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# Sodium Reduction in US Households' Packaged Food and Beverage Purchases, 2000 to 2014

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Supplemental content

**IMPORTANCE** Initiatives to reduce sodium in packaged foods have been launched in the United States, yet corresponding changes in the amount of sodium that US households obtain from packaged foods have not been evaluated, to our knowledge.

**OBJECTIVE** To assess 15-year changes in the amount of sodium that US households acquire from packaged food purchases, the sodium content of purchases, and the proportion of households that have purchases with optimal sodium density.

**DESIGN, SETTING, AND PARTICIPANTS** Longitudinal study of US households in the 2000 to 2014 Nielsen Homescan Consumer Panel, a population-based sample of households that used barcode scanners to record all packaged foods purchased throughout the year. Time-varying brand- and product-specific nutrition information was used for 1 490 141 products.

**MAIN OUTCOMES AND MEASURES** Sociodemographic-adjusted changes in mean sodium per capita (mg/d) and sodium content (mg/100 g), overall and for top food group sources of sodium, and the proportion of households that have total purchases with sodium density of 1.1 mg/kcal or less.

**RESULTS** In a nationwide sample of 172 042 US households (754 608 year-level observations), the amount of sodium that households acquired from packaged food and beverage purchases decreased significantly between 2000 and 2014 by 396 mg/d (95% CI, −407 to −385 mg/d) per capita. The sodium content of households' packaged food purchases decreased significantly during this 15-year period by 49 mg/100 g (95% CI, −50 to −48 mg/100 g), a 12.0% decline; decreases began in 2005 and continued through 2014. Moreover, the sodium content of households' purchases decreased significantly for all top food sources of sodium between 2000 and 2014, including declines of more than 100 mg/100 g for condiments, sauces, and dips (−114 mg/100 g; 95% CI, −117 to −111 mg/100 g) and salty snacks (−142 mg/100 g; 95% CI, −144 to −141 mg/100 g). However, in all years, less than 2% of US households had packaged food and beverage purchases with sodium density of 1.1 mg/kcal or less.

**CONCLUSIONS AND RELEVANCE** In this nationwide study, significant reductions in sodium from packaged food purchases were achieved in the past 15 years. Nonetheless, most US households had food and beverage purchases with excessive sodium density. Findings suggest that more concerted sodium reduction efforts are needed in the United States.

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Excessive dietary sodium intake has been established as a modifiable risk factor for hypertension and cardiovascular disease.[1-3] However, 89% to 90% of US children and adults exceeded the 2015-2020 Dietary Guidelines for Americans recommended limit for sodium intake in 2009-2012.[4] To lower population-level sodium intake of Americans, the Institute of Medicine recommends that reducing sodium in packaged foods is essential[5] because most sodium intake comes from store-bought foods[6] and is added during industrial food processing.[7] The Institute of Medicine called for the use of novel methods and data sources to enhance monitoring of sodium in the United States, particularly to evaluate the effectiveness of current voluntary initiatives by food manufacturers to reduce the sodium content of packaged foods, including the National Salt Reduction Initiative (NSRI) and sodium reduction pledges by companies, such as Nestlé and General Mills.[5,8,9]

Nonetheless, little is known about whether sodium in packaged foods has changed during the past 15 years. Prior studies[10-14] monitoring sodium intake using dietary self-report are limited by changes in assessment methods over time and lack of up-to-date food composition data for the diverse and constantly changing array of products in the US food supply. Few evaluations of changes in the sodium content of packaged foods using analytic or nutrition label data have been conducted in the United States, and these studies[8,9,15,16] evaluated only a limited number of products in selected food categories. To our knowledge, no studies have examined how changes in the sodium content of products translate to changes for households' grocery store purchases.

To address these knowledge gaps, this study used time-varying product- and brand-specific nutrition label data for approximately 1.5 million packaged foods purchased by a nationwide sample of US households. This study aimed to examine 15-year trends in the amount of sodium obtained by US households from packaged food purchases, to evaluate changes in the sodium content of packaged foods overall and for major food sources of sodium, and to determine whether the percentage of US households that have packaged food purchases with optimal sodium density changed between 2000 and 2014.

### Key Points

**Question** Did the amount of sodium in US households' packaged food purchases change in the past 15 years?

**Findings** In this longitudinal study of the Nielsen Homescan Consumer Panel, sodium acquired by US households from packaged food purchases decreased significantly between 2000 and 2014, and sodium content decreased significantly for packaged foods overall and for all top food sources of sodium. Nonetheless, more than 98% of households had packaged food purchases with sodium density exceeding optimal levels.

**Meaning** Significant progress toward sodium reduction in US packaged foods was achieved, but continued efforts are needed to prevent excess sodium intake.

## Methods

### Study Population

This study used data from the 2000 to 2014 Nielsen Homescan Consumer Panel, a prospective study of packaged food and beverage purchases by US households (data obtained from The Nielsen Company, 2014).[17] Homescan maintains a nationwide sample of 30 000 to 60 000 households each year using an open-cohort study design described in detail previously[18-20] and in the eMethods in the Supplement. Households are prospectively followed and record their purchases continuously throughout the year. Households must record purchases for at least 10 months and then may exit the study at any time; new households are enrolled to maintain national representativeness. Mean follow-up time was 4.4 years. The age and sex of each household member, race/ethnicity and educational level of the male and female heads of household, and household income were reported by questionnaire. This secondary data analysis was deemed exempt from University of North Carolina at Chapel Hill institutional review board approval.

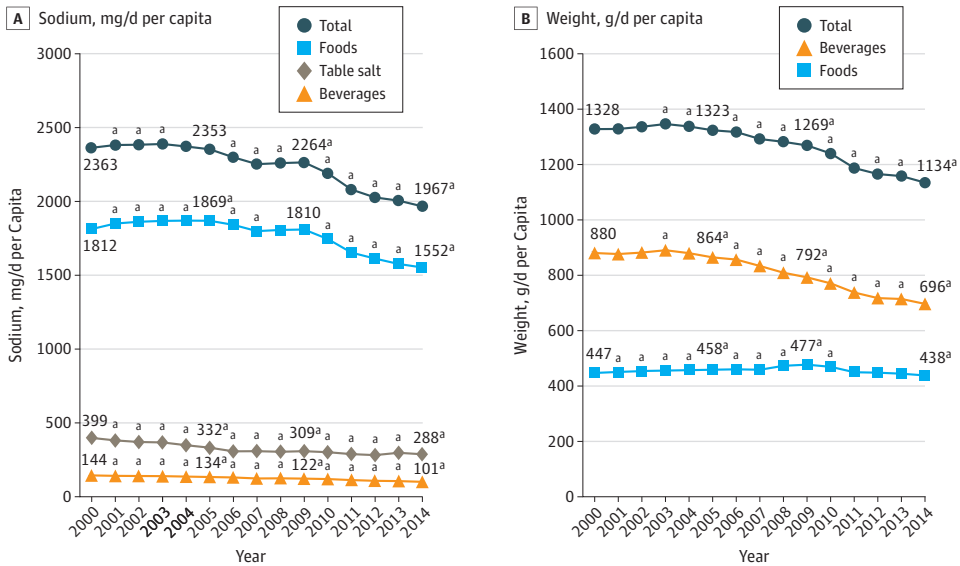
To best capture usual shopping habits throughout the year and to account for storage of products not consumed immediately, analyses used year-level purchases, generated by summing all purchases during a given calendar year for each household. As described previously, purchases during annual quarters were deemed unreliable by study investigators if thresholds for expenditures and the amount purchased were not met[21,22]; to ensure consistent reporting, household year-level observations that included more than 1 unreliable quarter or with extreme purchase amounts (<0.5th percentile or >99.5th percentile) were excluded (4.9%).

### Food and Beverage Purchase Data

Household members used a handheld Universal Product Code barcode scanner provided by The Nielsen Company to record each packaged food or beverage purchased from grocery, drug, and convenience stores; supermarkets; mass merchandisers; and all other retail food stores. As described elsewhere, our research team linked each barcoded product to its corresponding Nutrition Facts Panel to obtain brand- and product-specific calorie and sodium content at the time of purchase.[23,24] Product descriptions were used to categorize products at the barcode level into 40 food groups based on nutritional composition and eating behaviors (eTable 1 in the Supplement).[25] Foods and beverages without a barcode or a Nutrition Facts Panel, such as unpackaged fresh fruits and vegetables, fresh meat sold by weight, or store-prepared ready-to-eat dishes, were not included. Because some purchased foods may be wasted and not consumed by household members, sodium purchased may overestimate sodium intake.

We examined sodium in US households' food and beverage purchases using 3 measures. These included (1) sodium per capita, the amount of sodium (in milligrams) purchased daily per person; (2) sodium content, the amount of sodium relative to the amount of food (mg/100 g); and (3) sodium density, the amount of sodium relative to the energy in food (mg/1000 kcal).

Figure 1. Sodium From US Households' Packaged Food and Beverage Purchases and Trends in Total Purchases, 2000 to 2014




15-y Change

| Category | β (95% CI) | *P* Value for Trend |
|---|---|---|
| Total | −396 (−407 to −385) | <.001 |
| Foods | −260 (−267 to −253) | <.001 |
| Table salt | −111 (−116 to −105) | <.001 |
| Beverages | −43 (−44 to −42) | <.001 |

15-y Change

| Category | β (95% CI) | *P* Value for Trend |
|---|---|---|
| Total | −193 (−199 to −188) | <.001 |
| Foods | −9 (−10 to −7) | <.001 |
| Beverages | −184 (−188 to −179) | <.001 |

Values are the adjusted mean sodium (mg/d) (A) or weight (g/d) (B) per capita from households' packaged food and beverage purchases from retail food stores in a given year, determined from multivariable, longitudinal linear regression models regressing purchases on indicator variables for year; values for table salt were determined from a 2-part model, including (1) a longitudinal probit model of the probability of purchasing and (2) a longitudinal log-linear regression of the amount purchased among purchasers. *P* values for time trends were derived from multivariable regression models treating year as a continuous variable, including linear, quadratic, and cubic terms as appropriate. All models were adjusted for household size and composition, race/ethnicity, income, educational level, and geographic market, and means were predicted at the distribution of race/ethnicity by income from US Census Bureau data. Data are from the Nielsen Homescan Consumer Panel, including 172 042 US households (754 608 year-level observations).

[a] Significantly different from 2000 (*P* < .001 by Wald postestimation test).

## Statistical Analysis

All estimates of sodium from food and beverage purchases were determined using multivariable, longitudinal, random-effects regression models to control for changes in the sociodemographic characteristics of the Homescan sample over time and to account for the correlation between repeated measures within households. To assess the amount of sodium in households' purchases in each year between 2000 and 2014, linear models regressed sodium (mg/d) per capita in households' purchases on year (indicator variables) and sociodemographic covariates (described below). Separate models were used for the outcomes of total purchases, foods only, beverages only, and table salt. Longitudinal 2-part models were used for table salt as described in the eMethods in the Supplement. To put sodium trends in context, models were repeated for per capita weight (g/d) and energy (kcal/d) in total, food, and beverage purchases.

Top food group sources of sodium were identified by ranking based on unadjusted, survey-weighted mean sodium (mg/d) per capita from each group in 2014. Groups that included single-ingredient foods that contain only naturally occurring sodium (eg, milk or eggs) were excluded to be consistent with previous sodium reduction guidance.[26] Separate models were then used to assess the adjusted mean sodium per capita (mg/d) and percentage contribution to sodium in packaged food purchases (% mg) for each top food group source.

To evaluate changes in the mean sodium content of purchases overall and by food group, linear models regressed the sodium content (mg/100 g) of purchases on year, with adjustment for covariates. Separate models were used for total purchases, foods only, beverages only, and each top food group source of sodium. To examine variability in sodium content within food groups, quantile regression models with clustering on the household were used to predict the adjusted sodium content at the 5th, 25th, 50th (median), 75th, and 95th percentiles.

Finally, trends in the sodium density (mg/1000 kcal) of total packaged food and beverage purchases were examined using quantile regression models with clustering on the household to evaluate changes in sodium density at the 25th, 50th (median), and 75th percentiles. Scholars recommend that an optimal sodium density of 1.1 mg/kcal or less, based on the DASH-Sodium trial and the Healthy Eating Index-2010, can be used as a practical approach for monitoring sodium levels.[27-31] To determine whether the percentage of households that have total purchases with optimal sodium density changed between 2000 and 2014, longitudinal logistic regression

Table 1. Major Food Group Sources of Sodium in US Households' Packaged Food and Beverage Purchases, 2000 to 2014[a]

| Variable | Adjusted Mean (SE) 2000 | 2005 | 2009 | 2014 | 15-y Change (95% CI)[b] | *P* Value for Trend[c] |
|---|---|---|---|---|---|---|
| **Sodium, mg/d per capita[d]** | | | | | | |
| Condiments, sauces, and dips | 248 (1) | 248 (1) | 235 (1)[e] | 192 (1)[e] | −57 (−58 to −55) | <.001 |
| Mixed dishes | 199 (1) | 224 (1)[e] | 223 (1)[e] | 191 (1)[e] | −8 (−10 to −7) | <.001 |
| Salty snacks | 178 (1) | 178 (0) | 167 (0)[e] | 138 (0)[e] | −41 (−42 to −39) | <.001 |
| Breads | 187 (0) | 167 (0)[e] | 151 (0)[e] | 127 (0)[e] | −60 (−61 to −59) | <.001 |
| Processed meat | 101 (1) | 137 (0)[e] | 141 (0)[e] | 128 (0)[e] | 27 (26 to 29) | <.001 |
| Cheese | 109 (0) | 108 (0) | 116 (0)[e] | 104 (0)[e] | −5 (−5 to −4) | .004 |
| Soup | 117 (1) | 116 (0) | 112 (0)[e] | 101 (0)[e] | −16 (−17 to −14) | <.001 |
| Grain-based desserts | 85 (0) | 89 (0)[e] | 83 (0)[e] | 72 (0)[e] | −13 (−14 to −13) | <.001 |
| Vegetables | 79 (0) | 76 (0)[e] | 68 (0)[e] | 57 (0)[e] | −22 (−23 to −22) | <.001 |
| Breakfast cereal | 71 (0) | 69 (0)[e] | 69 (0)[e] | 49 (0)[e] | −22 (−23 to −22) | <.001 |
| **Sodium, %[f]** | | | | | | |
| Condiments, sauces, and dips | 12.6 (0.0) | 12.3 (0.0)[e] | 12.1 (0.0)[e] | 11.5 (0.0)[e] | −1.1 (−1.2 to −1.1) | <.001 |
| Mixed dishes | 10.2 (0.0) | 11.2 (0.0)[e] | 11.6 (0.0)[e] | 11.5 (0.0)[e] | 1.3 (1.2 to 1.3) | <.001 |
| Salty snacks | 9.2 (0.0) | 9.0 (0.0)[e] | 8.7 (0.0)[e] | 8.5 (0.0)[e] | −0.7 (−0.8 to −0.6) | <.001 |
| Breads | 9.6 (0.0) | 8.4 (0.0)[e] | 7.9 (0.0)[e] | 7.7 (0.0)[e] | −1.9 (−2.0 to −1.9) | <.001 |
| Processed meat | 5.0 (0.0) | 6.6 (0.0)[e] | 7.1 (0.0)[e] | 7.3 (0.0)[e] | 2.3 (2.3 to 2.3) | <.001 |
| Cheese | 5.5 (0.0) | 5.4 (0.0)[e] | 6.0 (0.0)[e] | 6.3 (0.0)[e] | 0.8 (0.7 to 0.8) | <.001 |
| Soup | 6.0 (0.0) | 5.8 (0.0)[e] | 5.8 (0.0)[e] | 5.9 (0.0)[e] | −0.1 (−0.1 to 0.0) | .30 |
| Grain-based desserts | 4.5 (0.0) | 4.6 (0.0)[e] | 4.4 (0.0) | 4.4 (0.0) | 0.0 (−0.1 to 0.0) | <.001 |
| Vegetables | 4.0 (0.0) | 3.7 (0.0)[e] | 3.5 (0.0)[e] | 3.4 (0.0)[e] | −0.6 (−0.6 to −0.6) | <.001 |
| Breakfast cereal | 3.9 (0.0) | 3.7 (0.0)[e] | 3.9 (0.0) | 3.2 (0.0)[e] | −0.7 (−0.7 to −0.6) | <.001 |

[a] Data are from the Nielsen Homescan Consumer Panel, including 172 042 US households (754 608 year-level observations). Major food group sources of sodium were selected as the 10 groups with the highest contribution to sodium in purchases in 2014. All values were determined from multivariable, longitudinal linear regression models regressing purchases on indicator variables for year, with adjustment for household size and composition, race/ethnicity, income, educational level, and geographic market. The adjusted means were predicted at the distribution of race/ethnicity by income from US Census Bureau data.

[b] Values are the change in mean sodium from households' purchases of the specified food group between 2000 and 2014.

[c] *P* values for time trends were derived from multivariable regression models treating year as a continuous variable, including linear, quadratic, and cubic terms as appropriate.

[d] Values are the adjusted mean (SE) sodium (mg/d) per capita from households' purchases of the specified food group in a given year.

[e] Significantly different from 2000 ($P < .001$ by Wald postestimation test).

[f] Values are the adjusted mean (SE) percentage of sodium from households' purchases of the specified food group in a given year.

models regressed the binary outcome of sodium density of 1.1 mg/kcal or less on year, with adjustment for covariates.

All models were adjusted for household composition (single or multiple adults with or without children), household size (the number of household members in each age and sex category), joint classification by race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or other races/ethnicities) and income (≤185%, 186%-400%, or >400% of the federal poverty level), educational level (maximum level attained by either head of household, categorized as less than high school, high school, or college or higher), and geographic market. The Homescan panel includes a higher proportion of non-Hispanic white, high-income, and highly educated households than the general US population (eTable 2 in the Supplement). Therefore, to more accurately represent trends in the US population, the adjusted mean purchases in each year were predicted using the coefficients from the fully adjusted models, the distribution of race/ethnicity by income reported by the US Census Bureau for 2014, and mean values in the Homescan sample for all other covariates.[32]

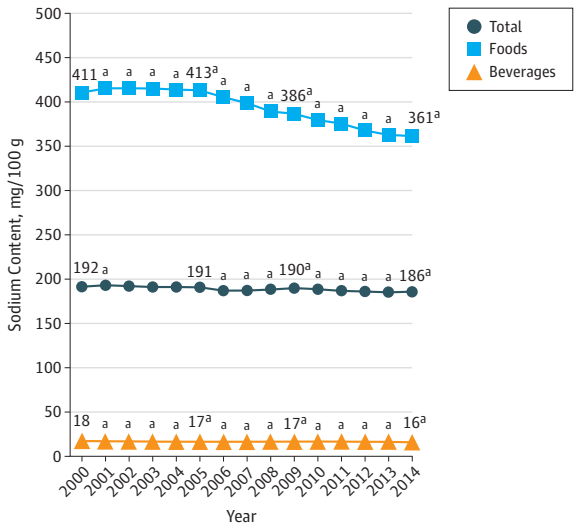
Trends over time were assessed by repeating models with year as a continuous variable; quadratic and cubic terms were tested and retained in the model when significant to capture potential nonlinear trends. Statistical significance was evaluated using Wald tests for the joint significance of all terms for time with 2-sided $\alpha = .001$ to account for multiple comparisons and the large sample size. All statistical analyses were conducted using Stata software (version 14; StataCorp LP).

## Results

### Amount of Sodium Purchased

This study included 172 042 US households (754 608 year-level observations) and used nutrition label data for 1 490 141 food and beverage products. The amount of sodium that US households acquired from packaged foods and beverages purchased from retail food stores decreased significantly between 2000 and 2014 by 396 mg/d (95% CI, −407 to −385 mg/d) per capita from 2363 to 1967 mg/d (**Figure 1**A and eTable 3 in the Supplement). During the 15-year study period, sodium obtained from packaged foods (excluding beverages) decreased by 260 mg/d (95% CI, −267 to −253 mg/d) per capita, and table salt purchases decreased by 111 mg/d (95% CI, −116 to −105

Figure 2. Sodium Content of Packaged Foods and Beverages Purchased by US Households, 2000 to 2014




| 15-y Change Category | β (95% CI) | *P* Value for Trend |
|---|---|---|
| Total | −6 (−7 to −5) | <.001 |
| Foods | −49 (−50 to −48) | <.001 |
| Beverages | −1 (−1 to −1) | <.001 |

Values are the adjusted mean sodium content of households' packaged food and beverage purchases from retail food stores in a given year, determined from multivariable, longitudinal linear regression models regressing purchases on indicator variables for year. *P* values for time trends were derived from multivariable regression models treating year as a continuous variable, including linear, quadratic, and cubic terms as appropriate. All models were adjusted for household size and composition, race/ethnicity, income, educational level, and geographic market, and means were predicted at the distribution of race/ethnicity by income from US Census Bureau data. Data are from the Nielsen Homescan Consumer Panel, including 172 042 US households (754 608 year-level observations).

[a] Significantly different from 2000 (*P* < .001 by Wald postestimation test).

mg/d) per capita. Between 2000 and 2014, total purchase amounts decreased by 193 g/d, primarily due to the 184 g/d per capita decrease (95% CI, −188 to −179 g/d) in beverage purchases (Figure 1B). However, the amount of packaged foods purchased by US households showed little change (−9; 95% CI, −10 to −7 g/d per capita).

The 10 top food group sources of sodium were identified and together provided approximately 70% of sodium in households' packaged food and beverage purchases in each year (**Table 1**). The amount purchased for each food group remained stable over time (eTable 4 in the Supplement).

### Sodium Content (mg/100 g) of Purchases

The sodium content of US households' packaged food purchases (excluding beverages) decreased significantly between 2000 and 2014 by 49 mg/100 g (95% CI, −50 to −48 mg/100 g), a 12.0% decline (**Figure 2** and eTable 5 in the Supplement); decreases began in 2005 and continued through 2014. Because total grams purchased decreased due to declining beverage purchases, decreases in the sodium content of total packaged food and beverage purchases were significant yet small (−6; 95% CI, −7 to −5 mg/100 g).

In addition, the mean sodium content of households' purchases decreased significantly for all top food sources of sodium between 2000 and 2014 (**Table 2**), including declines of more than 100 mg/100 g for condiments, sauces, and dips and salty snacks. Decreases were at least 10% for the sodium content of households' purchases of condiments, sauces, and dips (−14.0%); mixed dishes (−12.6%); salty snacks (−17.3%); breads (−10.5%); soup (−18.4%); vegetables (−17.1%); and breakfast cereal (−16.5%). The range between the 5th and 95th percentiles of sodium content showed wide variation that persisted in this 15-year period.

### Sodium Density (mg/1000 kcal) of Purchases

The median sodium density of households' overall packaged food and beverage purchases decreased significantly by 84 mg/1000 kcal (95% CI, −91 to −77 mg/1000 kcal) from 1712 to 1628 mg/1000 kcal between 2000 and 2014 (**Figure 3**A and eTable 6 in the Supplement). Sodium density also decreased significantly between 2000 and 2014 for all top food group sources of sodium (eTable 7 in the Supplement). Nonetheless, throughout the 15-year period, less than 2% of US households had total packaged food and beverage purchases with optimal sodium density (≤1.1 mg/kcal), although prevalence increases between 2000 and 2014 (+0.5 percentage point) were statistically significant (Figure 3B).

## Discussion

Using food composition data for approximately 1.5 million products, this study found that sodium from packaged food and beverage purchases decreased significantly by 396 mg/d per capita between 2000 and 2014 in a nationwide sample of US households. The sodium content of packaged food purchases declined by 12.0% overall and by at least 10% for 7 of 10 top food group sources of sodium. Although a significant 15-year reduction in the median sodium density of households' packaged food and beverage purchases was achieved, almost all US households had purchases exceeding optimal sodium density levels. In summary, sodium in US households' packaged food purchases decreased significantly and consistently for all 3 measures examined (mg/d, mg/100 g, and mg/1000 kcal), but further reductions are needed.

The significant 15-year decline in per capita sodium from packaged foods is potentially meaningful for population health; previous simulation studies predicted that a reduction in population-level sodium intake of this magnitude (approximately 400 mg/d) would reduce new cases of coronary heart disease by 20 000 to 40 000 and deaths from all causes by 15 000 to 32 000 annually.[33] However, further studies are needed to determine the extent to which reductions in sodium purchased translate to reductions in sodium intake. Previous analyses using self-reported dietary assessment found little[14,34] or no[35] decline in total sodium intake in the past 15 years but were based on data for fewer than 10 000 foods, in contrast to the 400 000 products available in the US marketplace each year, and did not consistently update food composition data to keep pace with rapid changes in the food supply.

Table 2. Sodium Content (mg/100 g) of Packaged Foods Purchased by US Households by Food Group, 2000 to 2014[a]

| Food Group | Adjusted Sodium Content, mg/100 g[b] | | | | 15-y Change (95% CI)[c] | *P* Value for Trend[d] |
|---|---|---|---|---|---|---|
| | 2000 | 2005 | 2009 | 2014 | | |
| **Condiments, Sauces, and Dips** | | | | | | |
| Mean (SE) | 818 (1) | 809 (1)[e] | 785 (1)[e] | 704 (1)[e] | −114 (−117 to −111) | <.001 |
| Median (25th to 75th percentiles) | 789 (675 to 923) | 785 (667 to 918) | 766 (647 to 898) | 686 (563 to 818) | −104 (−106 to −101) | |
| Range[f] | 490 to 1218 | 481 to 1214 | 454 to 1189 | 352 to 1114 | | |
| **Mixed Dishes** | | | | | | |
| Mean (SE) | 557 (1) | 551 (1)[e] | 517 (1)[e] | 487 (1)[e] | −70 (−71 to −68) | <.001 |
| Median (25th to 75th percentiles) | 527 (451 to 623) | 526 (458 to 610) | 496 (432 to 574) | 472 (411 to 544) | −55 (−57 to −53) | |
| Range | 357 to 837 | 368 to 798 | 344 to 752 | 327 to 707 | | |
| **Salty Snacks** | | | | | | |
| Mean (SE) | 821 (1) | 815 (1)[e] | 779 (1)[e] | 679 (1)[e] | −142 (−144 to −141) | <.001 |
| Median (25th to 75th percentiles) | 824 (727 to 921) | 815 (726 to 904) | 779 (695 to 864) | 677 (595 to 758) | −146 (−149 to −144) | |
| Range | 554 to 1094 | 572 to 1072 | 544 to 1025 | 445 to 909 | | |
| **Breads** | | | | | | |
| Mean (SE) | 565 (0) | 554 (0)[e] | 530 (0)[e] | 506 (0)[e] | −60 (−61 to −58) | <.001 |
| Median (25th to 75th percentiles) | 550 (512 to 598) | 539 (502 to 586) | 515 (482 to 557) | 493 (452 to 541) | −57 (−58 to −56) | |
| Range | 449 to 726 | 446 to 714 | 431 to 687 | 389 to 679 | | |
| **Processed Meat** | | | | | | |
| Mean (SE) | 908 (1) | 1034 (1)[e] | 938 (1)[e] | 880 (1)[e] | −28 (−31 to −26) | <.001 |
| Median (25th to 75th percentiles) | 893 (762 to 1021) | 1011 (885 to 1145) | 927 (821 to 1036) | 863 (769 to 964) | −30 (−33 to −27) | |
| Range | 576 to 1245 | 691 to 1468 | 661 to 1248 | 622 to 1197 | | |
| **Cheese** | | | | | | |
| Mean (SE) | 793 (1) | 752 (1)[e] | 757 (1)[e] | 719 (1)[e] | −73 (−76 to −71) | <.001 |
| Median (25th to 75th percentiles) | 746 (606 to 934) | 713 (589 to 877) | 723 (613 to 867) | 686 (589 to 813) | −60 (−63 to −56) | |
| Range | 446 to 1250 | 436 to 1173 | 477 to 1137 | 462 to 1065 | | |
| **Soup** | | | | | | |
| Mean (SE) | 445 (1) | 421 (0)[e] | 380 (0)[e] | 363 (0)[e] | −82 (−83 to −80) | <.001 |
| Median (25th to 75th percentiles) | 429 (372 to 506) | 403 (352 to 475) | 365 (316 to 427) | 347 (298 to 408) | −82 (−84 to −81) | |
| Range | 297 to 650 | 276 to 633 | 236 to 582 | 211 to 584 | | |
| **Grain-Based Desserts** | | | | | | |
| Mean (SE) | 392 (0) | 388 (0)[e] | 392 (0) | 376 (0)[e] | −17 (−18 to −16) | <.001 |
| Median (25th to 75th percentiles) | 384 (345 to 430) | 379 (342 to 426) | 383 (344 to 431) | 367 (329 to 415) | −16 (−17 to −15) | |
| Range | 287 to 523 | 282 to 522 | 282 to 529 | 268 to 516 | | |
| **Vegetables** | | | | | | |
| Mean (SE) | 244 (1) | 228 (0)[e] | 226 (0)[e] | 202 (0)[e] | −42 (−43 to −40) | <.001 |
| Median (25th to 75th percentiles) | 230 (159 to 309) | 214 (143 to 293) | 210 (138 to 293) | 183 (119 to 261) | −47 (−49 to −46) | |
| Range | 69 to 468 | 59 to 454 | 56 to 460 | 50 to 422 | | |
| **Breakfast Cereal** | | | | | | |
| Mean (SE) | 462 (1) | 447 (1)[e] | 450 (1)[e] | 386 (1)[e] | −76 (−78 to −75) | <.001 |
| Median (25th to 75th percentiles) | 471 (361 to 562) | 459 (339 to 556) | 467 (349 to 560) | 402 (291 to 489) | −69 (−71 to −67) | |
| Range | 152 to 695 | 135 to 693 | 142 to 678 | 97 to 607 | | |

[a] Data are from the Nielsen Homescan Consumer Panel, including 172 042 US households (754 608 year-level observations). Blank cells indicate not applicable.

[b] Values are the adjusted sodium content of households' food group purchases from retail food stores in a given year, determined from multivariable, longitudinal linear or quantile regression models regressing purchases on indicator variables for year. All models were adjusted for household size and composition, race/ethnicity, income, educational level, and geographic market. Means and percentiles were predicted at the distribution of race/ethnicity by income from US Census Bureau data.

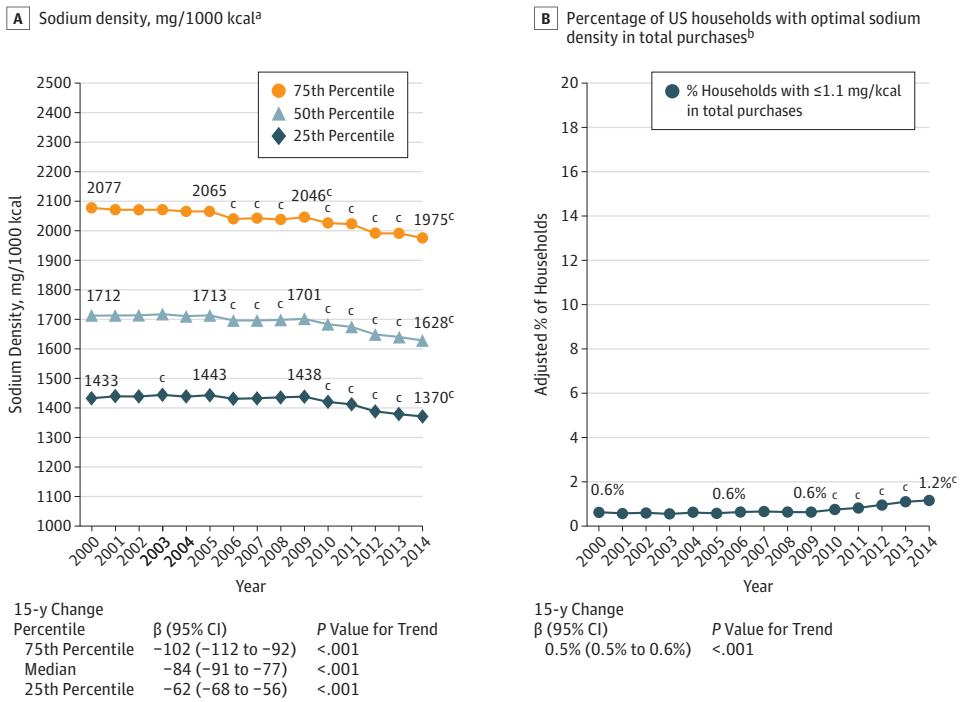
[c] Values are the change in mean or median sodium content between 2000 and 2014.

[d] *P* values for time trends were derived from multivariable regression models treating year as a continuous variable, including linear, quadratic, and cubic terms as appropriate.

[e] Significantly different from 2000 ($P < .001$ by Wald postestimation test).

[f] Values are the adjusted 5th to 95th percentiles of sodium content.

Figure 3. Sodium Density of Packaged Foods and Beverages Purchased by US Households, 2000 to 2014




Data are from the Nielsen Homescan Consumer Panel, including 172 042 US households (754 608 year-level observations). *P* values for time trends were derived from multivariable, regression models treating year as a continuous variable, including linear, quadratic, and cubic terms as appropriate. All models were adjusted for household size and composition, race/ethnicity, income, educational level, and geographic market, and values were predicted at the distribution of race/ethnicity by income from US Census Bureau data.

[a] Values are adjusted 25th, 50th (median), and 75th percentile sodium density of households' packaged food and beverage purchases from retail food stores in a given year, determined from multivariable quantile regression models regressing purchases on indicator variables for year with clustering on the household.

[b] Values are the adjusted percentage of households that have total packaged food and beverage purchases with sodium density of 1.1 mg/kcal or less in a given year, determined from multivariable longitudinal logistic regression models regressing the binary outcome of having purchases with sodium density of 1.1 mg/kcal or less on indicator variables for year.

[c] Significantly different from 2000 ($P < .001$ by Wald postestimation test).

Our study found that the sodium content of packaged food purchases decreased significantly between 2000 and 2014, both overall (−12.0%) and for all top food group sources of sodium. In contrast, one study[8] reported minimal declines (−3.5%) in sodium content by reformulation between 2005 and 2011 yet included only 402 packaged foods. Similar to our results, modest declines (−6.8%) in sales-weighted sodium content between 2009 and 2014 were found for food categories targeted by the NSRI, a coalition of local and state health organizations that set voluntary sodium reduction targets for packaged and restaurant foods.[9,36] Our examination of long-term trends revealed that decreases in sodium per capita and sodium content began in 2005, predating the NSRI's 2009 baseline.

Despite significant declines in the sodium density of purchases throughout the past 15 years, most US households had packaged food and beverage purchases with sodium density exceeding 1.1 mg/kcal. This finding is consistent with studies[14,30,35] showing that the mean sodium density of dietary intake from stores remained above the optimal level and that no significant reductions in the prevalence of excessive sodium intake were achieved between 2003 and 2010. Moreover, 15-year changes in total sodium per capita and sodium content of packaged foods in our study represent slow annual rates of decline (−1.1% and −0.8% per year, respectively), far slower than the rate recommended by the European Union Framework (−4% per year).[37] Our findings support the need for more concerted nationwide efforts to accelerate the pace of sodium reduction, and the US Food and Drug Administration's recently proposed phased targets for the sodium content of industrially processed foods will likely have a critical role.[26]

## Limitations and Strengths

A key limitation of this study is that households do not report whether all purchased foods are consumed, so these data cannot examine sodium intake. Purchases of table salt may not reflect consumption because of wastage and other uses.[38] However, results of waste collection studies[39,40] suggest that consumer-level food loss has not changed in the past 15 years; therefore, trends in sodium purchased may be an adequate reflection of trends in sodium intake. This analysis does not include foods without a barcode or a Nutrition Facts Panel, including cut-to-order lunch meat and store-prepared hot foods,

which may also be sources of sodium in store purchases. For a subsample of participants who manually recorded nonpackaged food purchases in addition to scanning packaged foods, packaged foods accounted for 78% of store expenditures[24]; however, because nonpackaged foods could not be linked to nutrition information, the proportion of sodium purchased from packaged foods cannot be determined. Additional studies are needed to examine whether decreases in sodium from packaged foods were offset by increases in sodium from away-from-home sources. The significant decreases in sodium purchased in our study may be attributable to changes in health-conscious purchasing behaviors by consumers or to reductions in the sodium content of packaged foods by manufacturers; however, there were no major shifts in the amount purchased for key food groups, suggesting that sodium declines may relate mainly to reformulation.

Although US Food and Drug Administration regulations allow sodium content stated on the Nutrition Facts Panel to deviate from actual content in a product by up to 20%,[41] experts found that the sales-weighted mean sodium content based on nutrition labels agreed closely with analytically assessed values (<10% difference) for most top food sources of sodium.[11,42] Moreover, these validation studies[11,42] indicate that discrepancies primarily occur for products with nutrition label sodium content that is higher than the analytic measurement, potentially because manufacturers have not made costly updates to labels when sodium reduction is within the allowed margin of error. Therefore, our results may underestimate actual sodium reductions. No recommendations exist for the overall sodium density of purchases, so sodium density was compared with the optimal level previously derived for dietary intake; however, this sodium density cutoff has been used by governmental advisory committees and researchers to evaluate store-bought foods and processed foods.[29-31]

Bias from underrecording of purchases may occur if participants are too busy to scan all items or selectively choose to not record products perceived as unhealthy; however, validation studies conclude that the accuracy of the Homescan data is comparable to other commonly used government-collected data sets.[18] Because scanning purchases is time consuming, selection bias is possible; the high proportions of non-Hispanic white and high-income households in our study suggest that some subpopulations might be better able to handle the burden of data recording and participate in the study. Consequently, findings may not be generalizable to the US population.

A main strength of this study is the use of time-varying brand- and product-specific sodium content data. Other strengths include objective scanning of purchases that avoids bias inherent in self-reported dietary intake, the large nationwide sample of households, and ability to monitor long-term trends.

## Conclusions

In this nationwide study, the amount of sodium that US households acquired from packaged foods and beverages decreased significantly between 2000 and 2014, with corresponding declines in the sodium content of packaged food purchases. Despite these improvements, almost all US households continue to have total packaged food purchases with excessive sodium density. The slow rate of decline in sodium from store-bought foods suggests that more concerted sodium reduction efforts are necessary in the United States. Future studies are needed to examine sodium trends by race/ethnicity and income to identify vulnerable subpopulations that further interventions should target.


### ARTICLE INFORMATION

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*Study concept and design:* Poti.
*Acquisition, analysis, or interpretation of data:* All authors.
*Drafting of the manuscript:* Poti.
*Critical revision of the manuscript for important intellectual content:* All authors.
*Statistical analysis:* Poti.
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