Published in final edited form as:

Public Health Nutr. 2020 February ; 23(3): 488–495. doi:10.1017/S1368980019002696.

Simulating the impact of sodium reduction from packaged foods on population sodium intake in US adults and children.

Elizabeth K Dunford^{1,2}, Jennifer M Poti³

¹Carolina Population Center, University of North Carolina at Chapel Hill, Chapel Hill, NC

²Food Policy Division, The George Institute for Global Health, University of New South Wales, Sydney, Australia

³Department of Nutrition, University of North Carolina at Chapel Hill, Chapel Hill, NC

Abstract

Objectives: To simulate the impact that sodium reductions in food categories that are the largest contributors to dietary sodium intake would have on population intake from packaged foods among US adults and children.

Design: 24hr dietary recall data were used. For each store-bought packaged food product reported by participants, we generated sales-weighted sodium content at the median and 25th percentile using Nutrition Facts Panel data from 193,195 products purchased by US households. The impact that sodium reductions would have on population intake, overall and by sociodemographic subgroup, was examined.

Settings: US households.

Participants: 2,948 children 2-18y and 4,878 adults >18y from the 2011-2012 National Health and Nutrition Examination Survey (NHANES).

Results: Sodium intake from packaged foods was 1258 (21) mg for adults and 1215 (35) mg for children. Top 10 packaged food group sources contributed 67% of sodium intake. For adults and children, there was a decrease of 8.7% (109mg) and 8.0% (97mg) respectively in sodium intake if the top 10 sources reduced sodium from the median to the 25th percentile. Although absolute reduction in intake varied between socio-demographic subgroups, significant differences weren't observed.

Conclusions: This study demonstrated that if sodium reduction shifted the top 10 packaged food group sources of dietary sodium intake from the median to 25th percentile, that population intake would be reduced by 9% in US adults and children. These findings will help inform the US

Corresponding author: Dr Elizabeth Dunford, Carolina Population Center, UNC-CH, Chapel Hill, NC 27516, Phone: 919-903-7863, Fax: N/A, edunford@georgeinstitute.org.au.

Authorship: E.D. and J.P. contributed to development of the research question and project design, as well as interpretation of the findings. J.P. oversaw the analysis. E.D. conducted the data analysis and lead the data interpretation. Both authors contributed to drafting the manuscript, and have reviewed and approved the contents of the final version.

Conflict of interest statement: ED and JP have no conflicts of interest.

Ethical Standards Disclosure: This study did not involve the participation of human subjects.

government's sodium reduction targets, as well as policymakers' understanding of differences in intake of critical sub-populations in the US.

Keywords

sodium intake; NHANES; reformulation; packaged foods

Introduction

Chronic diseases are the leading causes of premature death and disability and cause the greatest burden of disease in the US⁽¹⁾. These diseases are largely attributable to poor diet, with overnutrition a major cause of diet-related ill health⁽¹⁾. Cardiovascular disease (CVD) represents 30% of all global deaths⁽²⁾. High blood pressure is a major cause of CVD, and high dietary salt intake a key contributor⁽³⁾. Despite ongoing debate in the literature as to the optimal target for population reductions in salt intake⁽⁴⁾, all racial/ethnic and socioeconomic groups in the US are consuming levels well in excess of dietary guidelines⁽⁵⁾.

In the US, most food eaten is processed by the food industry^(8; 9), resulting in the population being exposed to foods that are high in energy, saturated fat, sugar, and salt⁽⁶⁾. Even small changes in levels of these adverse nutrients in the food supply have the potential to produce large health gains at low cost, and these changes are being promoted by public health experts as priority actions to address the chronic disease crisis⁽¹⁰⁾. The World Health Organization (WHO) has recommended sodium reduction as a 'best buy' and as one of the most cost-effective approaches to prevent chronic diseases⁽²⁾. Nutrition researchers have based their understanding of diet on foods reported in the National Health and Nutrition Examination Survey (NHANES), which is linked with nutrient information from US Department of Agriculture (USDA) food tables containing ~7,500 foods. These tables are useful but not updated annually. US consumers purchase >400,000 different packaged foods yearly that are rapidly changing due to product introduction and reformulation⁽¹¹⁾. Most studies to date that have examined trends in sodium intake have been limited by lack of up-to-date, product-specific food composition data needed to monitor the huge number and variety of products in the US food supply and continual product reformulations. Further, many US food manufacturers and retailers have pledged to reduce the sodium content of their packaged food products, yet there is no objective method to monitor whether these pledges are being followed. Although research exists that identifies priority food categories contributing to dietary sodium intake in the US population^(12; 13), there have been few studies that have examined what effect sodium reductions in these key food categories would have on population intake. Surprisingly little is also understood about whether differences exist among and within critical sub-populations for whom health inequality has risen over the past half century in the US⁽¹⁴⁾.

The objective of this study was therefore to simulate the impact that sodium reductions in food categories that are the largest contributors to sodium intake would have on population intake from packaged foods in US adults and children both overall and by race-ethnicity, education, income and weight status.

Methods

This study used 24-hour dietary recall data for a nationally representative US sample of 2,948 children 2-18y and 4,878 adults >18y from the 2011-2012 NHANES. NHANES is based on a multistage, stratified area probability sample of non-institutionalized US households. Detailed information about the survey and its sampling design has been published previously⁽¹⁵⁾, but in brief dietary intake data were obtained through standardized interviewer-administered 24-hr dietary recalls collected using the Automated Multiple-Pass Method initially in person with a second 24-hour diet recall collected by phone 3 to 10 days later. We only used the initial in-person 24-hr dietary recall rather than both diet recalls which is recommended by NHANES for undertaking analyses examining mean intake levels. Intake for any child under the age of 12 was reported by proxy, typically the adult most knowledgeable about the survey participant's intake. By utilizing secondary NHANES data, we were exempt from institutional review board concerns for this paper.

In previous work, we enhanced standard food composition data with time-varying product-specific nutritional information for packaged food products, by linking Nutrition Facts Panel data from 193,195 barcoded foods and beverages to codes for packaged foods consumed from stores and vending machines (hereafter referred to as "stores") by NHANES participants⁽¹⁶⁾. This enabled us to more closely estimate the sodium contribution of packaged food sources to dietary intake as the data were linked to foods that were actually purchased by US consumers. Using our Crosswalk-enhanced FNDDS food composition database, we generated sales-weighted mean sodium content (mg/100g) at various percentiles for each food code reported in NHANES corresponding to store-bought packaged food, with weighting derived from purchases by households in the nationwide Nielsen Homescan Consumer Panel in the corresponding period. The Nielsen Homescan data contain Universal Product Code (UPC)-level information about household food purchases among a nationally representative sample of 60,000 households each year^(17; 18; 19). These households report all UPC transactions from all outlet channels, including grocery, drug, mass-merchandise, and convenience stores. Data captured on each shopping occasion include: purchase date, retailer, every UPC purchased, number of units purchased, and item description and attributes.

The Crosswalk-enhanced database contains data from 2011-12, and so NHANES 2011-12 was selected to use in the analysis to ensure the time- and brand-specific nature of the Crosswalk database was fully utilized.

Top food group sources of sodium

To identify those food items contributing most to sodium intake, the food grouping system developed by the University of North Carolina at Chapel Hill (UNC-CH) was used. All the foods reported in NHANES were assigned to one of UNC-CH's food groups. The UNC-CH food grouping system has been previously used and described⁽¹⁶⁾. The sales-weighted mean sodium content (mg/100g) generated in the previous step using the Crosswalk-enhanced FNDDS food composition database for each packaged food code reported in NHANES from stores was used to identify the top 10 packaged food group sources of dietary sodium for both adults (>18 years) and children (2-18 years).

Simulation of sodium reduction

The Crosswalk-enhanced FNDDS food composition database was again used to simulate the impact that sodium reductions within the top 10 packaged food groups would have on population intake both overall and by socio-demographic subgroup for adults and children. This was done by replacing the weighted median sodium content with the sodium content at the 25th percentile for food codes (representing packaged foods) within the top 10 food groups contributing to dietary sodium intake (Table 2) and retaining the weighted median sodium content for all remaining food groups. We then simulated sodium intake if participants consumed foods with sodium content reduced to that 25th percentile level. This process was repeated by replacing the weighted median sodium content with the adjusted sodium content at the 25th percentile for *all* food codes.

Statistical analyses

Data are presented as means (SE). Results are presented separately for children (2-18 years) and adults (19+ years). Adults and children were then examined by three racial-ethnic groups (Non-Hispanic White, Non-Hispanic Black and Hispanic), three income groups (<185% Federal Poverty Level (FPL), 185% to 350% FPL and >350% FPL), four BMI categories (underweight, normal weight, overweight, obese), three education groups (Less Than High School, High School, More Than High School) and gender (Male or Female) (Table 1). In additional analyses, results were also examined by racial-ethnic group and gender (e.g. Hispanic Females, Hispanic Males). BMI classification used the CDC criteria and cut-offs for children and used NHLBI criteria for adults. Although results for “Other” race were included in analyses, results were not reported separately due to small numbers within this racial-ethnic group.

The top 10 food groups contributing the most to sodium intake from packaged foods are reported overall for adults and children, and by socio-demographic subgroup. For each sociodemographic subgroup, the proportion of sodium intake that the top 10 overall food group sources of sodium represented was examined by dividing the sum of each top food group’s contribution by the total sodium intake from packaged foods for each subgroup. Top food group sources were examined overall for adults and children, and in each socio-demographic subgroup to identify whether sodium reduction efforts would have a different impact across these sub-populations. Stata 14.1 was used for all analyses. Survey methods were used within Stata to account for the clustering and weighting that is inherent in the NHANES sampling methodology⁽²⁰⁾, so as to allow for statistically significant differences across the various sociodemographic subgroups to be identified using Student’s *t*-test. A *p* value of <0.05 was considered significant.

Results

Top 10 sources of sodium from stores

The total sodium intake purchased from stores identified using the Crosswalk-enhanced database was 1258mg (SE: 21mg) for adults and 1215mg (SE: 35mg) for children (Table 2). The top 10 sources of sodium intake from stores were similar for adults and children (Table 2), with “Breads, rolls and tortillas” the largest contributor in adults and “Processed meats

and poultry” in children. The top 10 food group sources contributed 53% of sodium intake from packaged foods for adults and 58% for children. The proportion of intake from the top 10 sources differed slightly when examined by socio-demographic subgroup. In adults, the top 10 sources of sodium overall contributed a lower proportion of intake from packaged foods in Non-Hispanic Whites compared to Hispanics and Non-Hispanic Blacks (Figure 1). Adults and children in the lowest income group (<185% FPL) and those in the lowest household education group (Less than high school) had a higher proportion of sodium intake deriving from the top 10 food group sources. Supplementary Figures 1 and 2 show the contribution of each top 10 food group source to sodium intake from packaged foods by socio-demographic subgroup in children and adults respectively.

Simulated reduction in sodium intake from packaged foods if sodium content of top 10 food groups was reduced

Figure 2A shows the reduction in intake that would be achieved by US adults and children, overall and by socio-demographic group, if packaged food products from the top 10 food group sources had sodium content reduced from the median to the 25th percentile. For adults and children overall, there was a decrease of 8.7% (109mg) and 8.0% (97mg) respectively in sodium intake if store-bought packaged foods from the top 10 food group sources had sodium content reduced from the median to the 25th percentile. Results varied slightly when examined by sociodemographic subgroup. For example, adults in the highest income group had the largest reduction in sodium intake (9.2%, 120mg) out of all income groups (Figure 2B) although these reductions were not significantly different between all groups. Significant differences were only observed between children in the lowest income group compared to those in the middle income group (Figure 2B; $p<0.05$). Adult males had a larger simulated reduction in sodium intake than females (9.0%/133mg versus 8.2%/87mg; $p<0.05$; Figure 2A), whereas male children had a smaller simulated percent reduction compared to females (7.8%/108mg versus 8.1%/85mg; Figure 2A). Adults and children in the highest education group had the largest reduction (9.0%/113mg and 8.1%/99mg; Figure 2C) although differences were not significant between education groups. Results were very similar between adult racial-ethnic groups, with small but significant differences observed between Hispanics and Non-Hispanic White adults (8.7%/93mg versus 8.6%/116mg; $p<0.05$; Figure 2D).

Simulated reduction in sodium intake from packaged foods if sodium content of all packaged foods were reduced

For adults and children overall, there was a decrease of 13.3% (167mg) and 11.9% (145mg) respectively in sodium intake from store-bought packaged foods when all products were reduced in sodium content (Figure 2A). When all store-bought packaged foods had sodium levels reduced to the 25th percentile, sodium intake from store-bought foods alone was 1149mg for adults and 1118mg for children. Results varied slightly when examined by socio-demographic subgroup. For income, a significant difference was only observed between children in the lowest income group compared to those in the middle-income group (Figure 2B; $p<0.05$). A significant difference was observed between males and females in both adults and children (Figure 2A; $p<0.05$), with adult males having a larger reduction in intake than adult females and male children having a smaller reduction than females. Adults

in the highest vs lowest education level had the largest reduction (13.8% vs 12.9%; Figure 2C), although differences were non-significant. Non-Hispanic Black children had a larger simulated reduction than other race groups (14.8%, 187mg), although significant differences were only observed between Hispanic and Non-Hispanic White adults (Figure 2D; $p<0.05$) with Non-Hispanic White adults having a significantly larger reduction. Results were very similar between racial-ethnic groups in children.

Discussion

This study demonstrated that if a sodium reduction shifted purchased packaged foods in the top 10 food group sources of dietary sodium intake from sodium levels at the median to 25th percentile, that population sodium intake from packaged food would be reduced by 9% in US adults and children. If these sodium reductions were implemented across all store-bought packaged foods, population intake from packaged foods could potentially be reduced further, by a total of just over 13%. Based on our analysis, current sodium intake from store-bought packaged foods was estimated to be 1258mg for adults and 1215mg for children. Hence, even if all store-bought packaged foods had sodium levels reduced to current concentrations at the 25th percentile, sodium intake from store-bought foods alone would still remain high at 1149mg for adults and 1118mg for children. The most recent NHANES showed that 61% of sodium intake was derived from store-bought foods, which is slightly higher than what we observed in our current analysis which contains up-to-date, brand-specific information describing the food supply⁽¹³⁾.

These results have important implications for policy. Currently in the US, two sets of sodium reduction targets have been initiated. In 2009 the National Salt Reduction Initiative released a set of 62 sodium reduction targets for manufacturers to reach by 2014⁽²¹⁾. Similar to the approach used with this analysis, the NSRI targets were developed by calculating a 25% reduction from the sales-weighted mean in each food category⁽²²⁾. However, by 2014 only 3% of the food categories met the 2014 targets⁽²³⁾. One modelling study also suggested that for the NSRI targets to have been successful at ensuring statistically significant population-level reductions in heart attack and stroke incidence and mortality, at least 65% of foods in each food category would need to meet the targets⁽²⁴⁾. More recently, the FDA has released a draft set of 150 sodium reduction targets, however these have yet to be finalized⁽²⁵⁾. Both sets of targets focus on key contributors to dietary sodium intake in the US. However, as our analysis shows, even if sodium content of all packaged foods were reduced from mean levels to levels currently met by the 25% of products with lowest sodium content, population intake would still remain too high. Another point to consider is the feasibility of reducing sodium content across the whole food supply. It is extremely unlikely this could be done, and it is more sensible to assume that larger reductions in some of the key contributors to sodium intake would be a more feasible approach to reduce population sodium intake.

The UK has, to date, the world's most successful salt reduction program, primarily due to its strong government leadership and collaborations between government, industry, the media and consumers. Research has estimated that the current UK salt reduction strategy has potentially prevented or postponed ~57,000 new cases and 12,000 deaths from cardiovascular disease in England⁽²⁶⁾. Furthermore, a 15% reduction in population salt

intake between 2003 and 2011 resulted in average blood pressure in the adult population falling by 3/1.4mm Hg over the same period⁽²⁷⁾. However, studies have also shown that when equity is considered, the impact of the UK strategy does not look as positive, and that the current UK policies may either have a neutral impact or may even worsen inequalities in the population⁽²⁶⁾. This is important to consider in light of the current analysis. We observed that reductions in the sodium content of the top 10 food group sources would have varying effects on population subgroups. For example, we found that adults in the highest income group and those in the highest education group would have the largest reduction in sodium intake. This could potentially indicate that implementation of a sodium reduction strategy in the US population targeting packaged food sources may not result in equal reductions in sodium intake among disadvantaged groups. Modelling studies have also shown that if the NSRI targets were to be met by all food companies, that Non-Hispanic Whites would have the largest reduction in stroke incidence and mortality⁽²⁴⁾. The most recent US-based modelling study found that if the 2014 NSRI targets were met, that the US population >1y could reduce sodium intake by 20%⁽²⁸⁾, which is a much larger reduction predicted than our current findings which indicate that even with across-the-board reductions in the sodium content of packaged foods, sodium intake would not be reduced by more than 13%. However, our analysis simulates the reductions that could be achieved if packaged store-bought foods alone had levels reduced, and do not take into account the impact that would be seen if sodium levels in foods consumed from restaurants or take-away foods were also reduced.

Although our results indicate that sodium reduction strategies focusing only on the top 10 food group sources will not result in population intake being reduced substantially, even a small reduction in salt intake at the population level can have substantial health and economic benefits. A recent meta-analysis of short-term salt reduction trials showed a dose-response relationship with a 1 g/day reduction in salt intake relating to an approximately 1 mm Hg fall in systolic blood pressure⁽²⁹⁾. On a global level, a 10% reduction in sodium consumption over 10 years is projected to avert approximately 5.8 million DALYs/year related to cardiovascular diseases⁽³⁰⁾.

Our analysis had some limitations. Collected dietary data has limitations in underreporting, particularly of food and beverages perceived as being less healthy, and these limitations can vary by age, race-ethnicity and body weight status^(31; 32; 33). The analysis for this research used nutritional values reported on product labels and so may not accurately represent what is in the foods. However prior studies suggest that nutrition label data are generally accurate and within the FDA limits⁽³⁴⁾. Our study only focused on packaged food products, and it will be important for policymakers to consider our results within the broader food environment. Consumers obtain dietary sodium from sources such as restaurant foods, salt added at the table and during cooking that were not considered in this study. For example, a recent modelling study from New Zealand estimated that a 36% reduction in the sodium content of all foods as well as a 40% reduction in discretionary salt use and foods eaten away from home would be required to reduce population intake levels to below the WHO recommendation of 5g/day⁽³⁵⁾.

A major strength of this study is our use of a comprehensive database of packaged food products with time-matched barcode-specific sodium data. Conversion of sodium content from “as purchased” to “as consumed” is an important advantage of our database that is essential for assessment of how product-level changes impact sodium intake. Further, our study used data from two nationally representative samples of the US population, first to generate sales-weighted mean sodium content of products purchased by households and also to translate these levels into impact on American’s sodium intake. Data from the Homescan Consumer Panel uniquely enabled us to identify the distribution of sodium content of products purchased by households, a key step for our simulation approach that allowed us to examine the simulated impact of changing sodium content to levels that are currently achieved by one-quarter of existing products. Thus, our results reflect achievable sodium reduction based on sodium content of currently purchased products, rather than hypothetical reductions that may not be technologically feasible from a food processing perspective.

Conclusion

This study demonstrated that if a sodium reduction that shifted purchased packaged foods in the top 10 food group sources of dietary sodium intake from sodium levels at the median to the 25th percentile, that population sodium intake from packaged foods would be reduced by no more than 9% in US adults and children, and no more than 14% if all food groups had reduced levels of sodium. The evidence generated herein will be essential in informing the US government’s sodium reduction targets, as well as policymakers’ understanding of differences in nutritional intake of critical sub-populations in the US. With emerging disparities in both the contribution of the food supply to dietary sodium intake⁽³⁶⁾ and in hypertension levels in the US⁽³⁷⁾ ensuring that national sodium reduction strategies reach important subpopulations is critical if sodium intake is to be reduced to below recommended levels.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

We would like to thank Donna Miles for data analysis support.

Financial support:

This work was supported by the Robert Wood Johnson Foundation (grant numbers 67506, 68793, 70017, 71837), NIH (grant numbers R01DK098072; DK56350) and CPC (grant number P2C HD050924).

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Figure 1: Proportion of sodium intake from packaged foods contributed by the top 10 food group sources for US adults and children

Notes: Authors' analyses and calculations based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol, for the 2011-2012 period for the US market (licensed from The Nielsen Company, 2014).

Figure 2:

Simulated reduction in mean daily sodium intake from packaged foods by socio-demographic subgroup if sodium levels of top 10 food groups were reduced from the median to 25th percentile sodium content of purchased products

(A)-Gender

* significantly greater reduction than males; $p < 0.05$

(B) – Income

* significantly greater % reduction than <185% FPL

(C) - Education

(D) - Race-ethnicity

* significantly greater % reduction than NH White; $p < 0.05$

** significantly greater % reduction than Hispanics; $p < 0.05$

(E) - Weight status

* significantly greater % reduction than Overweight

Notes: Authors' analyses and calculations based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol, for the 2011-2012 period for the US market (licensed from The Nielsen Company, 2014).

Table 1:

Sociodemographic characteristics of NHANES 2011=12 participants

	ADULTS	CHILDREN
Number of observations (n)	4,878	2,948
Gender, %		
Female	51.1	49.1
Male	48.9	50.9
Race-ethnicity (%)		
Hispanic	14.3	23.3
Hispanic males	7.2	12.5
Hispanic females	7.0	10.8
Non-Hispanic white	66.5	53.4
Non-Hispanic White males	32.8	26.5
Non-Hispanic White females	33.7	26.8
Non-Hispanic black	11.6	14.5
Non-Hispanic Black males	5.1	7.4
Non-Hispanic Black females	6.5	7.1
Household income (%)		
<185% federal poverty level	36.1	49.8
185-350% federal poverty level	23.0	23.1
>350% federal poverty level	40.9	27.1
Education (%)		
Household's education < high school diploma	16.4	24.2
Household's education high school diploma	19.6	20.0
Household's education >high school diploma	64.0	55.8
BMI category (%)		
Underweight	1.7	6.5
Normal weight	30.9	62.3
Overweight	33.0	17.9
Obese	34.4	13.3

Note: Sample includes only ages 2+ with reliable diet data who consumed at least one food from stores or vending sources. BMI in children was defined using CDC charts and cutoffs. All results are weighted an account for complex survey design. All values include all race-ethnicities, but race-ethnicity "Other" is not reported in its own row.

Table 2:

Top 10 food group contributors to dietary sodium intake from packaged foods for US adults and children 2011-12.

Food group	Mean per capita contribution to sodium intake, mg/day (SE)	
	Adults	Children
Breads, rolls, and tortillas	177 (7)	131 (5)
Processed meats, poultry, & products	154 (12)	140 (9)
Salty snacks	118 (6)	141 (6)
Cheese and cheese products	88 (6)	71 (6)
Grain-based desserts	69 (4)	78 (5)
Soups and stews	61 (8)	50 (8)
Ready-to-eat cereals	56 (3)	74 (3)
Pizza & calzone	45 (9)	40 (9)
Sauces and condiments	44 (4)	31 (3)
Salad dressings	33 (3)	-
Pasta and pasta dishes	-	55 (9)
Total from middle 10 food group sources	845	811
Total from all packaged food and beverage sources	1258(21)	1215 (35)

Notes: Authors' analyses and calculations based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol, for the 2011-2012 period for the US market (licensed from The Nielsen Company, 2014). No combination codes from FNDDS were used in analysis.