Does social class predict diet quality?[1–3]

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ABSTRACT
A large body of epidemiologic data show that diet quality follows a socioeconomic gradient. Whereas higher-quality diets are associated with greater affluence, energy-dense diets that are nutrient-poor are preferentially consumed by persons of lower socioeconomic status (SES) and of more limited economic means. As this review demonstrates, whole grains, lean meats, fish, low-fat dairy products, and fresh vegetables and fruit are more likely to be consumed by groups of higher SES. In contrast, the consumption of refined grains and added fats has been associated with lower SES. Although micronutrient intake and, hence, diet quality are affected by SES, little evidence indicates that SES affects either total energy intakes or the macronutrient composition of the diet. The observed associations between SES variables and diet-quality measures can be explained by a variety of potentially causal mechanisms. The disparity in energy costs ($/MJ) between energy-dense and nutrient-dense foods is one such mechanism; easy physical access to low-cost energy-dense foods is another. If higher SES is a causal determinant of diet quality, then the reported associations between diet quality and better health, found in so many epidemiologic studies, may have been confounded by unobserved indexes of social class. Conversely, if limited economic resources are causally linked to low-quality diets, some current strategies for health promotion, based on recommending high-cost foods to low-income people, may prove to be wholly ineffective. Exploring the possible causal relations between SES and diet quality is the purpose of this review. *Am J Clin Nutr* 2008;87:1107–17.

INTRODUCTION

Morbidity and mortality rates in industrialized societies follow a socioeconomic gradient (1–3). The more disadvantaged groups suffer from higher rates of obesity (4–6), diabetes (7, 8), cardiovascular disease (9), osteoporosis (10, 11), dental caries (12), and some forms of cancer (13). All of these diseases have a direct link to nutrition and diet (14). It has been suggested, more than once, that dietary factors may help explain some of the observed social inequities in health (15, 16). The more affluent population subgroups are not only healthier and thinner, but they also consume higher-quality diets than do the poor (17).

Diet quality is affected not only by age and sex, but also by occupation, education, and income levels (18–20)—the conventional indexes of socioeconomic status (SES) or social class (21). The different socioeconomic indicators appear to have similar, although independent, effects on nutrition and diet (18–20, 22). However, a convincing causal relation between SES indicators and diet quality still remains to be established. Given that SES variables are likely to affect all aspects of energy balance, from access to healthy foods to opportunities for physical activity, there is a pressing need to address them directly in the context of epidemiologic research. It may well turn out that the reported associations between diet quality and better health, found in so many epidemiologic studies, may have been confounded by unobserved indexes of socioeconomic status.

EVIDENCE OF A SOCIAL GRADIENT IN DIET QUALITY

Dietary energy density is one index of the overall quality of the diet (23). Diets high in whole grains, lean meats, fish, and fresh vegetables and fruit have a low energy density (defined as the available dietary energy per unit weight) and a high content of vitamins and minerals (23, 24). In many epidemiologic studies, their consumption has been associated with better health (14). Conversely, diets high in refined grains, added sugars, and added fats tend to be energy-dense but nutrient-poor (24). Such diets have been associated with higher energy intakes and with lower intakes of several micronutrients (23, 24). In epidemiologic studies, their consumption has been associated with higher disease risk and higher mortality rates (14). In some studies, dietary energy density was an independent predictor of obesity and the metabolic syndrome (25).

Studies suggest that energy-dense foods and energy-dense diets may predispose the consumer to overeating (26). Palatability is one explanation. Energy-dense foods, especially mixtures of sugars and fat, tend to be more palatable than foods of low energy density and high water content (27). A reduced volume of energy-dense foods is said to suppress satiation and satiety (26).

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For the same amount of food, a greater quantity of energy is consumed when the food is high in energy than when its energy density is low (27). The combined effects of high-energy density and large portion size may also lead to excess energy intakes and body weight gain (28). Reducing the energy density of the diet by replacing added sugars and fats with fresh vegetables and fruit has become a standard strategy for weight management (25). However, low-energy-density diets can entail substantially higher diet costs (29).

Alternative indexes of dietary quality have been based on compliance with dietary recommendations and guidelines. Higher values of the Healthy Eating Index (30), Diet Quality Index (31), dietary variety (32) and diversity (33) scores, and other diet-quality measures (22, 34–38) have all been associated with higher SES. The same positive relation with SES was observed for dietary patterns (16, 39). Similarly, studies of household food purchases, a proxy for food consumption, found a positive relation between household SES and the quality (20, 40) and variety (41) of purchased diets.

Index foods and food groups

Several cross-sectional dietary surveys have noted that the consumption of different types of foods by adults was unevenly distributed by SES variables. Data from such studies are summarized in **Table 1**. In some cases, particulars were given about the food type (eg, fresh vegetables and fruit), but in other cases they were not.

Most studies noted that the consumption of whole grains was associated with higher SES, whereas the consumption of refined cereals (white bread), pasta, and rice was associated with lower SES (18, 42, 49, 51, 52, 72). In the 1986–1987 dietary survey of British adults, a 4-fold difference was found between nonmanual and manual social classes in the consumption of whole grains (50). Lower SES groups also consumed significantly more potatoes (18, 43–46, 48, 72).

Higher SES groups were more likely to consume vegetables and fruit, particularly fresh, not only in higher quantities but also in greater variety (59). A recent meta-analysis of studies from 7 European countries showed that fruit and vegetable consumption was consistently higher in the highest than in the lowest SES group, defined by educational level. The estimated differences in fruit consumption were 24 g/d for men and 34 g/d for women, whereas the differences in vegetable consumption were 17 g/d for both men and women (56). In Australia, a 3-fold difference was found between bottom and top quintiles of income for not consuming fruit on the previous day (59). In the Netherlands, women with a basic education level were almost 3 times as likely to be low consumers of fruit than were the most educated groups (73). In a recent Canadian analysis

TABLE 1

Socioeconomic status (SES; education, income, and/or occupation) and food intakes: summary of findings from individual food consumption surveys in adults

High intakes among low-SES individuals	High intakes among high-SES individuals
Grains and starchy vegetables	
Bread, white, or unspecified (37, 42–46)	Whole bread (37, 44, 45, 47–50)
Pasta/rice/cereals, refined or unspecified (18, 42, 49, 51, 52)	
Potatoes (18, 43–46, 48)	
Legumes (32, 42)	
Vegetables and fruit	
	Fruit and vegetables, unspecified (44, 45, 53–61)
	Fruit and vegetables, fresh (62)
	Vegetables, unspecified (18, 19, 33, 37, 43, 47, 63, 64)
	Vegetables, fresh/frozen (15, 42, 65)
	Fruit, unspecified (15, 19, 33, 37, 45, 46, 48, 63, 66)
	Fruit, fresh (42, 43, 52)
	Fruit juices (19, 43, 46)
	Nuts (65)
Meat, fish, eggs	
Meat, unspecified (18, 44, 46, 48, 67)	Meat, unspecified (42, 47, 49)
Organ meats (51)	
Fatty/fried/canned/deli meats, sausage, stews (32, 37, 42, 43, 45, 48, 49, 51, 63, 65)	Lean meat (37, 45, 48)
Fish, fried/canned (32, 51)	Fish/seafood, unspecified (18, 19, 37, 46, 52, 63)
Eggs (32, 37, 68)	
Dairy products	
Milk, unspecified (43, 44)	Milk, low-fat (15, 37, 45, 47–49, 63, 69)
Milk, whole (49, 63, 64, 69)	Cheese (19, 37, 43, 44, 46–49, 70)
Fats and sweets	
Added fats, unspecified (19, 44, 45, 48, 71)	Added fats, unspecified (47)
Animal fats (42, 43, 70)	
Vegetable fats (46)	Vegetable fats (19)
Sugar (18, 42, 46, 49)	Candy (42)
Sweets/cakes (46, 48, 65)	Pastries/desserts (42, 47)
Beverages	
Sweetened beverages (37, 46)	
Beer (18, 45, 46)	Wine, alcohol (45, 46, 65)

of food budget surveys, the strongest positive relation between income and the quantities of food purchased was found for fruit and vegetables (74).

In some European countries, lower SES groups consumed more vegetables and fruit, as reported in food budget surveys in Greece, Spain, and Portugal (72, 75) and in the Eastern European countries Poland and Hungary (75). These countries also have the highest consumption rate of domestically produced foods (75). However, the gap in fruit and vegetables consumption between North and South Europe is narrowing (76), as class disparities are replacing geographic ones. Studies from the United Kingdom and the United States suggest that SES disparities in fruit and vegetables consumption have increased over time (77, 78). In contrast, in Finland, SES differences in vegetable consumption have slightly narrowed since 1979 (22).

Although there was no reported SES difference in total milk consumption (69), in most studies, skim or low-fat milk was the preferential choice for those in the highest SES categories, as was the consumption of cheese (70). A meta-analysis of dairy consumption in Europe showed that the consumption of cheese by the higher SES group exceeded consumption by the lower SES group by 7 g/d for men and by 9 g/d for women (69).

The consumption of lean meats, fish, and other seafood was associated with higher SES in a large number of studies (19, 37, 46, 63). Lower SES groups tended to consume larger quantities of fatty meats instead of the recommended lean meat items. Fried, breaded, and canned fish were all consumed in greater quantities by lower SES groups, who also consumed more stews (63) and fried foods (55).

Diets of lower SES groups were also characterized by more added fats (19, 44, 45, 48, 71), although only a few studies distinguished between animal fats and vegetable fats. There was less evidence that SES was related to sweets consumption. However, within the sweets category, higher SES groups consumed more candy and pastries (42, 47), whereas lower SES groups consumed more sugar and cake (18, 42, 46, 48, 49, 65).

A direct link between SES and the nutritional quality of diets was also reported among children and adolescents. A study in France showed that children of semiskilled and unskilled workers consumed significantly more sweets, bread, potatoes, cereals, and deli meats than did children from the upper SES group (79). In the United States, children and adolescents from low SES households consumed less fruit and vegetables (80, 81) and a more limited variety of produce (82). Children from families with lower education levels had the lowest fruit intakes and the highest consumption of sweetened beverages (83). Several European studies have also reported low fruit and vegetable intakes and a high frequency of soft drink consumption among low-SES children and adolescents (84–87).

In summary, the available evidence suggests that the consumption of whole grains, lean meats, fish, low-fat dairy products, and fresh vegetables and fruit was consistently associated with higher SES groups, whereas the consumption of fatty meats, refined grains, and added fats was associated with lower SES groups.

Fiber and micronutrient intakes

Intakes of some essential vitamins and minerals follow a socioeconomic gradient consistent with the food consumption patterns described above. As summarized in **Table 2**, higher SES groups had consistently higher intakes of most vitamins and minerals and fiber than did lower SES groups (15, 18, 37, 42, 43, 46, 48, 68, 78, 88–92). This was true regardless of whether the intakes were expressed in absolute amounts or were corrected for energy.

Consistent with a low consumption of fruit and vegetable by lower SES groups, intakes of dietary fiber were also consistently lowest in that group (18, 19, 37, 44, 45, 48, 49, 54, 55, 68, 88, 90–93). Low-SES groups also had the lowest consumption of vitamin C, β-carotene, and folate (15, 37, 42, 43, 48, 68, 78, 88–92), vitamin E (37), and plant-based polyphenols (98).

Low iron intakes among low-SES populations were found in most studies (37, 46, 48, 90, 91) and so were lower intakes of calcium and potassium (18, 37, 46, 48, 90, 91, 96, 97). Some studies showed significantly higher sodium intakes (90) or higher ratios of sodium to potassium (96) among lower SES respondents. Lower intakes of vitamin D were also observed (18), consistent with the low consumption of fish by lower SES groups.

Similar patterns of micronutrient intake were reported among lower SES children and adolescents (84–86). Dietary intakes of vitamin C, folate, and iron were insufficient to meet dietary recommendations (80, 99–101). These nutrient deficiencies may be exacerbated by low rates of breastfeeding among lower SES families (102–104), with potential consequences on iron nutrition status (105, 106) and future obesity risk (107).

Energy and macronutrient intakes

On the other hand, the association found between SES and energy intakes or the macronutrient composition of the diet intakes was either not statistically significant or inconsistent. As shown in Table 2, the associations observed between SES and protein consumption were positive (37, 45, 90), negative (88, 92), or not significant (18). No consistent SES gradient was obtained for carbohydrate intakes. Differences between SES categories were either not significant (18, 45, 46) or were variable depending on the study (36, 43, 68, 88–91). Some studies found higher intakes of sucrose in adults of lower SES (37, 88).

No consistent SES gradient was observed for total fat intakes. Some studies showed evidence of a higher fat intake among low-SES groups (48, 49, 54, 92); however, an equally large number of studies found no significant differences (18, 43, 46, 68, 78, 89, 94, 108). Other studies obtained results that differed according to country, ethnic origin, or type of SES indicator (19, 45, 55, 66, 88, 91, 95). In the recent analysis of the Canadian food budget surveys, fat was the only nutrient not related to income, whereas a positive income gradient was found for all of the micronutrients studied (74).

There may be some differences by SES in the types of fat consumed, although the data were inconsistent. Some studies reported higher energy contributions from saturated fats and/or cholesterol among lower SES groups (19, 37, 45, 91, 92); however, other studies did not (18, 33, 43, 46, 89, 94). Studies that analyzed ratios of polyunsaturated to saturated fatty acids produced inconsistent results, variously reporting lower ratios (45, 88), higher ratios (48), or no significant differences (63, 94) between low-SES groups and the rest of the population. A recent meta-analysis of European studies reported significantly higher total fat and saturated fat intakes in adults with a low SES (with occupation level as the indicator) than in those with a higher SES in the majority of countries, except Spain and Estonia (109). However, the differences were small, in the order of 1% and 0.2%

TABLE 2
Variation in energy and nutrient intakes by socioeconomic status (SES; education, income, and/or occupation): summary of findings from individual food consumption surveys in adults[1]

	High intakes among low-SES individuals	High intakes among high-SES individuals	Not statistically significant (or inconsistent)
Energy intakes			
Men	(19, 42, 43, 45, 46, 48, 68, 88)	(33, 90)	(18, 37, 91–93)
Women	(44, 45, 88)	(33, 90)	(18, 19, 37, 42, 43, 46, 48, 91, 92)
Carbohydrates			
Men	(88)		(18, 36, 43, 45, 46, 89, 91)
Women	(43, 89)	(36)	(18, 45, 46, 88, 91)
Proteins			
Men	(88, 92)	(37, 45, 90)	(18)
Women	(88, 92)	(37, 45, 90)	(18)
Fats			
Men	(48, 49, 55, 92)	(88)	(18, 19, 37, 43, 45, 46, 89, 91, 94, 95)
Women	(36, 37, 45, 48, 49, 54, 55, 88, 92)		(18, 19, 43, 44, 46, 89, 91, 94, 95)
Fiber			
Men		(18, 19, 37, 45, 48, 49, 55, 88, 90–93)	(43, 89)
Women		(18, 19, 37, 44, 45, 49, 54, 55, 88, 90–92)	(43, 48, 89)
Vitamin C			
Men		(15, 37, 42, 43, 68, 88–92)	(46, 48)
Women		(15, 37, 42, 43, 48, 88–92)	(46)
Folates			
Men		(37, 90–92)	
Women		(37, 90–92)	
β-Carotene			
Men		(15, 42, 43, 68, 88, 90)	(48, 89)
Women		(15, 42, 43, 48, 88, 90)	
Calcium			
Men		(18, 37, 46, 48, 90, 91, 96)	(89)
Women		(18, 37, 46, 48, 90, 91, 96, 97)	(89)
Iron			
Men		(18, 37, 46, 90, 91)	(48)
Women		(18, 37, 46, 48, 90, 91)	

[1] Macronutrient intakes were always expressed as a percentage of total energy or in daily quantities adjusted for total energy. Fiber and micronutrient intakes were analyzed after energy adjustment or expressed as nutrient densities except in references 42, 49, and 93. Nutrient intakes of men and women were analyzed separately in all studies, with few exceptions (15, 33). Only men were analyzed in references 68, 93, and 97. Only women were analyzed in references 44 and 54.

of energy intakes for total lipids and saturated fats, respectively, between extreme levels of SES (109). In fact, high- and low-SES groups seem to have different sources of saturated fats; the former use more cheese, whereas the latter use more butter and fatty meats (62).

The data on total energy intakes by SES were equally inconsistent. Several studies have reported higher energy intakes among populations of low SES (19, 42–46, 48, 68, 88). However, in most of those studies, this inverse relation between SES and energy intakes was observed primarily among men (19, 42, 43, 46, 48, 68). Other studies found that energy intakes did not vary with SES (18, 89, 92, 93) or found variations depending on country, ethnic origin, or type of SES indicator (37, 91). One problem is that underreporting of energy intakes is a major source of bias in dietary surveys, and its prevalence shows a marked inverse association with SES (89, 108). In contrast, in food budget surveys, the amount of energy purchased was higher among high-SES households because of a higher amount of food wasted in these households (74). As a result, there is no agreement as to the influence, if any, of social class on total energy intakes.

Dietary energy density has been used as another proxy measure of diet quality (23, 24). Because water contributes to energy density more than any macronutrient, dietary energy density measures are primarily influenced by the proportion of vegetables and fruit (27). A recent analysis of the National Health and Nutrition Examination Survey (NHANES) 1999–2002 observed a negative relation between SES and dietary energy density. Higher education and the highest income level were associated with lower dietary energy density (33). A negative relation was also found between income level and the energy density of food purchases among Canadian households (74). Recent data from the consumer panel on food expenditures in France similarly showed that higher incomes were associated with lower energy density and higher nutrient density of food purchases (110).

Vitamin and mineral status

Studies of plasma biomarkers of dietary exposure provide additional evidence that SES affects diet quality. However, it must be noted that these studies have typically focused on nutritionally at-risk groups, namely, elderly persons and pregnant and breastfeeding women.

In the recent European Prospective Investigation of Cancer–Norfolk study, low-SES individuals had significantly lower plasma vitamin C concentrations than did high-SES individuals. This SES gradient was found to be independent of cigarette and vitamin supplement use and was observed among both men and women (111). In a study of persons aged >65 y, conducted in the United Kingdom, plasma concentrations of vitamins C and B-12, riboflavin, and β-carotene (and other carotenoids) were lower in the low-SES group than in the high-SES group (90, 112). In this study, a 2-fold difference was observed in vitamin C intakes, and this was associated with a 4-fold difference in plasma vitamin C (90). Urinary measures of sodium and potassium indicated an imbalance in the ratio of sodium to potassium, with less favorable potassium concentrations found in the low-SES group (90). The French EVA study (113), conducted in persons aged 57–71 y, showed a positive association between participant SES and their selenium and carotenoid status, even after adjustment for a large number of potential confounding factors, such as age, sex, body mass index, alcohol, tobacco, and lipid variables. Other studies suggested that pregnant or breastfeeding women of low SES were at greater risk of insufficient vitamin and mineral intakes (114, 115), inducing iron (116) and vitamin A (117) deficiencies. In other studies, deficiencies in plasma vitamin A, iron, and selenium were more common among children in lower SES households (106, 118–123).

SEARCH FOR CAUSAL MECHANISMS

Associations found in cross-sectional studies are not, by themselves, evidence of causality. A plausible biological or behavioral mechanism is required to draw causal links between SES indicators and diet-quality measures. This can be a challenge, because the determinants of food choice are both complex and multifactorial. Rather than focus on individual nutrition knowledge (124) or on motivation or behavior (125, 126), the current trend is to emphasize structural factors such as access to grocery stores, transportation, and neighborhood safety as well as inequities in access to healthy foods (127–130). There is also an increasing awareness that healthier foods are associated with increased monetary and time costs (17).

Food prices and diet costs

The observed SES gradient in diet quality may be mediated by food prices and diet costs (17, 29, 131–133). It follows from economic theory that food price is an important determinant of food choice (134–137). Not surprisingly, the lowest-cost diets are also the least healthy (138–140). In general, high-energy-density diets are associated with lower costs (29), whereas nutrient-dense diets are associated with higher costs per megajoule (24, 141). As shown in **Figure 1**, on the basis of a large sample of self-selected diets in the French population, participants in the lowest quartile of energy cost had the highest energy intakes, the most energy-dense diets, and the lowest daily intakes of key vitamins and micronutrients (24); this has been attributed to the high water content and very low energy density of vegetables and fruit, which makes them expensive sources of energy (142). Lean meats, fish, or fresh fruit and vegetables are far more costly per calorie than are added sugars and added fats (17, 143). Diets composed of low-energy-density nutrient-rich foods are more expensive than are diets composed of refined grains, added sugars, and added fats (133).

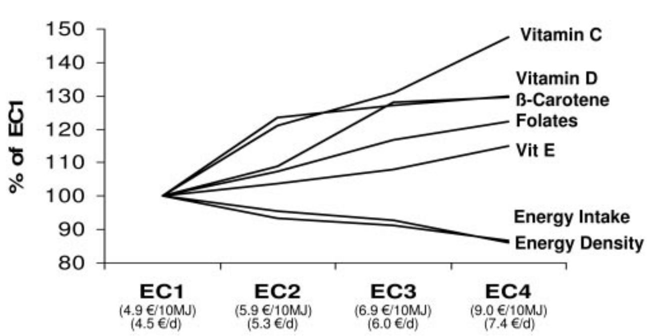

FIGURE 1. Evolution of daily energy intakes, dietary energy density, and daily intakes of selected vitamins per quartile of energy cost (EC) of diets of adults living in France. Adapted from reference 24.

Food costs are a barrier to the adoption of nutrient-dense diets, especially by the lower income groups (144, 145). One recent study, based on the US Department of Agriculture Thrifty Food Plan, reported that the cost of substituting healthier foods can cost up to 35–40% of an American low-income family's food budget (146). Other studies have shown that food costs are an obstacle to reducing fat intakes (147) or to increasing the consumption of fish (148), whole-grain products (149), or vegetables and fruit (59, 125). In a recent US study, women who considered food price very important were likely to live in low-income households and to have energy-dense diets (150). Several studies have emphasized that food budgets of the poor are insufficient to obtain a balanced diet (151–154). Even when low-income groups develop efficient purchasing strategies (155–158), the food budget may not be adequate to procure the recommended diet.

Poverty may lead to the selection of low-cost diets that are both energy rich and shelf stable. Foods with the longest shelf life are dry packaged foods (159) likely to contain refined grains, added sugars, and added fats. The emphasis on maximum calories and least waste and spoilage is another characteristic of poverty. Because trying a new food represents a risk of waste (160), diets of low-income households are often monotonous. Poverty is often accompanied by isolation, boredom, and depression—behaviors that may encourage snacking, simplifying or skipping meals, and sedentary behavior.

Food access and the food environment

Access to foods can also be a function of the physical environment (161, 162). Whereas supermarkets and grocery stores may cluster in the more affluent neighborhoods (129, 130, 163), some lower-income neighborhoods have been characterized as "food deserts" (164).

Some studies have viewed physical proximity to healthy food choices as the chief influence on diet quality. Easy access to supermarkets was shown to be associated with a higher intake of fruit and vegetables (162), even within a low-income population in the United States (163, 165). Living in lower-income neighborhoods has been associated with lower consumption of fruit, vegetables, and fish (161). The quality of food choices was directly influenced by the ease of access to a supermarket as well as to the availability and variety of healthy foods in neighborhood stores (162, 166). For example, foods recommended for the self management of diabetes are less likely to be stocked in East Harlem than on the Upper East Side (167).

Low-income families are less likely to own a car and may find it more difficult to reach out-of-town supermarkets, in urban (128) as well as in rural (168) areas. Deprived neighborhoods may limit not only food access but also opportunities for physical activity, because of the lack of facilities (169–173) or because of security issues (174). Physical activity levels are lower among low-SES groups (5, 175), and living and growing up in a high-poverty area represents in itself a risk factor for obesity (176, 177).

Education and culture

Studies of dietary habits of lower SES groups have emphasized lack of nutrition knowledge (124), lack of cooking skills, lack of motivation (125, 126), and a general disinterest in cooking (126). It is not clear that such reports are correct. One UK study found that cooking skills showed little differentiation by SES and that lower income groups are more likely to cook than are higher income groups (178). Similar observations were made in Canada (179) and in France (63, 180), where the middle and upper classes cook less and consume more convenience and ready-to-eat foods. Other studies found that low-income groups have adequate cooking skills (155, 181). In very poor families, the lack of cooking equipment will in itself discourage cooking.

A lack of nutrition knowledge (182), apathy toward nutrition prevention messages (183), and an erroneous perception of body weight (184–186) have all been cited as potential explanations for unhealthy dietary habits and high obesity rates among disadvantaged groups. However, nutrition knowledge alone may not necessarily be sufficient to initiate behavioral application of healthy diets (187, 188). Limited time for food shopping and cooking is an important factor influencing food intake among low-income mothers (189).

Residence, country of origin, and social integration are also determining factors of diet quality. Studies conducted in the US among poor families showed that establishment of a strong social network (190) and among migrants, the maintenance cultural traditions (191), were associated with a lower risk of food insecurity, independent of income level. In France, some studies suggest that immigrants of southern Europe (192) and elderly people living in rural areas in southern France (193) have maintained healthy Mediterranean food practices despite a lower SES than the general population.

MEDIATING FACTORS

The monetary and time cost of healthy foods may be the looked-for intermediate variable. Economic access is a factor, given that healthier foods and the more nutrient-dense diets cost more (142, 143) and seem to be preferentially selected by higher SES groups. Low-cost foods satisfy hunger and are more affordable and more accessible in low-income areas. Plausible biological mechanisms may also include the higher palatability and lower satiety value of energy-dense foods.

Such relations are difficult to explore in the course of intervention studies. Mathematical diet modeling studies were therefore conducted to simulate the impact of a decrease in the budget for food on the food choices made to select a diet that is socially acceptable while keeping energy intake constant. The most rational food choices were to decrease fruit, vegetables, meat, and fish intakes and to increase the intake of refined cereals, which resembled the food intake patterns observed among low socioeconomic groups (131). As shown in **Figure 2** (131), the cost constraint increased energy density and decreased nutrient densities, which suggests that economic considerations are likely to contribute to the high prevalence of obesity and nutrient deficiencies in these groups. In contrast, the constraint induced only a moderate increase in total lipid content. This is consistent with

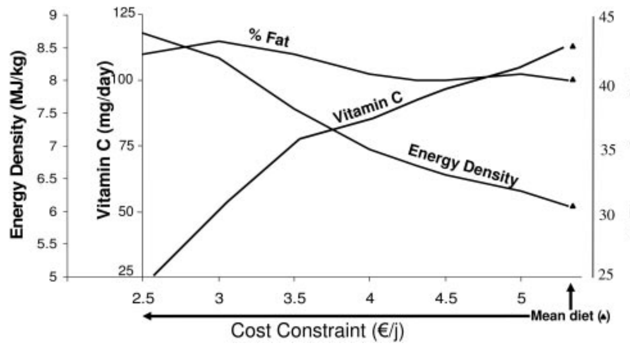

FIGURE 2. Impact of a cost constraint on the energy density, the vitamin C content, and the lipid content of diets modeled by linear programming. Adapted from reference 131.

the epidemiologic observations that micronutrient intakes are more affected than are macronutrients intakes by socioeconomic status and with the increasing contribution of refined cereals when income decreases.

Computer modeling studies also showed that forcing energy density to increase only moderately decreased diet cost, while forcing diet cost to decrease induced a dramatic increase in energy density (132). Therefore, it is possible to purchase an energy-dense diet for a relatively high cost, while economic constraints will necessarily increase energy density. In other words, the more affluent groups have a choice of high-energy-density or low-energy-density diets, whereas for low-SES groups, the ability to adopt a healthier diet may have less to do with motivation than with economic means. Recent studies from both the United Kingdom (194) and the United States (195) have shown that providing vouchers for purchasing fruit and vegetables was a simple and effective way of increasing fruit and vegetables intakes in low-income women, whereas dietary advice alone had no great effect (194).

CONCLUSIONS

The cross-sectional studies reviewed above permit the conclusion that higher-quality diets are, in general, consumed by better educated and more affluent people. Conversely, lower quality diets tended to be consumed by groups of lower SES and more limited economic means. This conclusion is based on a review of empirical data and some computer modeling of dietary habits subjected to cost and other constraints. The remaining question is whether the observed relation between SES and diet-quality measures can be characterized as causal.

The observed relation between SES indicators and diet-quality measures was consistent. The relation was observed in different groups by age and sex, with multiple measures of SES—occupation, education, and income (18–20, 22)—and with multiple measures of diet quality. It was observed with food purchase data at the aggregate household level (20, 41, 72, 75, 179) and with individual food consumption data (37, 89, 91, 92). It held for fiber and nutrient intakes and for selected plasma biomarkers. The data sets that the analyses were based on came from multiple European countries, Canada, Australia, and the United States.

The observed relation between SES variables and diet quality was graded rather than threshold dependent (16, 34, 35, 59, 74, 89, 91, 111). Diet quality showed a continued improvement across a wide range of economic strata, continuing to improve well above the poverty threshold.

The relation between SES indicators and diet-quality measures was strong. In the Whitehall II survey, employment grade was directly associated with sharply higher intakes of vitamin C (89). Whereas women in the lowest grade ($n = 6$) consumed 91 mg/d, those in the highest grade consumed 133 mg/d. Similar trends were observed for fiber and for other nutrients found in vegetables and fruit (89, 90). From 1971–1975 to 1999–2002, the mean energy density of the diet of US adults with >12 y of education was 1.59 kcal/g, a level equal to that of the mean energy density of the US diet in 1971–1975. In contrast, in those with <12 y of education, it was 1.71 kcal/g, a level equal to the mean energy density of the US diet in 1999–2002 (33). In other words, the education-dependent differences in dietary energy density in the United States were as strong as those induced by 30 y of secular trends. Recent data from Canada suggest that the relation between SES and the nutrient density of diets is growing stronger (74). Other data suggest that the price of vegetables and fruit has increased disproportionately over the past 20 y relative to sweets and fats (17). Increases in food availability and ongoing marketing incentives to consume large quantities of low-cost energy-dense foods may be particularly damaging to the health of lower SES groups, for whom such foods represent a source of affordable calories.

The present associations appear to meet some of the standard tests for causality. SES variables may have a causal influence on diet quality and on diet cost. The observed epidemiologic relations between diet quality and health outcomes may have been confounded by unmeasured SES factors. Persons with a certain type of dietary pattern may differ, in several unobserved ways, from persons with another type of dietary pattern. For the most part, indexes of SES are unobserved variables in many studies of diet and chronic disease risk. Thus, high vitamin C consumption may have been associated with better health outcomes, but persons in the top quintile of vitamin C consumption not only paid more for their diets but their financial resources may have been very different from those of persons in the bottom quintile of vitamin C consumption. In other words, it is difficult to tell whether improved health outcomes are attributable to vitamin C or to diet costs, poverty, or wealth.

British researchers have already issued the plea that nutrition research should not lose touch with reality (196). The promotion of high-cost foods to low-income people without taking food costs into account is not likely to be successful. Future studies of diet quality and SES need to use planned dietary interventions, many of which should be targeted at minorities and low-income and other vulnerable groups.

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REFERENCES

1. Kunst AE, Groenhof F, Mackenbach JP, Health EW. Occupational class and cause specific mortality in middle aged men in 11 European countries: comparison of population based studies. EU Working Group on Socioeconomic Inequalities in Health. BMJ 1998;316:1636–42.
2. Cavelaars AE, Kunst AE, Geurts JJ, et al. Morbidity differences by occupational class among men in seven European countries: an application of the Erikson-Goldthorpe social class scheme. Int J Epidemiol 1998;27:222–30.
3. Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. N Engl J Med 1993;329:103–9.
4. Molarius A, Seidell JC, Sans S, Tuomilehto J, Kuulasmaa K. Educational level, relative body weight, and changes in their association over 10 years: an international perspective from the WHO MONICA Project. Am J Public Health 2000;90:1260–8.
5. Lantz PM, House JS, Lepkowski JM, Williams DR, Mero RP, Chen J. Socioeconomic factors, health behaviors, and mortality: results from a nationally representative prospective study of US adults. JAMA 1998; 279:1703–8.
6. Brunner EJ, Marmot MG, Nanchahal K, et al. Social inequality in coronary risk: central obesity and the metabolic syndrome. Evidence from the Whitehall II study. Diabetologia 1997;40:1341–9.
7. Evans JM, Newton RW, Ruta DA, MacDonald TM, Morris AD. Socioeconomic status, obesity and prevalence of type 1 and type 2 diabetes mellitus. Diabet Med 2000;17:478–80.
8. Tang M, Chen Y, Krewski D. Gender-related differences in the association between socioeconomic status and self-reported diabetes. Int J Epidemiol 2003;32:381–5.
9. Lang T, Ducimetiere P. Premature cardiovascular mortality in France: divergent evolution between social categories from 1970 to 1990. Int J Epidemiol 1995;24:331–9.
10. Pearson D, Taylor R, Masud T. The relationship between social deprivation, osteoporosis, and falls. Osteoporos Int 2004;15:132–8.
11. del Rio BL, Romera BM, Pavia SJ, et al. Bone mineral density in two different socio-economic population groups. Bone Miner 1992;18: 159–68.
12. Reisine ST, Psoter W. Socioeconomic status and selected behavioral determinants as risk factors for dental caries. J Dent Educ 2001;65: 1009–16.
13. Melchior M, Goldberg M, Krieger N, et al. Occupational class, occupational mobility and cancer incidence among middle-aged men and women: a prospective study of the French GAZEL cohort. Cancer Causes Control 2005;16:515–24.
14. WHO. Diet, nutrition and the prevention of excess weight gain and obesity. Report of a joint WHO/FAO expert consultation. World Health Organ Tech Rep Ser 2003;916.
15. James WP, Nelson M, Ralph A, Leather S. Socioeconomic determinants of health. The contribution of nutrition to inequalities in health. BMJ 1997;314:1545–9.
16. Martikainen P, Brunner E, Marmot M. Socioeconomic differences in dietary patterns among middle-aged men and women. Soc Sci Med 2003;56:1397–410.
17. Drewnowski A, Darmon N. The economics of obesity: dietary energy density and energy cost. Am J Clin Nutr 2005;82(suppl):265S–73S.
18. Galobardes B, Morabia A, Bernstein MS. Diet and socioeconomic position: does the use of different indicators matter? Int J Epidemiol 2001;30:334–40.
19. Groth MV, Fagt S, Brondsted L. Social determinants of dietary habits in Denmark. Eur J Clin Nutr 2001;55:959–66.
20. Turrell G, Hewitt B, Patterson C, Oldenburg B. Measuring socio-economic position in dietary research: is choice of socio-economic indicator important? Public Health Nutr 2003;6:191–201.
21. Krieger N, Williams DR, Moss NE. Measuring social class in US public health research: concepts, methodologies, and guidelines. Annu Rev Public Health 1997;18:341–78.
22. Lallukka T, Laaksonen M, Rahkonen O, Roos E, Lahelma E. Multiple socio-economic circumstances and healthy food habits. Eur J Clin Nutr 2007;61:701–10.
23. Ledikwe JH, Blanck HM, Khan LK, et al. Low-energy-density diets are associated with high diet quality in adults in the United States. J Am Diet Assoc 2006;106:1172–80.
24. Andrieu E, Darmon N, Drewnowski A. Low-cost diets: more energy, fewer nutrients. Eur J Clin Nutr 2006;60:434–6.
25. Mendoza JA, Drewnowski A, Christakis DA. Dietary energy density is associated with obesity and the metabolic syndrome in U.S. adults. Diabetes Care 2007;30:974–9.
26. Rolls BJ, Bell EA. Intake of fat and carbohydrate: role of energy density. Eur J Clin Nutr 1999;53(suppl):S166–73.
27. Drewnowski A. The role of energy density. Lipids 2003;38:109–15.
28. Rolls BJ, Morris EL, Roe LS. Portion size of food affects energy intake in normal-weight and overweight men and women. Am J Clin Nutr 2002;76:1207–13.

29. Darmon N, Briend A, Drewnowski A. Energy-dense diets are associated with lower diet costs: a community study of French adults. Public Health Nutr 2004;7:21–7.
30. Loughley K, Basiotis P, Zizza C, Dinkins JM. Profiles of selected target audiences: promoting the dietary guidelines for Americans. Fam Econ Nutr Rev 2004;13:3–14.
31. Patterson RE, Haines PS, Popkin BM. Diet quality index: capturing a multidimensional behavior. J Am Diet Assoc 1994;94:57–64.
32. Worsley A, Blasche R, Ball K, Crawford D. Income differences in food consumption in the 1995 Australian National Nutrition Survey. Eur J Clin Nutr 2003;57:1198–211.
33. Kant AK, Graubard BI. Secular trends in the association of socioeconomic position with self-reported dietary attributes and biomarkers in the US population: National Health and Nutrition Examination Survey (NHANES) 1971–1975 to NHANES 1999–2002. Public Health Nutr 2007;10:158–67.
34. Robinson SM, Crozier SR, Borland SE, Hammond J, Barker DJ, Inskip HM. Impact of educational attainment on the quality of young women's diets. Eur J Clin Nutr 2004;58:1174–80.
35. Dynesen AW, Haraldsdottir J, Holm L, Astrup A. Sociodemographic differences in dietary habits described by food frequency questions–results from Denmark. Eur J Clin Nutr 2003;57:1586–97.
36. Kushi LH, Folsom AR, Jacobs DR Jr, Luepker RV, Elmer PJ, Blackburn H. Educational attainment and nutrient consumption patterns: the Minnesota Heart Survey. J Am Diet Assoc 1988;88:1230–6.
37. Shimakawa T, Sorlie P, Carpenter MA, et al. Dietary intake patterns and sociodemographic factors in the atherosclerosis risk in communities study. ARIC Study Investigators. Prev Med 1994;23:769–80.
38. Park SY, Murphy SP, Wilkens LR, et al. Dietary patterns using the Food Guide Pyramid groups are associated with sociodemographic and lifestyle factors: the multiethnic cohort study. J Nutr 2005;135:843–9.
39. Barker ME, McClean SI, Thompson KA, Reid NG. Dietary behaviours and sociocultural demographics in Northern Ireland. Br J Nutr 1990; 64:319–29.
40. Huot I, Paradis G, Receveur O, Ledoux M. Correlates of diet quality in the Quebec population. Public Health Nutr 2004;7:1009–16.
41. Thiele S, Weiss C. Consumer demand for food diversity: evidence for Germany. Food Policy 2003;28:99–115.
42. La Vecchia C, Negri E, Franceschi S, Parazzini F, Decarli A. Differences in dietary intake with smoking, alcohol, and education. Nutr Cancer 1992;17:297–304.
43. Roos E, Prattala R, Lahelma E, Kleemola P, Pietinen P. Modern and healthy?: socioeconomic differences in the quality of diet. Eur J Clin Nutr 1996;50:753–60.
44. Hupkens CL, Knibbe RA, Drop MJ. Social class differences in women's fat and fibre consumption: a cross-national study. Appetite 1997; 28:131–49.
45. van Rossum CT, van de MH, Witteman JC, Grobbee E, Mackenbach JP. Education and nutrient intake in Dutch elderly people. The Rotterdam Study. Eur J Clin Nutr 2000;54:159–65.
46. Hulshof KF, Brussaard JH, Kruizinga AG, Telman J, Lowik MR. Socio-economic status, dietary intake and 10 y trends: the Dutch National Food Consumption Survey. Eur J Clin Nutr 2003;57:128–37.
47. Cronin FJ, Krebs-Smith SM, Wyse BW, Light L. Characterizing food usage by demographic variables. J Am Diet Assoc 1982;81:661–73.
48. Hulshof KF, Lowik MR, Kok FJ, et al. Diet and other life-style factors in high and low socio-economic groups (Dutch Nutrition Surveillance System). Eur J Clin Nutr 1991;45:441–50.
49. Smith AM, Baghurst KI. Public health implications of dietary differences between social status and occupational category groups. J Epidemiol Community Health 1992;46:409–16.
50. Lang R, Thane CW, Bolton-Smith C, Jebb SA. Consumption of wholegrain foods by British adults: findings from further analysis of two national dietary surveys. Public Health Nutr 2003;6:479–84.
51. Mishra G, Ball K, Arbuckle J, Crawford D. Dietary patterns of Australian adults and their association with socioeconomic status: results from the 1995 National Nutrition Survey. Eur J Clin Nutr 2002;56: 687–93.
52. Larrieu S, Letenneur L, Berr C, et al. Sociodemographic differences in dietary habits in a population-based sample of elderly subjects: the 3C study. J Nutr Health Aging 2004;8:497–502.
53. Marmot MG, Smith GD, Stansfeld S, et al. Health inequalities among British civil servants: the Whitehall II study. Lancet 1991;337:1387–93.
54. Hjartaker A, Lund E. Relationship between dietary habits, age, lifestyle, and socio-economic status among adult Norwegian women. The Norwegian Women and Cancer Study. Eur J Clin Nutr 1998;52:565–72.
55. Johansson L, Thelle DS, Solvoll K, Bjorneboe GE, Drevon CA. Healthy dietary habits in relation to social determinants and lifestyle factors. Br J Nutr 1999;81:211–20.
56. Irala-Estevez JD, Groth M, Johansson L, Oltersdorf U, Prattala R, Martinez-Gonzalez MA. A systematic review of socio-economic differences in food habits in Europe: consumption of fruit and vegetables. Eur J Clin Nutr 2000;54:706–14.
57. Strain JJ, Elwood PC, Davis A, et al. Frequency of fruit and vegetable consumption and blood antioxidants in the Caerphilly cohort of older men. Eur J Clin Nutr 2000;54:828–33.
58. Wallstrom P, Wirfalt E, Janzon L, et al. Fruit and vegetable consumption in relation to risk factors for cancer: a report from the Malmo Diet and Cancer Study. Public Health Nutr 2000;3:263–71.
59. Giskes K, Turrell G, Patterson C, Newman B. Socio-economic differences in fruit and vegetable consumption among Australian adolescents and adults. Public Health Nutr 2002;5:663–9.
60. Dauchet L, Ferrieres J, Arveiler D, et al. Frequency of fruit and vegetable consumption and coronary heart disease in France and Northern Ireland: the PRIME study. Br J Nutr 2004;92:963–72.
61. Krebs-Smith SM, Kantor LS. Choose a variety of fruits and vegetables daily: understanding the complexities. J Nutr 2001;131(suppl):487S–501S.
62. Fuhrer R, Shipley MJ, Chastang JF, et al. Socioeconomic position, health, and possible explanations: a tale of two cohorts. Am J Public Health 2002;92:1290–4.
63. Perrin AE, Simon C, Hedelin G, Arveiler D, Schaffer P, Schlienger JL. Ten-year trends of dietary intake in a middle-aged French population: relationship with educational level. Eur J Clin Nutr 2002;56:393–401.
64. Prattala R, Berg MA, Puska P. Diminishing or increasing contrasts? Social class variation in Finnish food consumption patterns, 1979–1990. Eur J Clin Nutr 1992;46:279–87.
65. Fraser GE, Welch A, Luben R, Bingham SA, Day NE. The effect of age, sex, and education on food consumption of a middle-aged English cohort-EPIC in East Anglia. Prev Med 2000;30:26–34.
66. Swinburn BA, Walter L, Ricketts H, et al. The determinants of fat intake in a multi-ethnic New Zealand population. Fletcher Challenge–University of Auckland Heart and Health Study Management Committee. Int J Epidemiol 1998;27:416–21.
67. Hupkens CL, Knibbe RA, Drop MJ. Social class differences in food consumption. Eur J Public Health 2000;10:108–13.
68. Fehily AM, Phillips KM, Yarnell JW. Diet, smoking, social class, and body mass index in the Caerphilly Heart Disease Study. Am J Clin Nutr 1984;40:827–33.
69. Sanchez-Villegas A, Martinez JA, Prattala R, Toledo E, Roos G, Martinez-Gonzalez MA. A systematic review of socioeconomic differences in food habits in Europe: consumption of cheese and milk. Eur J Clin Nutr 2003;57:917–29.
70. Prattala RS, Groth MV, Oltersdorf US, Roos GM, Sekula W, Tuomainen HM. Use of butter and cheese in 10 European countries: a case of contrasting educational differences. Eur J Public Health 2003;13:124–32.
71. Linseisen J, Bergstrom E, Gafa L, et al. Consumption of added fats and oils in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres across 10 European countries as assessed by 24-hour dietary recalls. Public Health Nutr 2002;5:1227–42.
72. Trichopoulou A, Naska A, Costacou T. Disparities in food habits across Europe. Proc Nutr Soc 2002;61:553–8.
73. Giskes K, Lenthe FF, Brug HJ, Mackenbach J. Dietary intakes of adults in the Netherlands by childhood and adulthood socioeconomic position. Eur J Clin Nutr 2004;58:871–80.
74. Ricciuto LE, Tarasuk VS. An examination of income-related disparities in the nutritional quality of food selections among Canadian households from 1986–2001. Soc Sci Med 2007;64:186–98.
75. Roos G, Johansson L, Kasmel A, Klumbiené J, Prattala R. Disparities in vegetable and fruit consumption: European cases from the north to the south. Public Health Nutr 2000;4:35–43.
76. Naska A, Fouskakis D, Oikonomou E, et al. Dietary patterns and their socio-demographic determinants in 10 European countries: data from the DAFNE databank. Eur J Clin Nutr 2006;60:181–90.
77. Stables GJ, Subar AF, Patterson BH, et al. Changes in vegetable and fruit consumption and awareness among US adults: results of the 1991

and 1997 5 A Day for Better Health Program surveys. J Am Diet Assoc 2002;102:809–17.
78. Leather S, Dowler E. Intake of micronutrients in Britain's poorest fifth has declined. BMJ 1997;314:1412–3.
79. Rolland-Cachera MF, Bellisle F. No correlation between adiposity and food intake: why are working class children fatter? Am J Clin Nutr 1986;44:779–87.
80. Xie B, Gilliland FD, Li YF, Rockett HR. Effects of ethnicity, family income, and education on dietary intake among adolescents. Prev Med 2003;36:30–40.
81. Neumark-Sztainer D, Story M, Hannan PJ, Croll J. Overweight status and eating patterns among adolescents: where do youths stand in comparison with the healthy people 2010 objectives? Am J Public Health 2002;92:844–51.
82. Kirby SD, Baranowski T, Reynolds KD, Binkley D. Children's fruit and vegetable intake: socio-economic, adult-child, regional and urban-rural influences. J Nutr Educ 1995;27:261–71.
83. Cullen KW, Ash DM, Warneke C, de Moor C. Intake of soft drinks, fruit-flavored beverages, and fruits and vegetables by children in grades 4 through 6. Am J Public Health 2002;92:1475–8.
84. Serra-Majem L, Ribas L, Perez-Rodrigo C, Garcia-Closas R, Pena-Quintana L, Aranceta J. Determinants of nutrient intake among children and adolescents: results from the enKid Study. Ann Nutr Metab 2002; 46(suppl 1):31–8.
85. Haapalahti M, Mykkanen H, Tikkanen S, Kokkonen J. Meal patterns and food use in 10- to 11-year-old Finnish children. Public Health Nutr 2003;6:365–70.
86. Laitinen S, Rasanen L, Viikari J, Akerblom HK. Diet of Finnish children in relation to the family's socio-economic status. Scand J Soc Med 1995;23:88–94.
87. Vereecken CA, Inchley J, Subramanian SV, Hublet A, Maes L. The relative influence of individual and contextual socio-economic status on consumption of fruit and soft drinks among adolescents in Europe. Eur J Public Health 2005;15:224–32.
88. Bolton-Smith C, Smith WC, Woodward M, Tunstall-Pedoe H. Nutrient intakes of different social-class groups: results from the Scottish Heart Health Study (SHHS). Br J Nutr 1991;65:321–35.
89. Stallone DD, Brunner EJ, Bingham SA, Marmot MG. Dietary assessment in Whitehall II: the influence of reporting bias on apparent socioeconomic variation in nutrient intakes. Eur J Clin Nutr 1997;51: 815–25.
90. Bates CJ, Prentice A, Cole TJ, et al. Micronutrients: highlights and research challenges from the 1994–5 National Diet and Nutrition Survey of people aged 65 years and over. Br J Nutr 1999;82:7–15.
91. Dubois L, Girard M. Social position and nutrition: a gradient relationship in Canada and the USA. Eur J Clin Nutr 2001;55:366–73.
92. Friel S, Kelleher CC, Nolan G, Harrington J. Social diversity of Irish adults nutritional intake. Eur J Clin Nutr 2003;57:865–75.
93. Fulton M, Thomson M, Elton RA, Brown S, Wood DA, Oliver MF. Cigarette smoking, social class and nutrient intake: relevance to coronary heart disease. Eur J Clin Nutr 1988;42:797–803.
94. Lindstrom M, Hanson BS, Brunner E, et al. Socioeconomic differences in fat intake in a middle-aged population: report from the Malmo Diet and Cancer Study. Int J Epidemiol 2000;29:438–48.
95. Pomerleau J, Pederson LL, Ostbye T, Speechley M, Speechley KN. Health behaviours and socio-economic status in Ontario, Canada. Eur J Epidemiol 1997;13:613–22.
96. Gerber AM, James SA, Ammerman AS, et al. Socioeconomic status and electrolyte intake in black adults: the Pitt County Study. Am J Public Health 1991;81:1608–12.
97. Winzenberg TM, Riley M, Frendin S, Oldenburg B, Jones G. Sociodemographic factors associated with calcium intake in premenopausal women: a cross-sectional study. Eur J Clin Nutr 2005;59:463–6.
98. Arts IC, Hollman PC, Feskens EJ, Bueno de Mesquita HB, Kromhout D. Catechin intake and associated dietary and lifestyle factors in a representative sample of Dutch men and women. Eur J Clin Nutr 2001; 55:76–81.
99. Devaney BL, Gordon AR, Burghardt JA. Dietary intakes of students. Am J Clin Nutr 1995;61(suppl):205S–12S.
100. Johnson-Down L, O'Loughlin J, Koski KG, Gray-Donald K. High prevalence of obesity in low income and multiethnic schoolchildren: a diet and physical activity assessment. J Nutr 1997;127:2310–5.
101. Simon JA, Schreiber GB, Crawford PB, Frederick MM, Sabry ZI. Income and racial patterns of dietary vitamin C intake among black and white girls. Public Health Rep 1993;108:760–4.
102. Wright CM, Parkinson K, Scott J. Breast-feeding in a UK urban context: who breast-feeds, for how long and does it matter? Public Health Nutr 2006;9:686–91.
103. Li R, Ogden C, Ballew C, Gillespie C, Grummer-Strawn L. Prevalence of exclusive breastfeeding among US infants: the Third National Health and Nutrition Examination Survey (Phase II, 1991–1994). Am J Public Health 2002;92:1107–10.
104. Dubois L, Girard M. Social inequalities in infant feeding during the first year of life. The Longitudinal Study of Child Development in Quebec (LSCDQ 1998–2002). Public Health Nutr 2003;6:773–83.
105. Bonuck KA, Kahn R. Prolonged bottle use and its association with iron deficiency anemia and overweight: a preliminary study. Clin Pediatr (Phila) 2002;41:603–7.
106. Male C, Persson LA, Freeman V, Guerra A, van't Hof MA, Haschke F. Prevalence of iron deficiency in 12-mo-old infants from 11 European areas and influence of dietary factors on iron status (Euro-Growth study). Acta Paediatr 2001;90:492–8.
107. Armstrong J, Reilly JJ. Breastfeeding and lowering the risk of childhood obesity. Lancet 2002;359:2003–4.
108. Mattisson I, Wirfalt E, Gullberg B, Berglund G. Fat intake is more strongly associated with lifestyle factors than with socio-economic characteristics, regardless of energy adjustment approach. Eur J Clin Nutr 2001;55:452–61.
109. Lopez-Azpiazu I, Sanchez-Villegas A, Johansson L, Petkeviciene J, Prattala R, Martinez-Gonzalez MA. Disparities in food habits in Europe: systematic review of educational and occupational differences in the intake of fat. J Hum Nutr Diet 2003;16:349–64.
110. Nichèle V, Andrieu E, Boizot C, Caillavet F, Darmon N. La consommation d'aliments et de nutriments en France: évolution 1969-2001 et déterminants socio-économiques des comportements. (Food and nutrient intakes in France: 1969–2001 trends and socioeconomic determinants.) Report from the Consumption Research Laboratory of the INRA 2005. Internet: http://www.ivry.inra.fr/corela/telech.php (accessed 14 February 2008) (in French).
111. Shohaimi S, Bingham S, Welch A, et al. Occupational social class, educational level and area deprivation independently predict plasma ascorbic acid concentration: a cross-sectional population based study in the Norfolk cohort of the European Prospective Investigation into Cancer (EPIC-Norfolk). Eur J Clin Nutr 2004;58:1432–5.
112. Bates CJ, Schneede J, Mishra G, Prentice A, Mansoor MA. Relationship between methylmalonic acid, homocysteine, vitamin B12 intake and status and socio-economic indices, in a subset of participants in the British National Diet and Nutrition Survey of people aged 65 y and over. Eur J Clin Nutr 2003;57:349–57.
113. Berr C, Coudray C, Bonithon-Kopp C, Roussel AM, Mainard F, Alperovitch A. Demographic and cardiovascular risk factors in relation to antioxidant status: the EVA Study. Int J Vitam Nutr Res 1998;68: 26–35.
114. Rogers I, Emmett P, Baker D, Golding J. Financial difficulties, smoking habits, composition of the diet and birthweight in a population of pregnant women in the South West of England. ALSPAC Study Team. Avon Longitudinal Study of Pregnancy and Childhood. Eur J Clin Nutr 1998;52:251–60.
115. Doran L, Evers S. Energy and nutrient inadequacies in the diets of low-income women who breast-feed. J Am Diet Assoc 1997;97: 1283–7.
116. Bodnar LM, Cogswell ME, Scanlon KS. Low income postpartum women are at risk of iron deficiency. J Nutr 2002;132:2298–302.
117. Duitsman PK, Cook LR, Sherry A, Tanumihardjo SA, Olson JA. Vitamin A inadequacy in socioeconomically disadvantaged pregnant women as assessed by the modified relative dose response (MRDR) test. Nutr Res 1995;15:1263–76.
118. Lehmann F, Gray-Donald K, Mongeon M, Di Tommaso S. Iron deficiency anemia in 1-year-old children of disadvantaged families in Montreal. Can Med Assoc J 1992;146:1571–7.
119. Sherry B, Mei Z, Md RY. Continuation of the decline in prevalence of anemia in low-income infants and children in five states. Pediatrics 2001;107:677–82.
120. Spannaus-Martin DJ, Cook LR, Tanumihardjo SA, Duitsman PK, Olson JA. Vitamin A and vitamin E statuses of preschool children of

socioeconomically disadvantaged families living in the midwestern United States. Eur J Clin Nutr 1997;51:864–9.
121. Ford ES, Gillespie C, Ballew C, Sowell A, Mannino DM. Serum carotenoid concentrations in US children and adolescents. Am J Clin Nutr 2002;76:818–27.
122. Bates CJ, Thane CW, Prentice A, Delves HT, Gregory J. Selenium status and associated factors in a British National Diet and Nutrition Survey: young people aged 4–18 y. Eur J Clin Nutr 2002;56:873–81.
123. Schneider JM, Fujii ML, Lamp CL, Lonnerdal B, Dewey KG, Zidenberg-Cherr S. Anemia, iron deficiency, and iron deficiency anemia in 12–36-mo-old children from low-income families. Am J Clin Nutr 2005;82:1269–75.
124. Variyam JN, Blaylock J, Smallwood DM. Modelling nutrition knowledge, attitudes, and diet-disease awareness: the case of dietary fibre. Stat Med 1996;15:23–35.
125. Dibsdall LA, Lambert N, Bobbin RF, Frewer LJ. Low-income consumers' attitudes and behaviour towards access, availability and motivation to eat fruit and vegetables. Public Health Nutr 2003;6:159–68.
126. Henry H, Reimer K, Smith C, Reicks M. Associations of decisional balance, processes of change, and self-efficacy with stages of change for increased fruit and vegetable intake among low-income, African-American mothers. J Am Diet Assoc 2006;106:841–9.
127. Booth KM, Pinkston MM, Poston WS. Obesity and the built environment. J Am Diet Assoc 2005;105(suppl):S110–7.
128. Caraher M, Dixon P, Lang T, Carr-Hill R. Access to healthy foods: part I. Barriers to accessing healthy foods: differentials by gender, social class, income and mode of transport. Health Educ J 1998;57:191–201.
129. Powell LM, Slater S, Mirtcheva D, Bao Y, Chaloupka FJ. Food store availability and neighborhood characteristics in the United States. Prev Med 2007;44:189–95.
130. Morland K, Wing S, Diez RA, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. Am J Prev Med 2002;22:23–9.
131. Darmon N, Ferguson EL, Briend A. A cost constraint alone has adverse effects on food selection and nutrient density: an analysis of human diets by linear programming. J Nutr 2002;132:3764–71.
132. Darmon N, Ferguson E, Briend A. Do economic constraints encourage the selection of energy dense diets? Appetite 2003;41:315–22.
133. Drewnowski A, Darmon N, Briend A. Replacing fats and sweets with vegetables and fruit—a question of cost. Am J Public Health 2004;94:1555–9.
134. Lennernas M, Fjellstrom C, Becker W, et al. Influences on food choice perceived to be important by nationally-representative samples of adults in the European Union. Eur J Clin Nutr 1997;51(suppl):S8–15.
135. Glanz K, Basil M, Maibach E, Goldberg J, Snyder D. Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. J Am Diet Assoc 1998;98:1118–26.
136. Cabanac M. Palatability vs. money: experimental study of a conflict of motivations. Appetite 1995;25:43–9.
137. French SA. Pricing effects on food choices. J Nutr 2003;133(suppl):841S–3S.
138. McAllister M, Baghurst KI, Record S. Financial costs of healthful eating: a comparison of three different approaches. J Nutr Educ 1994;26:131–9.
139. Cade J, Upmeier H, Calvert C, Greenwood D. Costs of a healthy diet: analysis from the UK Women's Cohort Study. Public Health Nutr 1999;2:505–12.
140. Schroder H, Marrugat J, Covas MI. High monetary costs of dietary patterns associated with lower body mass index: a population-based study. Int J Obes (Lond) 2006;30:1574–9.
141. Maillot M, Darmon N, Vieux F, Drewnowski A. Low energy density and high nutritional quality are each associated with higher diet costs in French adults. Am J Clin Nutr 2007;86:690–6.
142. Darmon N, Darmon M, Maillot M, Drewnowski A. A nutrient density standard for vegetables and fruits: nutrients per calorie and nutrients per unit cost. J Am Diet Assoc 2005;105:1881–7.
143. Maillot M, Darmon N, Darmon M, Lafay L, Drewnowski A. Nutrient-dense food groups have high energy costs: an econometric approach to nutrient profiling. J Nutr 2007;137:1815–20.
144. Reicks M, Randall JL, Haynes BJ. Factors affecting consumption of fruits and vegetables by low-income families. J Am Diet Assoc 1994;94:1309–11.
145. Cox DN, Anderson AS, McKellar S, Reynolds J, Lean MEJ, Mela DJ. Vegetables and fruits: barriers and opportunities for greater consumption. Nutr Food Sci 1996;5:44–7.
146. Jetter KM, Cassady DL. The availability and cost of healthier food items. AIC Issues Brief. 2005. Internet: http://aic.ucdavis.edu (accessed 14 February 2008).
147. Lloyd HM, Paisley CM, Mela DJ. Barriers to the adoption of reduced-fat diets in a UK population. J Am Diet Assoc 1995;95:316–22.
148. Trondsen T, Scholderer J, Lund E, Eggen AE. Perceived barriers to consumption of fish among Norwegian women. Appetite 2003;41:301–14.
149. Chase K, Reicks M, Smith C, Henry H, Reimer K. Use of the think-aloud method to identify factors influencing purchase of bread and cereals by low-income African American women and implications for whole-grain education. J Am Diet Assoc 2003;103:501–4.
150. Bowman SA. A comparison of the socioeconomic characteristics, dietary practices, and health status of women food shoppers with different food price attitudes. Nutr Res 2006;26:318–24.
151. Vozoris N, Davis B, Tarasuk V. The affordability of a nutritious diet for households on welfare in Toronto. Can J Public Health 2002;93:36–40.
152. Morris JN, Donkin AJ, Wonderling D, Wilkinson P, Dowler EA. A minimum income for healthy living. J Epidemiol Community Health 2000;54:885–9.
153. Nelson M, Dick K, Holmes B. Food budget standards and dietary adequacy in low-income families. Proc Nutr Soc 2002;61:569–77.
154. Darmon N, Ferguson EL, Briend A. Impact of a cost constraint on nutritionally adequate food choices for French women: an analysis by linear programming. J Nutr Educ Behav 2006;38:82–90.
155. McLaughlin C, Tarasuk V, Kreiger N. An examination of at-home food preparation activity among low-income, food-insecure women. J Am Diet Assoc 2003;103:1506–12.
156. Crotty PA, Rutishauser IH, Cahill M. Food in low-income families. Aust J Public Health 1992;16:168–74.
157. Hersey J, Anliker J, Miller C, et al. Food shopping practices are associated with dietary quality in low-income households. J Nutr Educ Behav 2001;33(suppl):S016–25.
158. Grant DK, Maxwell S. Food coping strategies: a century on from Rowntree. Nutr Health 1999;13:45–60.
159. Drewnowski A. Energy density, palatability, and satiety: implications for weight control. Nutr Rev 1998;56:347–53.
160. Dowler E. Budgeting for food on a low income in the UK: the case of lone-parent families. Food Policy 1997;22:405–17.
161. Diez-Roux AV, Nieto FJ, Caulfield L, Tyroler HA, Watson RL, Szklo M. Neighbourhood differences in diet: the Atherosclerosis Risk in Communities (ARIC) Study. J Epidemiol Community Health 1999;53:55–63.
162. Morland K, Wing S, Diez RA. The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. Am J Public Health 2002;92:1761–7.
163. Zenk SN, Schulz AJ, Hollis-Neely T, et al. Fruit and vegetable intake in African Americans income and store characteristics. Am J Prev Med 2005;29:1–9.
164. Lang T, Caraher M. Access to healthy foods: part II. Food poverty and shopping deserts: what are the implications for health promotion policy and practice? Health Educ J 1998;57:202–11.
165. Rose D, Richards R. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. Public Health Nutr 2004;7:1081–8.
166. Cummins SC. The local food environment and health: some reflections from the United Kingdom. Am J Public Health 2003;93:521–2.
167. Horowitz CR, Colson KA, Hebert PL, Lancaster K. Barriers to buying health foods for people with diabetes: evidence of environmental disparities. Am J Public Health 2004;94:1549–54.
168. Kaufman PR. The rural poor's access to supermarkets and large grocery stores. Fam Econ Nutr Rev 1999;12:90–2.
169. Yen IH, Kaplan GA. Poverty area residence and changes in physical activity level: evidence from the Alameda County Study. Am J Public Health 1998;88:1709–12.
170. Parks SE, Housemann RA, Brownson RC. Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. J Epidemiol Community Health 2003;57:29–35.
171. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. Am J Prev Med 1998;15:379–97.

172. Cradock AL, Kawachi I, Colditz GA, et al. Playground safety and access in Boston neighborhoods. Am J Prev Med 2005;28:357–63.
173. Powell LM, Slater S, Chaloupka FJ, Harper D. Availability of physical activity-related facilities and neighborhood demographic and socioeconomic characteristics: a national study. Am J Public Health 2006; 96:1676–80.
174. Burdette HL, Whitaker RC. Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. Prev Med 2004;38:57–63.
175. Crespo CJ, Ainsworth BE, Keteyian SJ, Heath GW, Smit E. Prevalence of physical inactivity and its relation to social class in U.S. adults: results from the Third National Health and Nutrition Examination Survey, 1988–1994. Med Sci Sports Exerc 1999;31:1821–7.
176. Kinra S, Nelder RP, Lewendon GJ. Deprivation and childhood obesity: a cross sectional study of 20,973 children in Plymouth, United Kingdom. J Epidemiol Community Health 2000;54:456–60.
177. Lissau-Lund-Sorensen I, Sorensen TI. Prospective study of the influence of social factors in childhood on risk of overweight in young adulthood. Int J Obes Relat Metab Disord 1992;16:169–75.
178. Caraher M, Lang T. Can't cook, won't cook: a review of cooking skills and their relevance to health promotion. Int J Health Prom Educ 1999; 37:89–100.
179. Kirkpatrick S, Tarasuk V. The relationship between low income and household food expenditure patterns in Canada. Public Health Nutr 2003;6:589–97.
180. Monceau C, Blanche-Barbat E, Echampe J. La consommation alimentaire depuis quarante ans. De plus en plus de produits élaborés. (Fourty years of food consumption in France: more and more processed foods.) INSEE première 2002;846:1–4 (in French).
181. West E, Lamp C, Bloock Joy A, et al. Food preparation practices influence nutrition. California Agriculture 1999;Jan-Feb:32.
182. Wardle J, Parmenter K, Waller J. Nutrition knowledge and food intake. Appetite 2000;34:269–75.
183. Patterson RE, Satia JA, Kristal AR, Neuhouser ML, Drewnowski A. Is there a consumer backlash against the diet and health message? J Am Diet Assoc 2001;101:37–41.
184. Jeffery RW, French SA, Forster JL, Spry VM. Socioeconomic status differences in health behaviors related to obesity: the Healthy Worker Project. Int J Obes 1991;15:689–96.
185. Jain A, Sherman SN, Chamberlin DL, Carter Y, Powers SW, Whitaker RC. Why don't low-income mothers worry about their preschoolers being overweight? Pediatrics 2001;107:1138–46.
186. Paeratakul S, White MA, Williamson DA, Ryan DH, Bray GA. Sex, race/ethnicity, socioeconomic status, and BMI in relation to self- perception of overweight. Obes Res 2002;10:345–50.
187. Patterson RE, Kristal AR, White E. Do beliefs, knowledge, and perceived norms about diet and cancer predict dietary change? Am J Public Health 1996;86:1394–400.
188. Dallongeville J, Marécaux N, Cottel D, Bingham A, Amouyel P. Association between nutrition knowledge and nutritional intake in middle-aged men from Northern France. Public Health Nutr 2000;4: 27–33.
189. Dubowitz T, Acevedo-Garcia D, Salkeld J, Lindsay AC, Subramanian SV, Peterson KE. Lifecourse, immigrant status and acculturation in food purchasing and preparation among low-income mothers. Public Health Nutr 2007;10:396–404.
190. Martin KS, Rogers BL, Cook JT, Joseph HM. Social capital is associated with decreased risk of hunger. Soc Sci Med 2004;58:2645–54.
191. Mazur RE, Marquis GS, Jensen HH. Diet and food insufficiency among Hispanic youths: acculturation and socioeconomic factors in the third National Health and Nutrition Examination Survey. Am J Clin Nutr 2003;78:1120–7.
192. Darmon N, Khlat M. An overview of the health status of migrants in France, in relation to their dietary practices. Public Health Nutr 2001; 4:163–72.
193. Scali J, Richard A, Gerber M. Diet profiles in a population sample from Mediterranean southern France. Public Health Nutr 2001;4:173–82.
194. Burr ML, Trembeth J, Jones KB, Geen J, Lynch LA, Roberts ZE. The effects of dietary advice and vouchers on the intake of fruit and fruit juice by pregnant women in a deprived area: a controlled trial. Public Health Nutr 2007;10:559–65.
195. Herman DR, Harrison GG, Jenks E. Choices made by low-income women provided with an economic supplement for fresh fruit and vegetable purchase. J Am Diet Assoc 2006;106:740–4.
196. Lang T. Food control or food democracy? Re-engaging nutrition with society and the environment. Public Health Nutr 2005;8:730–7.