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The Real Contribution of Added Sugars and Fats to Obesity

Adam Drewnowski

From the Center for Public Health Nutrition and the Nutritional Sciences Program, School of Public Health and Community Medicine, University of Washington, Seattle, WA.

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Obesity rates in the United States are a function of socioeconomic status. Higher rates are found among groups with lower educational and income levels, among racial and ethnic minorities, and in high-poverty areas. Yet, the relation between obesity, nutrition, and diet continues to be viewed in biologic terms, with the search for likely causes focused on consumption of specific macronutrients, foods, or food groups. Epidemiologic evidence linking diet composition and body weight has mostly relied on ecologic comparisons, time trends, and analyses of cross-sectional studies. Plausible physiologic mechanisms have included the metabolic effects of dietary components, mostly sugars and fats, on regulation of food intake and deposition of body fat. However, the evidence could not have been convincing since the blame for rising obesity rates seems to shift regularly, every 10 years or so, from fats to sugars and then back again. This review demonstrates that much of past epidemiologic research is consistent with a single parsimonious explanation: obesity has been linked repeatedly to consumption of low-cost foods. Refined grains, added sugars, and added fats are inexpensive, good tasting, and convenient. The fact that energy-dense foods (megajoules/kilogram) cost less per megajoule than do nutrient-dense foods means that energy-dense diets are not only cheaper but may be preferentially selected by the lower-income consumer. In other words, the low cost of dietary energy (dollars/megajoule), rather than specific food, beverage, or macronutrient choices, may be the main predictor of population weight gain. Examining past studies of the contribution of added sugars and fats to obesity rates through the prism of food prices and diet costs is the purpose of this review.

beverages; diet; economics; energy intake; fats; obesity; poverty; sweetening agents

Abbreviations: BMI, body mass index; USDA, US Department of Agriculture.

INTRODUCTION

The obesity epidemic in the United States follows a sharp socioeconomic gradient (1). Most affected are population subgroups with lower educational and income levels (2–4). The impact of low socioeconomic status on obesity rates is most apparent for White women; associations of obesity with race, ethnicity, and socioeconomic status are more complex (4). Analyses of obesity rates by geographic location indicate that the rates are higher in lower-income states and low-income counties compared with more affluent areas (5). Absence of wealth, minority status, and living in impoverished neighborhoods appear to be the major predictors of both obesity (1–5) and type 2 diabetes (6). Prevalence rates for obesity and diabetes, based on national survey data for US adults by age, race, and education, are shown in figure 1. These disparities by race and social class persist as obesity rates continue to increase nationwide (2).

High obesity rates have also been linked, many times, to global dietary trends (7, 8) and to the current food environment (9, 10). For the most part, studies on obesity, nutrition, and diet have drawn evidence from ecologic comparisons, time trends, and cross-sectional surveys on diets and health. Several studies, most of them based on US data sets, have pointed to statistical links between obesity and the consumption of fats (11), sugars (12, 13), fast foods (14), snacks (15, 16), and caloric beverages (17, 18); larger food portions (19); and eating away from home (20). Fewer studies have focused on the low cost of energy-dense foods (21, 22) and on the links between household economic resources, diet quality, and diet cost (23, 24).

Correspondence to Dr. Adam Drewnowski, 305 Raitt Hall, Box 353410, University of Washington, Seattle, WA 98195 (e-mail: adamdrew@u.washington.edu).

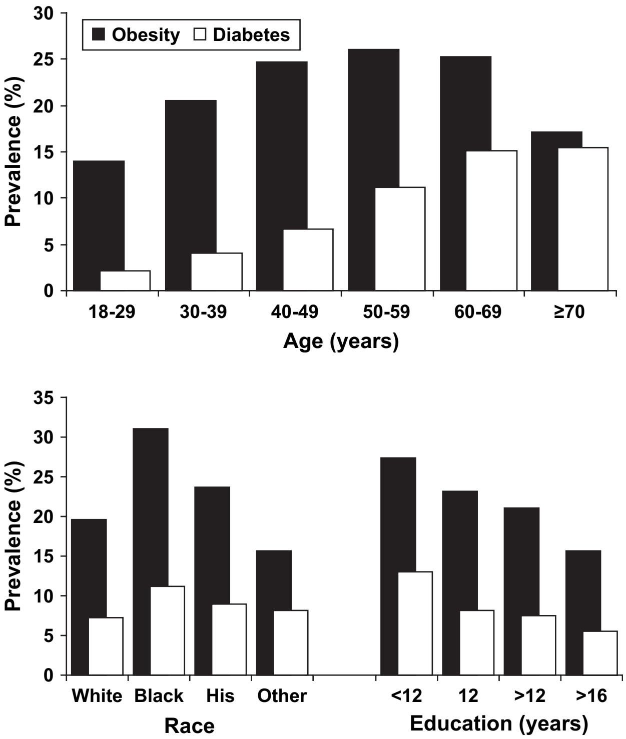

FIGURE 1. Prevalence of obesity and diabetes in the United States by age (top) and by race and education (bottom). Based on data from Mokdad et al. (2). His, Hispanic.

One requirement for establishing causality in epidemiologic studies is a plausible physiologic mechanism, which has led researchers to emphasize the impact of macronutrients on human metabolism and regulation of body weight. Dietary fat (11), starch (25), corn sweeteners (12, 13), and even protein (26) have all been linked, at different times and through a variety of metabolic mechanisms, to adiposity and weight gain. The impact of liquid beverages versus solid foods on short-term satiety was also explored, though sometimes with inconsistent results (27). Whereas some studies claimed that humans failed to compensate for dietary energy in caloric beverages (28), others reported that humans were ill adapted to energy-dense solid foods (29). Caloric high-fructose corn syrup (12) and noncaloric sweeteners (30) were each said to promote weight gain through some combination of physiology and behavior. Dietary practices were also scrutinized. Meals at fast-food and full-service restaurants were identified as one potential cause of obesity (14, 20), but so were between-meal snacks (16) and large portions of foods consumed in restaurants or at home (31).

One forgotten concept is that obesity rates in the United States are tied, perhaps inextricably, to social class (1, 32). Diet quality also follows a socioeconomic gradient (1). Existing measures of diet quality are invariably tied to age, educational, and income levels (1) and are likely to be associated with higher food expenditures (24).

The intrusion of class structure into epidemiologic studies on diets and health has multiple consequences. Different levels of dietary exposure for foods or nutrients may be associated with differences in wealth, social capital, and social context. In other words, people with one type of dietary pattern may differ in several unobserved ways from people with another type of dietary pattern. People who consume healthier diets may well be thinner (33), but they are also more affluent and may have more opportunities to purchase healthier foods or engage in physical activity (1). Such sociodemographic factors are either missing from epidemiologic studies altogether or, even when available, are treated as covariates rather than as important variables in their own right (34).

Interestingly, a single group of researchers has, in succession, identified dietary fats (11, 35), sugars and corn sweeteners (12, 36), soft drinks (11, 37), fast foods (38), snacks (16), and larger portion sizes (19) as potential culprits in the obesity epidemic. Their conclusions were mostly based on analyses of time trends, ecologic comparisons, and cross-sectional epidemiologic data. In each case, the researchers suggested that obesity was very likely caused by the particular dietary factor under study, which was duly identified as a cause for concern. To signify enthusiasm, titles of articles sometimes carried exclamation points for added emphasis (11, 16).

Given that epidemiologic research does in fact serve as the evidence base for modifying health policy (39, 40), there is a need for a critical review of the likely contribution of added sugars and added fats to rising obesity rates. However, whereas past research on obesity and diet composition has emphasized physiology and metabolism, the present focus is on the economics of food choice behavior (41, 42). Refined grains, added sugars, and added fats may contribute to obesity not because of any inherent metabolic effects but because they are readily available, highly palatable—and inexpensive (1, 22, 43). What different obesogenic diets may have in common is not their nutrient composition but their low energy cost (1, 22, 43). The inclusion of the cost variable would help explain why obesity is concentrated among the lower socioeconomic groups (1). Examining past literature on dietary factors in obesity through the prism of food prices and diet costs is the chief purpose of this review.

DIETARY TRENDS

Food supply trends in the United States

The US Department of Agriculture (USDA) has described food supply trends as more refined grains, more added sugars, and more added fats (44). Based on food disappearance data, these trends reflect the availability of commodities per capita, as opposed to actual measures of consumption, and have not been adjusted for waste (44, 45).

Per capita availability of flour and cereal products in year 2000 was estimated at 200 pounds (91 kg), a 48 percent increase from 1970–1974 (44). Most cereals were refined grains as opposed to the more costly whole grains (44, 45). The availability of added fats and oils reached an all-time high of 77 pounds (35 kg) per capita in 2000, a 38 percent increase from 1970–1974 levels (44). The availability of caloric sweeteners rose from 124 pounds to 149 pounds (56 kg to 68 kg), a 20 percent increase (44). Whereas consumption of cane and beet sugar declined by 35 percent, that of corn sweeteners, including high-fructose corn syrup, rose by 277 percent.

In contrast, by year 2000, the availability of fruit and fruit juices was only 1.4 servings per person per day. Half of this amount was accounted for by low-cost oranges, apples, and bananas, whereas consumption of melons, berries, fresh grapes, and other fruit was low. The food supply also provided 429 pounds (195 kg) of vegetables, equivalent to 3.8 daily servings. Half of this amount was supplied by low-cost frozen potatoes (mainly French fries), fresh potatoes, potato chips, canned tomatoes, and iceberg lettuce (44). The more expensive dark-green leafy vegetables and deep yellow vegetables accounted for only 0.4 servings per person per day (44, 46). Adding to the growing disparities in food costs, the retail prices of fruit and vegetables more than doubled between 1985 and 2000, whereas the price of added sugars and fats remained the same (44, 45).

Diet choices of lower-income groups

One question is whether lower-cost diets are preferentially selected by the lower-income consumer. Analyses of diets by poverty status (47, 48) showed little difference in energy intakes or in the total fat or carbohydrate content of the diet. There appeared to be no major differences by income group in consumption of major food groups, meat, dairy, or grains. However, finer-scale analyses demonstrated that food prices did affect household food choices. In 1992, US households in the top quintile by income, compared with lower-income households, bought higher-quality meats, more seafood, and more fruits and vegetables (49, 50). Lower-income households purchased lower-quality meats and less expensive fruits and vegetables. Bananas were selected in preference to more expensive berries and other fresh fruit (51). Higher-income households purchased more lettuce and lettuce-based salads, melons, and berries (48). In the 1994–1996 Continuing Survey of Food Intake of Individuals, consumers who ate more fruit and vegetables tended to be older, better educated, and more affluent (46).

The more affluent consumers not only purchased higher-quality diets but also were less likely to be either overweight or obese. Typically, lower obesity rates in such cross-sectional studies were ascribed to consumption of extra vegetables and fruit rather than to better economic resources or to greater wealth. For example, in one study, higher fruit consumption was linked with lower body mass index (BMI; weight (kg)/height (m)^2) values (52). Regression analyses controlled for the effects of age, gender, and race/ethnicity but did not control for any relevant economic variables, education, or income (52). Diet costs were not considered.

Interestingly, consumption of white potatoes was positively correlated with BMI for adult women and men. The authors speculated that the preparation of vegetables was the reason (52). An alternative explanation is that potatoes were cheaper than fresh fruit and were preferentially selected by the overweight, low-income consumer.

Low-income households saved money by purchasing more discounted foods, choosing generic products over brand names, taking advantage of volume discounts, or settling for less expensive products within a product class (51, 53). Despite buying lower-cost items, and higher-energy-density diets, lower-income households devoted a much higher percentage of their disposable income to food (44, 45). Whereas food costs may not be perceived as a barrier to dietary change by more affluent respondents, the proportion of persons who view costs as a barrier rises sharply as incomes drop (54).

Mean daily spending on foods and beverages has been estimated at approximately $8 per person per day (45). Assuming a daily ration of 2,500 kcal (10.4 MJ), each food dollar needs to yield approximately 300 kcal (1.3 MJ) of dietary energy, on the average. Processed food products high in refined grains, added sugars, and added fats easily provide 300–500 kcal/$ at retail, whereas fresh fruits and vegetables do not. Recent analyses of the national Continuing Survey of Food Intake of Individuals data set showed that groups of lower socioeconomic status consumed higher-energy-density diets (55), which were presumably associated with lower diet costs.

One interpretation of US dietary trends is that more consumers are purchasing more lower-cost foods. As a result, the proportion in the diet of refined grains, added sugars, and added fats continues to rise (1, 47). For example, analyses of nationally representative dietary intake data between 1977 and 1996 showed increases in portion sizes for specific foods (19). Substantial increases were observed for grains (salty snacks, desserts), sugars (soft drinks), and fats (burgers and French fries) both inside and outside the home. The largest portions were consumed at fast-food restaurants. The report concluded that education was the answer and that the public needed to be better educated about controlling portion size (19). An alternative explanation is that more Americans were simply consuming larger amounts of lower-cost foods at low-cost venues.

It is not clear whether those trends are susceptible to meaningful motivational, social marketing, or even economic interventions. A recent USDA study showed that low-income households spent about $1.43 less per person per week on fruit and vegetables compared with higher-income households (56). Whereas higher-income households did increase fruit and vegetable consumption following an increase in income, lower-income households did not. One interpretation is that fruit and vegetables were not a priority and that low-income households chose to spend limited resources on more essential items such as meat, clothing, or rent (56).

In summary, a number of cross-sectional studies, some conducted at the national level, have shown statistical associations between consumption of specific foods or food groups and body weight. However, eating habits are not randomly distributed in the population but follow a socioeconomic gradient. It may be that the observed association between eating patterns and obesity rates will be attenuated by appropriate measures of socioeconomic status (57).

FAT OR SUGAR?

Is dietary fat a major determinant of body fat?

For a period of time, at the height of the fat phobia in the 1990s, the percentage of energy from dietary fat was thought to be a major predictor of body fat. Three types of evidence were advanced to support the hypothesis.

First, between-population (ecologic) studies showed an association between estimated percentage of fat in the national diet and rates of obesity (BMI >30) or overweight (BMI >25) (11). In general, wealthier nations consumed more animal products, added sugars, and fats than did nations in early stages of economic development, and they also had higher rates of obesity, cancer, and cardiovascular disease (58). Ecologic comparisons of fat consumption in European countries showed a significant correlation between percentage of fat energy and national BMI values, but only for women and not for men (59).

Second, dietary trends, again at the national level, showed a temporal parallel between increasing fat consumption and population weight gain. Studies in China, cited by Bray and Popkin (11), showed a parallel between economic development, increasing fat consumption, and rising rates of overweight. The change in dietary patterns associated with nutrition transition was thus directly linked to obesity and weight gain.

Third, increasing dietary fat consumption in animal studies was said to accelerate the development of obesity, whereas the adoption of low-fat diets in human clinical studies led to weight loss (11). Among physiologic mechanisms invoked to explain why fat consumption should lead to greater body fat were high energy density and palatability of dietary fat (60, 61), its greater metabolic efficiency, weak satiating power, and weaker physiologic regulation of fat intake relative to carbohydrate intake (62, 63).

Each of those points was countered at the time by opposing arguments. First, between-population ecologic studies typically contrasted vastly different nations, from very rich to very poor. As noted by Willet (64, 65), such correlations are confounded by economic variables, food availability, and physical activity levels and can be completely misleading. The dietary fat variable, typically shown on the *x*-axis, could have been replaced by gross national product, number of cars, or any other index of economic development. Furthermore, the relation between obesity and socioeconomic status within nations depends not only on gender but also on level of economic development (32). In poor nations, it is the more affluent persons who are likely to be obese; the situation reverses in rich nations (66). In both cases, socioeconomic status has a more marked impact on the body weight of women than of men (66). The median BMI for a specific country may reflect no more than the age or the demographics of a particular population sample. It is unlikely that some of the data cited in earlier studies (11) were based on truly nationally representative samples of adults in such places as the Congo; more likely they were drawn from small and potentially biased samples of convenience.

Second, time trends are not in themselves sufficient to establish causality. Not only that, but a reexamination by Willett (64) of longitudinal analysis of dietary fat intake and weight gain in China showed that the association was in fact trivial. An increase of 10 percent of energy from fat would increase body mass indices 0.1 unit in adolescents and 0.03 unit in adults. The high observed prevalence of overweight in South Africa (>55 percent), despite low fat intakes (<22 percent energy), supported Willett's argument (64) that other dietary factors were also involved.

Third, clinical studies on the impact of low-fat diets on weight loss cited provided fodder for a lively controversy. Some researchers argued that low-fat diets were more effective than isoenergetic diets of different macronutrient composition (11). As long as the diets were low in fat, one argument went, calories made little difference. A critical examination of the impact of dietary fat on weight change in animals and humans is outside the scope of the present review. However, the then-popular argument that low-fat diets promoted weight loss, independent of energy intake, seems quaint now given the current emphasis on calories, not macronutrients, and the reported success of the high-fat Atkins diet (67, 68).

This particular controversy surrounding dietary fat peaked around 1997–1998, leading to a number of articles, rebuttals, editorials, and letters to the editor (11, 35, 64, 65, 69). The position taken by Willett (65, 69) was that the relation between dietary fat and obesity was unconvincing. The position taken by Bray and Popkin (11) was that dietary fat did, too, affect obesity, exclamation mark. Seidell (70) made the sensible observation that inferences about causality could not be made based on data from cross-sectional studies. Pointing to potential biases in the reporting of energy intake, dietary fat intake, physical activity, and height and weight, Seidell concluded that existing studies were unable to infer a causal relation between fat consumption and obesity and that prospective studies might be necessary. At that point there was no evidence that, under isoenergetic conditions, dietary fat intake promoted obesity more than any other macronutrient did (65, 69, 70).

One set of time trends deserves special mention. The argument that fat consumption played no role in obesity was based on the observation that obesity rates in the United States increased at the same time that fat consumption dropped (65, 71). One suggestion was that overemphasis on eating low-fat foods may have actually contributed to overweight among US adults (71). On the basis of this and other evidence, Willett (65) concluded that diets high in fat were not a primary cause of obesity and that reducing dietary fat was not a viable solution. Bray and Popkin (11, 35) argued that the apparent decline in the proportion of energy from fat was not only small (3–5 percent) but also very likely caused by underreporting.

However, underreporting was probably not the main issue. A closer examination of USDA data showed that only the percentage of fat in the diet decreased, whereas the absolute amount of fat expressed in terms of grams per capita per day was higher than ever. Extra calories in the diet were provided by carbohydrate, notably sugar. A few years later, media and public attention turned away from fat (72) and back toward sugar.

Is sugar a major determinant of body fat?

At the present time, much like in the 1980s (73), dietary sweeteners are again thought to be the major determinant of body fat (12, 13). Three types of evidence have been advanced to support the new hypothesis: ecologic comparisons, time trends, and cross-sectional studies, each supported by plausible metabolic mechanisms. Interestingly, the arguments now advanced for sugar were much the same as those proposed some 10 years previously, and by some of the same researchers (11, 35), for dietary fat.

First, between-country comparisons of intake of caloric sweeteners pointed to a major increase in sugars consumption between 1962 and 2000 (36). Those analyses were based on food disappearance data by country, maintained by the Food and Agriculture Organization of the United Nations. The increases were proportionately much higher for poor countries in the bottom quintile of gross national product (90–155 kcal/day) than for rich countries in the top quintile of gross national product (402–418 kcal/day). Urbanization in the developing world was highly correlated with rising sugar consumption. However, between-country comparisons are confounded by myriad economic variables, as had been noted previously by Willett (64, 65) in the context of dietary fat.

A similar ecologic comparison, based on annual consumption data in the United States over time, stressed temporal parallels between the growing consumption of refined carbohydrates and the epidemic of type 2 diabetes (13). Per capita nutrient consumption between 1909 and 1997 was compared with the available data for the same-year prevalence of diabetes by using multivariate analyses and controlling for energy intakes. Corn syrup was associated with type 2 diabetes, whereas protein and fat were not. The obligatory mention of plausible physiologic mechanisms now focused on the glycemic index, fructose metabolism, dyslipidemia, and the metabolic syndrome (13).

Another examination of time trends, based on the USDA food disappearance statistics, drew further parallels between the growing consumption of high-fructose corn syrup and rising obesity rates (12), both at the national level. The authors wrote that the increased use of high-fructose corn syrup mirrored the rapid increase in obesity in the United States, noting that the digestion, absorption, and metabolism of fructose differed from that of glucose (12). This time, the plausible physiologic mechanisms invoked satiety deficits following consumption of caloric beverages and the role of leptin and insulin resistance in the regulation of food intake (12).

Some studies narrowed the search for culprit foods from all sweeteners to sugars contained in caloric beverages (17). Examination of consumption time trends within the United States showed a mean increase of 83 kcal/day in sweetener consumption for all persons older than 2 years of age (17). Of this amount, 67 kcal/day was derived from caloric beverages and only 14 kcal from candy and desserts. Without arguing for causality, the researchers noted that excessive added sugar intake may contribute to higher obesity rates (17). A similar argument, also based on time trends, had been made previously for dietary fat.

Analyses of cross-sectional data by other research groups further explored the association between sugars consumption, mostly in the form of caloric beverages, and body weight in children, adolescents, and adults. The six or so studies were described and dissected in almost as many reviews (74–77) and will not be summarized here. Though largely based on analyses of cross-sectional data, many studies and reviews made repeated references to weight gain (75, 77). As had been pointed out before in the context of dietary fat, the dynamics of weight change cannot be inferred from data collected at a single point in time.

Physiologic mechanisms focused on glycemic index and fructose metabolism (78, 79). Studies were cited to show that fructose consumption in animal studies accelerated the development of obesity, whereas the removal of high-fructose corn syrup from soft drinks in studies with humans led to weight loss. Physiologic mechanisms invoked to explain why sugar (or high-fructose corn syrup) consumption should lead to greater body fat included high energy density and palatability of dietary sugars and weaker satiating properties of beverage calories relative to solid foods (80). In other words, many of the arguments made in support of a link between obesity and sugar consumption had been made before, sometimes by the same researchers, to establish a link between obesity and dietary fat.

Demographics of sweetener consumption

Although sugars consumption and obesity rates at the national level have both increased with time, temporal parallels do not mean that the highest sugars consumers are also the most overweight or obese. A recent USDA report on distribution of sweetener consumption by demographic characteristics provided a much-needed breakdown of sweeteners consumption in the United States by age, race/ethnicity, and social class (81).

On the national level, added sugars consumption increased by 23 percent between 1985 and 1999. The growth was only a modest 5.3 percent for refined sugar (sucrose) and much higher (27.7 percent) for high-fructose corn syrup. The authors then combined two USDA databases to examine sweetener consumption patterns by demographic characteristics of survey respondents (81). Analyses showed that sweetener consumption was 25 percent higher among men than women and that it dropped dramatically after the age of 24 years (81). Sweetener consumption was the same for Whites and for Blacks and was much higher than for Hispanics. Sweetener consumption was highest in suburban areas but was only slightly lower in rural areas, and it was higher in the Midwest than in the South. The distribution of sweetener consumption by incomes, expressed as percent poverty, showed that consumption of sugars, sweets, and beverages rose with increasing incomes and then fell. Consumption of sugar and corn sweeteners in milk and grain products rose with incomes (81). These data are summarized in figure 2.

It can be seen that the demographic distribution of sweetener consumption in the United States does not correspond to the demographic distribution of obesity. Obesity rates are higher for women than for men, and—as shown in figure 1—tend to increase with age, peaking for the age group 50–59 years. Obesity rates are much higher in the South and the Southeast than in the Midwest. Figure 1 also shows that obesity rates are higher among Blacks and Hispanics than among Whites, and they plunge dramatically with increased education and income, whereas consumption

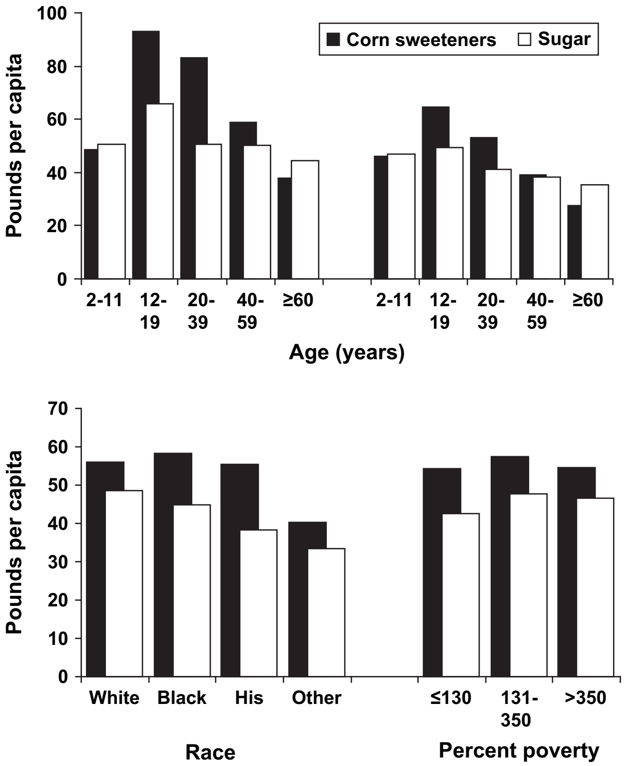

FIGURE 2. Sugars consumption in the United States by demographic characteristics (1 pound = 0.45 kg). Based on data from Haley et al. (81). His, Hispanic.

of sugars apparently does not. Clearly, ecologic comparisons at the national level do not translate well to population subgroups.

Ecologic comparisons have limited validity but can be useful for hypothesis testing. The USDA data are cited here because many published studies have made use of national statistics without exploring disparities in diet quality or obesity rates among population subgroups (12, 13). It would appear that the population subgroups at greatest risk of obesity are not necessarily those that consume the most sugar. Individual-level data on added sugars consumption by social class are not available at this time.

It has long been known that the highest consumers of sugar in all its forms are younger males, who are both thinner and more active than older persons, whose sugar consumption is low (82). Attempts to exonerate sugar, published during the period of fat phobia, pointed to studies showing that sugar consumption, as well as carbohydrate consumption, was associated with leanness rather than obesity (83–85). Some researchers even suggested that high sugar intakes, inversely associated with fat intakes, might protect consumers against obesity (84). However, that was another unwarranted causal inference based on cross-sectional data, very likely confounded by age and activity levels. Unfortunately, increasing sugar consumption was unlikely to make anyone thinner, younger—or male.

Are other foods or beverages to blame?

A number of studies have explored the contribution of fast foods, caloric beverages, and snacks to the obesity epidemic (15, 16, 38, 86). Three types of evidence were advanced to support those hypotheses: ecologic comparisons, time trends, and analyses of cross-sectional data. Although the researchers were by now careful not to claim causality, inferences were drawn to support interventions and other policy measures.

What most of the studies missed was the link between dietary patterns and affluence—and its implications. One study of water consumption, based on 2001 National Health and Nutrition Examination Survey data (86), showed that high-water consumers were better-educated older adults who were also more likely to have healthier dietary patterns. That group consumed more vegetables, fruit, and 100 percent fruit juices and more low-fat dairy products. That group was also less likely to consume fast foods, snacks, and caloric soft drinks (86). In other words, education, a proxy measure of socioeconomic status, was yet again associated with healthier eating habits and lower obesity risk.

Finding that water consumption was also associated with healthier eating patterns, the researchers suggested that younger and less-educated adults should be encouraged to drink more water to prevent obesity (84). Again, the policy suggestion was based on cross-sectional data confounded by social class. The study did not discuss the underlying differences in socioeconomic status between the two groups, the likely root cause of disparities in both diets and health. The notion that low-income youth should consume more water (as opposed to say, improve their economic situation) to escape obesity seems particularly callous.

Another study (38), based on cross-sectional analyses of data from the Coronary Artery Risk Development in Young Adults Study, showed that fast food but not restaurant food was positively associated with BMI. On the basis of year 7 data, each additional fast-food meal per week was associated with an increase of 0.13 in BMI, or 0.42 kg (38). In other words, an additional estimated 52,000 kcal/year or so was associated with a trivial weight difference of 420 g, suggesting that dietary data may have been unreliable. The researchers concluded that greater fast food consumption was associated with higher BMIs and called for policy makers to focus on potentially important differences between fast-food and restaurant food consumption (35). The researchers did not mention the difference in food prices per megajoule at fast-food outlets compared with full-service restaurants. As people who frequent fast-food restaurants well know, the most significant difference between fast-food outlets and full-service restaurants is the price of the meal.

A study of time trends in beverage consumption (17) by the same team examined data for children and adults in three cross-sectional national studies conducted between 1977 and 2001. Overall, intake of sweetened beverages increased by 135 percent, whereas consumption of fluid milk was reduced by 38 percent. The resulting increase in net dietary energy, undifferentiated by social class, was promptly linked to the obesity epidemic. The fact that soft drinks were sweetened with high-fructose corn syrup as opposed to sucrose was identified as an additional cause for concern (17). In another instance of basing public policy on time trend data, reducing consumption of soft drinks was described as one of the simpler ways to reduce obesity in the United States.

In summary, data from the various studies on obesity and diet composition are consistent with a simple economic hypothesis. In most such studies, stronger associations with obesity or ill health were obtained for soft drinks than for 100 percent juices (87), for refined grains as opposed to fiber-rich whole grains (88), for fast foods than for full-service restaurants (37), and for ''Western'' eating patterns as opposed to more ''prudent'' ones (89). In other words, the foods, beverages, snacks, or diets said to promote obesity were, in every case, inexpensive. In contrast, the more costly dietary patterns were associated with leanness, weight maintenance, or greater weight loss (90). What epidemiologic research seems to have shown, fairly consistently, is that obesity is most closely associated with habitual consumption of low-cost foods.

ECONOMICS OF FOOD CHOICE

The low cost of energy-dense foods

Developments in agriculture and food technology have made added sugars and vegetable oils accessible globally at a remarkably low cost. The commodity cost of refined sugar (sucrose) in global markets was recently about 9 cents a pound, while the cost of most vegetable oils was about 20 cents a pound (22). In other words, approximately 40,000 kcal from added sugars and fats could be obtained at world market rates for $2. Although there is little relation between commodity cost and retail cost of the finished food product, added sugars and fats may help to hold down diet costs (22). Although not all food purchases are price driven, the average American spends less than $8 per day on food and beverages, with low-income families spending as little as $25 per person per week (44, 45). However, the unspoken premise of many studies on diets and disease risk has been that healthy diets are largely a matter of awareness, motivation, and making the right choice.

Epidemiologic studies conducted in the United States have taken little notice of diet costs. Most of the available evidence comes from studies conducted in the European Union. A series of studies (10, 21) estimated diet costs based on mean national retail price for each of the 895 foods in the nutrient database. Energy density (kcal/100 g) was calculated by using food composition tables. Mean cost per edible portion of food was calculated, after adjusting for preparation and waste.

Figure 3 shows a scatter plot of the energy density of foods (megajoule per kilogram) and their energy cost (cents/10 MJ), separately for each food group. Energy cost is represented on a logarithmic scale. Fats and oils, sugar, refined grains, potatoes, and beans provided dietary energy at the lowest cost. At retail prices, the energy cost of sugar or oil was less than 10 eurocents per 1,000 kcal. In contrast, the cost per calorie of meats, fish and shellfish, dairy products, vegetables, and fruit was considerably higher. As figure 3 shows, added sugars and added fats and the recommended healthier foods were, in reality, separated by an immense gap in energy costs.

Studies also examined the relation between energy density and dietary energy cost (21, 23). The Val-de-Marne dietary survey, conducted in 1988–1989, assessed dietary intakes in terms of frequencies of consumption (per week) and quantities consumed (portion sizes) in a manner similar to a food frequency questionnaire. Analyses were based on 837 adults (361 men and 476 women) and on 57 food items, after excluding drinking water, alcoholic beverages, and baby foods. Dietary energy density (megajoules per kilogram) was obtained by dividing energy intakes by the estimated edible weight of all foods and caloric beverages (10, 21, 23). Diet costs were estimated by attaching a price to each of the 57 food items. Mean national retail prices for year 2000 for each of the 57 items were provided by the French National Institute of Statistics. A column of prices in Euros (1€ = 1.17 US$ in June 2003) was added to the Val-de-Marne food composition database. This procedure, which assumes that all foods were purchased and then prepared and consumed at home, is analogous in every way to procedures developed by the USDA to estimate the cost of healthful diets in the Thrifty Food Plan (91).

The more energy-dense diets were associated with higher consumption of grains, fats, and sweets and with lower consumption of fruit and vegetables, after adjusting for energy. Figure 4 shows that for each quintile of energy intake, energy density of the diet and energy cost were inversely linked (21). In regression models, each 100-g increment in fats and sweets was associated with a net saving in diet costs, up to 0.40 €/day depending on energy intakes. In contrast, fruit and vegetable consumption was associated with an increase in diet costs of 0.18–0.29 €/day, again depending on energy intakes. In other words, diets composed of sweets and fats cost less, whereas diets high in vegetables and fruit cost more (10, 21, 23, 24).

Do low-cost diets predict weight gain?

Population groups with higher educational and income levels tend to have higher-quality diets. Those groups consume fewer fast foods and soft drinks and more fruit, vegetables, low-fat dairy products, and water (38, 51, 92). The more affluent population groups with higher educational and income levels are also less likely to be obese (2–4). Diet quality and obesity rates in the United States appear to be influenced by social class, a variable rarely explored in epidemiologic studies (93). Few studies on obesity and diets have calculated food prices and diet costs or taken a full range of socioeconomic variables into account.

Nonetheless, one persistent research focus has been to identify the one food, beverage, or nutrient that has ''caused'' the observed rise in obesity rates. Current evidence showing that added fats, added sugars, refined carbohydrates, high-fructose corn syrup, fast foods, snacks, and caloric beverages are each associated with either obesity or weight gain can be interpreted by a single and parsimonious economic hypothesis. All these foods are inexpensive and

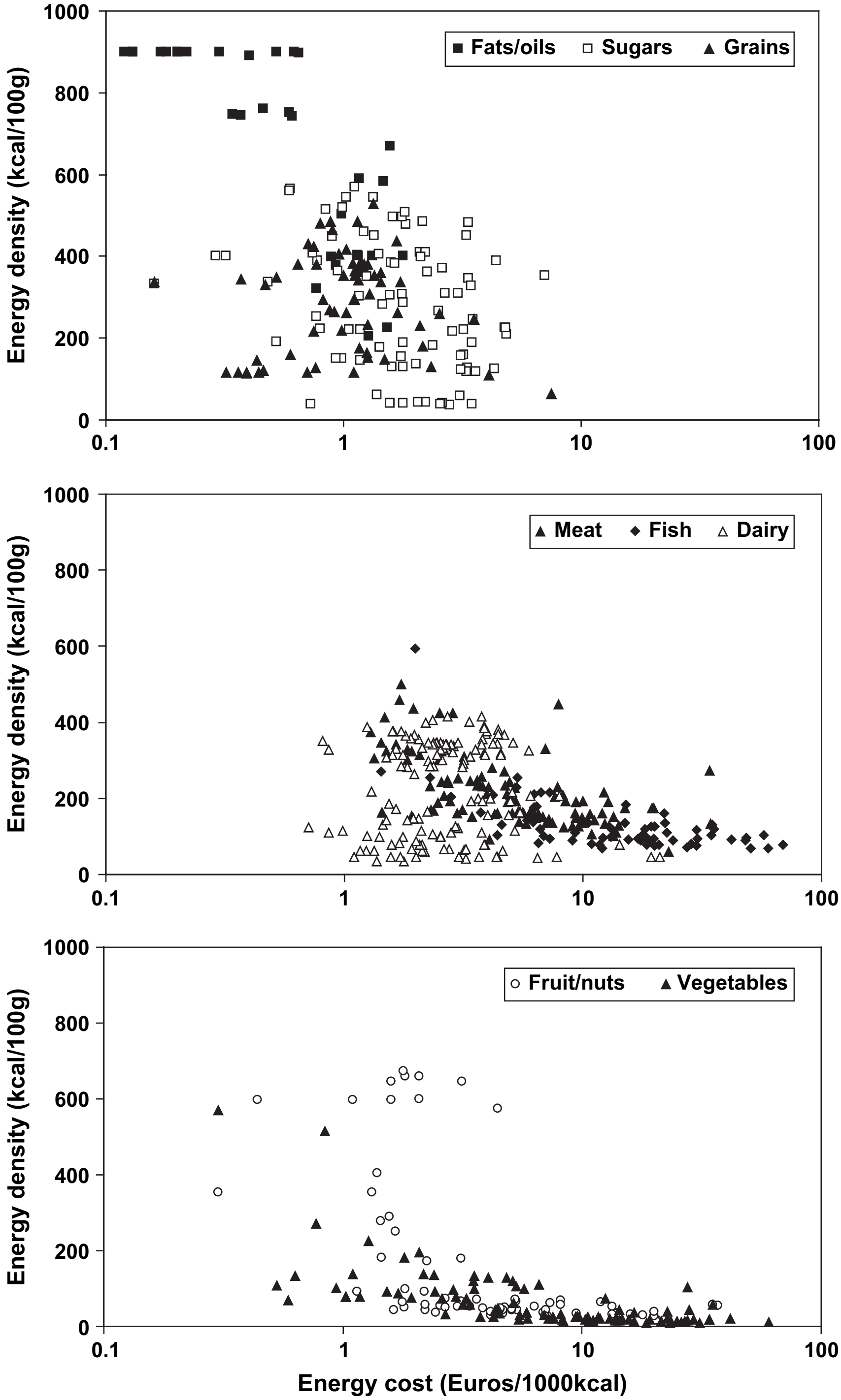

FIGURE 3. Relation between energy density (kcal/100 g) and energy cost (Euros/100 kcal). Reprinted with permission from Am J Clin Nutr (2005;82(suppl):265S–273S), American Society for Nutrition.

are likely to be selectively purchased by the lower-income consumer. In contrast, foods with supposed protective power, such as lean meats, fish, vegetables, and fruit, are not only more expensive but also likely to be selected by the more affluent groups. As a result, it has been difficult to assign the blame for the obesity epidemic to a single food, beverage, or nutrient, independent of socioeconomic status of the consumer.

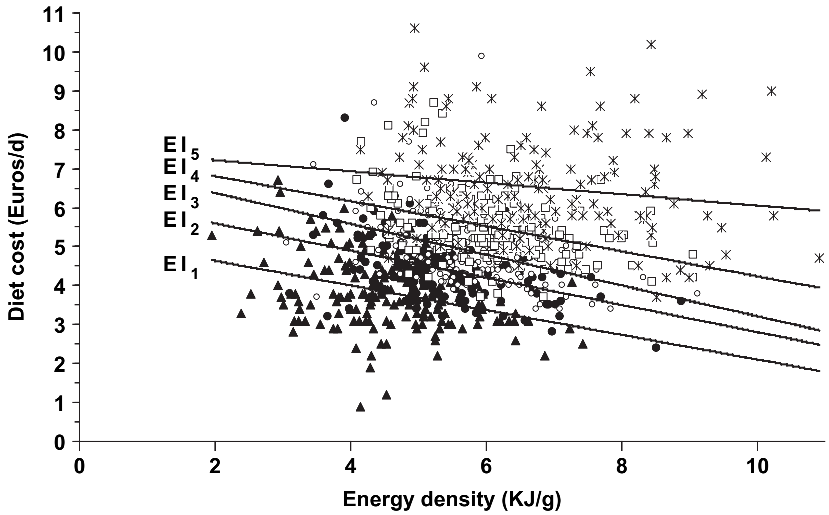

FIGURE 4. Inverse relation between energy density and daily diet cost (Euros/day (d)) at each quintile of energy intake (EI). Asterisk, EI quintile 5; square, EI quintile 4; open circle, EI quintile 3; solid circle, EI quintile 2; solid triangle, EI quintile 1. Reprinted with permission from J Nutr (2005;135:900–4), American Society for Nutrition.

Defining social class can be problematic (57). Perhaps for those reasons, the dietary behaviors of obese persons continue to be viewed through the prism of physiology and medicine. Cravings for energy-dense fats and sweets have been explained by neurotransmitter imbalance (94, 95). Excess consumption of energy-dense foods, added sugars, and added fats has been explained in terms of satiety deficits and passive overeating (94, 95). Consumption of sweets and

TABLE 1. The many prices of sugar*,†,‡

Beverage	Sugar (g/100 g)	$/MJ
Tampico Tropical Punch[1]	10.8	0.25
Safeway Select Cola[2]	12.1	0.32
Reduced-fat Chocolate Milk[3]	12.3	0.38
A&W Root Beer[4]	12.9	0.40
Coca Cola Classic[5]	11.3	0.44
Sunny D Tangy Original (5% juice)[6]	11.3	0.44
Hi-C Blast Fruit Pow (10% juice)[5]	12.7	0.66
Safeway White Grape Juice (100% juice)[2]	15.8	0.77
Welch's Grape Juice (100% juice)[7]	16.7	0.82
Ocean Spray Cranberry Juice Cocktail (27% juice)[8]	13.8	0.89
Minute Maid Orange Juice (100% from concentrate)[5]	10.0	0.94
Tropicana Orange Juice (100% pure squeezed)[9]	9.2	1.08
V8 Fusion Fruit & Vegetable Juice[10]	11.2	1.49
Slim Fast Optima French Vanilla (low sugar)[11]	4.8	1.59
Slim Fast French Vanilla Classic (original formula)[11]	10.8	1.59
Odwalla Orange Juice (100% juice squeezed)[5]	10.0	2.92

* Reprinted with permission from Am J Clin Nutr (2007;85:851–61), American Society for Nutrition.

† Prices were obtained from the following website: www.safeway.com (accessed March 2006).

‡ Manufacturers: [1] Heartland Farms, City of Industry, CA 91748; [2] Safeway Inc., Pleasanton, CA 94588; [3] Darigold Dairies, Seattle, WA 98119; [4] Dr. Pepper/SevenUp Inc., Plano, TX 75086; [5] Coca Cola Company, Atlanta, GA 30313; [6] Sunny Delight Beverages, Cincinnati, OH 45242; [7] Welch Foods Inc., Concord, MA 01742; [8] Ocean Spray Cranberries Inc., Lakeville-Middleboro, MA 02349; [9] PepsiCo Inc., Purchase, NY 10577; [10] Campbell's, Camden, NJ 08103; [11] Unilever, Vlaardingen, The Netherlands.

desserts has been explained in terms of an addictive personality, stress, depression, and seeking comfort in high-fat foods. The failure to select healthy diets has been explained in terms of physical access to supermarkets and grocery stores, marketing and distribution of healthy foods, urban sprawl, and the time spent commuting to work (96).

The importance of economic factors when it comes to sugars consumption is illustrated in table 1. Shown are the relative prices per kilocalorie for a number of sugar-containing beverages, from generic cola to 100 percent fruit juices and meal replacement products. Although the prices per 100 kcal varied by an order of magnitude, the sweetener content per 100 g was much the same. The same caloric sweeteners, differently priced, have been associated in epidemiologic and in clinical studies with both weight gain and weight loss. Previous studies have associated the low-cost sugars with obesity and weight gain, whereas the higher-cost juices and meal replacement shakes have been associated with weight maintenance or weight loss (90, 97). The present point is that these beverages, containing added or natural sugars, may be selected by consumers at different levels of socioeconomic status. It would appear that the relevant obesogenic factor is not the sugar content of foods but its price.

CONCLUSION

Epidemiologic analyses have shown numerous associations between consumption of refined grains, added sugars, and fats and higher rates of obesity and diabetes in both the United States and elsewhere. As the present review demonstrates, such low-cost, energy-dense diets are indeed consumed by lower-income people, who are also more likely to be overweight. Diets of lower–socioeconomic status households provide cheap, concentrated energy from fat, sugar, cereals, potatoes, and fatty meats, but they offer little in the way of whole grains, fish, vegetables, and fruit (98, 99). Likewise, low-income consumers are more likely to be frequent users of fast-food as opposed to full-service restaurants and are more likely to live in areas with less physical access to healthier foods. In contrast, costly diets consumed by more-affluent people are likely to be associated with less obesity and better health outcomes (1).

The search for obesity-causing foods or macronutrients needs to take food prices and diet costs into account. The present unifying hypothesis is that low cost of dietary energy (dollars per megajoule) (40) may be a more powerful predictor of weight gain than any one food or beverage. The real contribution of added sugars and fats to obesity may be through reduced energy costs (100, 101). Future studies should examine the relative costs of healthy and unhealthy diets in relation to the purchasing power of the obese consumer. There is convincing evidence that obesity in the United States is an economic issue.

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