Dietary fat and obesity: an epidemiologic perspective[1,2]

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ABSTRACT The observation that dietary fat has an effect on weight gain and the development of obesity that is larger than would be expected on the basis of fat's energy value is mainly experimental. Several methodologic problems limit the interpretation of epidemiologic studies of the association between dietary fat intake and obesity. Among the issues relevant in this context are underreporting of energy and fat intakes, dieting behavior, inadequate control for variables such as energy expenditure, and limited between-subject variation in fat intake in developed countries. Different types of epidemiologic studies suffer from different types and magnitudes of bias and many conflicting results can be obtained. Ecologic and cross-sectional studies especially suffer from these biases. The more appropriate type of study (ie, prospective studies of fat intake and subsequent weight gain) was carried out in several countries but conflicting results were obtained. Overall, the observed associations seem to depend on the stage of cultural transition of the population studied (eg, modernization compared with postmodernization). Current epidemiologic methods are inadequate for performing valid studies of the relation between percentage of energy from dietary fat and obesity. Specifically designed prospective studies of unbiased estimates of energy balance are necessary. Appropriate control for confounders and emphasis on the possibility that genetic predisposition plays a role will also be necessary. At this stage there is no conclusive evidence from epidemiologic studies that under isoenergetic conditions dietary fat intake promotes the development of obesity more so than other macronutrients. *Am J Clin Nutr* 1998;67(suppl):546S–50S.

KEY WORDS Obesity, dietary fat, epidemiology, energy balance, body weight, bias, confounders

INTRODUCTION

Obesity results from an imbalance between energy intake and energy expenditure. Relative excessive energy intake can of course result from excess fat intake. Because diets high in fat are usually energy dense and palatable, a diet relatively high in fat usually leads to an increase in energy intake (1). In addition, it has been proposed that fat intake is less well regulated than carbohydrate intake (2).

There seems to be little disagreement that, through these mechanisms, high fat intakes may promote obesity. Much more controversial is the concept that high-fat diets are more likely to lead to weight gain and obesity than isoenergetic low-fat diets. I evaluate the epidemiologic evidence that high-fat diets lead to obesity in populations independently of total energy intake.

LIMITATIONS OF EPIDEMIOLOGIC MEASURES

The most important limitation of epidemiologic studies is that the key variables in the association between dietary fat intake and obesity can be measured only by proxy and are usually subject to important bias. The most important variables are energy and fat intakes, energy expenditure, and obesity.

Energy and fat intakes can be measured by various techniques ranging from 24-h recalls and food-frequency questionnaires to multiple-day, weighed-food records (3). The precision and reproducibility of measurements of energy and fat intakes vary greatly between methods. More importantly, errors are related to the degree of obesity. Reported energy intakes are usually much lower than expected or measured energy expenditure. As shown in **Figure 1,** reported energy intakes in American women are ≈3–4 MJ/d lower than energy expenditures calculated from studies using the doubly labeled water method (4, 5). The discrepancy increases with increasing body mass index (BMI).

In addition, it has been suggested in some studies that underreporting of fat intake by obese subjects may be even greater than that of energy intake (6). This severely limits the possibility of studying the relation between energy from fat and obesity in epidemiologic studies. As shown in **Table 1**, Ballard-Barbash et al (4) showed that, among American white women, underreporting was related to education, leisure activity, smoking habits, and health status. All characteristics are potential confounders in the association between percentage of dietary energy from fat and obesity. Moreover, low-energy and low-fat dieting attenuated the inverse association between energy intake and BMI (4). Because obesity may lead to dieting behavior, spurious associations between energy and fat intakes and obesity may be observed among those who attempt to lose weight.

Even if measured adequately, in some populations energy intake can be lower than in others despite higher levels of obesity. This seems to be a paradox but can in some instances be explained by differences in energy expenditure. Taylor et al (7), for instance, showed that rural inhabitants of Pacific Island countries were leaner but had higher energy intakes than did their urban counterparts. The proportion of energy from fat was lower in the diet of the rural population, however. The authors con-

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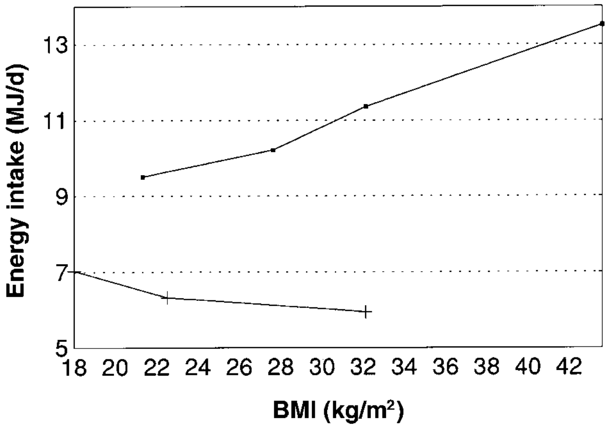

FIGURE 1. Relation between BMI and reported 24-h energy intake in US women (lower line; adapted from reference 4) and between BMI and 24-h energy expenditure measured by the doubly labeled water method (upper line; adapted from reference 5).

TABLE 1
Prevalence of underreporting of energy intake and prevalence of overweight [BMI (in kg/m^2) > 27.3] in US women in relation to weight-related characteristics[1]

Weight-related variable	Percentage underreporting	Percentage overweight
	%	
Education (y)		
< 12	60	29
12	55	27
≥ 12	45	19
Leisure-time activity		
Light	54	31
Moderate	51	21
Heavy	48	12
Smoking behavior		
Current	54	21
Former	49	28
Never	51	24
Health status		
Excellent	48	16
Very good	51	23
Good	55	32
Fair	64	38
Poor	70	46

[1] Underreporting was defined as energy intake < 1.06 × (estimated) basal metabolic rate. From reference 4.

cluded from these data that both exercise and diet have significant effects on the differences in obesity prevalence between rural and urban populations on these islands. They also concluded that, in this study, energy intake probably reflected energy expenditure.

The lower energy intakes reported by obese individuals have also been proposed to be due to lower expenditures of energy through physical activity. Studies in which doubly labeled water methods were used, however, showed that obese individuals, except for severely obese men, expend more energy during activity over 24 h on average than do nonobese individuals (4). The ratio of total energy expenditure to basal metabolic rate (as an indicator of physical activity) was constant across categories of BMI (4). On the other hand, lower reported levels of voluntary physical activity in obese than in nonobese individuals were observed in several surveys (8). Similar types and intensity of activities lead to higher energy expenditures among obese subjects. Energy expenditure through voluntary physical activity is difficult to assess by current epidemiologic methods. Even if instruments are reasonable, some studies have suggested that subgroups of obese subjects also overreport their physical activity to a greater degree than normal-weight individuals (9). The use of doubly labeled water in combination with measurements of basal metabolic rate is usually unfeasible in epidemiologic studies because of the high cost involved. It is clearly important to be able to interpret data on dietary intakes in light of estimates of energy expenditure.

Finally, obesity is usually measured by BMI calculated from reported or measured height and weight. BMI is an imperfect measure of energy stored in the form of triacylglycerol in the body. Moreover, reported weights are increasingly unreliable with increasing degree of obesity. In some studies, associations were observed between fat intake and BMI compared with fat intake and skinfold-thickness measurements (10).

STUDIES OF POPULATIONS

Ecologic studies have shown positive as well as negative associations between the percentage of energy from fat and average BMI in populations (11). Positive associations are usually observed in studies that include populations consuming diets relatively low in fat, such as the Seven Countries Study, which included Japanese cohorts who consumed a diet with < 10% of energy from fat. In selective studies, Lissner and Heitmann (12) also showed associations between fat percentage in the diet as based on food balance sheets and mean BMI. Such associations are problematic for several reasons. First, there are considerable regional differences in average BMI, whereas food disappearance data are collected nationally. Second, there are considerable differences in mean BMI between men and women within populations. There is much more variation in prevalence among women than among men and the correlation between median BMI of men and women in the World Health Organization MONICA study was only 0.41 (**Figure 2**) (11).

These data suggest that, with presumably similar diets, men and women can differ considerably in average fatness. Lissner and Heitmann (12) noted a negative association between median BMI and percentage of energy available from fat in women but did not mention the direction or strength of such an association in men.

Within populations it is possible to compare average fat intake and average BMI over time or between subgroups of the population. Time trends differ depending on the phase of transition from one type of culture to another. Modernization of hunter-gatherers usually leads to decreased energy expenditure and increased consumption of energy-dense diets (high in fat and refined carbohydrate and low in complex carbohydrates and fiber) and results in increases in average BMI and the proportion of obese individuals.

Examples of these simultaneous changes in multiple lifestyle factors during modernization were shown in Polynesians (13), native populations in North America such as Pima Indians (14)

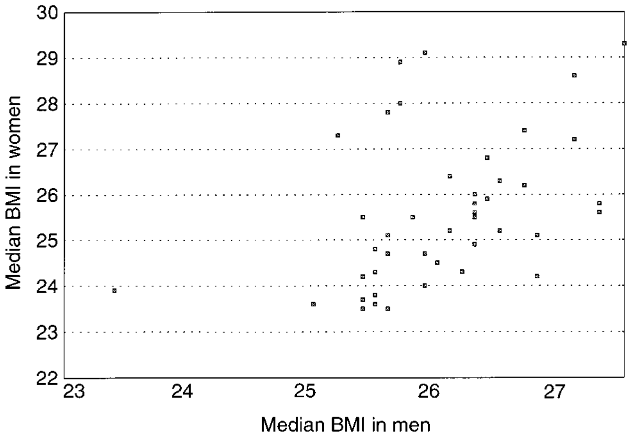

FIGURE 2. Association between median BMI in men and that in women in the World Health Organization MONICA study (adapted from reference 11). Each point represents the data of one center (town or region). $r = 0.43$.

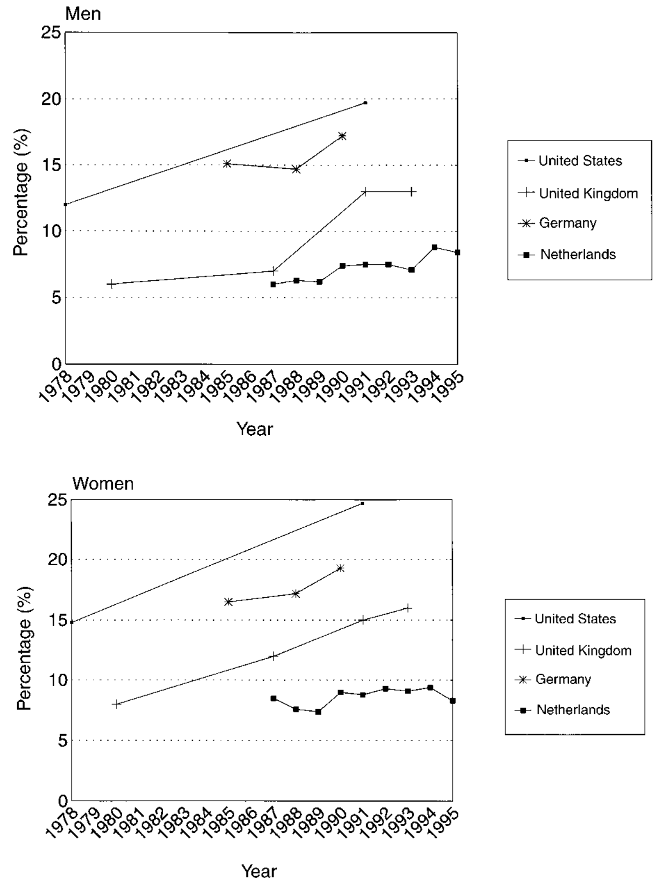

FIGURE 3. Time trends in the prevalence of obesity [BMI (in kg/m^2) > 30] in some European countries and in the United States (partly adapted from reference 21).

and Alaska natives (15), Chinese (16), New Guineans (17), and Australian Aborigines (18). Usually it is impossible to differentiate between the effects of reduced physical activity, reduced energy intake, and relative increase in fat intake under these circumstances. In some of these populations it has been suggested that the extremely high rates of obesity are a result of an interaction between modernization and a strong genetic predisposition for obesity (13).

Other studies focused on immigrants from traditionally lean populations to affluent countries. Well-known examples are immigrants from Japan to California and Hawaii (19). Obesity is much less common in Japan than in Japanese immigrants to the United States. Total energy intake was not shown to be very different between groups, but percentage of energy intake as fat was about two times higher in Hawaii and California than in Japan (which may illustrate again that total energy intake may also reflect higher energy expenditure).

Modernization may be followed by trends described by Stern et al (20) as postmodernization. In European, Australian, and US populations this can be simplified as an increase in reported leisure-time physical activity, reduced fat intakes, and reduced smoking rates. In other words, in these cultures there is adherence to some of the basic lifestyle recommendations and this is usually accompanied by decreases in blood pressure and total cholesterol. Paradoxically, this is also accompanied by increases in the prevalence of obesity (21–23). As shown in **Figure 3**, the prevalence of obesity varies widely among countries that are geographically not very distant (eg, Netherlands and neighboring Germany) and is increasing in most European countries as well as in the United States. In the case of Netherlands, the United Kingdom, and the United States, data suggest that self-reported energy and fat intakes have both decreased in the same period.

The validity of trends in self-reported energy and fat intakes can be questioned, however, particularly when obesity rates are increasing and because obesity is associated with underreporting of dietary intake. Smoking cessation accounts for a relatively small proportion of this increase in obesity (24, 25). Other explanations include the failure of people to accurately report physical activity and energy and fat intakes. Another possibility is that total energy expenditure (particularly as a result of very low energy expenditure during those periods not dedicated to physical exercise during leisure time) is reaching such low levels that it is virtually impossible to adjust dietary habits to those necessary to maintain a stable body weight. Decreased transportation by walking or cycling and increased numbers of hours spent by children watching television and videos are among the societal changes that have been proposed to play a role in this phenomenon (26, 27).

STUDIES IN INDIVIDUALS: CROSS-SECTIONAL COMPARED WITH LONGITUDINAL RESEARCH

Apart from the fact that there may be serious bias in the reporting of energy intake, dietary fat intake, physical activity, and height and weight, which increases with the degree of obesity, inferences about causality cannot be drawn from cross-sectional studies. Lissner and Heitmann (12) recently compiled the data from cross-sectional studies and concluded that in most studies there is a positive association between percentage of energy from fat and BMI in modernized populations. Bolton Smith and Woodward (28) suggested that the ratio of fat to extrinsic sugar intake was an even better predictor of obesity in such analyses than was fat alone. Some have gone so far as to suggest that a high sugar intake may in fact protect individuals against obesity (29). There are too many problems with reported food intakes in obese compared with normal-weight individuals,

TABLE 2
Description of prospective studies of the relation between percentage of energy from fat and weight gain in adults

Author	Year	Population	Association
Rissanen et al (30)	1991	Adult Finns	Positive in women,[1] no association in men
Colditz et al (31)	1990	US nurses	No association
Klesges et al (34)	1992	US adults	Positive in men and women
Heitmann et al (32)	1993	Adult Swedish women	Positive only in genetically predisposed women
Kant et al (33)	1995	US adults	No association in men and women

[1] Dietary fat energy, not adjusted for total energy intake.

however, to allow us to make valid conclusions.

Because of the limitations of cross-sectional studies, prospective studies are preferable, although these same biases may already be present at baseline. In addition, usually little is known about changes in dietary behavior during follow-up. Weight change in adults is usually a much better indicator of changes in energy balance and fatness than BMI measured simultaneously with the dietary information. This is not true for younger subjects, who are still growing, or in older subjects, in whom changes in weight are more likely to be attributable to changes in lean body mass.

An overview of some prospective studies of dietary fat intake and weight gain is given in **Table 2**. The results are clearly not consistent. There are also some problems in the interpretation of each of the studies. In the study by Rissanen et al (30), no adjustments were made for total energy intake. Colditz et al (31) found no relation between percentage of energy from fat and weight gain prospectively, but did find a positive association between previous weight gain and relatively high fat intake. Heitmann et al (33) observed a positive association between dietary fat intake and weight gain only in women who were genetically predisposed for obesity. Women who were already overweight at baseline and who had at least one parent who reportedly was obese were considered genetically predisposed for obesity. However, it is unclear why women who had similar family histories of obesity but were not overweight at baseline could not be considered predisposed for obesity. Although there are some limitations, this study was the first to show that there may be subgroups of individuals who are more likely than others to gain weight in response to a relatively high-fat diet. Further research in this direction is clearly needed.

In the study by Kant et al (34), no significant association was observed between percentage of energy from fat and weight change in men. Among women aged < 50 y, an inverse relation between percentage of energy from fat and weight change was observed. After the exclusion of respondents with any morbidity, percentage of energy from fat and weight change were positively associated in men but not in women. In the remaining studies (30–33), the failure to find an association between relative fat intake and weight gain was usually attributed in part to the small range of relative fat intakes observed in these populations.

Although most cross-sectional studies do suggest an association between percentage of energy from fat and obesity, the results of prospective studies are clearly inconsistent. Given the limitations in measurement of the key variables, this does not allow us to make any firm conclusions about a possible association between dietary fat and obesity. It is likely that with current measurement instruments it is not possible to perform valid epidemiologic studies of dietary fat intake and obesity unless such studies are specifically designed to do so.

Dietary counseling focusing on fat reduction rather than dietary restriction in promoting long-term weight loss is therefore not warranted on the basis of epidemiologic evidence. Lowering fat intake, however, may of course have several other potential health benefits (such as lowering LDL cholesterol and triacylglycerol) and drawbacks (such as lowering HDL cholesterol) as described in other contributions in this supplement (35, 36). Lissner and Heitmann (12) reviewed six randomized dietary fat intervention studies without energy restriction with a duration from 6 wk to 6 mo and changes in energy intake from fat of from 30–40% to 20–30%. Weight loss in trials of short duration was ≈1 kg; in trials lasting 3–6 mo, weight loss was ≈3–4 kg. Longer trials have usually shown disappointing results with respect to weight maintenance. Jeffery et al (37) designed a study specifically to evaluate the effects of fat restriction compared with energy restriction on body weight in obese subjects. Among obese subjects, a low-fat diet compared with a diet based on energy restriction led to similar weight loss and regain but better compliance (37). In addition, the low-fat diet was rated as being more palatable and binge eating was reduced with this diet. Moreover, change in fat intake predicted weight change better than change in total energy intake. In populations who suffer from modernization in terms of obesity, it has frequently been shown that a return to a more traditional diet induces weight loss (18, 38).

In summary, it is likely that current epidemiologic methods are inadequate for performing valid studies of the relation between percentage of energy from dietary fat and obesity. This should be done in studies specifically designed to examine this association prospectively, with estimates of energy intake and energy expenditure as well as of dietary fat intake measured with errors unrelated to the degree of obesity. Appropriate control for confounders and emphasis on the possibility that genetic predisposition plays a role will be necessary. At this stage there is no conclusive evidence from epidemiologic studies that dietary fat intake promotes the development of obesity independently of total energy intake.

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