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Development of a food composition database to monitor changes in packaged foods and beverages

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Abstract

In order to monitor nutritional changes in the US food supply and assess potential impact on individual dietary intake, an approach was developed to enhance existing standard food composition tables with time-varying product- and brand-specific information for barcoded packaged foods. A "Crosswalk" was formed between barcoded products and USDA foodcodes in a time-specific manner, such that sales-weighted average nutritional profiles were generated for each foodcode based on corresponding products (275,000 to 350,000 per 2-year cycle). This Crosswalk-enhanced food composition table was applied to dietary intake data from the National Health and Nutrition Examination Survey (cycles 2007–2008, 2009–2010, and 2011–2012). Total energy density of foods consumed by Americans from stores/vending was stable over time and differed by <5 kcal/100g using the Crosswalk-enhanced vs standard database. However, changes in the energy density of food groups were found utilizing the Crosswalk that were not detected using the standard database. Likewise, significant declines in energy intake from beverages among children (288±7.3 to 258±6.8 kcal/d) were found using the Crosswalk-enhanced database but were non-significant using the standard database. The Crosswalk approach can potentially augment national nutrition surveys by utilizing commercial food purchase and nutrient databases to capture changes in the nutrient content of packaged foods.

Keywords

Food composition; Food analysis; Product reformulation; Branded food database; Packaged food; Nutrition facts panels; Dietary intake; NHANES

1 Introduction

Packaged foods and beverages represent a major segment of the US food supply. Previous studies estimate that retail food stores, including grocery stores and supermarkets, provide

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approximately two-thirds of calorie intake for US children and adults (Poti and Popkin, 2011; Ng et al., 2014). For these store-bought products, data from a nationally representative sample of US households indicate that packaged foods and beverages comprise about 80% of store expenditures (Slining et al., 2013b; Stern et al., 2016) and that US households purchase about 1200–1300 calories of packaged products per capita each day from retail food stores (Poti et al., 2015). Despite the dominant role of these packaged foods and beverages in the purchases and diets of Americans, existing food composition databases are limited in their ability to capture accurate nutrient content information for these products due to the complex, dynamic nature of this important part of the US food supply (Leclercq et al., 2001; Pennington et al., 2007; Ng and Dunford, 2013).

The packaged food sector is highly complex, including a wide array of diverse products. Between 2000 and 2012, US households purchased over 1.2 million barcoded products, yet most food composition databases include aggregate nutrition information for only a limited number of items (Ng and Dunford, 2013; Poti et al., 2015). For example, nutrition researchers rely on What We Eat in America (WWEIA), the dietary intake component of the National Health and Nutrition Examination Survey (NHANES), to study dietary intake among Americans. Nutrient information for all food and beverages reported by NHANES participants comes from the United States Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies (FNDDS) for the corresponding survey cycle (USDA Agricultural Research Service, 2010, 2012, 2014). While FNDDS 2011–2012 includes nutrient values for 7,618 foods and beverages, over 300,000 packaged foods were purchased in this time span (Ng and Dunford, 2013; USDA Agricultural Research Service, 2014).

The packaged food and beverage segment of the food supply is also dynamic, characterized by continuous change and turnover as new products are introduced to and less-favored products are removed from the retail market (Pennington et al., 2007; Ng and Dunford, 2013). Existing products may be reformulated, particularly to reduce *trans* fat, added sugar, or sodium content (Mozaffarian et al., 2010; Jacobson et al., 2013; Otite et al., 2013; Briguglio et al., 2015). Indeed, several major food manufacturers and retailers have made pledges to improve the nutritional quality of their products (Ng and Popkin, 2014; Taillie et al., 2015, 2016). These constant changes require food composition databases to be continuously updated (Pennington et al., 2007; Ng and Dunford, 2013). However, the USDA lacks the resources needed to update nutrient values for all foods in each NHANES cycle, and only specific food categories are selected for review (National Research Council, 2005; USDA Agricultural Research Service, 2010). For example, pizza, ready-to-eat cereal, and cereal/snack bars were among the limited set of categories reviewed for FNDDS 4.1 (USDA Agricultural Research Service, 2010).

To address these research gaps, we aimed 1) to develop an approach for enhancing the existing FNDDS food composition table with time-varying product- and brand-specific nutrition information for the diverse array of packaged foods and beverages in the US food supply and 2) to illustrate advantages of using this novel approach for monitoring changes in the nutrient content of packaged foods over time and assessing corresponding changes in individual dietary intake of American children and adults. To the best of our knowledge, no previous studies have examined the impact of changes in the nutrient content of packaged foods and beverages available in the US food supply on what is actually consumed by Americans.

2 Materials and Methods

2.1 Data sources

Our approach builds a "Crosswalk" between packaged foods and beverages purchased by US households and foods reported as consumed by NHANES participants. Our food composition database relies on data from three primary sources: 1) purchases of packaged foods and beverages by a nationally representative sample of US households; 2) Nutrition Facts Panel (NFP) data for barcoded packaged products; and 3) FNDDS for agricultural commodities, single ingredient foods, and home-prepared recipes.

2.1.1 Commercially available food purchase data—A vast number of products are available in the US market, but not all are widely purchased; this uneven sales distribution (i.e., higher sales volume of market leaders and lower sales of less-popular products) must be taken into account in nutrition surveillance (Ni Mhurchu et al., 2011; Korosec and Pravst, 2014). To generate sales-weighted nutrient profiles for packaged foods, we used data from the 2007–2012 Nielsen Homescan consumer panel, a nationwide study of packaged food and beverage purchases by US households (The Nielsen Company). The Homescan study design has been described in detail previously (Ng and Popkin, 2012; Poti et al., 2015). Briefly, panel households record all purchases from retail food stores using a handheld Universal Product Code (UPC) barcode scanner, as well as the date of each shopping episode, number of units purchased, weight (g), and price paid for each product. Data include product attributes for each barcoded item, including characteristics such as flavor (e.g., vanilla or chocolate ice cream), formula (e.g., low-fat or regular cheese), type (e.g., instant or regular oatmeal), or salt content (e.g., regular or low-sodium). Approximately 60,000 households from 76 geographic markets throughout the US participated each year. These data were used to quantify household purchases of packaged foods and beverages with barcodes. Foods and beverages without a barcode (e.g., unpackaged fresh fruits and vegetables) and products sold by variable weight that are assigned a barcode by the store where they are packaged (e.g., fresh meats sold by weight, meats cut to order then wrapped in-store by a butcher, or bulk foods with UPC printed at the weigh station) cannot be linked to nutrient composition data and were not included in the Crosswalk database. Fresh fruits and vegetables with a barcode (e.g., bagged salad, baby carrots, and bags of apples) were linked to nutrient composition data.

2.1.2 Commercially available NFP food composition data—Our research team linked each barcoded product to a corresponding NFP, obtained from various sources including the Mintel Global New Products Database, as described in detail in earlier publications (Ng and Popkin, 2012; Slining et al., 2013b). As required by the US Food and Drug Administration (FDA), NFP data includes the product's serving size and total energy, total fat, saturated fat, *trans* fat, total sugar, carbohydrate, protein, dietary fiber, sodium, cholesterol, vitamin A, vitamin C, calcium, and iron per serving (US FDA, 2013). The label data also provides each product's ingredient list and all information included on the product's package. All NFP records include the date of data collection. Our Crosswalk-enhanced 2007–2012 FNDDS database includes NFP data collected between 1996 and 2013.

2.1.3 Publically available FNDDS food composition data—FNDDS is the database of foods/beverages and their nutrient values that is used to process dietary recalls collected from participants in NHANES (USDA Agricultural Research Service, 2010, 2012, 2014). FNDDS provides nutrient values for approximately 7,200–7,600 foodcodes per 2-year NHANES cycle and is based on the National Nutrient Database for Standard Reference (SR) (USDA Agricultural Research Service). Our database uses FNDDS 4.1 (SR Release 22), FNDDS 5.0 (SR Release 24), and FNDDS 2011–2012 (SR Release 26) which correspond to NHANES 2007–2008, 2009–2010, and 2011–2012, respectively.

2.1.4 Publically available dietary intake data—To illustrate potential advantages of using NFP data to enhance FNDDS when studying dietary intake, we used data from three cycles of NHANES, collected in 2007–2008, 2009–2010, and 2011–2012 (USDA and CDC/National Center for Health Statistics, 2010, 2012, 2014). NHANES is a cross-sectional survey that uses a complex, stratified, multistage probability cluster sampling design to select a nationally representative sample of the civilian non-institutionalized US population. One 24-hour dietary recall was collected in-person by trained interviewers using the USDA's 5-step Automated Multiple-Pass Method, and a second recall was collected by phone 3–10 days later. Our analysis used only the first recall, as recommended by NHANES analytic guidelines in order to generate group mean intake (USDA and CDC/National Center for Health Statistics).

For each food or beverage reported, the participant provided the location where the item was obtained. Because our database focuses on packaged foods and beverages, our study included only foods reported from stores or vending machines and excluded items reported from restaurants, fast food establishments, and all other away-from-home food sources. All reported items were aggregated into 59 mutually exclusive food and beverage groups based on nutritional content and eating behaviors, as described in Supplementary Table S1 and elsewhere (Popkin et al., 1999; Slining et al., 2013a).

Our study included children aged ≥2 y (n=8,974) and adults (n=16,267) with one 24-hour dietary recall deemed reliable by study administrators.

2.2 Linkage of barcoded products to FNDDS foodcodes

These sources of data were used to create "Crosswalk-enhanced" FNDDS food composition tables for 2007–2008, 2009–2010, and 2011–2012 in a multi-step process described in detail below. The goal was to generate a time-specific database including mean nutrient profiles for each FNDDS foodcode by survey cycle using sales-weighted NFP data from corresponding packaged foods and beverages.

2.2.1 Identification of FNDDS foodcodes for packaged foods from stores—First, all FNDDS foodcodes reported by NHANES participants during the first 24-hour recall and obtained from stores or vending machines were identified and were eligible for linking to NFP data; identification of foodcodes for linking was conducted separately for each 2-year NHANES cycle. Because the purpose of our database is to better understand packaged foods, foodcodes for home-cooked dishes were not linked to NFP data; these foodcodes were identified by food descriptions including terms such as "homemade," "home-made style," or "from home recipe." Although NFP data are advantageous for capturing product- and brand-specific variation in nutrient content as well as product reformulations and turnover, FNDDS is the gold-standard for raw agricultural commodities and single-ingredient foods (USDA Agricultural Research Service, 2010, 2012, 2014). For these items, FNDDS foodcodes link directly to single foods in SR that have nutrient content primarily derived analytically by the USDA Nutrient Data Laboratory. Because these items are not industrial formulations that might be modified over time, our database retains nutrient values from FNDDS for these items, including fresh fruits and vegetables, meats, eggs, dried beans, oil, and sugar.

2.2.2 Linkage of barcoded products to FNDDS foodcodes—After FNDDS foodcodes for packaged products were identified, a team of registered dietitians (RDs) linked UPCs for packaged products to each FNDDS foodcode in a time-specific manner. RDs made all linkages manually after reviewing the UPC's item description, brand name, attributes, ingredients, and marketing, as described previously (Slining et al., 2015). To standardize the linkages, the research team jointly determined the decision rules to apply when matching UPCs to each FNDDS foodcode. For each foodcode, however, a single RD performed the linking process after documenting the rationale for matching specific products to the foodcode. A separate database of UPC-foodcode links was created for each NHANES cycle. Multiple NFP records may exist for a given UPC if the product has been reformulated over time; the NFP record(s) dated closest to the time of reported consumption was selected for each cycle. If a given UPC was reformulated and multiple formulations were purchased within one NHANES cycle, both UPC-NFP versions were linked. Barcoded products were linked to one or more corresponding FNDDS foodcodes for each cycle, as appropriate; for example, a UPC for 2% fat chocolate milk would be linked to the FNDDS foodcode for "Milk, chocolate, reduced fat milk-based, 2%" as well as to the foodcode for "Milk, chocolate, NFS" (Not Further Specified).

2.2.3 Conversion of nutrient information as purchased to as consumed—FNDDS provides nutrient values for foods in the form in which they are consumed, which may differ from the form of the food when purchased for products such as dry/powdered drink mixes, baking mixes, dried hot cereal or grains, dry pudding or gelatin mixes, condensed soup, and mixed dish/meal kits or mixes. Methodology used to convert nutrition information from "as purchased" to "as consumed" form is described elsewhere and in Supplementary Appendix A (Slining et al., 2015).

2.3 Estimation of sales-weighted nutrient profiles for FNDDS food codes

For each 2-year NHANES cycle, nutrient values per 100g for all UPC-NFP records linked to a given FNDDS foodcode were weighted by sales (g) within that 2-year period in order to calculate the weighted average nutrient profile per 100g for that foodcode in that survey cycle.

2.4 Application of quality control measures

A series of quality control checks were used to monitor the accuracy of Crosswalk-generated profiles, as described in Supplementary Appendix B.

2.5 Creation of Crosswalk-enhanced FNDDS Versions 1 and 2

For many FNDDS foodcodes, the food description does not specify whether the item is home- prepared from scratch, home-prepared from packaged ingredients, or industrially pre-prepared. For example, the foodcode “Pancakes, plain” could represent pancakes prepared from a home-recipe, pancakes prepared from a boxed dry mix, or frozen ready-to-heat pancakes; however, the Crosswalk approach can only represent the latter two packaged options. To incorporate this uncertainty and to avoid the assumptions about home- vs industrial-food preparation, we created two alternate versions of our food composition database. For any foodcode that could be used to report a food prepared from a home-recipe or an industrially-prepared packaged food, the Crosswalk-enhanced FNDDS Version 1 used the FNDDS nutrient profile based on a “recipe” of SR food ingredients, whereas Version 2 used the Crosswalk-based nutrient values. However, if the FNDDS nutrient profile was based on a “recipe” of SR codes including industrial ingredients (e.g., “modified food starch”) or based on a single SR code for a commercially prepared item (e.g., the foodcode “Pie, pumpkin” uses SR nutrient values for “Pie, pumpkin, commercially prepared”), both Versions 1 and 2 used Crosswalk-based nutrient profiles because nutrient values for a home-prepared food were not available in FNDDS.

2.6 Application of Crosswalk-enhanced FNDDS to dietary intake

To evaluate the utility of our Crosswalk database for studying dietary intake, nutrient intake from each food reported from stores/vending by NHANES participants was calculated using three alternate food composition tables: FNDDS only, Crosswalk-enhanced FNDDS Version 1, and Crosswalk-enhanced FNDDS Version 2. First, nutrient intake from each foodcode was determined using nutrient values from FNDDS alone for all foodcodes, which is the standard approach for analyzing NHANES data. Next, nutrient intake from each foodcode from stores/vending was calculated using nutrient values from the Crosswalk-enhanced FNDDS Version 1 (which reflects a scenario with minimal levels of industrially-prepared packaged food consumption) and additionally using nutrient values from Crosswalk-enhanced FNDDS Version 2 (which reflects a scenario with maximal levels of industrially-prepared packaged food consumption and minimal consumption of home-prepared foods). For each approach, nutrient intake from each foodcode was calculated as grams reported consumed by the participant multiplied by the nutrient value per 100g for each foodcode; calculations were made separately for each of the three food composition tables.

Some foodcodes can be reported using modification codes to indicate adjustment to recipe ingredients, such as the type of milk used in food preparation or type of fat used in cooking, to more closely match the food/beverage reported. Methods used to account for reporting with modification codes are described in Supplementary Appendix C. Foods consumed together as part of a single dish may be reported as individual foodcodes linked together using a combination code variable. We used combination codes to sum nutrient values for all components into a single food item as described previously (Slining et al., 2013a).

2.7 Use of the Crosswalk-enhanced FNDDS for monitoring trends in energy density and dietary intake

To illustrate the use of the Crosswalk-enhanced FNDDS for monitoring changes in the US food supply, we used NHANES 2007–2012 data to examine trends in the energy density of food groups and trends in dietary intake reported from stores and vending machines calculated using the three approaches described above: FNDDS only, Crosswalk-enhanced FNDDS Version 1, and Crosswalk-enhanced FNDDS Version 2.

To determine whether the energy density of packaged foods changed between 2007–2008 and 2011–2012, we calculated mean energy density for all items reported by an individual, both overall and by food group. Survey-weighted unadjusted total mean energy density was calculated across all individuals separately for each survey cycle; mean energy density of food groups was calculated among food group consumers only. Trends over time were tested using post-estimation Wald tests to compare estimated energy density in 2009–2010 and 2011–2012 to that in 2007–2008 for FNDDS only, Crosswalk Version 1, and Crosswalk Version 2.

To determine whether trends in dietary intake differed when estimated using the standard FNDDS food composition table compared with the Crosswalk-enhanced FNDDS Versions 1 or 2, survey-weighted unadjusted mean total energy intake and per capita food group intakes were determined for each NHANES cycle using FNDDS only, Crosswalk Version 1, and Crosswalk Version 2. Post-estimation Wald tests were used to compare mean intake in 2009–2010 and 2011–2012 with intake in 2007–2008 for each of the three approaches. Intake trends were examined separately for children aged 2–18 y and for adults >18 y.

Database creation and calculation of Crosswalk-based weighted nutrient profiles were conducted using Excel and SAS version 9.4 (SAS Institute Inc., Cary, NC). All statistical analyses were conducted using survey commands in Stata 14 (StataCorp LP, College Station, TX) to incorporate survey weights and account for complex survey design. This secondary data analysis was deemed exempt from review by the University of North Carolina Institutional Review Board.

3 Results

The Crosswalk-enhanced FNDDS food composition table included NFP-based nutrient profiles for n=4,872 (Version 1) or n=6,032 (Version 2) foodcodes reported from stores or vending machines by NHANES participants in any survey cycle between 2007–2008 and 2011–2012. For Crosswalk-enhanced FNDDS Version 1, 73% of store/vending energy intake among children and 62% of intake among adults was derived from Crosswalk-based nutrient profiles, with the remaining intake derived from FNDDS. For Version 2, 81% of store/vending energy intake among children and 71% of intake among adults was derived from Crosswalk-based nutrient profiles.

For foods and beverages obtained from stores or vending machines during the first dietary recall among NHANES participants, FNDDS provides nutrient values for 3,509 foods/beverages in 2007–2008, 3,669 in 2009–2010, and 3,738 in 2011–2012 (Table 1). Nutrient values for these foodcodes in the Crosswalk-enhanced FNDDS Versions 1 and 2 were based on 276,056 – 291,884 UPCs in 2007–2008, 315,355 – 329,384 in 2009–2010, and 328,330 – 345,899 in 2011–2012. Similar patterns of >150-fold difference in the number of UPCs and corresponding FNDDS foodcodes were observed for food groups including cheese, yogurt, nuts and nut butters, salad dressing, dips and spreads, granola bars and other bars, dairy-based desserts, salty snacks, water, sugar sweetened beverages (SSBs), fruit juice, and milk. For example, approximately 13,000 – 14,000 UPCs for SSBs were represented by ~50 FNDDS foodcodes.

Trends in energy density and dietary intake were similar when estimated using the Crosswalk-enhanced FNDDS versions 1 and 2; thus, we focus on version 2 and have provided version 1 results as Supplementary Material.

Mean energy density of all foods and beverages, foods only, or beverages only differed by <5 kcal/100g when estimated using these alternate food composition tables for intake from stores/vending (Table 2 and Supplementary Table S2). No significant trends in energy density between 2007–2008 and 2011–2012 were observed for total, food, or beverage intakes from stores/vending. However, differences were observed within food groups. Estimated mean energy density of yogurt was 8–14 kcal/100g lower using the Crosswalk-enhanced FNDDS vs standard FNDDS; for example in 2011–2012, the Crosswalk-enhanced energy density was 79 ± 1.5 kcal/100g compared to 92 ± 0.9 kcal/100g in FNDDS. Significant declines in the energy density of fried potatoes were found when estimated using the Crosswalk-enhanced FNDDS, but not using the standard FNDDS; moreover, energy density for this food group was lower in 2011–2012 when estimated using the Crosswalk-enhanced (192 ± 7.8) vs standard (214 ± 5.5) FNDDS.

The mean decrease in energy intake among children between 2007–2008 and 2011–2012 was slightly larger when estimated using the Crosswalk-enhanced FNDDS compared with using the standard FNDDS (-35 vs -20 kcal/d); however, the decrease was not statistically significant using either approach (Table 3 and Supplementary Table S3). A significant decline in total beverage intake among children was found using the Crosswalk-enhanced FNDDS but not using the standard FNDDS, primarily because of slightly larger estimated declines in SSB and milk intakes when estimated using the Crosswalk-enhanced vs standard FNDDS.

Among adults, mean energy intake overall and for food groups was similar when estimated using the Crosswalk-enhanced or standard FNDDS (Table 4 and Supplementary Table S4). Significant declines in SSB intake were identified using both food composition tables.

4 Discussion

We developed a multi-step approach for incorporating time-varying product- and brand-specific nutrition information from NFP data for >300,000 packaged foods and beverages purchased by US households into time-specific food composition tables for use with nationally representative dietary intake surveys. We demonstrate how this “Crosswalk” between packaged products in the US food supply and food consumption data can be used to study trends in the nutrient content of foods consumed by Americans and the impact of these changes on estimated dietary intake trends. The large number of barcoded products (275,000 to 350,000 per 2-year cycle) that were linked to foods consumed by US children and adults confirms the need for food composition databases to account for the complex, diverse nature of the US food supply. Although we found that the overall energy density of foods consumed by Americans from stores/vending was stable between 2007–2008 and 2011–2012, our approach was able to identify changes in the energy density of foods groups that were not detected using the standard FNDDS. Likewise, declines in energy intake among US children and adults during this time span were small, yet utilizing the Crosswalk-enhanced FNDDS enabled us to detect significant declines in energy intake from beverages among children that were non-significant with the standard approach. Further studies are needed to determine whether our approach can identify more nutritionally meaningful changes in the nutrient content of store-bought foods and corresponding changes in dietary intake, which may be more readily apparent for other nutrients such as sugar or sodium than shown here for calories.

Many scholars have recognized the need for branded food databases as well as the challenges of creating such tools (National Research Council, 2005; Pennington et al., 2007; Ng and Dunford, 2013). To the best of our knowledge, no other existing US database has integrated comprehensive sales-weighted barcode-specific nutrition information into a time-specific food composition table for use with dietary intake data (Ng and Dunford, 2013; The Food Monitoring Group, 2013; Slining et al., 2015). By identifying differences in nutrient content estimated using the Crosswalk-enhanced vs standard FNDDS, our database can help identify food groups to target for updating in FNDDS; examples identified in our study include yogurt and fried potatoes. In addition, the Crosswalk can identify newly emerging products that are not yet included in FNDDS, such as Greek yogurt, and could thereby help in updating FNDDS to capture these newer products. Our Crosswalk-enhanced database also revealed significant declines in total beverage intake among children. As currently only ~50 FNDDS foodcodes are available to represent ~14,000 barcoded SSBs purchased by US households, brand-specific foodcodes for these beverages may be advantageous.

4.1 Potential applications of the Crosswalk-enhanced FNDDS food composition database

An important application of the Crosswalk-enhanced FNDDS food composition database is to examine changes in the saturated fat, sugar, and sodium content of foods reported from stores/vending. In particular, due to recent efforts to reduce the sodium content of packaged foods, such as the National Salt Reduction Initiative, we expect that changes in sodium captured by our Crosswalk database will be more nutritionally meaningful than the minor differences we observed for calories (New York City Department of Health and Mental Hygiene, 2010; Levings et al., 2012; Curtis et al., 2016). Extension of our database to future years can facilitate a comprehensive evaluation of sodium reduction in packaged foods in response to voluntary sodium reduction targets recently proposed by the FDA (US FDA, 2016b). Further, we developed an approach to estimate the added sugar content of industrially formulated packaged foods using linear programming, and Crosswalk-based added sugar profiles can be incorporated into our database (Ng et al., 2015). Thus, the Crosswalk can provide an essential tool for monitoring changes in the added sugar content of packaged foods in response to new regulations requiring inclusion of added sugar on NFPs and corresponding changes in dietary intake among Americans (US FDA, 2016a).

Another potential application of the Crosswalk approach is to generate subpopulation-specific food composition tables to reflect the product or brand preferences of groups by race, ethnicity, income, region, or presence of children in the household. For example, scholars have noted limitations of dietary assessment when foods familiar to or preferred by different racial and ethnic groups are not adequately captured (Signorello et al., 2009; Mossavar-Rahmani et al., 2013). Yet only one prior study has developed race-specific food composition tables; this novel approach revealed that black-white differences in nutrient intakes were underestimated among women using standard vs population-specific food databases (Signorello et al., 2009). In our nationally representative sample of US households, we can determine the exact brands and products purchased by each subpopulation, weight nutrient profiles of products accordingly, and thus generate Crosswalk databases specific for each population.

4.2 Limitations

Several major limitations of our approach are related to the proprietary nature of NFP databases and household purchase data. Commercial datasets are costly to obtain, update, and maintain in order to accurately capture variation in products available and purchased over time. Because this proprietary data are licensed from commercial vendors, our Crosswalk-enhanced FNDDS cannot be shared with other researchers, limiting transparency and replication of our findings. Moreover, this restriction limits the utility of this approach for improving public health.

Although use of NFP data was a key innovation of our database that provided up-to-date product-specific nutrient information, it was also a key limitation. The accuracy of NFP labels is limited because federal regulations require that nutrient content on the label only be within 20% of the actual value, and substantial rounding of nutrient values is allowed (US FDA, 2011). Previous studies have found that the stated energy content of packaged foods such as frozen meals or snack foods was not consistently accurate (Urban et al., 2010; Jumpertz et al., 2013). Although data quality and missing nutrients are additional concerns, our team of RDs does review NFP labels to screen out implausible data.

Our approach is time- and labor-intensive. Thus, because of the large number of UPCs included in our database, we did not have sufficient resources to use a double entry method to link UPCs to FNDDS foodcodes. Another important limitation is that we do not have a system to check the validity and reliability of the RDs' coding; as described in Appendix B, our quality control measures include checks of the nutrient profile distribution for each foodcode to inspect for potential extreme values and to verify the plausibility of estimates, but do not include checks of the linking of UPCs to FNDDS foodcodes. Further research is needed to develop a method to validate our database and evaluate its accuracy. Conversion of nutrition information from "as purchased" to "as consumed" is a major advantage of our packaged food database, yet this process is complex and cannot account for consumer-level variation in food preparation. Changes in energy density of food groups over time might reflect product reformulations, introduction and removal of products from the market, or shifts in the types of foods purchased and consumed; however, the Crosswalk approach cannot distinguish changes resulting from these different explanations. WWEIA does not collect information about whether a consumed food was home-prepared or an industrially-prepared packaged food; this lack of information limits our ability to determine when use of our NFP-derived nutrient profiles is appropriate.

4.3 Strengths

Our study has important strengths. We used data from two nationally representative samples of the US population to develop our food composition database and demonstrate its application to monitor dietary intake of individuals. The Crosswalk-enhanced FNDDS was developed using an unprecedented amount of time-matched brand- and product-specific food composition data, as it includes ~300,000 branded products per NHANES cycle. A unique advantage of our approach is the review and correction of NFP label data by our team of RDs. Another major innovation of our packaged food database is the conversion of nutrient content from "as purchased" to "as consumed" form to match how foods are reported in WWEIA.

5 Conclusion

Our Crosswalk approach can potentially augment national nutrition surveys by utilizing commercial food purchase and food composition databases to capture changes in the nutrient content of packaged foods and beverages. This system has the potential to advance our understanding of the packaged food sector of the US food system and the impact of product reformulations, introduction of new products, and shifts in purchasing patterns on human health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- A standard food composition database was enhanced using Nutrition Facts Panel data.
- A “Crosswalk” was formed between USDA foodcodes and time-matched barcoded products.
- Foodcode nutrient values were generated by sales-weighting ~300,000 barcoded foods.
- Trends in dietary intake were detected using Crosswalk-enhanced nutrient profiles.
- Our approach revealed changes in energy density of select food groups from stores.

Table 1

Counts of foodcodes and barcoded food products contributing to nutrient profiles in the Crosswalk-enhanced FNDDS food composition table for use with NHANES 2007–2008, 2009–2010, 2011–2012 consumption from stores/vending[a]

	# FNDDS codes			# Barcodes[b]		
Food group	**2007–2008**	**2009–2010**	**2011–2012**	**2007–2008**	**2009–2010**	**2011–2012**
All foods and beverages	3,509	3,669	3,738	276,056 – 291,884	315,355 – 329,384	328,330 – 345,899
Foods						
All food groups	3,182	3,336	3,406	234,282 – 249,863	270,944 – 284,646	279,982 – 297,161
Cheese	67	70	66	26,763	32,751	24,102
Yogurt	16	17	20	4,121	7,889	8,246
Other dairy products	39	39	38	4,300	4,691	4,886
Meat	123	133	121	149 – 454	184 – 550	189 – 403
Meat dishes with starch/veg	66	74	71	62 – 647	0 – 603	0 – 591
Poultry	119	125	114	407 – 563	445 – 640	510 – 722
Poultry dishes with starch/veg	56	66	62	83 – 352	92 – 424	96 – 431
Processed meat	114	114	100	8,186 – 8,312	10,969 – 11,122	12,189 – 12,347
Processed meat dishes with starch/veg	20	26	16	56 – 79	57 – 95	92 – 129
Fish & shellfish	86	90	116	512 – 942	372 – 857	564 – 1078
Fish & shellfish dishes with starch/veg	30	36	35	0 – 183	0 – 180	0 – 182
Processed fish & shellfish	12	17	12	1,069	1286	1166
Meat substitutes	13	18	19	448 – 455	469	541
Eggs & egg dishes	48	57	77	144 – 275	180 – 281	732 – 829
Legumes & legume dishes	55	55	70	1,845 – 2,103	1,840 – 2,132	1,870 – 2,210
Nuts, nut butters, & seeds	48	49	56	10,661	11,395	14,012
Breads	112	122	116	15,624 – 16,574	21,014 – 21,244	22,258 – 23,473
Quick breads	59	61	56	4,238 – 4,699	4,672 – 5,174	4,501 – 5,011
Ready-to-eat cereals	144	148	151	13,161	12,907	17,431
Fruit	116	129	121	9,780	10,865	10,315 – 10,316
Vegetables	307	310	337	15,668 – 16,718	19,745 – 20,271	16,959 – 18,324
Non-starchy vegetable dishes	13	14	15	626 – 677	617 – 710	777 – 834
Starchy vegetables & dishes	146	130	148	10,643 – 12,006	9,570 – 10,620	9,456 – 10,576

Food group	# FNDDS codes			# Barcodes[b]		
	2007–2008	2009–2010	2011–2012	2007–2008	2009–2010	2011–2012
Fried potatoes	10	11	13	1,340 – 1,377	1,112 – 1,149	1,756 – 1,807
Fats & oils	32	36	33	1,087	1,302	1,147
Sweeteners, syrups, & toppings	48	47	52	4,209	4,029	4,289
Salad dressings	33	34	28	5,460 – 5,469	6,010 – 6,039	6,418
Sauces & condiments	56	65	66	4,801 – 5,279	5,573 – 6,020	6,147 – 6,995
Dips & spreads	19	16	17	2,575 – 3,750	2,818 – 4,086	2,877 – 4,378
Grain-based desserts	275	253	214	16,702 – 20,527	17,213 – 19,827	17,684 – 21,059
Granola bars & other bars	33	37	36	6,038	9,746	10,256
Candy & sweet snacks	117	121	130	18,062 – 18,139	18,037 – 18,125	19,361 – 19,425
Dairy-based desserts	88	97	85	13,137 – 13,297	15,117 – 15,311	13,373 – 13,540
Salty snacks	84	91	97	14,026 – 14,198	15,247 – 15,452	15,964 – 16,181
Soups & stews	166	180	172	6,192 – 7,520	8,000 – 9,181	13,636 – 14,646
Frozen meals	46	50	42	1,373	1,801	503
Sandwiches	28	18	45	255 – 574	273 – 347	354 – 412
Hamburgers	3	3	.	11	80	0
Tortilla- & corn-based dishes	61	61	84	122 – 407	305 – 580	155 – 590
Pasta & pasta dishes	81	99	103	3,044 – 3,994	3,689 – 5,366	4,091 – 5,794
Rice, grains, & rice/grain dishes	144	157	192	5,512 – 5,930	6,629 – 7,096	8,944 – 9,746
Pizza	32	45	32	1,679	1,771	1,909
Baby food & formula	16	14	24	111	182	226
Beverages						
All beverage groups	327	333	332	41,774 – 42,021	44,411 – 44,738	48,348 – 48,738
Water	9	10	10	2,632	3,198	3190
Coffee & tea	60	59	62	4,752 – 4,874	6,195 – 6,335	6,111 – 6,256
Sugar sweetened beverages	48	50	51	13,078	13,199	14,329
Fruit juice	44	47	40	8,512 – 8,589	7,924 – 8,051	9,076 – 9,253
Vegetable juice	10	9	9	532	570	563
Milk	59	59	61	9,242	10,621	10,643
Soy-, yogurt-, & milk-based beverages	16	18	16	1,063 – 1,080	1,195 – 1,226	1,379 – 1,412
Meal replacement beverages	19	20	27	36	66	35

	# FNDDS codes			# Barcodes[b]		
Food group	2007–2008	2009–2010	2011–2012	2007–2008	2009–2010	2011–2012
Sports drinks	5	7	6	516	556	642
Energy drinks	10	10	11	634	704	803
Other beverages	16	14	14	777 – 808	183 – 212	1,577 – 1,612

Note: FNDDS, Food and Nutrient Database for Dietary Studies (FNDDS); NHANES, National Health and Nutrition Examination Survey; UPC, Universal Product Code

[a]Crosswalk-enhanced FNDDS nutrient profiles were created for all FNDDS foodcodes reported by participants aged 2 years and older during the first day of 24-hour dietary recall and obtained from stores or vending machines in the 2007–2008, 2009–2010, and 2011–2012 NHANES.

[b]Number of unique UPC barcodes used to generate the sales-weighted nutrient profile for all FNDDS food codes in the specified food group for the Crosswalk-enhanced FNDDS Version 1 and Version 2. Version 1 defaults to the FNDDS nutrient profile for FNDDS food codes that may be home-prepared/not packaged and for which FNDDS is based on nutritional composition for a “recipe” of basic foods. Version 2 uses the Crosswalk-based nutrient profile for all FNDDS food codes for which a packaged/barcoded version of that food is available. Unique UPCs may or may not represent unique product formulations.

Table 2

Trends in mean energy density of foods consumed from stores/vending using FNDDS and Crosswalk-enhanced FNDDS food composition tables, NHANES 2007–2008 to 2011–2012[a]

	Mean energy density (kcal/100g)[b]											
	FNDDS[c]				Crosswalk-enhanced FNDDS[d]				Difference, FNDDS and Crosswalk-enhanced FNDDS			
Food group	**2007-2008**	**2009-2010**	**2011-2012**	**Time trend[e]**	**2007- 2008**	**2009- 2010**	**2011- 2012**	**Time trend**	**2007- 2008**	**2009- 2010**	**2011- 2012**	**Time trend**
All foods and beverages	213	213	214	1	212	211	212	0	−1	−2	−2	−1
Foods												
All food groups	280	275	278	−2	277	273	276	−1	−3	−2	−2	1
Yogurt	92	92	92	0	78	84*	79	1	−14	−8	−13	1
Tortilla- & corn-based dishes	241	235	240	−1	235	235	232	−3	−6	0	−8	−2
Fried potatoes	226	235	214	−12	221	208	192*	−29*	−5	−27	−22	−17
Grain-based desserts	406	413*	422*	16*	418	419	421	3	12	6	−1	−13
Granola bars & other bars	412	406	408	−4	385	392*	395*	10*	−27	−14	−13	14
Candy & sweet snacks	398	395	392	−6	394	389	386	−8	−4	−6	−6	−2
Dairy-based desserts	202	205	207	5	214	211	211	−3	12	6	4	−8
Salty snacks	492	484*	485	−7	487	484	486	−1	−5	0	1	6
Beverages												
All beverage groups	38	39	40	2	39	39	40	1	1	0	0	−1
Sugar sweetened beverages	30	30	31	1	31	31	31	0	1	1	0	−1
Milk	53	52	54	1	56	53*	54	−2	3	1	0	−3
Sports drinks	26	26	27	1	21	21	20	−1	−5	−5	−7	-2

Note: FNDDS, Food and Nutrient Database for Dietary Studies (FNDDS); NHANES, National Health and Nutrition Examination Survey

[*] Indicates mean is different from 2007–2008 at $P<0.05$.

[a] Crosswalk-enhanced FNDDS nutrient profiles were created for all FNDDS food codes reported by participants aged 2 years and older during the first day of 24-hour dietary recall and obtained from stores or vending machines in the 2007–2008, 2009–2010, and 2011–2012 NHANES. Crosswalk-enhanced nutrient profiles are derived from Nutrition Facts Panel information on packaged foods and beverages purchased from grocery stores, supermarkets, convenience stores, and all other retail food stores by US households participating in the Nielsen Homescan Consumer Panel.

[b]Values are the survey-weighted unadjusted mean energy density (kcal/100g) among consumers of any foods included in the specified food group. Combination codes were not applied. All estimates are weighted to be nationally representative and take into account complex survey design. Selected example food groups shown; all food groups shown in Supplemental Table 2.

[c]Energy density of foods obtained from stores and vending machines was calculated using FNDDS.

[d]Energy density of foods obtained from stores and vending machines was calculated using the Crosswalk-enhanced FNDDS Version 2, which defaults to the Crosswalk-based profile for mixed dish recipe foods.

[e]Values are the difference in energy density between 2007–2008 and 2011–2012.

Table 3

Trends in mean per capita energy intake from stores/vending among US children using FNDDS and Crosswalk-enhanced FNDDS food composition tables, NHANES 2007–2008 to 2011–2012[a]

	Mean energy intake (kcal/d) from stores/vending[b]											
	FNDDS[c]				Crosswalk-enhanced FNDDS[d]				Difference, FNDDS and Crosswalk-enhanced FNDDS			
Food group	**2007- 2008**	**2009–2010**	**2011–2012**	**Time trend[e]**	**2007–2008**	**2009–2010**	**2011–2012**	**Time trend**	**2007–2008**	**2009–2010**	**2011–2012**	**Time trend**
All foods and beverages	1260	1320 *	1240	−20	1256	1309 *	1221	−35	−4	−11	−19	−15
Foods												
All food groups	980	1034 *	978	−2	967	1022 *	963	−4	−13	−12	−15	−2
Yogurt	7	12 *	12 *	5 *	6	11 *	11 *	5 *	−1	−1	−1	0
Tortilla- & corn-based dishes	36	48	57 *	21	35	47	57 *	22 *	−1	−1	0	1
Fried potatoes	6	7	6	0	6	7	6	0	0	0	0	0
Grain-based desserts	92	95	113 *	21 *	95	96	111	16	3	1	−2	−5
Granola bars & other bars	8	8	12	4	7	8	11	4	−1	0	−1	0
Candy & sweet snacks	54	43 *	35 *	−19 *	53	42 *	34 *	−19 *	−1	−1	−1	0
Dairy-based desserts	34	30	27	−7	37	31	28	−9	3	1	1	−2
Salty snacks	95	98	91	−4	93	98	90	−3	−2	0	−1	1
Beverages												
All beverage groups	279	286	262	−17	288	287	258 *	−30 *	9	1	−4	−13
Sugar sweetened beverages	86	86	74	−12	90	88	73	−17	4	2	−1	−5
Milk	120	124	117	−3	126	125	118	−8	6	1	1	−5
Sports drinks	7	8	7	0	5	7	6	1	−2	−1	−1	1

Note: FNDDS, Food and Nutrient Database for Dietary Studies (FNDDS); NHANES, National Health and Nutrition Examination Survey

[*] Indicates mean is different from 2007–2008 at $P<0.05$.

[a] Data from children aged 2–18 years participating in the 2007–2008 (n=2930), 2009–2010 (n=3097), and 2011–2012 (n=2947) NHANES.

[b] Values are survey-weighted unadjusted mean per capita energy intake (kcal/d) from the specified food group for foods reported during the first day of 24-hour dietary recall and obtained from stores or vending machines. All estimates are weighted to be nationally representative and take into account complex survey design. Selected example food groups shown; all food groups shown in Supplemental Table 3.

[c] Energy intake from foods obtained from stores and vending machines was calculated using the reported amount consumed and kcal/100g from FNDDS.

[d] Energy intake from foods obtained from stores and vending machines was calculated using the reported amount consumed and kcal/100g from the Crosswalk-enhanced FNDDS Version 2, which defaults to the Crosswalk-based profile for mixed dish recipe foods.

[e] Values are the difference in energy intake between 2007–2008 and 2011–2012.

Table 4

Trends in mean per capita energy intake from stores/vending among US adults using FNDDS and Crosswalk-enhanced FNDDS food composition tables, NHANES 2007–2008 to 2011–2012[a]

	Mean energy intake (kcal/d) from stores/vending[b]											
	FNDDS[c]				Crosswalk-enhanced FNDDS[d]				Difference, FNDDS and Crosswalk-enhanced FNDDS			
Food group	**2007–2008**	**2009–2010**	**2011–2012**	**Time trend[e]**	**2007–2008**	**2009–2010**	**2011–2012**	**Time trend**	**2007–2008**	**2009–2010**	**2011–2012**	**Time trend**
All foods and beverages	1444	1501	1458	14	1448	1498	1447	−1	4	−3	−11	−15
Foods												
All food groups	1123	1168	1151	28	1116	1160	1141	25	−7	−8	−10	−3
Yogurt	10	11	12	2	8	10	10	2	−2	−1	−2	0
Tortilla- & corn-based dishes	48	40	60	12	46	40	59	13	−2	0	−1	1
Fried potatoes	10	13	9	−1	9	10	7	−2	−1	−3	−2	−1
Grain-based desserts	90	94	102	12	92	95	101	9	2	1	−1	−3
Granola bars & other bars	12	10	10	−2	11	10	10	−1	−1	0	0	1
Candy & sweet snacks	43	37	34	−9	42	36	33	−9	−1	−1	−1	0
Dairy-based desserts	40	40	33	−7	42	41	34	−8	2	1	1	−1
Salty snacks	79	71	77	−2	78	71	77	−1	−1	0	0	1
Beverages												
All beverage groups	321	333	307	−14	332	338	305	−27	11	5	−2	−13
Sugar sweetened beverages	90	82	70*	−20*	96	86	72*	−24*	6	4	2	−4
Milk	63	65	59	−4	67	67	60	−7	4	2	1	−3
Sports drinks	7	5	7	0	6	4	6	0	−1	−1	−1	0

Note: FNDDS, Food and Nutrient Database for Dietary Studies (FNDDS); NHANES, National Health and Nutrition Examination Survey

* Indicates mean is different from 2007–2008 at $P<0.05$.

[a] Data from adults aged >18 years participating in the 2007–2008 (n=5516), 2009–2010 (n=5873), and 2011–2012 (n=4878) NHANES.

[b] Values are survey-weighted unadjusted mean per capita energy intake (kcal/d) from the specified food group for foods reported during the first day of 24-hour dietary recall and obtained from stores or vending machines. All estimates are weighted to be nationally representative and take into account complex survey design. Selected example food groups shown; all food groups shown in Supplemental Table 4.

[c]Energy intake from foods obtained from stores and vending machines was calculated using the reported amount consumed and kcal/100g from FNDDS.

[d]Energy intake from foods obtained from stores and vending machines was calculated using the reported amount consumed and kcal/100g from the Crosswalk-enhanced FNDDS Version 2, which defaults to the Crosswalk-based profile for mixed dish recipe foods.

[e]Values are the difference in energy intake between 2007–2008 and 2011–2012.