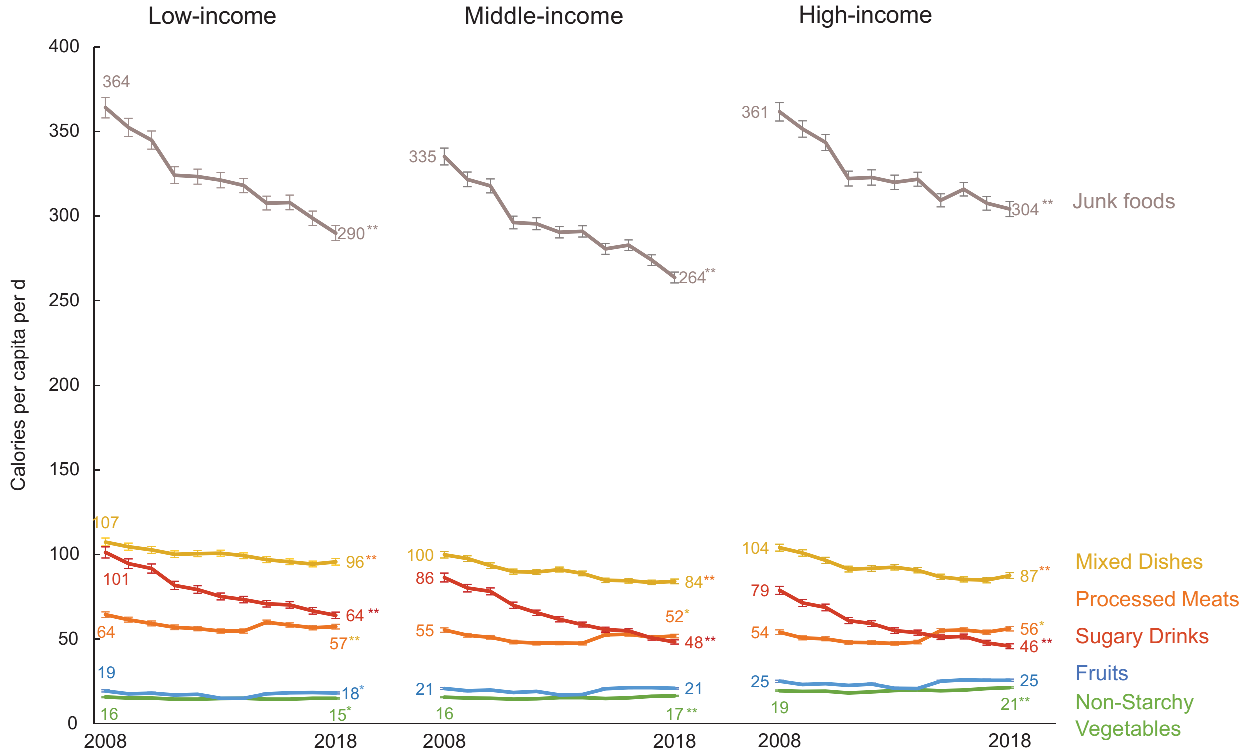

Fig. 1 (colour online) Model-adjusted trends in packaged foods and beverage purchases (PFP) calories from healthy and unhealthy food groups from 2008 to 2018, by household income tertile[a]. [a]Models were survey-adjusted and controlled for education, race/ethnicity, household composition and year, with an interaction between income tertile and year when significant. [b]Mixed dishes include foods like canned soups and frozen entrees, while junk foods include salty snacks, candies, sweeteners and desserts (see online supplementary material, Supplementary Table 1 for more examples). *Significant difference between 2008 and 2018 for given income tertile, $P < 0{\cdot}01$. **Significant difference between 2008 and 2018 for given income tertile, $P < 0{\cdot}001$

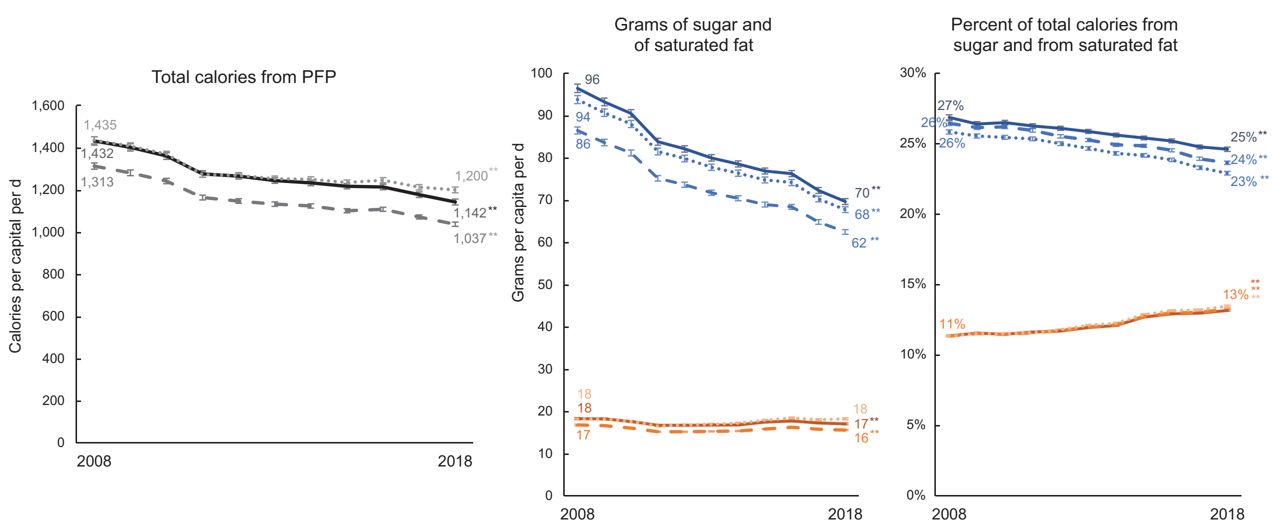

Fig. 2 (colour online) Model-adjusted trends in total calories and nutrients in packaged foods and beverage purchases (PFP) from 2008 to 2018, by household income tertile[a]. [a]Models were survey-adjusted and controlled for education, race/ethnicity, household composition and year, with an interaction between income tertile and year when significant. **Significant difference between 2008 and 2018 for given income tertile, $P < 0{\cdot}001$. ——, low income; - - -, middle income; ········, high income; ——, sugar; ——, saturated fat

Disparities by race/ethnicity

Compared with analyses by income and education, we did not observe consistent trends in unhealthy purchasing patterns for any race/ethnic group (see online supplementary material, Supplementary Figs. 5–7). For example, White households purchased more junk foods compared with all other households, whereas Black households purchased more processed meats and SSB compared with

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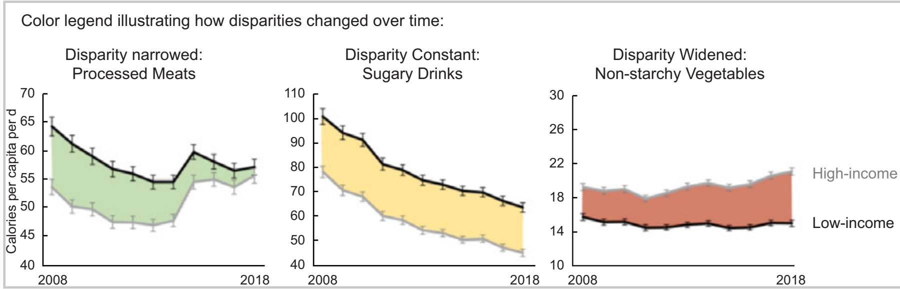

Nutritional Outcomes	Differences or Disparities[a] Between High and Low Purchasing Groups	Income tertile: Low income Middle income High income	Education: High school or less Some college College graduate Post college grad	Race / Ethnicity: Hispanic (any race) Non-hispanic White Non-hispanic Black Non-hispanic Other
Total calories	Highest Lowest Change over time?	High income Middle income Difference widened by 40 kcal/person/d [95 % CI, 15,66]	High school or less Post college grad Disparity constant	White Hispanic & Other Race Difference widened by 67 kcal/person/d [95 % CI, 23,110]
Processed meats	Highest Lowest Change over time?	Low income High & Middle income Disparity narrowed by 9·1 kcal/person/d [95 % CI, 6·7,11·6]	High school or less Post college grad Disparity narrowed by 6·4 kcal/person/d [95 % CI, 3·5,9·3]	Black Other Race Disparity constant
SSBs	Highest Lowest Change over time?	Low income High income Disparity constant	High school or less Post college grad Disparity constant	Black Other Race Difference narrowed by 10·3 kcal/person/d [95 % CI, 1·9,18·7]
Junk Foods	Highest Lowest Change over time?	High income Middle income Difference widened by 14·1 kcal/person/d [95 % CI, 5·5,22·6]	High school or less Post college grad Disparity constant	White Hispanic & Other Race Difference constant
Fruit[b]	Highest Lowest Change over time?	High income Low income Disparity widened by 1·8 kcal/person/d [95 % CI, 0·7,3·0]	Post college grad High school or less Disparity widened by 3·2 kcal/person/d [95 % CI, 1·7,4·8]	Mixed Mixed n/a
Non-starchy Vegetables[b]	Highest Lowest Change over time?	High income Low income Disparity widened by 2·6 kcal/person/d [95 % CI, 1·8,3·3]	mixed mixed Disparity widened by 2·8 kcal/person/d [95 % CI, 1·8,3·7]	White Hispanic Disparity widened by 1·2 kcal/person/d [95 % CI, 0·4,2·1]
Sugar, % of total calories	Highest Lowest Change over time?	Low income High income Disparity widened by 0·67% [95 % CI, 0·37%,0·96%]	High school or less Post college grad Disparity widened by 0·84% [95 % CI, 0·46%,1·21%]	Black Mixed Black-White disparity constant
Sugar, g	Highest Lowest Change over time?	Low income High income Disparity constant	High school or less Post college grad Disparity constant	White Hispanic & Other Race Difference widened by 4·2 g/person/d [95 % CI, 1·1,7·4]
Saturated fat, % of total calories	Highest Lowest Change over time?	High income Low income Difference widened by 0·33% [95 % CI, 0·20%,0·62%]	Mixed Post college grad n/a	White Black Difference widened by 0·53% [95 % CI, 0·39%,0·67%]
Saturated fat, g	Highest Lowest Change over time?	High income Middle income Difference widened by 1·3 g/person/d [95 % CI, 0·8,1·7]	High school or less Post college grad Disparity narrowed by 1·4 g/person/d [95 % CI, 0·9,2·0]	White Hispanic & Other Race Difference widened by 1·5 g/person/d [95 % CI, 0·9,2·1]
Sodium, mg	Highest Lowest Change over time?	Low income Middle income Disparity constant	High school or less Post college grad Disparity constant	White Hispanic & Other Race Difference widened by 122 mg/person/d [95 % CI, 25,220]

Fig. 3 (colour online) Trends in differences and disparities[a] for all sociodemographic subgroups and nutritional outcomes, 2008–2018. [a]Disparities are those differences where the more vulnerable demographic group also has an unhealthier purchasing pattern, that is, purchases fewer calories from healthy food groups, more calories from unhealthy food groups, or more of a nutrient of concern. In the table, disparities are bolded. Disparities that have narrowed are shaded in green, those that have remained constant are shaded in yellow and those that have widened are in red. The line graphs are selected examples included as illustration of changes in income disparities. [b]Fruits and non-starchy vegetables are the only two outcomes for which a greater value for the outcome is indicative of a healthier purchasing pattern. Therefore, for these outcomes, differences are considered disparities when the more vulnerable demographic group purchases fewer calories per capita/d

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White households. Although White households purchased more saturated fat and sugar in grams compared with all other race/ethnic groups, Black households purchased a greater percentage of calories from sugar compared with other households. However, households identifying as Hispanic or Other Race typically had healthier nutritional outcomes compared with White households, as indicated by fewer calories from processed meats and fewer grams of saturated fat, sugar and Na.

Discussion

Our analysis of nationally representative purchase data with up-to-date nutrition information showed that the nutritional quality of PFP in the USA was poor from 2008 to 2018, with high levels of sugar and Na and purchases of unhealthy food groups, particularly junk foods. However, we also found that some measures of nutritional quality improved over time, as indicated by decreases in calories from SSB and junk foods and in sugar. Despite overall population-level improvements in the quality of PFP, we found persistent disparities by income and race/ethnicity, with the greatest disparities by education.

The decline in calories from PFP is consistent with previous research[12,42] and supported by data showing that the share of household expenditures on food from retail stores is decreasing[43]. This study adds that the nutritional quality of PFP is generally unhealthy. Our data on processed meats PFP align with evidence that consumption has also not declined, despite growing public health concerns[44]. Although there has been a focus on reducing SSB[45,46], we found the number of calories from other unhealthy food groups was similar or greater than those from SSB, highlighting the need to expand existing policies beyond SSB taxes to further improve dietary quality. To reduce the high purchases of junk foods in particular, US policymakers should consider policies from other countries, such as front-of-package labelling[47,48], marketing restrictions to children[49,50] and junk food taxes[51,52].

Despite these indicators of poor quality, we found signs of improvement. Purchases of SSB and junk foods have declined. Sugar from PFP has also decreased, both in absolute (g) and relative terms (as percentage of calories). The absolute decline is likely attributable to fewer purchases of SSB[12,53] and junk foods, and the relative decline may be due to factors such as product reformulation[54] or increased use of nutrition labels by purchasers[55].

It is important to understand the policy implications of disparities in PFP, where the more socially vulnerable demographic group is also associated with less healthy nutritional outcomes. Interventions that rely on individual agency may widen disparities because they are more beneficial for those with higher incomes and education[56,57]. Therefore, we will focus on population-level interventions, adjusted to the needs of specific vulnerable groups where appropriate[58].

High-income households purchase more healthy fruits and NS vegetables and fewer unhealthy processed meats and SSB compared with low- and middle-income households. In cases where disparities have narrowed (e.g. processed meats), the decrease has been small, while disparities in sugar have widened. More research is needed to understand to what extent these disparities in healthy and unhealthy foods are related to access, such as the types of food stores and quality of their PFP in low- *v.* high-income areas[59–61] or whether households participating in food assistance programmes have access to eligible stores, which have minimum stocking requirements for healthy foods[62]. Changing the environment inside stores is a potential strategy to reduce disparities – in one study, small, inexpensive packs of fruits and vegetables near checkout were purchased more by Supplemental Nutrition Assistance Program participants than the average shopper[63].

We also find that low- and high-income households purchase significantly more total calories and calories from junk foods than middle-income households. This result for total calories was surprising, since high-income households have more disposable income to spend on food than low-income households. To further investigate, we ran our analysis using total expenditures on PFP and total volume as additional outcomes. We found that high-income households spend significantly more than low- and middle-income households (which were not statistically different): about $3·40/person per d in 2008 compared with $2·90, and $3·80/person per d in 2018 compared with $3·10. In comparison, the *volume* of purchases did not differ between high- and low-income households. Since low-income households purchase the same amount of calories as high-income households but have lower expenditures, low-income households purchase more calories per dollar spent on PFP. Furthermore, following our main findings, the nutritional quality of these calories is lower (e.g. higher percentage sugar and fewer fruits and vegetables compared with high-income households). In prior research on overall dietary cost and quality, Drewnowski and Darmon[64] also found that lower expenditures (e.g. cost) are associated with lower quality of PFP. However, unlike Drewnowski and Darmon, we do not find lower costs are also associated with higher energy density (calories/volume). Further research is needed to determine whether a healthier profile of PFP is necessarily more expensive or whether high-income households are willing to pay more for PFP that are marketed as healthier and may be more expensive[65–67].

Similar to income, differences by education in the nutritional quality of PFP almost always reflect disparities. Most importantly, the magnitude of disparities by education often exceed those found by income or by race/ethnicity. These findings add to a growing body of evidence that education may be more strongly associated with healthy dietary behaviours[68,69] than income and that health and

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mortality disparities by education are widening in the USA[70]. While most resources from population-level interventions to improve diet focus on income, research is needed to understand what mediates the relationship between educational attainment and the healthfulness of food purchasing independently of income[71,72]. For example, while the effects of nutrition labelling do not vary by educational attainment[73,74], the combination of improved labelling and nutrition education has potential to reduce disparities and warrants further investigation[75]. Other possible systemic changes include regulation of misleading product package health claims, as low education has been associated with use of health claims more often than high education[76]. In addition to intervening on mediators between education and food purchases, it is also necessary to consider systematic factors that are associated with educational attainment in the first place, particularly if such factors are also associated with the nutritional quality of packaged food purchases. For example, residential segregation and neighbourhood poverty are associated with educational attainment[77] as well as the availability of supermarkets[78,79], which have higher quality PFP than convenience stores[80]. Ultimately, fully reducing diet-related disparities will necessitate addressing upstream determinants outside the food system[69,81].

Although we did not find disparities between Hispanic and White households, Black households purchase more processed meats, SSB and foods higher in sugar than White households. In contrast, one recent study found similar consumption of processed meat by Black and White individuals[44]. Therefore, before implementing policies to reduce processed meat consumption[82], more research is needed to avoid exacerbating disparities in purchases, such as identifying which processed meat products drive higher purchases among Black households. The higher levels of sugar in purchases by Black households are likely driven by SSB, whereas White households purchase more junk foods. To reduce SSB purchases among Black households, public health efforts should include combatting marketing campaigns that specifically target minority communities[58,83]. While SSB taxes have been shown to promote health equity between low and high socioeconomic groups[84,85], race/ethnic disparities in store purchases could be reduced by earmarking tax revenues for programmes in minority communities focused on social equity[86]. Examples include programmes in Boulder[87], Seattle[88] and San Francisco[89]. Tax revenues could also be earmarked to fund subsidies for healthy foods[90].

There are several limitations to our study. First, it is unclear to what degree trends in nutrients are due to changes in the types of PFP purchased or in potential reformulation of PFP. Second, purchase data are an incomplete picture of the diet. While the proportion of food purchased at stores may vary by sociodemographic group[91], we control for these characteristics in our analysis. Ongoing research is needed using a variety of sources of dietary data to provide context on trends in overall dietary quality – for example, NHANES data indicate that high-income groups consume more calories from processed meat in their overall diet than low-income households[44], in comparison with our finding that calories from processed meat PFP have converged. Third, purchases do not equal consumption. However, although we are unable to account for food waste, the nutritional profile of purchases is correlated with the quality of food consumed[92]. Fourth, the high burden of recording all purchases likely leads to some underreporting, but the accuracy of Homescan data is comparable to other commonly used economic data sets[93]. While research has demonstrated that lower-educated people are less likely to participate in Nielsen[94], no study to our knowledge has explored whether misreporting differs by sociodemographic group. Last, there is evidence that association between SES and dietary quality differs by race[95]. While we examine income, education and race/ethnicity separately, there is considerable correlation between these three demographic variables and likely a multiplicative effect for households at the intersection of marginalised identities[31,96]. A limitation of using Nielsen data is that Black households are slightly more educated than White households. We use Nielsen's household weights and control for education in our race/ethnic models to control for this bias. However, given that disparities by education are large, an underrepresentation of Black households with low education likely means our estimates of Black–White disparities are conservative.

Despite these limitations, using household purchase data has several advantages in comparison with other measures of dietary intake. First, Homescan is an open cohort with year-round data collection, which allowed us to capture usual purchase patterns and avoid bias from seasonal changes in diet. In comparison, dietary intake data based on 24-h recalls may be weaker indicators of usual diet[97]. In addition, intake data lack specificity because items are linked to the Nutrition Facts Database from the USDA, which only captures a small fraction of the total packaged products in the US food system and is not updated often enough to keep pace with a rapidly changing food supply[22,97]. Linking scanned barcodes to time- and product-specific nutrition facts panel information allows for improved measurement of nutrients of concern, including saturated fat and sugar[11]. Finally, unlike store sales data of food purchases, household purchase data are linked to the sociodemographic characteristics of households, allowing for epidemiological and subpopulation analysis that is nationally representative.

Conclusion

Although there have been promising trends in the nutritional quality of packaged food and beverage purchases from 2008 to 2018, there is still much room for

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improvement. Public health policy should include junk food reduction efforts to build on their decline in purchases, as well as explore ways to decrease the consumption of processed meats and increase fruits and NS vegetables. Our study finds persistent disparities in the quality of packaged foods that help explain disparities in overall diet quality. This research will help policies promote equity by focusing on specific nutrients and food groups in store-bought foods to improve the health of vulnerable populations. Further longitudinal research should build on our findings to understand how trends in disparities in the nutritional quality of different components of the diet are related (i.e. PFP, other food at home and food away from home) and whether they change in response to policy implementation or household shocks, such as the COVID-19 pandemic.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021000367

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