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High-Fructose Corn Syrup: Is this what's for dinner?

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Abstract

Background—Research on trends in consumption of added sugar and high fructose corn syrup (HFCS) in the U.S. has largely focused on calorically-sweetened beverages, ignoring other sources.

Objective—To examine U.S. consumption of added sugar and HFCS to determine long-term trends in availability and intake from beverages and foods.

Design—We used two estimation techniques and data from the Nationwide Food Consumption Surveys (1965 and 1977), Continuing Survey of Food Intake in Individuals (1989–1991) and the National Health and Nutrition Examination Surveys (1999–2000, 2001–2002 and 2003–2004) to examine trends in HFCS and added sugar, including: (a) overall trends, and (b) within certain food and beverage groups.

Results—Availability and consumption of HFCS and added sugar increased over time until a slight decline between 2000 and 2004. By 2004, HFCS provided roughly 8% of total energy intake compared to total added sugar of 377 kcal/person/d, accounting for 17% of total energy intake. While food and beverage trends were similar, soft drinks and fruit drinks provided the most HFCS (158 and 40 kcal/person/d in 2004, respectively). Moreover, among the top 20% of individuals, 896 kcal/person/d of added sugar was consumed compared to 505 kcal/person/d of HFCS. Among consumers, sweetened tea and desserts also represented major contributors of calories from added sugar (over 100 kcal/person/d).

Conclusion—While increased intake of calories from HFCS is important to examine, the health affect of overall trends in added caloric sweeteners should not be overlooked.

Keywords

artificial sweeteners; fructose; added sugar; trends; food intake; epidemiology

INTRODUCTION

Over the past decade extensive research has focused on understanding both the trends and consequences of the large increases in caloric sweeteners consumed in the U.S. Much of the research has focused on the beverage sector, where several excellent meta-analyses have examined the effects of calorically-sweetened beverage drink intake on energy intake, weight gain, and diabetes (1–3). Extensive research has documented both the large amounts of added caloric sweeteners in the diet and the large increases in the consumption of these sweeteners over the past two decades (4–9) . High fructose corn syrup (HFCS) has been used increasingly as a replacement for other caloric sweeteners, first in beverages and more recently, as a replacement for sugar in thousands of other processed and packaged foods (10). A causal link between increased consumption of HFCS and obesity has been hypothesized (10) and although

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animal research (11–14) and a small number of human studies (15,16) support this hypothesis, Bray et al note that extensive human research on this topic is limited and deserves further attention (10).

HFCS is interesting for many reasons. At equal caloric value, HFCS is both sweeter and less expensive than other added sweeteners. Thus, food and beverage manufacturers were able to increase the sweetness of their products for a fraction of the price. The overall result has been an increase in the intensity of the sweetness of soft drinks and other caloric beverages (10, 17). There is some potential for disagreement on this point, but only indirect evidence exists (18).

In part, the shift from using sucrose to HFCS was encouraged by extensive government subsidies of corn farmers, with a majority of U.S. farm policies focused on promoting increased production of inexpensive corn. One study showed that as a result of such subsidies, the consumer price of corn (and its byproducts) remained approximately 25%–30% below cost (of production) between 1997 and 2005 (19). For beverage manufacturers, in particular, lower sweetener costs allowed increased serving sizes (which would be only marginally more expensive for the consumer), thus freeing money for marketing campaigns (20). Although far less studied, similar trends have likely occurred in other food sectors. However, HFCS should not be studied independently of the context of trends in total caloric sweetener consumption. With rising corn prices and a farm bill proposing to remove some of the corn subsidies, it is possible that HFCS prices will begin to rise considerably. Were this to occur, it may result in the substitution of another caloric sweetener for HFCS, resulting in continued consumption of sweetened, refined carbohydrates in the U.S.

This study focuses on updating our understanding of consumption of both HFCS and other added caloric sweeteners. Essentially, these added sugars are found in thousands of food items consumed in the U.S. and globally (21,22). Unlike prior studies, the present study expands the efforts of previous researchers to estimate added sugars and HFCS consumption from both beverages *and* foods. This approach more accurately reflects the contribution of these energy sources to the U.S. diet.

METHODS

Availability of HFCS

Given the absence of direct measures of HFCS consumption, food disappearance data provide the best indirect estimate of HFCS availability in the U.S. We used data from the United States Department of Agriculture’s Economic Research Service Food Availability Databases (23) to examine the availability of total sugars and HFCS. Measures of total caloric sweetener and HFCS availability were taken directly from this data. Using measures of total HFCS availability in pounds/person/day, we further calculated the proportion of HFCS that is HFCS-42 versus HFCS-55. These two formulations of HFCS refer to the percentage of the sweetener that is fructose, i.e. HFCS-42 has 42% fructose and 58% glucose. HFCS-55 has sweetness equivalent to sucrose and is used in many carbonated soft drinks, particularly in the US. HFCS-42 is somewhat less sweet and is used in many fruit-flavored noncarbonated beverages, baked goods and other products. All results account for production and import, and adjust for loss, waste, and spoilage. Data were available from 1970 through 2004 (23).

Foods containing HFCS

Comprehensive information on foods and beverages containing HFCS is not readily available and must be pieced together from various sources. It is clear that HFCS accounts for almost all added caloric sweeteners used by manufacturers of soft drinks and fruit drinks as well as

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other specialty calorically-sweetened beverages (24,25). In addition, HFCS can be found in numerous processed foods, including canned foods (eg, soups, fruits), cereals and baked goods, desserts, sweetened and flavored dairy products (eg, yogurt, condiments, and jellies), candies, and many fast food items. A majority of the information on availability comes from lists compiled by individuals who have examined ingredients of foods in their homes or from organizations concerned with HFCS-related food allergies (26–28). Direct measurements of HFCS composition of foods are not available from manufacturers or publicly available food composition tables. For the purposes of this paper, foods that had either added sugar or fructose were considered to potentially contain HFCS.

Estimating HFCS and added sugar in foods

We obtained direct estimates of added sugar using the USDA food composition table and its recipe and servings files. The recipe and servings files provide a direct measure of added sugar in each food. Since direct estimates of HFCS are not available, and because the existing literature on this topic is scarce, we elected to estimate the HFCS content in foods and beverages using two different techniques referred to as the NDS and Glinsmann methods. These are discussed in detail below.

NDS Method

This method uses measured total fructose and added sugar from the University of Minnesota's Nutrition Coordinating Center (NCC) Nutrient Database System's (NDS) sugars file and measures of added sugar from the USDA food composition table (FCT). The USDA Nutrient Data Laboratory is the primary source of nutrient values and nutrient composition within NDS. However, these values are supplemented by food manufacturers' information and data that are available in the scientific literature (29). Using data from NDS was the only way to obtain direct measures of fructose for sample foods. For all foods and beverages, except soda and fruit drinks (for which HFCS was assumed to be 100% of added sugar), we used a three-step process to estimate HFCS. The steps are as follows:

1) Calculation of the proportion of added sugar that is fructose—Using added sugar and fructose values provided for 988 foods in the NDS sugars database, we determined the proportion of added sugar that is fructose (P_f) by dividing fructose (g/100g of food) by added sugar (g/100g of food). This calculation was carried out for each food code individually.

2) Estimation of the amount of added sugar that is HFCS

a. We found direct matches between NDS and USDA food codes for roughly 50% of the data. For these foods, the proportion of added sugar that is fructose (P_f) was multiplied by the amount of added sugar in each food as reported by the USDA. This resulted in an estimate of the gram amount of HFCS per food code. This value was then multiplied by the amount of added sugar per food reported for a total estimate of HFCS by food for each respondent. For example, "fruit flavored juice drinks" had 13.575g fructose/100g of drink and a 37.078g total added sugar/100g drink. The estimated proportion of added sugar that is fructose (P_f= [13.575/37.078] *100=36.6%] is multiplied by the amount of "fruit flavored juice drinks" reported consumed by each respondent.

b. For food codes where no direct match between NDS and USDA was possible, we multiplied the mean proportion of fructose (P_f) assigned to each food codes' larger food group (described in detail below) by the amount of added sugar in each food as reported by the USDA.

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3) Generation of measure of HFCS by food group—HFCS consumption was calculated for each food and summed across food groups. Data are presented by food group across time.

Glinsmann Method

In 1986, a task force for the Food and Drug Administration (FDA) produced estimates of intake of natural and added sugars, including HFCS, sucrose, and other corn sweeteners (30). Using HFCS and added sugar availability (by food group) data, Glinsmann et al created category-wide estimates of the proportion of added sweetener that is HFCS. For example, of the 1,684.24 million kg (3,713.12 million lbs) of added sweetener available to the bakery and cereal industry in 1984, 278.00 million kg (612.87 million lbs, or 16.5%) was HFCS. Thus, a factor of 0.165 was multiplied by the amount of added sugar in the "Grains" food group to obtain an estimate of HFCS. As with the previous method, 100% of added sugar in soda and fruit drinks was assumed to be HFCS. Within food groups, we generated estimates of HFCS by applying these factors to the amount of added sugar reported in the USDA FCT and summed intake by food group.

Although we present results from both methods for comparison (Figure 1), the results reported in this paper are based on the Glinsmann Method of estimation. This method was selected for several reasons. First, unlike the NDS Method, the proportions estimated by Glinsmann et al had been successfully implemented in at least one prior study of HFCS consumption (10). Secondly, NCC data were not intended, nor established, for application to the USDA survey data, and used a different set of food identifiers. Additionally, the NCC data use the NDB foods, which were divided differently from the USDA survey foods, which further complicated the matching process. This meant that matching with USDA survey data was poor, resulting in a 50% match rate. For the remaining 50% of foods, food group means were applied. This may have resulted in a "washing out" of our HFCS estimates. Furthermore, the total fructose value provided by NDS required assumptions (not based on scientific literature) about the proportion of added sugar that is HFCS versus some other form of fructose sweetener.

Estimated timing of HFCS use in the food supply

Precise information on the introduction of HFCS as an added sweetener into the food supply was not available. Various sources cited the early 1980s as the years when Coca-Cola and Pepsi introduced the reformulation of their beverages to include HFCS (20,31), at which point HFCS was the sole added sweetener in these beverages. For non-beverage categories, there is evidence of HFCS use starting in the late 1980s. However, information that would allow for accurate estimates of the amount used is not available until the last period, 1999– 2004. For these years, adequate evidence shows that HFCS was used much more widely in the general food supply. Thus, we apply the mean proportion of fructose (P_f) for each food group's added sugar for this period only.

Food group creation

Foods were initially grouped using the University of North Carolina (UNC) food-grouping system (32), which places foods and beverages into nutrient-based subgroups based on fat and fiber content. However, these food groups varied widely with respect to added sugar values. Since these groups would ultimately be used to provide estimates of the fructose proportion for foods that did not have a direct match between NDS and USDA, the original food groups were modified. Fat and fiber distinctions were removed, and foods were regrouped according to added sugar. For example, the Low, Medium, and High-Fat Dairy UNC food groups were separated into Dairy No Sugar Added, Dairy Low Sugar Added (below the mean for grams of added sugar), and Dairy High Sugar Added (at or above the mean for grams of added sugar). Finally, the beverage groups, which were combined with all other food groups in the original

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UNC food grouping system (ie, low fat milk was grouped with low fat dairy products, such as cottage cheese), were redefined and categorized in accordance with the Beverage Guidance Panel (33). For the examination of trends, the sugar groups were combined (ie, no sugar, low sugar, and high sugar desserts presented as desserts).

Consumption data

We used data from the Nationwide Food Consumption Survey (NFCS 1965–1966 [n=13,549], 1977–1978 [n=29,553]), the Continuing Survey of Food Intake in Individuals (CSFII 1989–1991 [n=14,689]) and the National Health and Nutrition Examination Survey (NHANES 1999–2004 [n=25,482]) to examine trends in estimated HFCS consumption. Dietary intake data from NCFS 1965–1966 was collected using a single, interviewer-administered 24-hour recall. Data from NCFS 1977–1978 and CSFII 1989–1991 was collected over three consecutive days using a single interviewer administered 24-hour recall followed by a 2-day self-administered diet record. Information on all foods and beverages consumed, regardless of location, was recorded. We used only the first day's 24-hour recall to maintain consistency in data collection methods between these study years (i.e. 1965–1991).

Beginning with NHANES 1999–2000, a validated (34), semi-automated (fully automated in 2002) multiple pass method of an interviewer administered 24-hour dietary collection was introduced. This 5-step computer assisted dietary recall instrument has been cited as an improvement over previous methods for collecting dietary recall information as it includes multiple probes for potentially forgotten foods and beverages and asks about preparation methods and specifics about each eating occasion (35). For NHANES 2003–2004, two days of data were collected: the first day of intake was collected using the computer assisted, in-person interviewer administered 24-hour recall, while the second days' intake was collected using a telephone administered (computer assisted) survey. Because of differences in data collection methods, only the first day of intake was used.

Analyses were completed using SAS (v.9.1.3, SAS Institute Inc., Cary, NC 27513) and Stata (v.9.2, Stata Corp LP, College Station, TX 77845). We weighted means to be nationally representative, and adjusted the standard errors to account for stratified and clustered sample design. Data are presented as means per year for Americans aged 2 and older, with significance set to α=0.01 level. Trends for Americans 2–18 years versus 19 years and older did not differ; thus, results for all ages are combined.

RESULTS

Availability of HFCS in our food supply

When it was initially introduced in the 1970s, HFCS represented less than 1% of all caloric sweeteners available for consumption in the United States, but replacement of sugar and other sweeteners with HFCS increased rapidly in the 1980s, and by 2004 HFCS (of any kind) represented 42% of all caloric sweeteners (Table 1) (23). Initially HFCS-42 was the only HFCS component, but by the early 1980s HFCS-55 became the major source and represented 59.5% of HFCS used in 2004, down just slightly from its peak use in 2000 (61.9%). While these data are useful for studying trends, they likely overestimate actual intake. Furthermore, it is important to realize that although HFCS represents roughly 40% of the per capita caloric sweetener consumed in the U.S., this proportion is significantly greater in selected foods and beverages.

Trends in HFCS availability

Data on availability of HFCS, free fructose, and total fructose are shown in Figure 1. These data are compiled by the United States Department of Agriculture's Economic Research

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Service; the HFCS data are those from 1. Total fructose is defined as the sum of free fructose plus fructose contained in the disaccharide sucrose (assumed to be 50%). Free fructose is defined as the monosaccharide in HFCS plus other small amounts found in honey (assumed to be 38.5%), for example. Total fructose has changed relatively little over the past 34 years compared to the change in HFCS availability. Since 1970, total fructose availability has increased nearly 18%, from 45.7 to 53.7 g per capita per day while HFCS availability increased from 0.5 to 52.4 g per capita per day over the same time period. Availability of both total and HFCS appear to be slightly declining since 2000, although the continued direction of the trend is difficult to predict.

Consumption of Total added sugar and HFCS

Between 1977 and 2000, consumption of added sugar increased until a slight decline between 2000 and 2004 (Table 2). Added sugar accounted for approximately 17% of total energy intake in 2004, up from 15% in 1965 (down from a high of 18% in 2000). Between 1965 and 1977, there was a significant decline in the intake of added sugar, but since 1977 there has been a statistically significant increase (compared to the previous year) in total added sugar and added sugar as a percent of total carbohydrates consumed. By 2004, added sugar represented almost 32% of carbohydrates for Americans 2 y and older.

Between 1989 and 2000, total caloric intake from HFCS jumped dramatically, from 77 kcal/person/d to189 kcal/person/d (Table 2). At its peak in 2000, HFCS represented 9% of total energy intake and 16.5% of total carbohydrate consumption among Americans. Between 2000 and 2004, there was a small (10 kcal/person/d), although not statistically significant, decline in the estimated caloric intake from HFCS. Despite this slight decline, HFCS still accounted for 8.3% of total energy intake and 15.7% of total carbohydrates consumed in 2004.

These trends are similar between age groups (Figure 2). Calories from added sugar decreased from 1965 to 1991, but then increased significantly between 1991 and 2000. The greatest changes were observed among those aged 2–18 years and 19–39 years—declines of 49 and 52 kcal/person/d, respectively, with a subsequent increase of 164 and 217 kcal/person/d, respectively. At each time point, these age groups have had the greatest caloric intake from added sugar. By 2004, intake of added sugar had leveled off or begun to decline slightly. Consumption of HFCS increased considerably between 1991 and 2000, with the largest change (+172 kcal/person/d) among 19 to 39 year olds. Americans aged 2–5 and over 60 had the lowest increase in consumption. HFCS intake in these two age groups remained stable from 2000 to 2004, while there was a slight decline over this same period in the 2–18 and 19–39 year old age groups.

Added sugar and HFCS from beverages

Nearly all beverages, save vegetable juice, unsweetened coffee, unsweetened tea, and water (data for these beverages are not shown), were estimated to contain at least some amount of HFCS. For all beverages, there was a trend of increased per capita caloric consumption from HFCS between 1989–1991 and 2004. By far, fruit drinks and soft drinks accounted for the greatest caloric intake of HFCS, providing 40 kcal/person/d and 158 kcal/person/d, respectively (Figure 3). These values represent an increase of 18 kcal from fruit drinks and 82 calories from soft drinks over a 15-year period. As a percent of total energy, soda represented nearly 7% of per capita energy intake and 13% of energy from carbohydrates among Americans 2 years and older. Increases in other beverages also occurred, although these beverages accounted for a smaller proportion of calories. For example, in 1989–1991, HFCS from sports drinks provided <1 kcal/person/d; this figure increased to 3 kcal in 2004 (Figure 4). Nearly 10 kcal of HFCS were consumed from sweetened tea in 2004, up 6 kcal from 1989–1991 values.

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There was a trend of increased caloric intake from added sugar obtained from beverages between 1989 and 2004. Aside from the obvious contributors—soda and fruit drinks—many additional beverages provided a sizeable number of calories from added sugar (Figure 4). Sweetened tea, for example, was estimated to provide roughly 14 kcal/person/d in 2004, an increase of 7 calories since 1989. Sports drinks, which also accounted for roughly 3 calories of HFCS in 2004, accounted for 4.5 calories of added sugar, up 4.4 calories from 1977. High fat milk (including chocolate milk) accounted for an additional 5 kcal/person/d. In 2004, alcohol and sweetened coffee were estimated to account for an additional 3 kcal/person/d, collectively (data not shown).

Added sugar and HFCS from foods

We assume that HFCS was introduced into food manufacturing in the early to mid 1990s. Thus, we estimated HFCS consumption from foods starting with the NHANES 1999–2000 survey. Certain food groups showed the largest differences in estimated HFCS using the two estimation techniques. A comparison of the estimates for these food groups is shown in Figure 5.

In general, the contribution of HFCS to caloric intake from various food groups has remained relatively stable between 2000 and 2004. However, compared to the caloric contribution of HFCS from soda and fruit drinks, foods provide considerably fewer calories from HFCS overall. Desserts (including pudding, cakes, cookies, and pies) provided the greatest percent of total energy (approximately 1%) and percent carbohydrates (approximately 3%) at each year (Figure 3). Total calories of HFCS from desserts declined slightly between 2000 and 2002, but then increased to 29 kcal/person/d by 2004. By far, desserts provided the largest source of calories from HFCS; almost 94% more calories compared to the next highest food groups, ready-to-eat cereals and breads (including bread, bagels, tortillas, biscuits, and muffins), which accounted for roughly 2 kcal/person/d of HFCS each in 2004 (Figure 5). Certain fast food groups, (ie, Hamburgers & Cheeseburgers) also provided a small number of calories of HFCS (Figure 4), although this accounted for an insignificant proportion of total energy intake in all three years (< 1% total energy intake).

Although HFCS does not appear to contribute meaningful amounts to per capita caloric intake from many foods, added sugar is estimated to provide considerably more calories. Within food groups, the overall trends in added sugar consumption are not as clear as the trends within beverage groups. For example, the per capita daily caloric intake of added sugar from snacks increased from 1965 to 2000 (+2.3 kcal/person/d) but then decreased slightly to 2 kcal/person/d in 2004 (Figure 4). Similar trends were observed for cereal (Figure 4), salad dressing (data not shown), and dairy food groups (data not shown). There was an increase in calories of added sugar from these foods between 1965 and 2000 (2002 for dairy), followed by a leveling off or slight decrease by 2004.

Desserts (Figure 3) provided significantly more calories from added sugar compared with any other food group, although trends were not consistent: per capita daily calories decreased by 36 calories from 1965 to 1991 (not shown) increased by 20 calories to 74 calories between 1991 and 2000, and decreased again by 7 calories in 2004. Similar cyclical trends were observed for breads (Figure 4). Interestingly, breads accounted for considerably more calories of added sugar in 1965 compared with cereals, but by 2004, these two food groups contributed equally to per capita energy intake from added sugar. Overall, however, foods accounted for ≤ 1% of total energy and < 1% of total carbohydrates, save cereal, breads, and desserts, which accounted for between 1% (cereal) and 6% (desserts) of total carbohydrates in 2004.

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Estimates among consumers

Among consumers, caloric intake from added sugar and HFCS among the top foods and beverages is considerably greater than per capita estimates (Table 3). For example, although a relatively small (10%) percent of persons report consuming sweetened tea, sweetened tea provides an estimated 134 kcal/consumer/d compared with an estimated per capita amount of 14 kcal/person/day from added sugar (95 kcal/consumer/d vs. 10 kcal/per capita/d from HFCS). Likewise, 24% of cereal consumers obtain 40 more calories (53 vs. 13) from added sugar compared with the per capita estimates, and for the 46% of reported soda consumers, there is a 98% increase in energy from added sugar (as HFCS). Per capita and per consumer estimates do not differ greatly for breads.

Distribution of added sugar is important

There are important differences in calories from added sugar among those in the top 20% of the caloric distribution (Table 4). In 1965, the highest quintile consumed an average 640 more kcal/person/d from added sugar than the lowest quintile. This discrepancy had increased to 840 kcal/person/d in 2004. Between 1965 and 2004, calories of added sugar from beverages increased by 158% within the top quintile (393 kcal/person/d difference from 1965 to 2004) of the distribution, but calories of added sugar decreased by 28% (−163 kcal/person/d difference from 1965 to 2004) from foods.

With respect to beverages, persons in the lowest quintile (Q1) of the population consumed zero calories of added sugar, and although the bottom 60% of the distribution (Q1-Q3) increased caloric intake from added calories, persons in the upper two quintiles (Q4 and Q5) appeared to be driving the overall trends (Table 4). Similar differences between the highest and lowest quintiles are observed within foods; however, persons at the lowest end (Q1) of the distribution obtained some calories from added sugar (20 kcal/person/d in 2004). Between 1965 and 2004, the trend in for consumption of added sugar from foods all quintiles appeared to be decreasing (Table 4).

Total caloric intake from HFCS increased almost 100% to 505 kcal/person/d between 1989–1991 and 2004 among the top 20% of the population. Similarly to added sugar, the overall trends were driven by the top quintiles: persons in the top 60% of the population increased caloric intake from HFCS, while those in the bottom 40% decreased caloric intake from HFCS slightly between 1989–1991 and 2003–2004. Beverages provided 450 calories of HFCS to persons in the top 20% of the population and zero calories to those in the lowest 20%. Everyone consumed at least some calories of HFCS from foods (3 vs. 122 kcal; data not shown).

DISCUSSION

Consumption of added sugar, generally, and HFCS, specifically, has been hypothesized as a contributing factor to the rising rates of obesity observed over the past few decades. Mechanistically, this hypothesis is based on differences in the rates of digestion and absorption between fructose and glucose (36–39) and the observation that increased consumption of sugar-sweetened beverages is associated with weight gain over time (15,40–42). These topics are beyond the scope of this paper, but are addressed elsewhere in this supplement. The purpose of this paper was to examine the trends and patterns of HFCS and added sugar consumption in both beverages and foods.

We report that daily per capita intake of calories from HFCS and added sugar has followed a general upward trend since the mid-1960s. Despite a drop in sugar consumption between 1965 and 1977, added sugar accounted for 17% of total daily energy intake and 32% of total carbohydrate intake among Americans 2 years and older. These values represented an increase

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of 31% (from the lowest value in 1977) and 23% (from the lowest value in 1991), respectively. The trend in HFCS consumption has been steadier; between 1991 and 2000 there was a 120% increase in calories from HFCS, and since 2000, calories from HFCS have remained relatively stable. These values represented 8.5% of total energy and 15.9% of carbohydrates in 2004—an increase of 67% and 57%, respectively, from estimated intake in 1989.

Our results are consistent with those reported elsewhere by our research team. In a study examining worldwide shifts in added sugar availability and consumption, Popkin and Nielsen reported an increase from 235 calories from added sugar in 1977 to 318 calories from added sugar in 1996 (43). Similar trends in the number of calories from added sweetener by food group were also reported. Using the same Glinsmann method as reported here, Bray et al (10) examined HFCS consumption between 1977 and 1998 for a select set of food groups, namely soft drinks, fruit drinks and desserts. As reported in our paper, Bray et al. found a general increasing trend in added sugar and HFCS consumption from the three food sources they examined. The present study expanded on these results by estimating HFCS contribution to caloric intake from numerous additional food sources over a longer time period.

The patterns we have observed are also consistent with recent literature on trends in the location and types of foods being consumed. Between 1977 and 1996, salty snacks, pizza, and sugar-sweetened beverages showed the largest increases in consumption among all age groups, but the largest changes were observed in the younger (2–18 and 19–39) ages (44). Location of energy consumption is also shifting, with energy from fast food places and restaurants replacing energy consumed at home (44). Furthermore, people reported that foods that can be easily obtained from these food sources (ie, hamburgers and cheeseburgers) were almost exclusively consumed away from home, suggesting that the types of foods prepared at home have shifted (44).

Our study shows that calories from added sugar and HFCS from similar types of foods (i.e. hamburgers, snacks, sodas) has continued to rise, or at least reached a plateau, since 1996. Many of these foods, particularly sugar- sweetened beverages, account for a greater percent of total energy intake in 2004 than they did even 20 or 30 years ago. Furthermore, since foods & beverages are typically not consumed independently of one another, contribution of any food or beverage to an individuals' total daily energy intake is potentially much larger.

This paper has several limitations. First, because of the lack of available data, the amount of HFCS in foods had to be estimated. Since little work has been done to estimate HFCS intake, we employed two different estimation methods—one based on availability (Glinsmann Method) and one on measured fructose (NCC Method) in foods. For some key food groups, these methods resulted in significantly different estimates (ie, the desserts food group). These differences are likely the result of differences between the two estimation techniques, each of which required acceptance of certain assumptions.

With respect to the NCC (measured fructose) Method, a direct measure of fructose was not available for all foods reportedly consumed in the USDA database; linkage codes between NCC and USDA data were available for only about 1,000 foods. For foods where no direct link was possible, we applied an average fructose value (based on the food group to which that particular food was assigned), which likely resulted in a misestimation of fructose, and HFCS, for many foods. However, it is impossible to predict the direction of this misestimation for any individual food/beverage item. To reduce misestimation, we grouped foods according to their added sugar content. However, within some food groups, a large range of added sugar and fructose would result in a dilution of average values within a food group. Additionally, for some foods from NHANES 2003–2004, direct measures of added sugar were not available. For these foods, we applied sugar values from the closest matching 8-digit USDA food code

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from the previous time point (NHANES 2001–2002). When there were no comparable foods in previous USDA files (ie, Propel Fitness water), we used nutritional information provided by the manufacturers and calculated added sugar values from this information. Our estimates of HFCS consumption using the Glinsmann Method are based on availability of data from the mid-1980s; they are likely to under-represent HFCS availability within these sectors today.

Second, our data are limited by differential collection methods between exams and differential time spans over which data were collected. The first three exam periods (1965, 1977, 1989–1991) cover a span of more than 15 years, while the last three periods (1999–2000, 20001-2002 and 2003–2004) cover just five years, which may not be long enough to observe sensitive changes in consumption patterns. To create more comparable time spans between studies, we combined the NHANES data into a single survey and reexamined trends. Although the trends in added sugar were slightly clearer using the combined surveys, HFCS could not be estimated (recall that HFCS was not widely used in food products until the late 1990s). Thus we elected to keep each NHANES survey separate. Some of the differences in observed consumption may also be due to changes in data collection methods. In 2000, the automated multiple pass method was used for dietary collection. This tool is designed with internal prompts to help decrease the incidence of underreporting, thereby increasing the accuracy of data collection. While this may result in an increase in reporting frequency of foods and beverages, it is unlikely to account for the large changes reported here.

In general, availability and consumption of HFCS and added sugar has increased over the past three decades. We report that the types of foods and beverages contributing to daily energy intake from HFCS have shifted over the past several decades: desserts accounted for roughly 4% of total energy intake in 1965. This number dropped to 3% by 2004, while soda accounted for 6.8% of total energy intake in the same year. Although sweetened beverages, such as soda and fruit drinks, currently account for the largest proportion of energy from HFCS, we report that other beverages (sports drinks) and foods (desserts, breads, and ready-to-eat cereals) are also contributing considerable amounts of per capita energy intake. These are foods that are often consumed as snacks rather than meals (44,45), so ultimately, it seems that HFCS (and other added sugar) is not what's *for* dinner, it's what's *in addition* to dinner.

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REFERENCES

1. Vartanian L, Schwartz M, Brownell K. Effects of Soft drink Consumption on Nutrition and Health: A Systematic Review and Meta-Analysis. Am J Public Health 2007;97
2. Ebbeling CB, Feldman HA, Osganian SK, Chomitz VR, Ellenbogen SJ, Ludwig DS. Effects of decreasing sugar-sweetened beverage consumption on body weight in adolescents: a randomized, controlled pilot study. Pediatrics 2006;117:673–680. [PubMed: 16510646]
3. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. Am J Clin Nutr 2006;84:274–288. [PubMed: 16895873]
4. Nielsen SJ, Popkin BM. Changes in beverage intake between 1977 and 2001. Am J Prev Med 2004;27:205–210. [PubMed: 15450632]
5. Popkin BM, Nielsen SJ. The sweetening of the world's diet. Obes Res 2003;11:1325–1332. [PubMed: 14627752]

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6. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS. Effects of fast-food consumption on energy intake and diet quality among children in a national household survey. Pediatr 2004;113:112–118.

7. Harnack L, Stang J, Story M. Soft drink consumption among US children and adolescents: nutritional consequences. J Am Diet Assoc 1999;99:436–441. [PubMed: 10207395]

8. French SA, Lin BH, Guthrie JF. National trends in soft drink consumption among children and adolescents age 6 to 17 years: prevalence, amounts, and sources, 1977/1978 to 1994/1998. J Am Diet Assoc 2003;103:1326–1331. [PubMed: 14520252]

9. Duffey K, Popkin BM. Shifts in patterns and consumption of beverages between 1965 and 2002. Obesity research in press.

10. Bray GA, Nielsen SJ, Popkin BM. Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. Am J Clin Nutr 2004;79:537–543. [PubMed: 15051594]

11. Jurgens H, Haass W, Castaneda TR, et al. Consuming fructose-sweetened beverages increases body adiposity in mice. Obes Res 2005;13:1146–1156. [PubMed: 16076983]

12. Sclafani A. Starch and sugar tastes in rodents: an update. Brain Res Bull 1991;27:383–386. [PubMed: 1959034]

13. Rizkalla SW, Boillot J, Tricottet V, et al. Effects of chronic dietary fructose with and without copper supplementation on glycaemic control, adiposity, insulin binding to adipocytes and glomerular basement membrane thickness in normal rats. Br J Nutr 1993;70:199–209. [PubMed: 8399102]

14. Luo J, Rizkalla SW, Lerer-Metzger M, et al. A fructose-rich diet decreases insulin-stimulated glucose incorporation into lipids but not glucose transport in adipocytes of normal and diabetic rats. J Nutr 1995;125:164–171. [PubMed: 7861242]

15. Tordoff MG, Alleva AM. Effect of drinking soda sweetened with aspartame or high-fructose corn syrup on food intake and body weight. Am J Clin Nutr 1990;51:963–969. [PubMed: 2349932]

16. Anderson JW, Story LJ, Zettwoch NC, Gustafson NJ, Jefferson BS. Metabolic effects of fructose supplementation in diabetic individuals. Diabetes Care 1989;12:337–344. [PubMed: 2721342]

17. Bray GA, Nielsen SJ, Popkin B. High fructose corn sweeteners and the epidemic of obesity. Am J Clin Nutr 2002;79:537–543. [PubMed: 15051594]

18. Schiffman SS, Sattely-Miller EA, Graham BG, et al. Effect of temperature, pH, and ions on sweet taste. Physiol Behav 2000;68:469–481. [PubMed: 10713286]

19. Starmer, E.; Witteman, A.; Wise, T. GDAE Working Paper. Medford, MA: Tufts University; 2006. Feeding the Factory Farm: Implicit Subsidies to the Broiler Chicken Industry.

20. Warner M. A Sweetener with a Bad Rap. The New York Times 2006 July2. 2006

21. Steyn NP, Myburgh NG, Nel JH. Evidence to support a food-based dietary guideline on sugar consumption in South Africa. Bull World Health Organ 2003;81:599–608. [PubMed: 14576892]

22. WHO/FAO. Expert Consultation on Diet, Nutrition and the Prevention of Chronic DiseasesReport of the joint WHO/FAO expert consultation. Geneva: World Health Organization; 2003.

23. Economic Research S. Economic Research Service, U.S. Dept. of Agriculture. Food Consumption (Per Capita) Data System. 2004.

24. Park Y, Yetley E. Intakes and food sources of fructose in the United States. Am J Clin Nutr 1993;58 (suppl):737s–747s. [PubMed: 8213605]

25. Smith S. High fructose corn syrup replaces sugar in processed food. Environmental Nutrition 1998;11:7–8.

26. Hurt-Jones, M. Free of All Common Food Allergens. Emmaus, PA: Rodale Press; 2002. The Allergy Self-Help Cookbook: Over 350 Natural Food Recipes.

27. Hopkins, K. Foods and Products Containing High Fructose Corn Syrup (HFCS). In: Hedonist, A., editor. website listing of foods containing High-Frutose Corn Syrup. 2005.

28. Kuhl, K. Blog maintained with information about fast food places. [Accessed 3.12.07]. Fast Food Facts and Fast Food News 2005. http://www.foodfacts.info/high-fructose-corn-syrup.shtml.

29. Bialostosky K, Wright JD, Kennedy-Stephenson J, McDowell M, Johnson CL. Dietary intake of macronutrients, micronutrients, and other dietary constituents: United States 1988–94. Vital Health Stat 2002;11:1–158.

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30. Glinsmann W, Irausquin H, Park Y. Evaluation of health aspects of sugars contained in carbohydrate sweeteners:Report of Sugars Task Force. J Nutr 1986;116:S1–S216. [PubMed: 3543257]
31. Bovard J. The Great Sugar Shaft. Freedom Daily 1998 April. 1998
32. Popkin BM, Haines PS, Siega-Riz AM. Dietary patterns and trends in the United States: the UNC-CH approach. Appetite 1999;32:8–14. [PubMed: 9989908]
33. Popkin BM, Armstrong LE, Bray GM, Caballero B, Frei B, Willett WC. A new proposed guidance system for beverage consumption in the United States. Am J Clin Nutr 2006;83:529–542. [PubMed: 16522898]
34. Blanton CA, Moshfegh AJ, Baer DJ, Kretsch MJ. The USDA Automated Multiple-Pass Method accurately estimates group total energy and nutrient intake. J Nutr 2006;136:2594–2599. [PubMed: 16988132]
35. Dwyer J, Picciano MF, Raiten DJ. Collection of food and dietary supplement intake data: What We Eat in America-NHANES. J Nutr 2003;133:590S–600S. [PubMed: 12566509]
36. Edwards D, Todd J, Mahmoudi M, et al. Glucagon-like peptide 1 has a physiological role in the control of postprandial glucose in humans: studies with the antagonist exendin 9–39. Diabetes 1999;48:86–93. [PubMed: 9892226]
37. Vilsboll T, Krarup T, Madsbad S, Holst J. Both GLP-1 and GIP are insulinotropic at basal and postprandial glucose levels and contribute nearly equally to the incretin effect of a meal in healthy subjects. Regul Pept 2003;114:115–121. [PubMed: 12832099]
38. Curry D. Effects of mannose and fructose on the synthesis and secretion of insulin. Pancreas 1989;4:2–9. [PubMed: 2654926]
39. Sato Y, Ito T, Udaka U, et al. Immunohistochemical localization of facilitated-diffusion glucose transporters in rat pancreatic islets. Tissue Cell 1996;28:637–643. [PubMed: 9004533]
40. Bes-Rastrollo M, Sanchez-Villegas A, Gomez-Gracia E, Martinez JA, Pajares RM, Martinez-Gonzalez MA. Predictors of weight gain in a Mediterranean cohort: the Seguimiento Universidad de Navarra Study 1. Am J Clin Nutr 2006;83:362–370. [PubMed: 16469996]quiz 394-5.
41. Berkey CS, Rockett HR, Field AE, Gillman MW, Colditz GA. Sugar-added beverages and adolescent weight change. Obes Res 2004;12:778–788. [PubMed: 15166298]
42. Schulze MB, Manson JE, Ludwig DS, et al. Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. Jama 2004;292:927–934. [PubMed: 15328324]
43. Popkin B, Nielsen S. The Sweetening of the World's Diet. Obesity Research 2003;11:1325–1332. [PubMed: 14627752]
44. Nielsen S, Siega-Riz A, Popkin B. Trends in Energy Intake in the U.S. between 1977 and 1996: Similar Shifts Seen Across Age Groups. Obes Res 2002;10:370–378. [PubMed: 12006636]
45. Nielsen S, Siega-Riz A, Popkin B. Trends in Food Locations and Sources Among Adolescents and Young Adults. Preventive Medicine 2002;35:107–113. [PubMed: 12200094]
46. Economic Research Services USDoAe. Food Availability Data System. [Accessed 2.26.07]. http://www.ers.usda.gov/data/foodconsumption/FoodAvailSpreadsheets.htm#sweets

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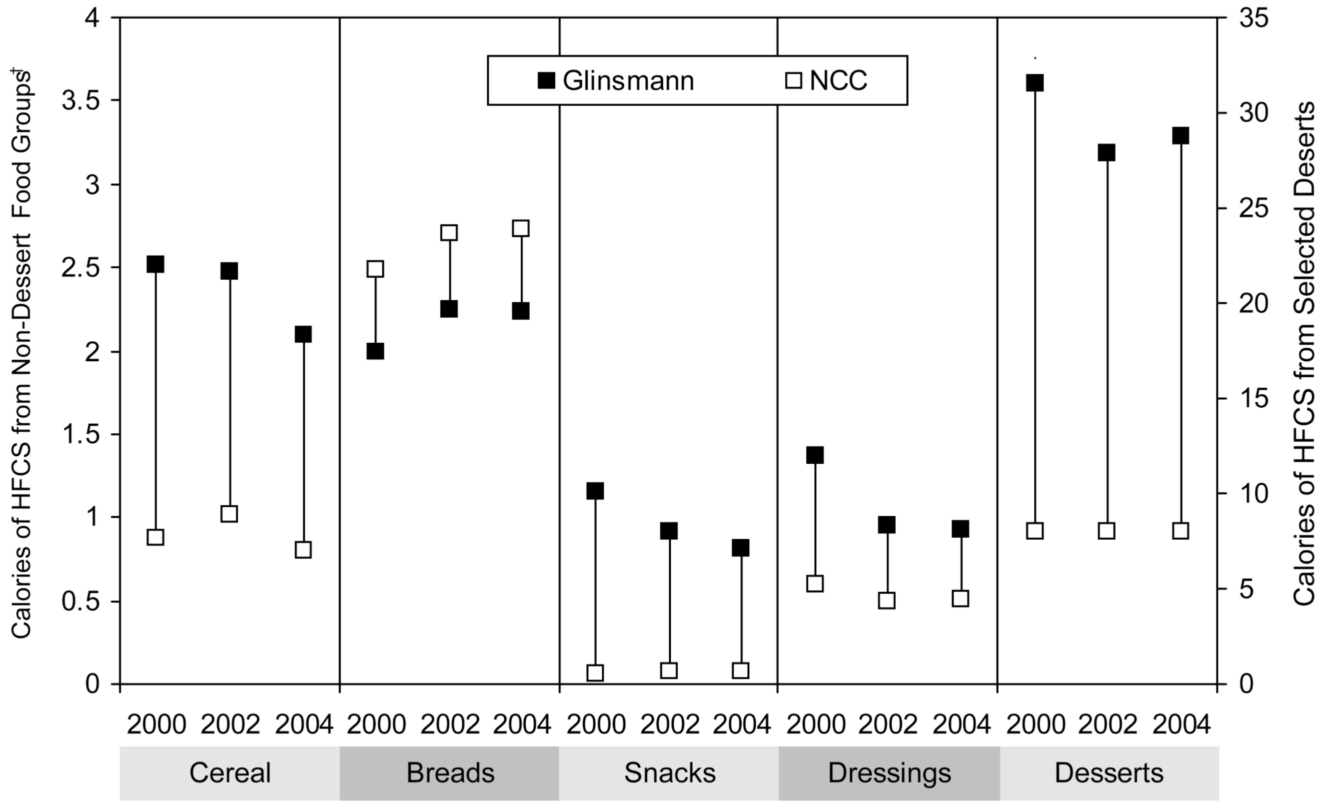

Figure 1.
Range of high fructose corn syrup (HFCS) in selected food groups derived from two methods* of estimation
*NCC method (measured fructose values) and Glinsmann method (HFCS availability data).
† Right-hand axis refers to estimated calories of HFCS from cereal, breads, snacks and dressings only. Left-hand axis refers to estimated calories of HFCS for desserts only.

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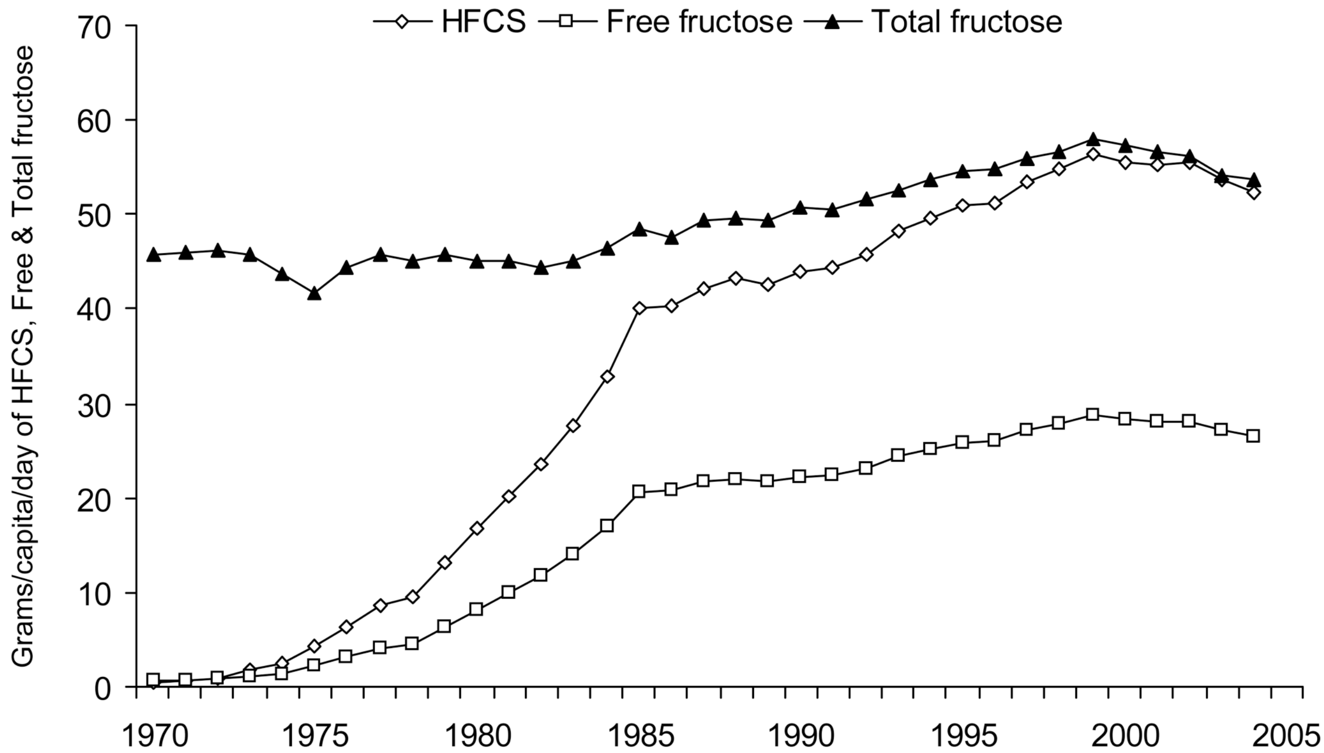

Figure 2.
Trends in fructose and high fructose corn syrup (HFCS) availability* in the U.S., 1970–2004
*Data from reference (45)

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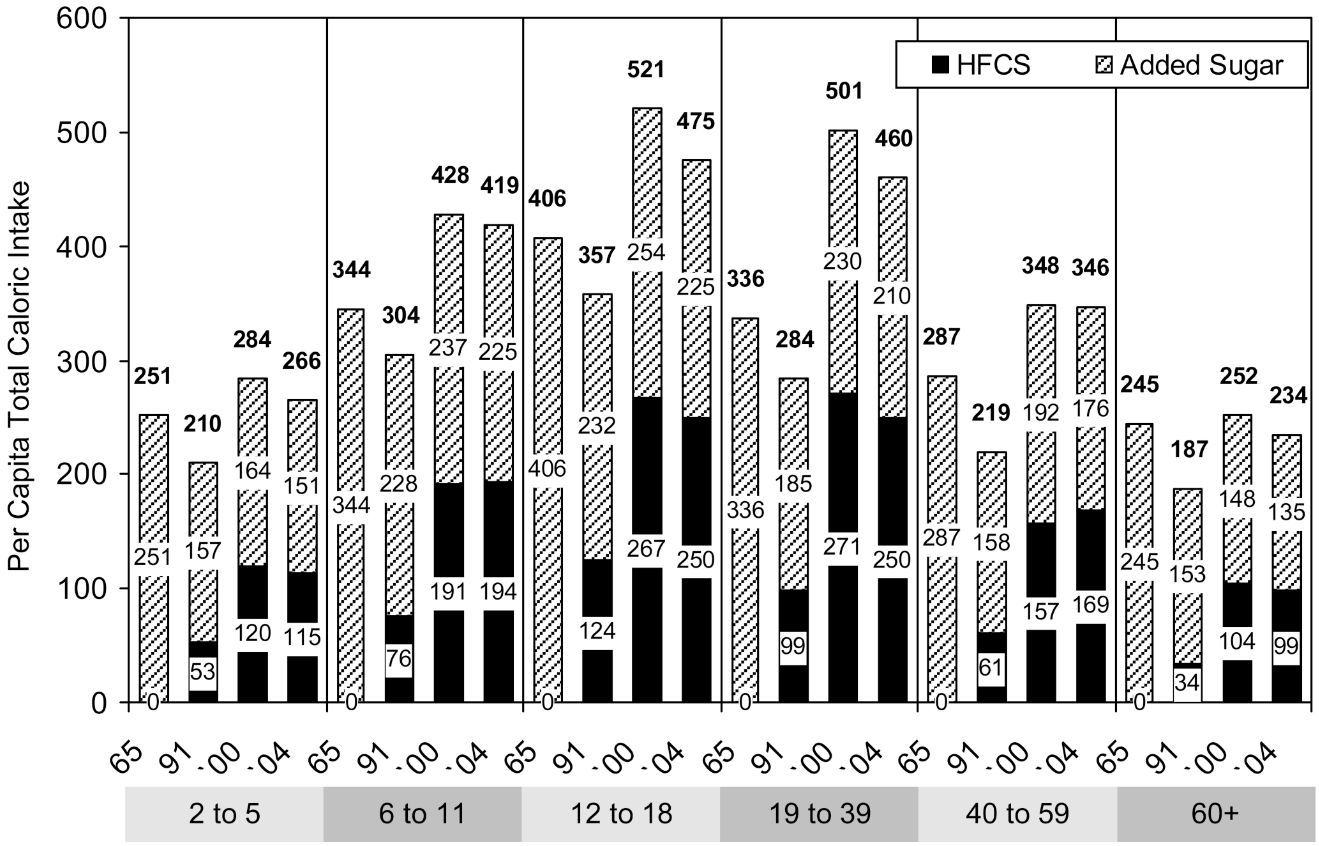

Figure 3.
High fructose corn syrup (HFCS) and added sugar consumption* by age group and year
*Data are from NFCS 1965 (beverages & foods, n=13,549), CSFII 1989–91 (beverages, n=14,689), and NHANES 1999–2000 (foods, n=8,173) and 2003–2004 (beverages and foods, n=8,275); results use survey designs to account for clustering, and are weighted to be nationally representative.

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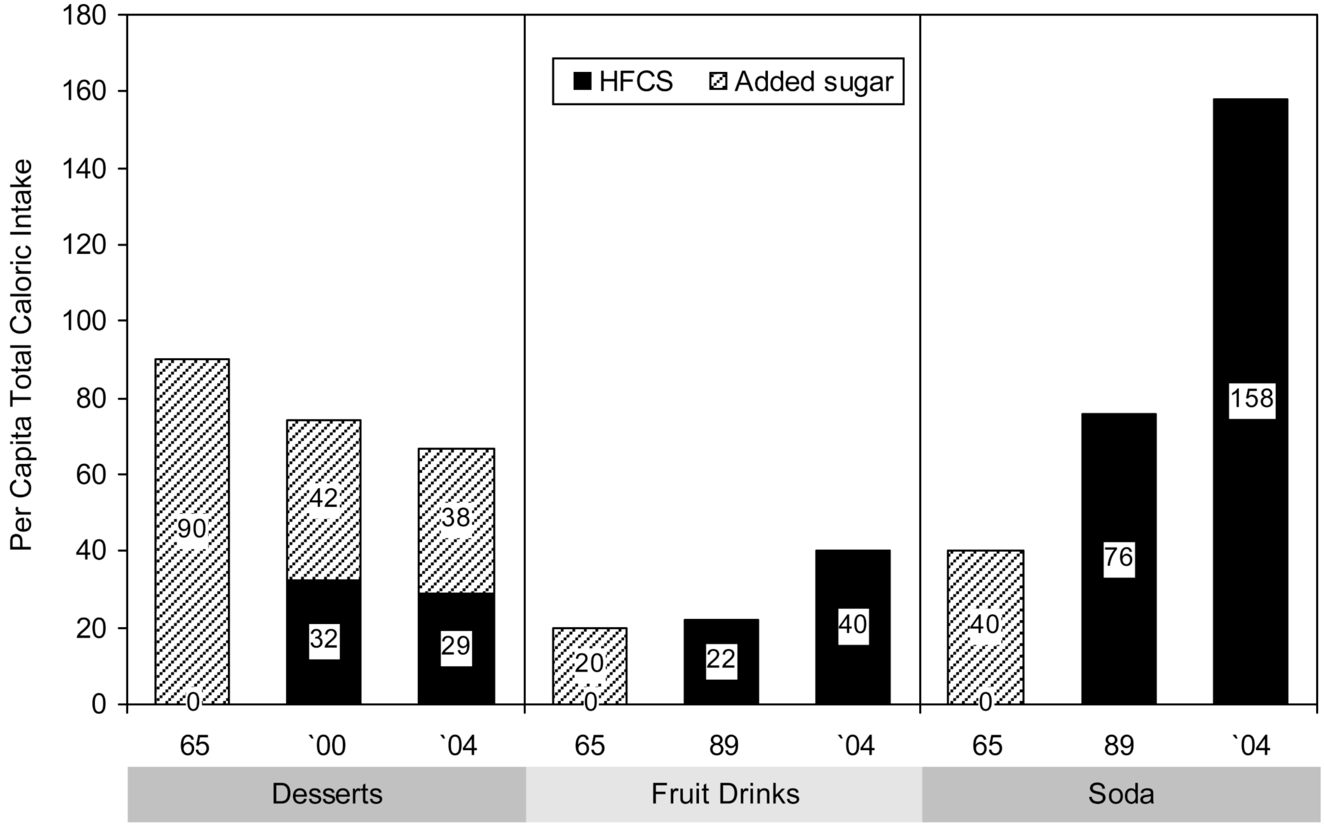

Figure 4.
Calories of high fructose corn syrup (HFCS) and added sugar* from selected food and beverage groups.
*Data are from NFCS 1965 (beverages & foods, n=13,549), CSFII 1989–91 (beverages, n=14,689), and NHANES 1999–2000 (foods, n=8,173) and 2003–2004 (beverages and foods, n=8,275); results use survey designs to account for clustering, and are weighted to be nationally representative.

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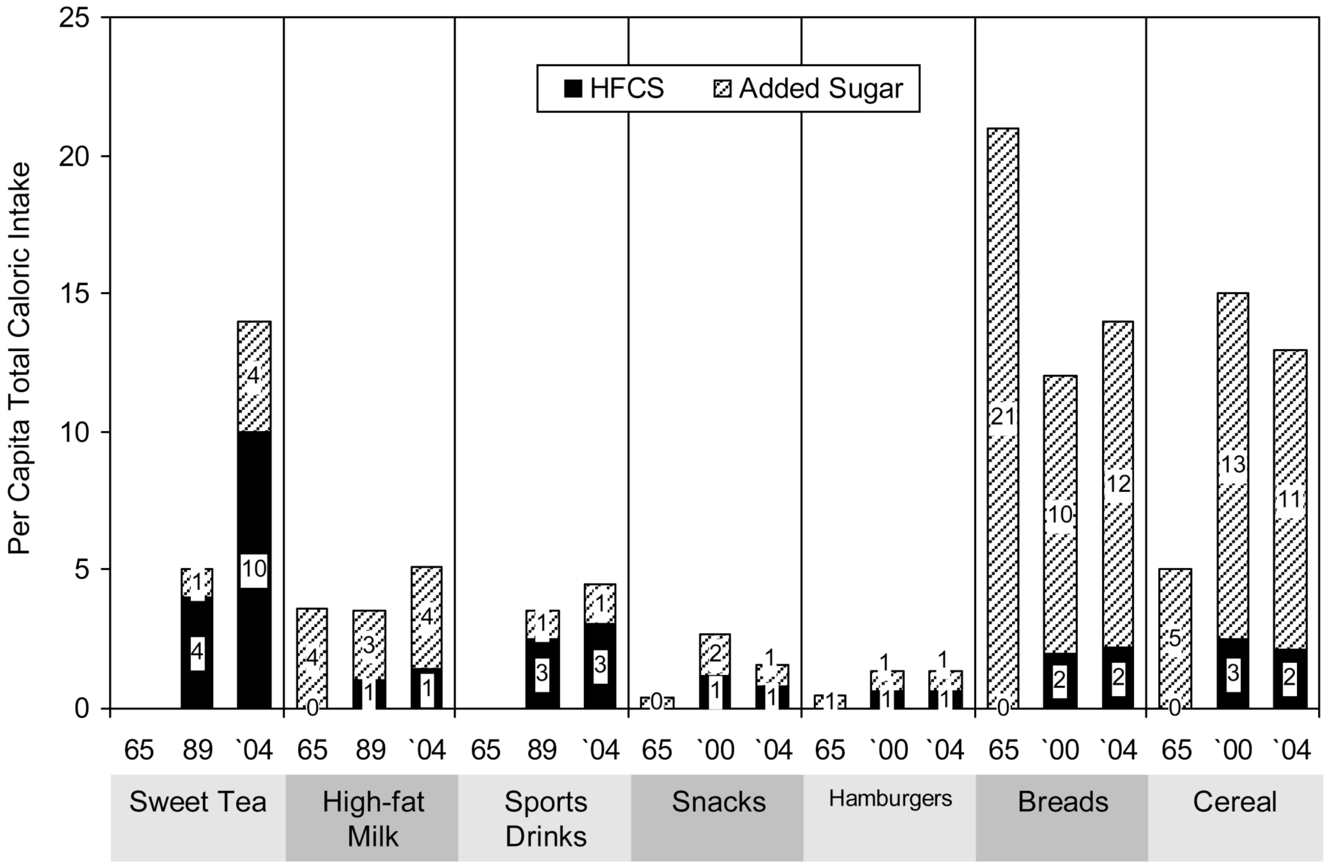

Figure 5.

Calories of high fructose corn syrup (HFCS) and added sugar* from selected food and beverage groups

***Data are from NFCS 1965 (beverages & foods, n=13,549), CSFII 1989–91 (beverages, n=14,689), and NHANES 1999–2000 (foods, n=8,173) and 2003–2004 (beverages and foods, n=8,275); results use survey designs to account for clustering, and are weighted to be nationally representative**.

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Table 1

The availability of high fructose corn syrup (HFCS) by type in the U.S. caloric sweetener supply

	HFCS (g/capita/d)	Total Caloric Sweetener (g/capita/d)	HFCS as a % of Total Sweetener	% of HFCS from HFCS-42	% of HFCS from HFCS-55
1970	0.5	105.4	0.5	100	0
1975	4.3	100.7	4.3	100	0
1980	16.8	106.4	15.8	71.2	28.8
1985	40.0	111.6	35.8	34.3	65.7
1990	43.9	117.2	37.5	41.0	59.0
1995	51.0	127.5	40.0	39.9	60.0
2000	55.4	131.7	42.1	38.1	61.9
2004	52.4	124.8	42.0	40.5	59.5

Source: USDA/Economic Research Service (ERS) food disappearance data (46)

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Table 2

Total daily intake* of added sugars and HFCS among Americans ≥ 2 years old

	Added Sugar		HFCS	
	Mean	99% Confidence Interval	Mean	99% Confidence Interval
Intake (kcal/person/d)				
1965	316	(301–331)	n/a	n/a
1977	240	(230–249)†	n/a	n/a
1989–1991	258	(245–270)†	77	(72–83)
1999–2000	405	(368–443)†	199	(175–222)†
2001–2002	376	(358–394)†	186	(174–198)†
2003–2004	377	(353–400)	189	(173–205)
Percentage of Total Energy				
1965	15.4	(14.7–15.6)	n/a	n/a
1977	13.1	(12.7–13.6)†	n/a	n/a
1989–1991	13.6	(13.0–14.1)	4.2	(3.9–4.5)
1999–2000	18.3	(16.8–19.8)†	9.0	(8.0–9.9)†
2001–2002	17.0	(16.0–18.0)†	8.3	(7.7–9.0)
2003–2004	16.8	(15.8–17.7)	8.3	(7.7–9.0)
Percentage of Total Carbohydrates				
1965	32.6	(31.8–33.4)	n/a	n/a
1977	27.7	(27.0–28.4)†	n/a	n/a
1989–1991	26.6	(25.6–27.5)†	7.9	(7.4–8.5)
1999–2000	34.0	(31.5–36.6)†	16.5	(14.8–18.2)†
2001–2002	31.7	(30.0–33.4)†	15.4	(14.3–16.5)†
2003–2004	31.9	(30.1–33.7)	15.7	(14.5–17.0)

*Data are from NFCS 1965 (n=13,549) and 1977 (n=29,553), CSFII 89–91 (n=14,689), and NHANES 1999–2000 (n=8,173), 2001–2002 (n=9,034) and 2003–04 (n=8,275); results are weighted to be nationally representative and are adjusted for stratified, non-random sampling.

†Mean (99% Confidence Interval [CI]) is significantly different from the previous year using student's t-test, $p<0.01$.

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Table 3

Per capita and per consumer estimates[*] of top six foods and beverages contributing to added sugar and HFCS intake, among persons ≥2 years.

Kcals	Added Sugar			HFCS[†]	
	Per capita kcals	**% consuming[‡]**	**Per consumer kcals**	**Per capita kcals**	**Per consumer kcals**
Soft Drinks					
1965	40.3 (35.9, 44.6)	24	167.0 (158.0, 176.0)	-	-
1977	51.4 (48.2, 54.7)[§]	30	180.6 (175.2, 186.0)[§]	-	-
1989–91	73.5 (68.1, 78.9)[§]	34	224.2 (215.2, 233.3)[§]	51.9 (48.1, 55.7)	158.3 (151.9, 164.7)
1999–00	153.5 (126.1, 180.9)[§]	50	309.8 (276.2, 343.3)[§]	108.3 (89.0, 127.7)[§]	218.7 (195.0, 242.4)[§]
2001–02	138.8 (121.1, 156.7)	46	303.6 (284.9, 322.3)	98.0 (85.5, 110.5)	214.3 (201.1, 227.6)
2003–04	158.1 (137.4, 178.8)	46	312.7 (288.4, 337.0)	111.6 (97.0, 126.3)	220.8 (203.6, 237.9)
Fruit Drink					
1965	20.1 (17.3, 22.9)	16	128.7 (120.8, 136.6)	-	-
1977	191 (17.1, 21.1)	14	139.1 (132.7, 145.5)[§]	-	-
1989–91	19.5 (17.5, 21.6)	15	152.1 (142.2, 162.1)[§]	13.8 (12.3, 15.2)	107.4 (100.4, 114.4)
1999–00	37.7 (33.3, 42.1) [§]	20	191.2 (177.4, 204.9)[§]	26.6 (23.5, 29.7) [§]	135.0 (125.3, 144.7)[§]
2001–02	39.8 (32.0, 47.5)	21	191.9 (163.1, 220.7)	28.1 (22.6, 33.6)	135.5 (115.2, 155.8)
2003–04	40.3 (33.8, 46.8)	20	181.6 (164.7, 198.4)	28.5 (23.9, 33.1)	138.2 (116.3, 140.1)
Sweet Tea					
1965	n/a	n/a	n/a	-	-
1977	7.3 (5.5, 9.1)	5	137.7 (128.1, 147.4)	-	-
1989–91	4.6 (3.1, 6.2) [§]	6	91.5 (74.5, 108.6)[§]	3.3 (2.2, 4.4)	64.6 (52.6, 76.7)
1999–00	12.2 (6.9, 17.5)[§]	9	134.6 (112.9, 156.2)[§]	8.6 (4.8, 12.3)[§]	95.0 (79.7, 110.3)[§]
2001–02	12.0 (7.0, 16.9)	10	125.4 (101.2, 149.6)	8.4 (4.9, 11.9)	88.5 (71.4, 105.6)
2003–04	13.5 (8.1, 18.8)	10	134.4 (114.2, 154.6)	9.5 (5.7, 13.3)	94.9 (80.7, 109.2)
Desserts					
1965	90.0 (38.6, 96.4)	65	139.0 (132.4 (145.5)	-	-
1977	55.1 (52.3, 57.9) [§]	49	118.5 (114.0, 123.0)[§]	-	-
1989–91	49.1 (45.6, 52.7) [§]	45	121.3 (115.2, 127.4),	-	-
1999–00	73.8 (64.5, 83.1) [§]	55	134.0 (120.8, 147.2)	31.5 (27.6, 35.5)	57.2 (51.6, 62.9)

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Kcals	Added Sugar			HFCS[†]	
	Per capita kcals	% consuming[‡]	Per consumer kcals	Per capita kcals	Per consumer kcals
2001–02	65.4 (60.2, 70.6) [§]	56	116.0 (111.3, 120.6)[§]	27.9 (25.7, 30.1) [§]	49.5 (47.5, 51.5)[§]
2003–04	67.3 (60.7, 73.8)	57	118.7 (109.2, 128.1)	28.7 (25.9, 31.5)	50.7 (46.7, 54.7)
Cereal					
1965	5.2 (4.5, 5.8)	26	19.9 (18.0, 21.7)	-	-
1977	6.7 (6.3, 7.1) [§]	27	26.1 (24.6, 27.5)[§]	-	-
1989–91	11.0 (10.0, 12.1) [§]	28	40.9 (37.2, 44.5)[§]	-	-
1999–00	15.2 (12.9, 17.6) [§]	26	58.9 (54.8, 63.0)[§]	2.5 (2.1, 2.9)	9.7 (9.1, 10.4)
2001–02	15.1 (13.0, 17.1)	27	55.1 (49.8, 60.4)	2.5 (2.1, 2.8)	9.1 (8.2, 10.0)
2003–04	12.8 (11.0, 14.5) [§]	24	53.1 (49.0, 57.2)	2.1 (1.8, 2.4)[§]	8.8 (8.1, 9.4)
Breads					
1965	20.6 (19.5, 21.7)	92	22.3 (21.2, 23.4)	-	-
1977	14.8 (14.2, 15.3)[§]	85	17.5 (16.9, 18.2)[§]	-	-
1989–91	12.3 (11.5, 13.1)[§]	79	16.1 (14.9, 17.2)[§]	-	-
1999–00	12.1 (10.7, 13.5)	75	16.0 (14.3, 17.7)	2.0 (1.8, 2.2)	2.6 (2.4, 2.9)
2001–02	13.6 (12.0, 15.2)	76	17.9 (16.0, 19.9)[§]	2.3 (2.0, 2.5)	3.0 (2.6, 3.3)[§]
2003–04	13.5 (12.3, 14.7)	76	17.8 (16.3, 19.3)	2.2 (2.0, 2.4)	2.9 (2.7, 3.2)

[*] Data are from NFCS 1965 (n=13,549) and 1977 (n=29,553), CSFII 89–91 (n=14,689), and NHANES 1999–2000 (n=8,173), 2001–2002 (n=9,034) and 2003–04 (n=8,275); results are weighted to be nationally representative and are adjusted for stratified, non-random sampling.

[†] HFCS estimates are derived using the Glinsmann method.

[‡] The same values for percent consuming each food and beverage groups are applicable for HFCS, data are not repeated.

[§] Means are statistically different from the previous year using student's t-test, p<0.01.

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Table 4

Average per capita caloric intake* from added sugar by quintiles, among persons ≥2 years

	Q1	Q2	Q3	Q4	Q5
Total					
1965	61 (58, 63)	162 (160, 163)	262 (260, 263)	396 (393, 398)	701 (687, 716)
1977	32 (31, 33)	114 (113, 114)	195 (194, 196)	299 (298, 300)	560 (551, 569)
1989–1991	29 (28, 30)	113 (111, 116)	206 (203, 208)	324 (322, 327)	616 (598, 634)
1999–2000	62 (59, 65)	194 (190, 197)	321 (318, 324)	491 (487, 496)	956 (898, 1019)
2001–2002	59 (56, 61)	176 (173, 178)	300 (297, 304)	464 (458, 471)	882 (858, 906)
2003–2004	56 (53, 58)	172 (169, 174)	295 (292, 298)	464 (496, 468)	896 (867, 925)
Beverages					
1965	0	0	0.2 (0.2, 0.3)	84 (82, 86)	248 (240, 257)
1977	0	0	7 (6, 8)	118 (117, 120)	292 (285, 299)
1989–1991	0	0	12 (11, 13)	149 (146, 151)	361 (245, 376)
1999–2000	0	10 (9, 11)	140 (137, 142)	272 (267, 276)	654 (609, 699)
2001–2002	0	7 (6, 8)	130 (127, 133)	265 (262, 268)	629 (606, 652)
2003–2004	0	8 (7, 9)	133 (130, 136)	267 (265, 270)	642 (614, 670)
Foods					
1965	42 (40, 43)	118 (117, 119)	197 (196, 199)	306 (304, 308)	585 (570, 599)
1977	17 (16.7, 18)	60 (59.9, 61)	113 (112.5, 114)	187 (186, 188)	390 (383, 397)
1989–1991	14 (13, 15)	49 (48.5, 50)	104 (102, 105)	179 (177, 181)	385 (368, 402)
1999–2000	19 (18, 20)	71 (69.7, 72)	134 (133, 136)	224 (220, 227)	490 (467, 512)
2001–2002	19 (18, 20)	69 (68, 70)	123 (122, 125)	203 (200, 205)	429 (412, 445)
2003–2004	19 (18, 20)	67 (65, 68)	119 (118, 121)	197 (194, 199)	422 (404, 440)

* Data are from NFCS 1965 (n=13,549) and 1977 (n=29,553), CSFII 89–91 (n=14,689), and NHANES 1999–2000 (n=8,173), 2001–2002 (n=9,034) and 2003–04 (n=8,275); results are weighted to be nationally representative and are adjusted for stratified, non-random sampling. Values are means (99% CI) within quartile;