Increased food energy supply is more than sufficient to explain the US epidemic of obesity\textsuperscript{1,2}

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ABSTRACT

Background: The major drivers of the obesity epidemic are much debated and have considerable policy importance for the population-wide prevention of obesity.

Objective: The objective was to determine the relative contributions of increased energy intake and reduced physical activity to the US obesity epidemic.

Design: We predicted the changes in weight from the changes in estimated energy intakes in US children and adults between the 1970s and 2000s. The increased US food energy supply (adjusted for wastage and assumed to be proportional to energy intake) was apportioned to children and adults and inserted into equations that relate energy intake to body weight derived from doubly labeled water studies. The weight increases predicted from the equations were compared with weight increases measured in representative US surveys over the same period.

Results: For children, the measured weight gain was 4.0 kg, and the predicted weight gain for the increased energy intake was identical at 4.0 kg. For adults, the measured weight gain was 8.6 kg, whereas the predicted weight gain was somewhat higher (10.8 kg).

Conclusions: Increased energy intake appears to be more than sufficient to explain weight gain in the US population. A reversal of the increase in energy intake of \( \approx 2000 \text{ kJ/d (500 kcal/d)} \) for adults and of 1500 kJ/d (350 kcal/d) for children would be needed for a reversal to the mean body weights of the 1970s. Alternatively, large compensatory increases in physical activity (eg, 110–150 min of walking/d), or a combination of both, would achieve the same outcome. Population approaches to reducing obesity should emphasize a reduction in the drivers of increased energy intake.

INTRODUCTION

The relative contributions of increased total energy intake (TEI) and reduced physical activity to the obesity epidemic have long been debated (1–3), and quantitative methods are needed to estimate these relative contributions. Whereas a healthy, low-energy diet and regular physical activity need to be promoted to prevent weight gain and improve other health outcomes, it is important to know whether one side or the other of the energy balance equation is the major driver of the increase in obesity. This would help to prioritize policies and programs so that prevention efforts could be better targeted toward reducing the underlying drivers of the epidemic. It also has clinical implications for understanding and countering weight gain in individuals.

We previously analyzed the relations between body weight, TEI, and total energy expenditure (TEE) measured by using doubly labeled water techniques for children (\( n = 963 \)) (4) and adults (\( n = 1399 \)) (5). Energy flux was assumed to equal TEI and TEE because, on any given day, a population is virtually weight stable. Because these cross-sectional relations are constrained by the first law of thermodynamics, the equations can be used to predict changes in weight in response to changes in energy intake and physical activity. A scatter plot between body weight and energy flux for adults is shown in Figure 1 (5). From the starting point of the mean energy flux and mean weight, a population can gain weight by increasing TEI alone (white arrow), decreasing physical activity alone (black arrow), or some combination of the 2 (vector lines between the 2 arrows).

We inserted food energy supply data from the 1970s and the 2000s into the equations for the white arrow to predict the weight increases, thus helping to answer the question about whether the observed increase in food energy supply (and thus food energy intake) was sufficient to explain actual weight increases for the US population over the same period. This analysis demonstrates the practical application of these equations to answer important public health questions.

METHODS

The National Health and Nutrition Examination Surveys (NHANES) (6) provided the measured mean weights for the US children and adults in the 1970s (1971–1976) and the 2000s (1999–2002). The US food supply data for those same years, adjusted for food loss (spoilage and other waste), were used to estimate the per capita energy supply (7). The food supply data represent the food available for consumption rather than the amount of food actually ingested, so these estimates of per capita energy supply are overestimates of actual consumption, even after adjustment for food loss. In addition, food loss, particularly at the consumer level, is by nature difficult to measure accurately, and the US Department of Agriculture (USDA) acknowledges that even their updated estimates of retail, food service, and

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consumer food losses are probably understated (7, 8). Nevertheless, the USDA states that the food supply data provide a useful indicator of trends in consumption over time because many of the errors in the data are likely to be systematic, thus cancelling out when changes over time are examined (7).

The per capita energy supply was then apportioned between children (2–18 y) and adults. To do this, the 1970 and 2000 US census data (9) were used to derive the child:adult population proportions, and the doubly labeled water studies (4, 5) were used to derive data for energy intake proportions between children and adults (by using the appropriate mean age and weight from the census and NHANES data). The apportioned energy supply data (henceforth called estimated energy intake) were then included in the equations for children (4) and adults (5) to derive predicted weight gains, which were compared with their respective measured gains.

RESULTS

The estimated food energy intake for children was 7.10 MJ/d (1690 kcal/d) in the 1970s and 8.58 MJ/d (2043 kcal/d) in the 2000s and for adults was 10.07 MJ/d (2398 kcal/d) in the 1970s and 12.16 MJ/d (2895 kcal/d) in the 2000s (Figure 2). These data were combined with the mean (± SEM) measured weights from the 2 NHANES surveys for children (39.1 ± 0.9 and 43.1 ± 0.9 kg) and adults (72.2 ± 0.3 and 80.8 ± 0.4 kg) to form the darker solid lines in Figure 3. The predicted body weights from the equations are plotted against the estimated energy intake and are shown as the lighter dashed lines in Figure 3. For children, the predicted mean weights for the 2 periods were 35.1 to 39.1 kg, which made the predicted increase identical to the measured increase (4.0 kg). For adults, the predicted mean weights for the 2 periods were 68.0 to 78.8 kg, which made the predicted increase (10.8 kg) slightly larger than the measured increase (8.6 kg).

The fact that the predicted weight increase was greater than the measured increase implies that, if anything, concurrent physical activity may have increased over this time period, but this was not directly measured.

DISCUSSION

The predicted changes in weights derived from the equations suggest that increase in estimated energy intake is sufficient, by itself, to explain the increase in weight in the US population. Such

![Figure 1](image1.png)

**FIGURE 1.** The relation between energy flux (total energy intake = total energy expenditure) and body weight (values normalized by logarithmic transformation) for a population of adults. The changes in mean population weight in response to increasing energy intake alone (white arrow) and decreasing physical activity alone (black arrow) are shown.

![Figure 2](image2.png)

findings are supported by studies using other approaches to the same question (10) and by epidemiologic data showing that physical activity levels have not decreased, or have even increased, over the period of time that obesity prevalence has been increasing (11–14). For example, Westerterp and Speakman (11) compiled data from 13 US doubly labeled water studies over 2 decades and showed that physical activity energy expenditure had apparently increased over that time.

The limitations of this study included the crudeness of the food supply figures and the assumptions made in allocating them across children and adults. The absolute differences between the measured mean body weights and the prediction equation estimations at each time point (equations underestimated by ≈2–4 kg) were undoubtedly due to the different methods of the approaches. However, it is the comparison of the changes over time that is important because the systematic methodologic differences will cancel out. Nevertheless, it is possible that secular changes in food supply errors may have introduced a bias in the estimates over time. For example, high failure rates for new food products may have increased retail food losses in recent years as the number of new products introduced has risen (8); however, an increase in retail food losses is not supported by recent data indicating that directly measured aggregate supermarket losses are very similar to the estimates derived by using the traditional USDA methods of calculating retail food loss (15). Similarly, an increasing trend toward eating away from home may have resulted in recent increases in food service food losses, whereas, in contrast, technologic advances in food processing may have decreased food production losses over time (8).

A further assumption is that the relation between energy flux and body weight, as shown in Figure 1, is assumed to apply to the US population over the time period studied. The multicountry data used to generate those equations suggests that this positive relation between energy flux and body weight is applicable across populations.

These US findings probably apply to other high-income countries, where increases in obesity have occurred without marked changes in urbanization, car ownership, or the built environment. However, whereas reductions in physical activity do not appear to be driving the increase in obesity in the United States, the dominance of car transport in the United States has probably allowed a steeper trajectory of weight gain than, for example, the Netherlands or Denmark, where active transport is more the norm. This clarifies the role of energy intake and physical activity in the 3 major obesity epidemic questions: what are the drivers of the increasing prevalence (this study suggests it is dominantly energy intake), what are the moderators that influence the steepness of the trajectory of weight gain (population differences in energy intake and/or physical activity levels), and what are the solutions to reversing the epidemic (see below)? Countries such as China are undergoing a nutrition transition along with rapidly increasing urbanization, mechanization, and car ownership (16, 17). Thus, their rise in obesity is likely due to a combination of increasing energy intake drivers and the declining moderators of active transport and physically active occupations.

For the US population to return to the mean weights of the 1970s, the increased energy intake of ≈1500 kJ/d (350 kcal/d) for children (about one can of soda and a small order of French fries) and 2000 kJ/d (500 kcal/d) for adults (about one large hamburger) would need to be reversed. Alternatively, compensatory increases in physical activity (≈150 and 110 min/d of extra walking respectively) would achieve similar results.

This study has important policy implications. Whereas ongoing efforts are needed to increase physical activity levels in the population, the priorities for reversing the obesity epidemic should focus on energy intake by addressing the obesogenic food environment drivers of the current energy overconsumption.

The authors’ responsibilities were as follows—BS and ER: developed the initial concepts; GS: undertook the analyses; and BS: mainly responsible for the writing of the manuscript. All authors contributed to the interpretation of the results. All authors declared that they had no competing interests.

REFERENCES