The economics of obesity: dietary energy density and energy cost[1–4]

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ABSTRACT

Highest rates of obesity and diabetes in the United States are found among the lower-income groups. The observed links between obesity and socioeconomic position may be related to dietary energy density and energy cost. Refined grains, added sugars, and added fats are among the lowest-cost sources of dietary energy. They are inexpensive, good tasting, and convenient. In contrast, the more nutrient-dense lean meats, fish, fresh vegetables, and fruit generally cost more. An inverse relationship between energy density of foods (kilojoules per gram) and their energy cost (dollars per megajoule) means that the more energy-dense diets are associated with lower daily food consumption costs and may be an effective way to save money. However, economic decisions affecting food choice may have physiologic consequences. Laboratory studies suggest that energy-dense foods and energy-dense diets have a lower satiating power and may result in passive overeating and therefore weight gain. Epidemiologic analyses suggest that the low-cost energy-dense diets also tend to be nutrient poor. If the rise in obesity rates is related to the growing price disparity between healthy and unhealthy foods, then the current strategies for obesity prevention may need to be revised. Encouraging low-income families to consume healthier but more costly foods to prevent future disease can be construed as an elitist approach to public health. Limiting access to inexpensive foods through taxes on frowned upon fats and sweets is a regressive measure. The broader problem may lie with growing disparities in incomes and wealth, declining value of the minimum wage, food imports, tariffs, and trade. Evidence is emerging that obesity in America is a largely economic issue. *Am J Clin Nutr* 2005; 82(suppl):265S–73S.

KEY WORDS Obesity, poverty, energy density, energy intake, food prices, diet cost, economics

INTRODUCTION

Energy-dense foods and energy-dense diets have been blamed for the global obesity epidemic (1–5). In a number of studies, fast foods (6–9), snacks, sweets, and desserts (10, 11), sweetened soft drinks (12–14), and large portion sizes (15, 16) have all been linked to greater obesity risk.

Studies on obesity and the food environment have focused on the interaction between human physiology and the changing nature of the food supply. At different times, corn sweeteners (12), sucrose (17), protein (18), fat (19), and starch (20) were all said to promote overweight through a variety of metabolic mechanisms. Physiologic systems regulating food intake were said to be at fault. Whereas some researchers suggested that humans fail to compensate for calories in energy-dilute beverages (21), others blamed our weak innate ability to recognize calories in energy-dense foods (8). Whereas some implicated the consumption of sucrose (17), others reported that high-fructose corn syrup was responsible for high obesity rates (12). Still others suggested that the body's natural ability to count calories was impaired by noncaloric sweeteners (22). Where the food was eaten was another contributing factor. Whereas some reports identified away from home foods and restaurant meals as a potential cause of obesity (6, 7, 23, 24), others pointed to the key role of between-meal snacks (10) and growing portions of foods consumed at home (25).

In other words, published scientific research suggests that obesity is caused by the following: excessive consumption of protein, starch, sugar, and fat; by caloric and noncaloric sweeteners; by meals and by snacks; by beverages and by solid foods; by eating in fast-food and in full-service restaurants, as well as by eating at home. Only vegetables and fruit have not been linked to higher obesity rates, as yet (26, 27).

Modifying the food environment has risen to the top of public policy agenda (28, 29). Many such efforts have focused on removing the offending foods from the consumers' reach. Fear of the "toxic" food environment has led to proposed taxes on fats and sweets, to both discourage consumption and promote alternative healthier diets (30). Policy approaches to improving nutrition at schools have called for limiting access to vending machines containing beverages and snacks (3, 14, 31) and regulating the sale of competitive foods. Agricultural policy options include the provision of economic incentives for the production of healthier foods (31, 32) and the removal of existing subsidies. In addition, various sectors of the food, grocery, and restaurant business have found themselves exposed to lawsuits for their alleged role in causing obesity among their customers (33–35). Although most lawsuits were dismissed, future plaintiffs may

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[2] Presented at the symposium "Science-Based Solutions to Obesity: What Are the Roles of Academia, Government, Industry, and Health Care?", held in Boston, MA, March 10–11, 2004 and Anaheim, CA, October 2, 2004.

[3] Supported in part by the National Research Initiative of the USDA Cooperative State Research Education and Extension Service grant 2004-35215-14441.

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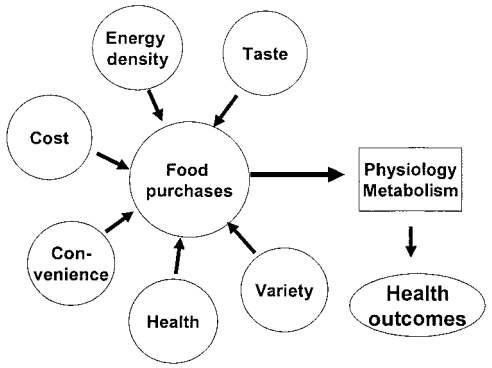

FIGURE 1. The influences on food purchases: consumer and marketing approach. Reprinted with permission from reference 38.

benefit from novel legal theories linking the food environment to greater obesity risk (36).

Although the dramatic rise in obesity rates can only be explained by environmental factors, there has been little emphasis on the obese persons' economic environment (24). In particular, there has been little research on diet quality and the economics of food choice (37–39). Existing studies suggest that the high cost of healthier diets may contribute to the obesity epidemic, especially among the lower-income groups (40, 41). Examining the links between dietary energy density, food prices, and diet costs is the chief focus of this report.

HOW DO PEOPLE MAKE FOOD CHOICES?

Identifying factors responsible for food selection should precede any effort at dietary change. Food choices are made on the basis of taste, cost, and convenience, and, to a lesser extent, health and variety (42). Taste refers to the sensory appeal of foods, such as palatability, aroma, and texture (43). The concepts of taste and energy density are intertwined, because the most energy-dense foods are usually the most palatable and vice versa (44). Energy density of foods is defined as the energy per unit weight or volume (kcal/100 g or megajoules per kilogram). Cost refers to the purchase cost per unit of energy (Euros/1000 kcal or dollars per megajoule) or the purchase cost of a daily diet (Euros of dollars per day). Convenience refers to the time spent on buying, preparing, and cooking food. Variety refers to the innate drive to secure a varied diet, whereas health refers to concerns with nutrition, chronic disease, and body weight. A model representing these factors is shown in **Figure 1**.

The literature on health promotion has emphasized the psychosocial aspects of food selection (45–47). The unspoken premise has been that adherence to healthy diets is essentially a matter of awareness, motivation, and making the right food choices. Largely missing from the literature has been any mention of limited economic resources and high diet costs (48). The average American spends less than $8.00/d on food and beverages, with low-income families spending as little as $25 per person per week (49). Although not all food purchases are price driven, each adult needs to obtain an energy ration of 2000–2500 kcal (8.32–10.4 MJ) each day at an affordable cost.

Researchers at the US Department of Agriculture (USDA) have pointed out that the American diet is inconsistent with the Food Guide Pyramid (50). The consumption of fats and sweets at the Pyramid's tip far exceeds recommendations, especially when compared with the low use of green leafy vegetables and fruit. There is a reason why refined grains, fats, and sweets have come to dominate the food supply. They are good tasting, energy dense, convenient to use, and inexpensive (49). Limited financial resources may be one reason why people are not eating more healthfully (40, 41).

In general, healthier diets cost more. Developments in agriculture and food technology have made added sugars and vegetable oils accessible globally at a remarkably low cost. The cost of producing sugar is Brazil is as low as 4¢/lb (9¢/kg) (51). The commodity cost of refined sugar (sucrose) in global markets is in the order of 9¢/lb (20¢/kg), whereas the cost of most vegetable oils is approximately 20¢/lb (44¢/kg) (38). In other words, ≈40 000 kcal (167 MJ) from added sugars and fats can be obtained at world market rates for only $2.00. Although there is little relationship between commodity cost and the retail cost of the finished food product, caloric sweeteners, grains, and added fats help to hold down the cost of the daily diet. Americans have the lowest cost food supply in the world. The typical American diet derives almost 40% of daily energy from added sugars and from added fats (50).

Diet quality, both in the US and elsewhere, is a function of social class. It is well known that older and wealthier consumers have higher quality, healthier, and more varied diets, with a higher proportion of high-quality meats, seafood, vegetables, and fruit (52–55). In contrast, lower-income households tend to select diets high in low-cost meats, inexpensive grains, added sugars, and added fats (56–59). In a recent study of low-income families, fruit and vegetable expenditures were low. Bananas were far more likely to be purchased than were the more expensive berries and other fruit (55). Food assistance recipients, taking part in USDA focus groups, were primarily concerned with obtaining sufficient calories at low cost, so that nobody would complain they were still hungry (60). Diet quality is influenced by socioeconomic position and may well be limited by financial access to nutrient-dense foods.

ENERGY-DENSE FOOD COST LESS

Teaching the poor how to satisfy protein and energy needs at the lowest cost was an early task of Wilbur Atwater (61). Historians regard that work as the beginning of significant nutrition research in the United States (62). At the time, working families spent ~50% of their income on food (62). Atwater's calculations established that wheat flour and dried beans provided energy and protein at a lower cost than did either meat or fruit. This hierarchy of food prices has remained primarily unchanged in more than 120 y. Dry foods with a stable shelf life are still less costly (per 1000 kcal or per megajoule) than are perishable meats, fish, dairy, or fresh produce. However, only limited contemporary data exist on the relationship between energy density and energy cost (63, 64). One obstacle is the lack of an updated food price database for the United States.

The INCA study (Etude Individuelle et Nationale sur les Consommations Alimentaires) was a national study of food consumption conducted by the French government. We were able to assign mean national retail price to each of the 895 foods in the nutrient database. Prices for most foods ($n = 760$) were based on a marketing database obtained from the Société d'Etudes de la Consommation, de la Distribution, et de la Publicité (SECODIP); other prices were obtained from the French National

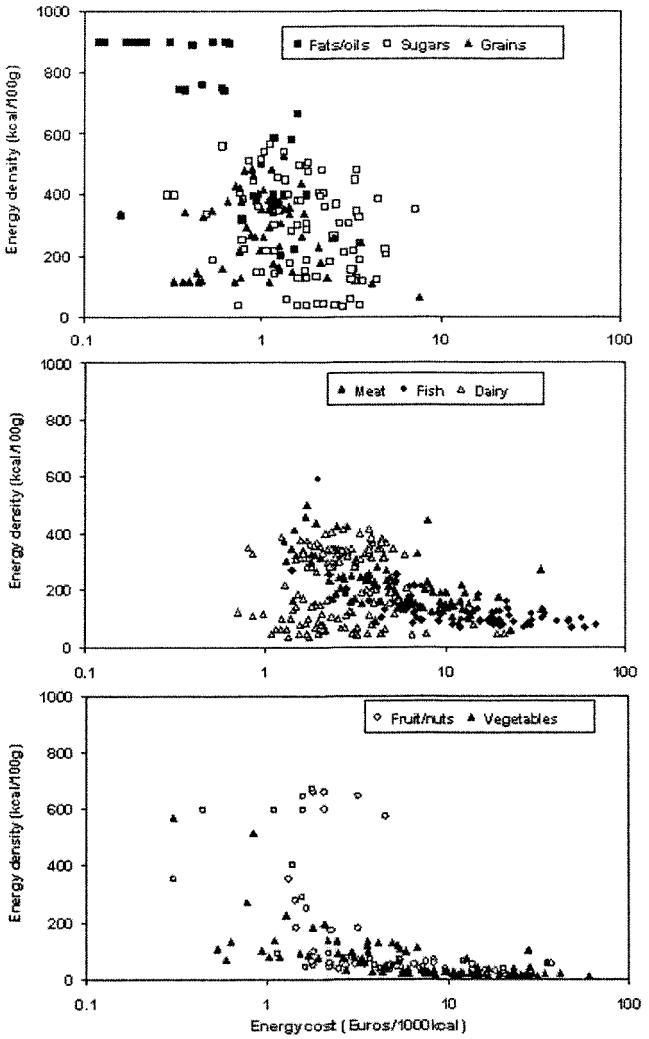

FIGURE 2. Relationship between energy density (kcal/100 g) and energy cost (Euros/1000 kcal).

Institute of Statistics [Institut National de la Statistique et des Etudes Economiques (INSEE)] and from supermarket websites. Energy density (kcal/100 g) was calculated using food composition tables. Mean cost per edible portion of food was calculated, after adjusting for preparation and waste (65).

Figure 2 shows a scatter plot of energy density of foods and their energy cost (in Euros/1000 kcal), 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, energy cost of sugar or oil was in the order of 0.1 Euros/1000 kcal. In contrast, the cost per calorie of meats, fish and shellfish, dairy products, vegetables, and fruit was much higher. As indicated by the logarithmic scale, the differential in energy costs between the "healthy" and "unhealthy" foods was several thousand percent. The frowned-upon fats and sweets and the recommended fresh produce were, in reality, separated by an immense gap in energy costs.

HEALTHIER DIETS COST MORE

If healthier foods cost more, then so will healthier diets. Our hypothesis was that dietary energy density and daily diet costs would be inversely linked, after adjusting for energy intakes. We therefore examined, for the first time, the relationship between energy density and the cost of freely chosen diets in a French community study (63). The Val-de-Marne dietary survey, conducted in 1988–1989, used probability sampling and a two-stage cluster-design procedure (66, 67). Dietary intakes were estimated using a dietary history interview, based on daily intakes representative of a habitual diet over 6 mo (68). Food consumption was assessed in terms of frequencies (per week) and quantities consumed (portion sizes) in a manner similar to a food frequency questionnaire. The analyses were based on 837 adults aged ≥18 y (361 men and 476 women) and on 57 food items, after excluding drinking water, alcoholic beverages, and baby and infant formula products. The complete Val-de-Marne nutrient database has been published previously (66).

Dietary energy density (megajoules per kilogram) was obtained by dividing energy intakes by the estimated edible weight of all foods and caloric beverages (69, 70). 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 (INSEE 2000). A column of prices in Euros (1€ = 1.17 US$ in June 2003) was added to the Val-de-Marne food composition database. The price of red meat was based on frozen hamburger, whereas the price of poultry was based on chicken breasts. The prices of hard cheese and soft cheese were based on the price of Emmental and Camembert cheeses. The vegetable category was represented by prices for potatoes, tomatoes, carrots and endives (all fresh), mixed vegetables, peas and beans (all canned), and dried lentils. The foods selected to represent the cost of diets were the more frequently consumed and lower-cost options, including some frozen and canned foods. The present method of estimating diet costs is based on the assumption that all foods were purchased and then prepared and consumed at home. The same exact assumption had been made by the US Department of Agriculture in developing the Thrifty Food Plan (71). Diet costs were estimated based on retail food prices, assuming that the foods were prepared and consumed at home (71).

Mean energy intakes without alcohol in the Val-de Marne dietary survey were 9.89 MJ for men and 7.38 MJ for women. The more energy-dense diets were associated with a higher consumption of grains, fats, and sweets and negatively with the consumption of fruit and vegetables, after adjusting for energy. Dietary energy density (megajoules per kilogram) was associated with higher energy intakes ($R^2 = 0.31$, $P < 0.0001$), consistent with previous reports.

Mean estimated diet cost was 5.59 €/d for men and 4.63 €/d for women. That estimated daily diet cost of approximately 5 €/d was very close to the mean national expenditures for at-home foods, as calculated by INSEE from the National Budget Survey (4.9 € per person per day) (72). Energy density of the diet and energy cost were inversely linked (73). Women consumed more vegetables and fruit and had more energy-dilute diets; mean estimated energy cost per 10 MJ was higher for women (6.56 €/d) than for men (5.85 €/d) (73).

Participants were then split by quintiles of energy intake (megajoules per day), and the relationship between diet composition and diet costs was assessed separately for each quintile in a regression model, adjusted for sex and age. The question was whether replacing fats and sweets with more vegetables and fruit would be associated with higher diet costs. **Figure 3** shows that,

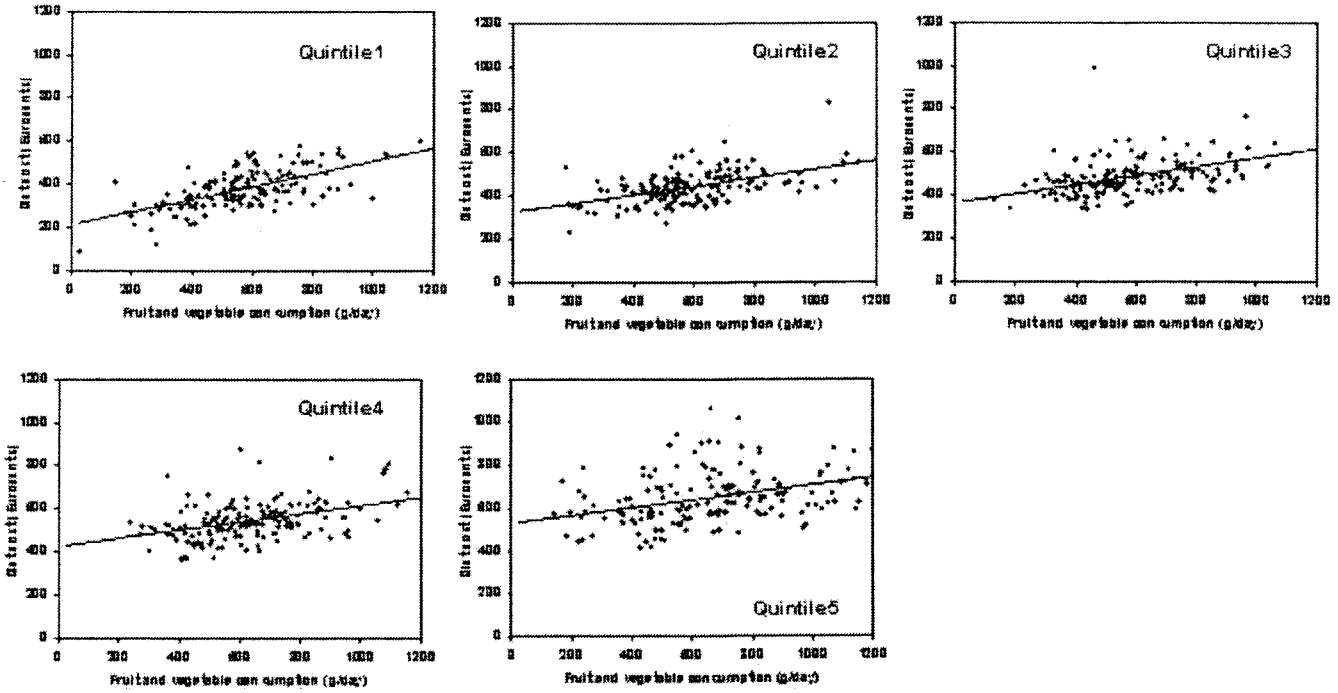

FIGURE 3. Relationship between fruit and vegetable consumption (grams per day) and diet costs (Euros per day). Regressions are for each quintile of energy intake.

depending on energy intakes, each 100 g increment in fruit and vegetables consumption was indeed associated with an increase in diet costs of 0.18–0.29 €/d.

In contrast, higher consumption of fats and sweets was associated with a net saving in diet costs (74). **Figure 4** shows that, for persons in the lowest energy quintile, each 100 g of fats and sweets was associated with a 0.40 €/d reduction in daily diet costs. The relationship flattened as energy intake increased, but even for persons in the highest energy quintile, each 100 g of fats and sweets was associated with a saving of 0.13 €/d. In other

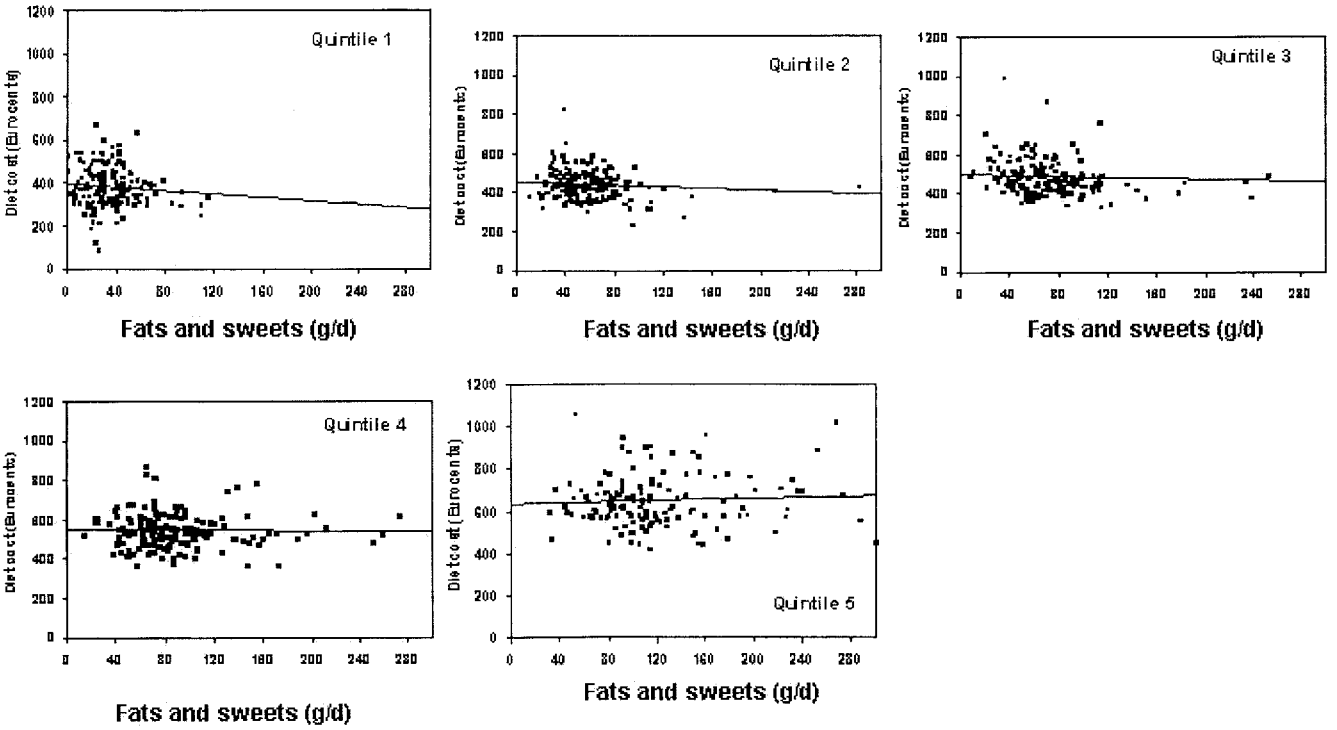

FIGURE 4. Relationship between fats and sweets consumption (grams per day) and diet costs (Euros per day). Regressions are for each quintile of energy intake.

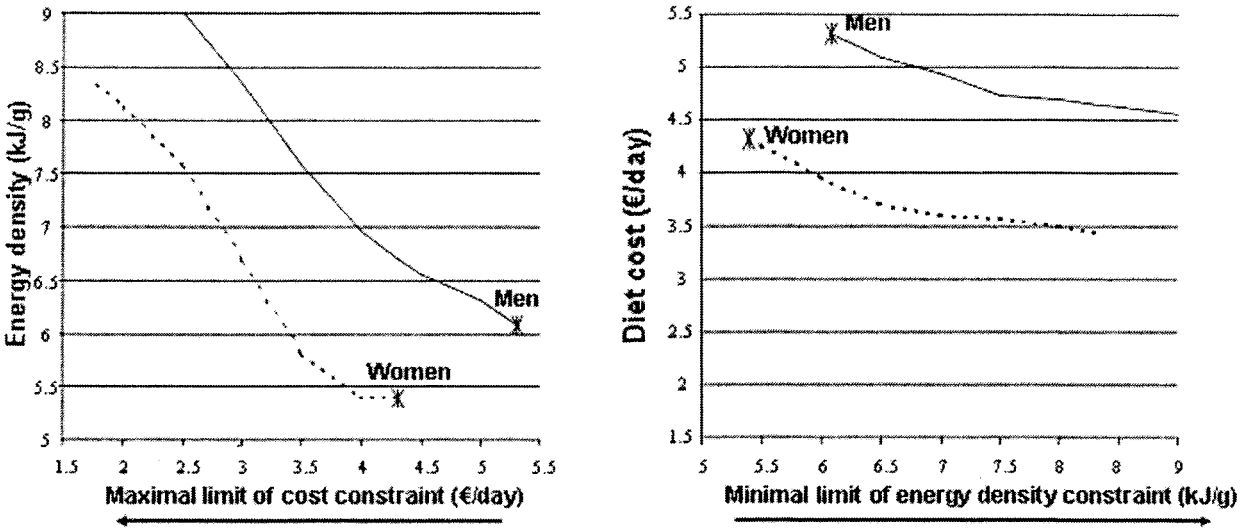

FIGURE 5. Left, Impact of a cost constraint on dietary energy density in a linear programming model. Right, Impact of an energy density constraint on the cost of diets in a linear programming model. Printed with permission from reference 41.

words, sweets and fats cost less, whereas energy-dilute diets high in vegetables and fruit cost more (74).

ESTABLISHING CAUSAL PATHWAYS

The present hypothesis is that reducing diet costs will lead to a lower-quality diet. The observed inverse association between diet quality and diet costs was based on a cross-sectional community study of French adults (73, 74). The causality hypothesis was tested using linear programming models, as applied to those freely chosen diets.

Linear programming models optimize a given function, subject to a variety of constraints. They have been used to design least-cost nutritious diets that were minimally acceptable to the consumer (75–77). Our goal was to explore the impact of economic constraints on the nutritional quality of the diet while keeping palatability high. Nutritional constraints were not included in the model whose objective was to minimize deviations from the usual French diet while progressively decreasing diet cost. The question was what kind of a diet can be obtained at low cost if economic resources are limited and the consumer is unwilling to adopt unfamiliar eating habits.

Imposing a progressive cost constraint, exclusive of nutritional considerations, led to a low-cost energy-dense diet (41). The consumption of vegetables and fruit was low, and dietary energy was primarily provided by cereals and added fats. In contrast, deliberately increasing energy density of the diet did not lead to a major decline in diet costs (41). **Figure 5** shows that the impact of cost on energy density (left panel) was much greater than the impact of energy density on cost (right panel).

In other words, deliberately selecting an energy-dense diet need not lead to lower diet costs. Conversely, restricting food expenditures will inevitably lead to more energy-dense diets. Consumers on a limited budget will find it difficult to find healthier diets unless they are willing to adopt unfamiliar eating habits, depart from social norms, and subsist on unpalatable foods. Strategies for dietary change, including the USDA Thrifty Food Plan (71), generally assume that the low-income consumers will do just that (78). Whereas good nutrition in the form of liver, dry legumes, peanuts, and canned fish can be inexpensive, such a diet scores low on taste, variety, enjoyment, and convenience. Although healthy diets can be assembled using inexpensive products (79, 80), USDA researchers acknowledge that this "may require some sacrifices in taste" (48). Persons facing economic constraints will preferentially select lower-cost energy-dense diets rather than abandon their usual eating habits. Strategies for dietary change ought to take food preferences and the usual eating habits into account.

Additional support for a causal link between poverty and obesity is provided by the growing price gap between healthy and unhealthy foods. Analyses of price increases during the period 1985–2000, shown in **Figure 6**, show that the cost of sweets, fats, and caloric beverages fell substantially in relation to fresh vegetables and fruit. Whereas the retail price of fresh vegetables and fruit registered a 120% increase, food items that best held their price were fats and sweets. If anything, these trends accentuate income-based disparities in the access to healthy diets.

Such disparities may not be remedied by small shifts in either incomes or in food prices. A recent USDA study showed that low-income households spent approximately $1.43 less per person per week on fruit and vegetables compared with higher-income households (81). Whereas higher-income households

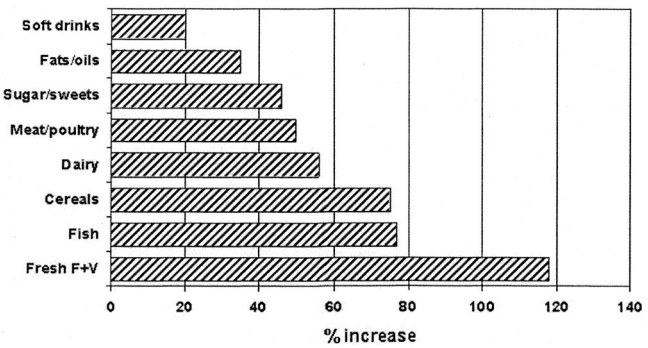

FIGURE 6. Increase in retail prices in 1985–2000 for foods in different categories. Data source: Economic Research Service of the USDA, FoodReview 2002 (108).

did increase fruit and vegetable consumption after 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 their limited resources on items that were perceived as more essential such as meat, clothing, or rent (81).

Americans have the lowest-cost food supply in the world and spend the lowest proportion of disposable income on food (~12%) (82). Until recently, no one has seriously questioned whether a low-cost food supply brought anything but benefits to the United States. However, studies are beginning to link the low cost of foods with the obesity epidemic. One study found that technological advances led to a decline in the price of food, which in turn led to higher energy intakes (83). The drop in food prices was said to account for up to 40% of the increase in body mass index since 1980 (83). Another study, based on national Behavioral Risk Factor Surveillance System data, linked higher obesity rates to lower food prices, a growing number of restaurants, and the higher cost of cigarettes (24). However, not all food prices have dropped. The downward trend in food prices, relative to other goods, was most marked for energy-dense foods, added sugar, and added fat.

To close the price gap between healthy and unhealthy foods, many policy options now call for taxes and levies on snacks, fats, and sweets (30, 31). However, such measures are primarily aimed at the lower-income consumer and have been criticized as punitive. It is the population subgroups with least resources that are most vulnerable to the obesity epidemic.

WHY POVERTY AND OBESITY ARE CAUSALLY LINKED

The rates of obesity and type 2 diabetes in the United States and other industrialized countries follow a socioeconomic gradient, with highest rates observed among minorities and the poor (52, 84–88). At the individual level, obesity rates are linked to low incomes, low education, minority status, and a higher incidence of poverty (52, 84, 85, 89). At the environmental level, obesity rates were higher in lower-income neighborhoods, legislative districts, and low-income states (90). Although obesity rates have been increasing steadily in both sexes, at all ages, in all races, and at all educational levels (85, 91), highest rates continue to be observed among the most disadvantaged groups.

The Healthy People 2010 report (92) acknowledged that obesity rates were higher among adolescents from poor households relative to middle- and high-income households; among African American women relative to white women, and among low-income relative to the more affluent groups. However, the dietary behaviors of obese persons continue to be viewed through the prism of medicine, physiology, and behavior. Cravings for energy-dense fats and sweets have been explained by neurotransmitter imbalance (44, 93, 94). Excess consumption of added sugars and fats has been explained using such concepts as satiety deficits and passive overeating (5, 43, 44, 95, 96). The consumption of sweets and desserts has been explained in terms of an addictive personality, stress, depression, and seeking comfort in familiar foods. The failure to adhere to 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 (97).

The present hypothesis is that the observed links between poverty and obesity are primarily accounted for by purely economic variables (40). What refined grains, added sugars, and added fats have in common is their low energy cost. Diets of lower-income households provide cheap, concentrated energy from fat, sugar, cereals, potatoes, and meat products but offer little in the way of whole grains, vegetables, and fruit (98-100). 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. It is well established that higher diet quality, as measured by the Healthy Eating Index, is associated with higher incomes, more education, and with lower rates of obesity and overweight (39, 101).

OBESITY PREVENTION AND THE COST OF DIETS

The observation that healthier diets are likely to cost more poses some problems for the current strategies for health promotion. Although recognizing higher obesity rates among the more disadvantaged groups, the Surgeon General's Call to Action for obesity prevention called for more nutritious diets, including more vegetables and fruit (102). The National Institutes of Health Obesity Education Initiative advised obese patients to look for guavas, persimmons, star fruit, kiwi, and papaya in preference to bologna and American cheese (103). Dietary recommendations in the Healthy People 2010 report mentioned a healthful assortment of vegetables, fruit, whole grains, low-fat milk products, and fish, lean meat, poultry, or beans (92). African American men have been the focus of a public awareness cancer prevention campaign that encourages them to consume nine servings of fruit and vegetables per day (104).

Seemingly, the issue of diet costs has not been a concern. However, studies conducted in Australia, Canada, and the European Union have found that healthier diets cost more. One United Kingdom study (38) found that vegetarian diets high in fruit and vegetables were associated with higher diet costs. The direct monetary cost of the diet was calculated using average national prices from the 1995 United Kingdom National Food Survey and the Tesco home shopping catalog (38). In Denmark, low-fat diets for children were associated with higher costs (105). In another French study, diets with a higher content of vitamins and minerals were associated with higher diet costs (106). These studies contrast with the prevailing United States view that healthful diets do not represent an increased financial burden to the consumer and may actually cost less (79, 80).

The view that all foods are equally affordable is challenged by some recent reports. **Figure 7**, based on the Val-de-Marne data set, shows that meat, vegetables, and fruit contributed more to diet cost than to dietary energy, whereas grains, fats, and sweets provided energy at a lower cost. Diets that replace starches and fats with isocaloric amounts of lean meats and fresh produce are likely to cost more. Indeed, the average cost of the Atkins diet was recently estimated at $14.27/d, whereas the South Beach Diet was estimated at $12.78/d (107). Those figures contrast with the estimated $4 per person per day that some low-income families spend on food.

THE ECONOMICS OF OBESITY

Food policy interventions at the national and international level may be the most promising approach to making healthy

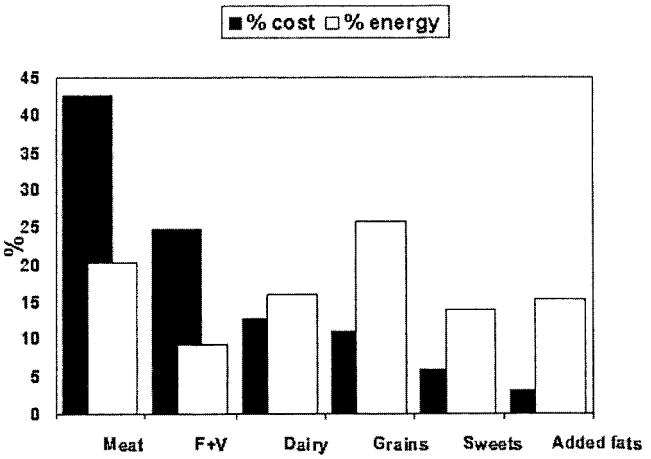

FIGURE 7. Relative contribution to dietary energy intakes and to diet cost of foods from six major food groups in the Val-de-Marne study.

foods affordable and accessible to all (1). The World Health Organization (1) stated that the key to maintaining healthy weight was an affordable supply of fresh nutrient-rich foods. Such access could be facilitated through a combination of agricultural subsidies, pricing policies, regulatory action, and consumer education. Such approaches involve a cooperation between governments, academia, and the food industry.

Total US expenditures on all foods and beverages were estimated at $900 billion in 2002 (108), the lowest-cost food supply in the world. Annual medical expenditures in the United States that can be attributed to obesity were estimated at $75 billion in 2003 (109). To save on medical costs, consumers are encouraged to select healthier and more nutrient-dense diets. However, an increase in daily food expenditures of as little as 75¢ per person per day would mean an added expense of some $80 billion per year in diet costs. It is unclear how these costs are to be absorbed by the consumer.

Obesity lawsuits draw heavily on the parallels made between the food and the tobacco industries (36). However, the aptness of this analogy may require more careful thought. Stemming the obesity epidemic cannot be separated from stemming the tide of poverty. Are the various sectors of the food, grocery, and restaurant business legally liable for providing low-income consumers with inexpensive foods? Or is it possible that the rising obesity rates reflect an increasingly unequal distribution of incomes and wealth (110)? Does the obesity problem lie with fast-food outlets and vending machines, or are there broader societal issues that have to do with the falling value of the minimum wage, the lack of health and family benefits, and declining neighborhood resources? These issues need to be addressed through a concerted program of environmental and policy interventions There is growing evidence that obesity in America is a largely economic issue.

Both AD and ND contributed to formulating research questions regarding diet quality among low-income groups. AD was responsible for the literature search on the economics of obesity and writing of the manuscript. ND was responsible for the analyses of the relationship between diet quality and diet cost. Neither AD nor ND has a financial interest in this work or a conflict of interest with the sponsors of this study.

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