Evidence Implicating Eating as a Primary Driver for the Obesity Epidemic

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This article addresses the extent to which increases in energy intake as opposed to decreases in energy expenditure are driving the obesity epidemic. It argues that while both intake and expenditure are plausible and probable contributors, the fact that all intake is behavioral, whereas less than half of expenditure is behavioral, makes intake a conceptually more appealing primary cause. A review of per capita food disappearance trends over time and of trends in individual intakes is presented to support the plausibility of this perspective. Increases in energy intake mirror increases in body weight quantitatively and are equally widely distributed across diverse groups within the larger population. *Diabetes* 56:2673–2676, 2007

Obesity is the number one nutritional issue in the U.S. and in much of the rest of the world today. More than two-thirds of U.S. adults have body weight exceeding recommended ranges, putting these individuals at increased risk for a variety of adverse health outcomes (1–3). Compounding concern about high rates of population obesity is the fact that obesity prevalence rates are rising rapidly. The proportion of the population affected by obesity has more than doubled in the last 20–30 years, the rate of increase holding steady at approximately one percentage point per year. So far, there is no evidence to suggest that the obesity trend will slow any time soon. The rapid increase in obesity rates is why it is now often called an "epidemic," and both scientific researchers and public health officials are energetically seeking answers to two closely related questions, i.e., what is causing it, and how can we reverse it?

Conceptually, obesity is a state in which an individual has stored body fat in amounts far exceeding biological need. Usually it is a result of a small but chronic positive energy imbalance that continues over many years. The reason why the problem is so widespread and why it suddenly worsened dramatically starting around 1980 is not well understood. We know where energy comes from, i.e., food. We also know how the body uses it. More than half is used to perform obligatory biological functions, such as maintenance of body temperature, metabolism, and tissue repair. The rest is used to power the muscular work required for human beings to interact with their environment. If food energy intake exceeds energy requirements, excess energy is stored as body fat. If energy expenditure exceeds energy intake, energy fat stores are tapped to make up the difference. Changes in the rate at which body fat is accumulated over time are thus intimately linked to patterns of food intake and physical activity.

In trying to understand the evolving obesity epidemic, the relative contribution of declining energy expenditure and increasing energy intake to the problem has yet to be determined conclusively, and there is disagreement among health professionals about the importance of the two (4–6). The purpose of this article is to review scientific data implicating increased energy intake as the cause of rising body weight. Companion Perspectives articles in this issue review the data on energy expenditure (7) and discuss the economic burden of obesity (8).

BACKGROUND

Temporal and socioeconomic trends in obesity. Excellent representative weight and height data are available in the U.S. going back at least to the early 1960s. Population surveys conducted between that time and today indicate that changes in body weight, which can be indexed either by mean population BMI or by the proportion of individuals in the population who are obese (BMI $\geq$30.0 kg/m^2), have been substantially upward during that time. Figure 1 shows time trends in obesity prevalence between 1960 and 2000. Between 1960 and 1980, BMI increase in our population was slow, about one-tenth of 1% per year or a 1% increase in relative weight per decade. The trend during this period was not desirable, but also not alarming. Starting about 1980, however, there was a dramatic shift upward in the rate of change in relative weight. The rate jumped 5- to 10-fold in a very short time interval and from 1980 to present has increased about one-half to one percentage point per year. Twenty-five years of weight increasing at this rate has resulted in the average adult in the U.S. now being over 20% heavier, equating for age and height, than in 1980. It is noteworthy that the surveys, which have been used to estimate these population trends in relative body weight, have also been examined in different age-groups, in both sexes, and in a number of ethnic subgroups. Figures 1, 2, and 3 show changes in obesity prevalence over time for three age-groups, for men compared with women, and for African Americans and Hispanic Americans compared with European Americans. Figure 4 shows time trends for children expressed as the percentage exceeding criteria for "overweight" (3). These different population subgroups differ substantially in absolute levels of obesity. Middle-aged adults weigh substantially more than young adults, and African Americans

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NHANES, National Health Nutrition Examination Survey.

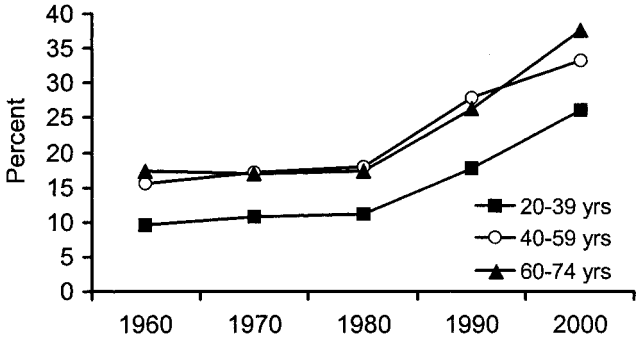

FIG. 1. Prevalence of obesity (BMI ≥30 kg/m^2) in U.S. adults by age, 1960-2000 (ref. 1).

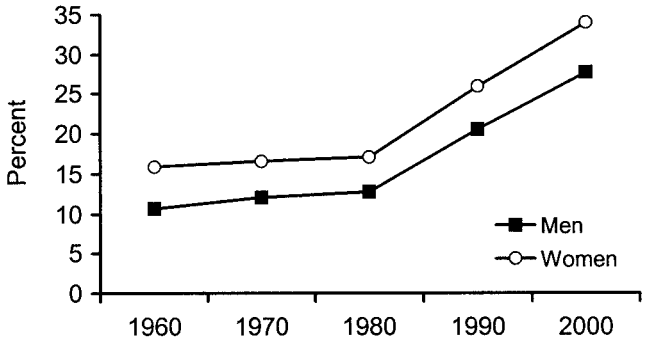

FIG. 2. Prevalence of obesity (BMI≥30 kg/m^2) in U.S. adults, 1960-2000 (refs. 1,2).

weigh substantially more than individuals of European ethnicity. Nevertheless, the time trends of increase in relative body weight have been remarkably similar across all of these groups.

Taken together, we believe these data have important implications for investigating the causes of rising obesity rates. Whatever the cause of this epidemic, it is affecting young children approximately the same as the elderly, it is affecting women about the same as men, and it is affecting all ethnic subgroups similarly. Any explanation of the obesity epidemic with respect to eating or physical activity must therefore take into account two critical factors: first, the abrupt change in obesity rates beginning at a particular point in time (e.g., around 1980), and second, the pervasiveness of the phenomenon across every segment of society.

Biological constraints on energy intake and expenditure. Biological feasibility should also be considered in apportioning responsibility for the obesity epidemic to energy intake versus expenditure (9). Although a variety of biological feedback mechanisms exert influence over energy consumption, eating is 100% behavioral in the sense that it always involves eating and is therefore quite modifiable. Over short periods of time (e.g., 24 h), a range of eating from well below to several times the amount of food needed to meet energy requirements in the same time period is both feasible for most people and commonly observed. Naturally occurring variability in intake is associated with a variety of factors including individual differences in biology, food availability, food palatability, energy density of food, variety of food, and purposeful food choices made by individuals based on religious beliefs, cultural norms, and desire to exert control over body weight.

Energy expenditure by comparison entails much less volitional flexibility. In most human populations, the majority of energy expenditure is obligatory and not modifiable. Body temperature has to be kept in a very narrow range, and body metabolic processes have to function in narrow tolerance limits in order for humans to survive. In relatively sedentary populations, such as that in the U.S., it has been estimated that as much as 60–80% of energy expenditure is not modifiable, and even in very active populations, the modifiable portion is seldom as high as 50%. Modifiability of expenditure is also limited by biological limits of the physical capacity for work. In most people, energy expenditure at rates higher than 5–7 kcal/min cannot be sustained for more than a short period of time.

The inherent asymmetry in our ability to acquire energy compared with our ability to use it has obvious advantages for survival, as well as for lifestyle diversity. However, it is good to keep in mind the implication of these facts when examining the causes of population obesity. We have seen increases of ~20% in the population prevalence of obesity and relative body weight. Energy needs are not literally proportional to body weight for a variety of reasons; e.g., fat tissue is less metabolically active than lean tissue. To produce a 20% increase in body weight, however, ~20% more calories would have to be consumed per unit time. To produce a similar change in energy balance by reducing energy expenditure would require a much more profound change in the modifiable portion of energy expenditure, i.e., physical activity. In a relatively sedentary population, with 30% of its energy being used for physical activity, a 20% reduction in total energy expenditure would require a 67% reduction in physical activity. Even in very active individuals whose total energy expenditures comprise 50% modifiable work, a 20% reduction in total energy expenditure would require a 40% reduction in active work. In sum, explaining any change in body weight in terms of changing

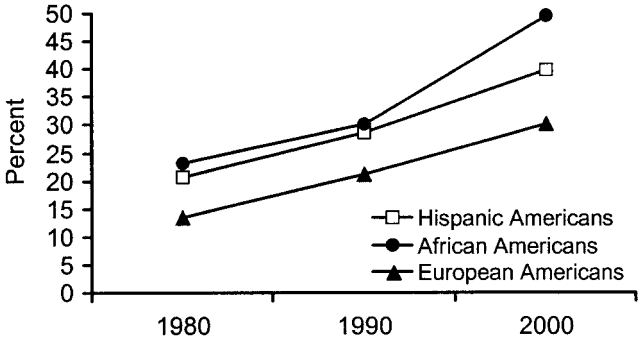

FIG. 3. Prevalence of obesity (BMI ≥30 kg/m^2) in U.S. adults by ethnicity, 1980-2000 (ref. 2).

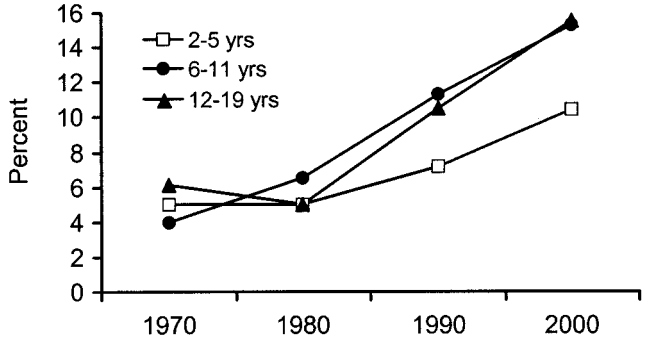

FIG. 4. Prevalence of overweight in U.S. children, 1970-2000 (ref. 3).

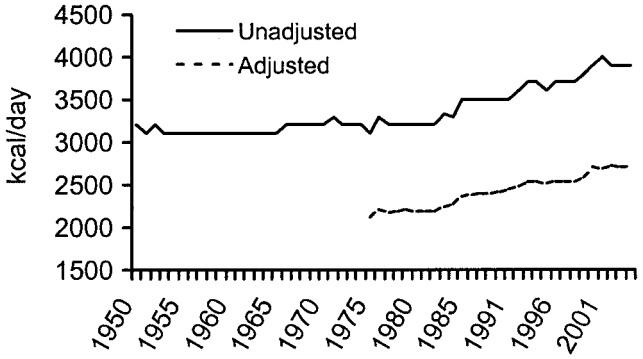

FIG. 5. Annual per capita availability of energy adjusted and unadjusted for waste (U.S. Food Supply Series) (refs. 5–7,10).

energy intake is inherently more plausible biologically than explaining the same change through changes in volitional physical activity.

METHODS AND RESULTS

Long-term trends in energy intake. The U.S. Food Supply Series, which provides annual estimates of per capita availability of foods and nutrients (10–12), provides a picture of long-term trends in energy intake. This data source indicates that the per capita availability of energy has increased steadily in the U.S. since the 1960s (Fig. 5), with the greatest change occurring between 1982 and 2004, which matches the time course of the obesity epidemic. The magnitude of per capita availability of energy also roughly matches the obesity epidemic data, increasing from 3,200 kcal/day (1982) to 3,900 kcal/day (2004) or 22%.

Strengths of the U.S. Food Supply Series data include its reliance on objective measures of food availability and the consistent manner in which the data has been collected and analyzed over time. The primary limitation of the data relates to its representation of food availability rather than consumption. Because food that is wasted or that spoils during the marketing process or in the home is not subtracted in calculating food available for consumption, estimates of per capita availability are overestimates of actual consumption. Thus, food-disappearance data are not useful for estimating absolute intake. However, the data may be a useful indicator of trends in consumption over time, assuming that food spoilage and waste remain constant. The U.S. Department of Agriculture Economic Research Service has developed a method for adjusting Food Supply Series data for spoilage, plate waste, cooking, and other losses in the home and marketing system and

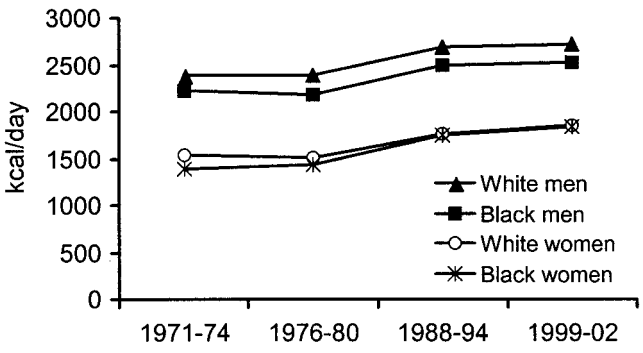

FIG. 7. Age-adjusted mean energy intake (kcal/day) among white and black men and women, NHANES 1971-1974 through 1999-2002 surveys (ref. 12).

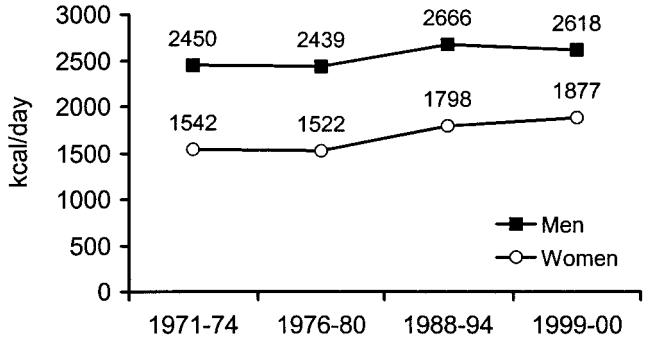

FIG. 6. Age-adjusted mean energy intake (kcal/day) by sex, NHANES 1971-1974 through 1999-2000 surveys (ref. 11).

has applied these adjustments to Food Supply Series data collected since 1970 (13). Trends in per capita availability adjusted for these sources of spoilage and wastage (Fig. 5) are similar to trends seen with unadjusted estimates. Overall, trends in per capita energy availability from the Food Supply Series data correspond well with trends in the prevalence of overweight and obesity.

Robustness of trends across demographic groups. Like trends in the prevalence of overweight and obesity, increases in energy intake have been observed across age, sex, and ethnic groups. The most widely accepted data documenting patterns of diet change in different population subgroups on an individual level are from the National Health Nutrition Examination Survey (NHANES). Between 1971–1974 and 1999–2000, NHANES data indicate that average energy intake has increased significantly among both men and women (Fig. 6) (14). Similarly, average energy intake has increased among both white and black Americans (Fig. 7) (15). With regard to age, increased energy intake has been observed among both adolescents (16) and adults (14). In addition, among adults increased energy intake has been observed among all age strata (Fig. 8).

Energy intake estimates from NHANES must be interpreted with caution due to several methodological shortcomings. First and foremost, estimates are based on 24-h dietary recalls, a self-report methodology for assessing dietary intake. Underreporting of dietary intake is a well-documented shortcoming of this methodology (17), and it has been speculated that the magnitude of underreporting of intake may be growing over time (18,19). Indeed, it is well known that underreporting of intake is greater among overweight than nonoverweight individuals (17). Hence, the magnitude of underreporting of intake in surveys is

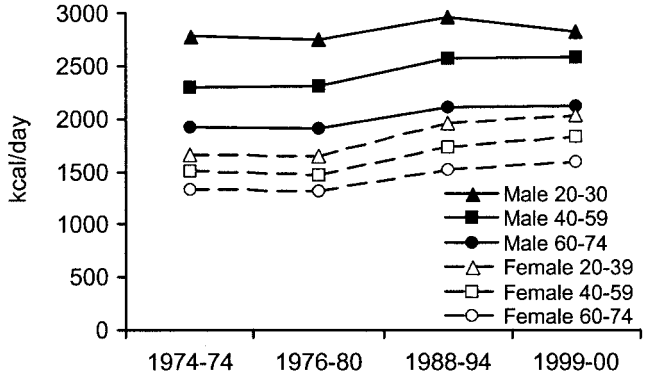

FIG. 8. Age-adjusted mean energy intake (kcal/day) by sex and age, NHANES 1971-1974 through 1999-2000 surveys.

likely increasing along with prevalence of obesity. Also, larger-sized food portions tend to be underestimated (20–22), which may contribute to growing underestimation of intake with the increasing availability and consumption of larger-sized food products (23). If underestimation of intake is increasing over time, upward trends in energy intake may be even greater than observed across NHANES surveys.

Another methodological consideration relates to changes made in the dietary intake assessment method used across survey periods (14). Most notably, beginning in 1988, the dietary recalls were collected for weekend days as well as weekdays; because food consumption is higher on weekend days than weekdays (24), this methodological change would be expected to increase average energy intake estimates. Also, the interview format was revised to include questions that might have resulted in more complete reporting of dietary intake. This change would also be expected to result in higher energy intake estimates relative to earlier survey methodologies. It is interesting to note that upward trends in energy intake have persisted beyond those seen in the survey period following initiation of these methodology changes, suggesting that upward trends observed are unlikely to be completely artifactual.

DISCUSSION

Based on results from national dietary surveys and food disappearance data, there is little doubt that energy intake in the U.S. population has increased in tandem with rising rates of obesity. Furthermore, like upward trends in obesity rates, energy intake appears to be increasing among men and women, blacks and whites, and all age-groups. Thus, it may be concluded that dietary changes are contributing to the obesity epidemic, playing a role in its etiology across all segments of the population.

Although methodological concerns noted above preclude a precise quantitative estimate, the magnitude of the shift in energy intake observed at the population level is substantial and probably enough to account for a substantial portion of the increase seen in body weight. Among U.S. men, energy intake increased from an average of 2,450 kcal/day in 1971–1974 to 2,618 kcal/day in 1999–2000, an increase of 168 kcal/day or 7% (14). The upward shift was greater among women, increasing by 335 kcal/day or 22% (14). Weight increases during the same time period were ~15%.

A final observation on the relative plausibility of population weight changes being driven by changes in intake versus expenditure is the consideration of the behavior changes needed in order to shift energy balance by 300 kcal/day to reverse recent gain in body weight. On the eating side, replacing two sweetened beverage drinks per day with noncaloric drinks would achieve this goal. On the physical activity side, a 300 kcal increase in energy expenditure would require ~60 min of walking. Thus, regardless of the relative importance of intake versus expenditure in causing population weight gain, changing eating behavior as well as physical activity would seem to be a more feasible approach to weight loss than changing physical activity alone.

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