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Diet and Obesity

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WEIGHT AND ENERGY BALANCE

Obesity has been included with anorexia nervosa and bulimia under the psychiatric label of *eating disorders*. The implication of this is that if eating is normal, weight also will be normal, and if weight is excessive, food intake must be abnormal. Work by Sims et al. (1) has demonstrated that extra calories consumed cannot be reliably accounted for by extra weight gained. It is also clear that obese people do not necessarily eat more than their thin counterparts. Adoption studies, such as those published by Stunkard et al. (2) in 1986, have emphasized the role of inheritance in obesity, with monozygotic twins showing closer correlation in body composition than either dizygotic twins or siblings from the same family. How the inheritance of obesity operates is unclear, as are the many psychosocial and lifestyle factors that contribute. It is considered to be of multifactorial etiology.

The concept that obesity is an energy imbalance disorder makes allowance for both environmental and inherited factors to contribute to the gain in body weight. Increased body fat (greater than 25% of total body weight in males and greater than 30% in females) (3) could be due to an increase in food intake at a time when energy expenditure is constant or to a reduction in energy expenditure with constant energy input or to both an increase in food intake and reduced expenditure. The concept of excess weight being equal to energy intake as food and beverage minus energy expenditure as basal metabolic rate and physical activity is simplistic. There are many interrelationships between the two sides of the energy equation, such as that contributed by thermogenesis induced by food substances, as will be discussed later.

HUNGER AND SATIETY, APPETITE AND THE LOSS OF IT

It is important to differentiate between hunger—that is, the sense of needing food—and appetite, which is more the desire to eat or interest in food. It is possible to experience hunger and, if the available foods are in some way not palatable, to have a loss of appetite. In the same sense, satiety is the antithesis of hunger—it is the sense of having had sufficient (4).

PATHOGENESIS AND DIET

Genetic Factors

Twin studies, such as those by Stunkard et al. (5), have shown that concordance rates for degrees of overweight are twice as high for monozygotic as for dizygotic twins. Body mass index (BMI) was highly correlated with heritability for BMI estimated at 0.77 at induction and 0.84 at the 25-year follow-up. The results are further supported by the adoption study of human obesity (2), which concluded that family environment does not significantly determine human fatness. Poehlman et al. (6) have suggested that the thermogenic effect of food has an inherited component and, therefore, have suggested one mechanism for diet and heredity to interact in human obesity.

Age

Adiposity is known to increase at many stages during life. This can occur from infancy through to adult life, although it is commonly thought that fat acquired as a child is associated with an increase in numbers of fat cells (hyperplasia), whereas that acquired in later life is due to fat cells increasing in size (hypertrophy). More recently, it has been shown that there are cells indistinguishable from fibroblasts that can become adipocytes if body fatness increases even in adult life. Sjostrom (7) has suggested that it may be possible to increase human fat cells after the age of 20 and that the "critical period concept" for fat cell replication should be reevaluated. Infantile obesity, such as that studied by Poskitt and Cole (8), may actually be more readily resolved than fat acquired later in childhood (9). Despite these findings, studies such as Mossberg's, have shown that obesity in childhood is associated with a high morbidity and mortality in adulthood (10). The prevalence of obesity increases prepubertally and then decreases, especially in males, in early and midadolescence. The weight gain seen in late adolescence and early adulthood may be related to a failure to reduce energy intake after the growth spurt (or failure to increase or maintain energy expenditure). Postpartum is another life stage at which body fatness often is increased. Durnin et al. (11) considered that this may be because recommended energy intakes during pregnancy are greater energy increments than are needed for an individual woman. In later years, it is likely that an increased level of adiposity will result if food intake is not adjusted according to the gradual reduction in energy expenditure (12).

Energy Balance

Twenty-four hour energy expenditure has been divided into four components. These are resting metabolic rate (RMR), the thermic effect of feeding (TEF), the thermic effect of exercise (TEE), and adaptive thermogenesis (AT) (13). The relative

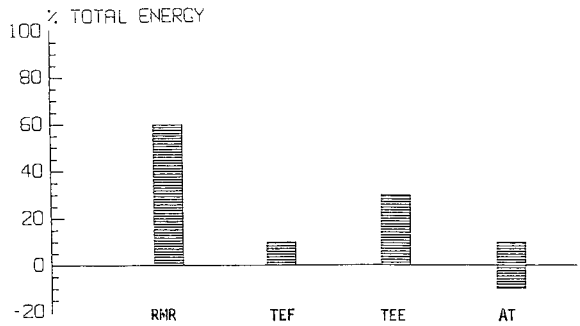

FIG. 1. Components of daily energy expenditure.

contributions of these components are shown in Fig. 1. RMR is a measure of the energy expended for maintenance of normal body function and can be influenced by nutritional state, thyroid function, age, and gender, as well as body composition. Although it is not ideal, fat-free body mass seems to be the best available predictor of resting metabolic rate (14).

Restriction of food intake may lead to a loss of fat-free body mass with a corresponding reduction in metabolic rate. According to the prospective Zutphen study in The Netherlands (15), those who had a higher energy intake lived longer, and in the prospective study of Morris et al. (16), men were less likely to die of coronary heart disease if energy intakes were higher. Similar findings were obtained in two other prospective studies, the Ireland-Boston Diet Heart Study (17) and the Western Swedish Women Study (18) (Table 1). Thus, to achieve lower levels of adiposity, reducing energy intake may not be the most desirable method. The maintenance of fat-free mass, preferably by increasing physical activity (19) to maintain energy expenditure, may be a more appropriate means of achieving reduction in body fat.

The *TEF* is a measure of increased energy expenditure after food ingestion. Different macronutrients have different energy costs associated with their processing, with fat requiring the least. Diets with higher fat content are associated with greater weight gain (20), although a subgroup of obese individuals may be sensitive to dietary

TABLE 1. *Energy balance and prospective mortality studies*

Energy plane	Mortality	
	Cardiovascular	Total
London (16)	↓	↓
Zutphen (15)	↓	
Boston-Ireland (17)	↓	
Western Swedish Women (18)	↓	

carbohydrate (21). This would not appear to be peculiarly sucrose and, in any case, may not matter unless accompanied by fat (22). Evidence is emerging that even micronutrients and food interactions can significantly alter the TEF (23–25). Furthermore, TEF may have a genetic component, as suggested by the twin studies of Poehlman et al. (6).

The *TEE* also has been called the thermic effect of physical activity and is the most variable component (13). It can be affected by shivering or fidgeting as well as strenuous exercise and can account for up to 30% of the total energy requirements.

Adaptive thermogenesis (AT) is an attempt to quantitate the changes in metabolic rate due to environmental influences. It relates to energy expended due to drug or hormone responses, stress reactions, and adapting to climatic changes. It also includes the changes in the quantity and composition of the diet and can be 10 to 15% of total energy expenditure. Over long periods, this could account for significant differences in energy utilization (13) and is thought to be of particular importance in individuals subject to either undernutrition or overnutrition and exercise training.

Exercise

It has been suggested that physical inactivity in adult life leads to a reduction in life expectancy possibly because of the increased tendency to obesity (26,27), whether operating through cardiovascular disease, cancer rates (28), or some other means. This is thought to be related to a failure to reduce energy intake corresponding to the reduced activity level.

Physical exercise appears to be of benefit in both protection against and treatment of obesity by virtue of its direct energy cost. In addition, it has been shown to influence resting metabolic rate as well as the thermic effect of food (13). Recent work has shown that although vigorous exercise may not return the resting metabolic rate to its preenergy-restriction level, it nonetheless improves the efficacy of fat loss (29).

In the intervention study of Wood et al. (19), overweight men were placed on programs of either diet alone or exercise alone. In both, significant weight loss was seen, although in the exercisers there was substantial sparing of lean body mass as compared with the dieters. Thus, exercise with no change in overall energy intake may be a method of decreasing body fatness.

This evidence has been incorporated into the US Surgeon General's Report on Nutrition (30) and has resulted in the conclusion that "increased levels of physical activity are important for attaining desirable body weights among the general population."

There are sex differences in the consequences of physical training (31) that have implications for the treatment and prevention of obesity. Bjorntorp (32) has found that women with gluteal-femoral adiposity actually increase body fat mass during training, probably due to a difference in food-intake regulation.

TABLE 2. *Assessing energy balance*

Sources of error
Intake
Food composition
Atwater factors
What is eaten
What is malabsorbed
Expenditure
Metabolic rate
Technique
Numbers of observations possible
Nonsteady-state conditions
Basis
Lean mass
Physical activity
Thermogenic effects of food

SOURCES OF ERROR

In assessing energy balance, there are multiple independent sources of error that can arise. On the food intake side, it is difficult to assess food composition accurately given the large variety of foodstuffs available. The Atwater factors that are used to calculate the energy content of macronutrients have not been revised since they were first described at the turn of the century, particularly in regard to the types of fat. It also is difficult to determine the exact amount of food consumed and, in patients with malabsorption, the percentage absorbed. Energy expenditure is technically difficult to ascertain, as steady-state conditions often are not obtained (Table 2).

DIETARY INTERVENTION

Selection of Diet as a Strategy

Although the multifactorial concept of obesity is widely accepted, the majority of treatment regimens revolve around diet. The extent to which this is used in addition to other therapies, such as behavioral approaches, exercise programs, or surgery, varies and may depend on the degree of adiposity (33).

It is, therefore, important before beginning dietary intervention to *make some assessment of the degrees of excess adiposity and of the associated health problems.* Garrow (34) has described obesity using a grading system 0 to III (Table 3).

The concept of BMI as a predictor of body fatness has been discussed by Garrow (34). Although a large muscle mass as occurs in athletes may spuriously elevate the BMI, once a level of 30 has been reached, body fat usually is increased significantly. BMI on its own can be related to mortality, but morbidity also is very relevant. The distribution of body fatness has been equated with morbidity from ischemic heart

TABLE 3. *Assessment of likely severity of obesity*

Body mass index	Grade	Clinical significances
20–24.9	0	Minimal mortality/preferred body mass index
25–29.9	I	Slight increase in mortality
30–40	II	Mortality double that of grade 0
>40	III	Incompatible with normal employment or health

disease and stroke (35). This distribution can be assessed by using waist/hip measurement ratios; a level above 0.9 can be seen to increase significantly the individual's risk of morbidity related to obesity, independent of BMI. It is of particular use in patients whose family history predisposes them to a higher risk of these diseases.

Another factor to be considered before dietary intervention is what Garrow described as "assessing priorities" (34). The expectations as well as the motivation driving the patient to desire weight reduction may play a large role in determining the outcome. The end point for dietary management of obesity is not always weight reduction. Other goals (Table 4) may be more readily achievable and actually benefit the patient to a greater extent.

Dietary Methods

Dietary methods available for treatment of obesity are not necessarily based on reduction of energy intake (Table 5). There are many variables, such as dietary composition, the thermogenic effect of food, and satiety induction, that need to be considered. The various interventions are explained in more detail in the following sections.

"No Change in Energy" Diet

Repeated attempts to lose weight actually may increase the difficulty of losing weight. Recently, the yo-yo syndrome, where weight loss is largely due to reduction

TABLE 4. *Goals in dietary management of obesity*

Change toward a nutritionally adequate diet
Management of other nutrition-related disorders, such as hypertension through sodium and ethanol intake and hyperlipidemia through saturated fat intake
Change in body composition toward less abdominal obesity, perhaps by reduction in alcohol consumption, especially beer
Encouraging adequate intake and essential nutrient intake to improve feeling of well-being and allow physical exercise to be undertaken
Prevention against effects of obesity, e.g., a high-carbohydrate, high-dietary fat, low-fat diet can alter expression of coronary heart disease and type II diabetes (15)

TABLE 5. *Methods of nutritional intervention*

"No change in energy" diets
Low-energy diets
Very low-energy diets
Diet and behavior therapy
Food therapy
Thermogenic effects of food interactions
Chili/mustard (24)
P:S fat ratio (23)
Satiety induction
Fiber, bulk fillers
Flavor, texture
Appetite control
Carbohydrate and neurotransmitters
Artificial sweeteners
Eating pattern
Adjuvant drug therapy
To reduce appetite or hunger
To alter food choices
To increase thermogenesis
Surgically induced
Gastric stapling
Gastric bypass
Jaw wiring

in lean body mass and subsequent weight gain is due to increase in fat mass, has been considered to be contributory to excess adiposity. Brownell et al. (36) have shown that obese rats return to their predieting weight more readily and with a lower food intake after the second of two episodes of weight reduction. However, it is not yet proven that humans behave in the same manner, although it is possible.

With this in mind, it may be of greater benefit to a patient with mild to moderate obesity to increase energy expenditure rather than energy intake as a means of reducing body fatness. Exercise is one method of achieving this (Table 6), although other techniques, such as altering the dietary composition of either macronutrients or micronutrients, also may be useful.

Low-Energy Diets

Diets that provide reduced energy [1,000–1,500 kcal/day (4.2–6.3 mJ)] and hence a negative energy balance while maintaining adequate protein and carbohydrate intake are the preferred method of dietary intervention.

TABLE 6. *Role of exercise in achieving energy balance*

Appetite control
Lean mass
Activity itself
Self-esteem and influence on food behaviors

If this method is followed, it is vital to encourage physical exercise to maintain fat-free mass and metabolic rate. Too often, patients are discouraged by a seeming lack of success (or initial success followed by a plateau of body weight) and discontinue the diet. One of the most important aspects of this treatment is the continuing education process and encouragement given by the treating physician. Obesity management should be seen as a long-term challenge rather than confined to the immediate morale boost that occurs with rapid weight loss. The rapid weight loss seen in starvation initially may be due to changes in body water, glycogen, or protein and not be related to change in body fatness. Ultimately, maintenance of reduced body fatness will be safer and more sustainable through increased physical activity (energy expenditure) than decreased energy intake.

In suggesting a diet for a patient, there are many factors, such as food preference, lifestyle, cultural influences, and food availability, that need to be considered. Patients will fail to maintain a diet that, although nutritionally sound, may not be appropriate for their individual needs. Thus, time and effort must go into any recommendation for dietary changes.

Very Low-Energy Diets

As has been mentioned, the reduction of calories (dietary energy) below a level at which sufficient protein and carbohydrate can be supplied actually may reduce fat-free body mass in preference to reducing body fat. Patients given a choice of foods within a daily limit of 1,000 kcal (4.2 mJ) may choose a diet with inadequate protein content (34).

Very low-energy diets are available, which under controlled circumstances can be used to achieve more rapid weight reduction (37,38). These should supply a minimum of 40 g of protein for women and 50 g of protein for men as well as other essential nutrients to form a nutritionally complete formula feed (37,39). The lower energy value of 300 to 500 kcal (1.25–2.0 mJ) usually is sufficiently less than basal metabolic rate to create a significant negative energy balance and allow weight loss to occur while maintaining the fat-free body mass.

This method of treatment is of value in the short-term only, although in selected patients it can be extended beyond the usual 1 to 2 months limit (39). It must be undertaken with very careful medical supervision as well as nutritional advice and behavioral therapy. The aim of this method of treatment is to allow rapid weight loss while reeducating the patient and gradually reintroducing a nutritionally adequate, fat-reduced food intake pattern that can be followed indefinitely.

Diet and Behavioral Therapy

To regard behavioral therapy as a separate type of dietary intervention understates its importance in every aspect of obesity management. In patients who are slightly overweight, it may be sufficient to attempt changes in eating behavior, such as using

smaller plates to make food appear larger or chewing food for longer periods of time. Food diaries are of use for both the patient and the physician to document worthwhile food intake changes as an end in itself and to develop insight into food practices. Strategies, such as always eating meals at regular times and in designated places, can have great benefit, particularly if combined with exercise (with its own requirements for behavioral change, such as drinking more and walking to work) to maintain lean body mass and an energy-reduced diet. Behavioral therapy usually is incorporated into programs that also include nutrition education, exercise, and cognitive restructuring (40). It is of major importance both in achieving desirable body weight and composition and in their maintenance.

Food Therapy

Thermogenic effects of food interactions

Macronutrient balance has emerged as a factor controlling human energy homeostasis (20). Although imbalance between fat and carbohydrate intake may be important, fat intake itself appears to contribute to less correct appreciation of energy intake (41). In hyperlipidemic and normolipidemic men followed at 3-month intervals, it has been demonstrated that plasma phospholipid pattern, expressed as polyunsaturated (largely arachidonic)/saturated ratio is a determinant of degree of fatness, as BMI ($r = 0.97$, $p < 0.01$) (41). Further, the degree of unsaturation of dietary long-chain fatty acids may influence the partitioning of fat between oxidation and storage. Moreover, the thermogenic effect of food has been shown to increase by 17% for subjects on a high polyunsaturated/saturated ratio diet compared to those on a low P:S ratio diet (23). In other words, it may be qualitative as well as quantitative fat intake that influences body weight.

Minor constituents (nonnutrients) of the diet, such as caffeine and associated methylxanthines in tea and coffee, also have been shown to increase metabolic rate (25). Intriguing work from Henry and Emery (24) has looked at the effect of spiced foods on thermogenesis. Evidence is accumulating that the combination of chili and mustard can increase the thermogenic effect of food, and this may be of benefit in weight reduction and maintenance. Confirmation and clarification of these findings is being obtained by other workers (M. G. Clark and E. Q. Colquoun, University of Tasmania, personal communication). Further studies, including prospective trials, are needed to look at the physiological effects on human nutrition and metabolism. Another feature of diet-induced thermogenesis is its possible augmentation by exercise. Poehlman and Horton (13) have suggested that moderate levels of exercise training may be associated with enhanced postprandial energy expenditure, and this would be of benefit in long-term regulation of body weight. Further studies are indicated to ascertain the clinical usefulness of this phenomenon.

Satiety induction

Fiber, bulk fillers. One popular method of inducing satiety is to increase dietary fiber (42). Fiber-depleted carbohydrates, such as apple juice as compared to whole

apples, have been shown to be less satiety-inducing. In addition, fiber-depleted foods allow faster and easier ingestion and have a tendency to allow more rapid falls in blood glucose. This fall inhibits the satiety center and is thought to promote eating behavior earlier than would occur if the same food was consumed in a fiber-replete form. Inappropriate insulin secretion, as may occur with refined foods (fiber-depleted) favors synthesis and deposition of fat (42). A study (43) has suggested that fiber added to a diet may have a role in weight control, although the absolute value of this maneuver is unclear.

Flavor, texture. The role of taste and smell in achieving satiety is not well defined, although Schiffman (44) has suggested that binging during dieting may be a compensatory mechanism for lack of flavor. In a study on overweight patients, use of flavor sprays (nonenergy-providing) was associated with greater weight loss compared to no flavor enhancement in two groups on low-energy diets (1,000 kcal/day). In addition to adding flavor with sprays or natural spices, Schiffman has suggested methods, such as using warm food (as opposed to cold) to increase volatile molecules reaching the olfactory receptors and prevent taste deprivation. Switching from one food to another as a means of reducing sensory fatigue is another practice advocated to gain maximum stimulation from minimum amounts of food. The long-term benefits of these suggestions may be able to be evaluated, since some weight-reducing programs are incorporating Schiffman's ideas into their products.

Appetite control

Wurtman (21) has observed that a significant proportion of obese subjects have strong carbohydrate cravings and can consume as much as 50% of their total daily energy as carbohydrate-rich snacks. Carbohydrate ingestion decreases plasma concentrations of large neutral amino acids and, in a manner similar to monoamine oxidase inhibitors and tricyclic antidepressants, acts to increase brain levels of serotonin. In this subgroup of obese patients, eating carbohydrate leads to a feeling of relaxation and peace and may actually be as Wurtman suggests "a form of self-medication." Unfortunately, most carbohydrate-rich foods used as snacks are also high in fat and contribute toward adiposity (22).

It may be possible to change snacking behavior toward carbohydrate-containing foods, such as pasta, rice, bread, or potatoes, that do not intrinsically contain a large amount of fat (usually the fat is added as either sauces or margarine or butter). In this case, drug therapies to alter brain serotonin levels and thereby carbohydrate intake may not be required (45).

Artificial sweeteners

As the focus switches from sugar craving to carbohydrate craving as one of the contributing factors to obesity, the value of sugar substitutes as a form of treatment becomes less clear (21).

Moreover, so-called carbohydrate foods are in reality often high in saturated fat, for example, pastries, sweet biscuits, ice cream, chocolate. It is arguable just how

adverse carbohydrate ingestion might be where there is little coingested saturated fat. Indeed, the inherent plant-derived foods, for which carbohydrate has been a marker for most of human evolution, may have survival value. Milk sugar, tissue glycogen, and honey (from bees or ants) represent the few animal-derived carbohydrates for human ingestion. The appetite or hunger for it may be less appropriate, however, the more dissociated from the parent plant the carbohydrate is, and the more association with long-chain saturated fat, the less correct would choice of carbohydrate-containing foods appear to be. There also would appear to be less error in intake where the level of physical activity is high. Stellman and Garfinkel (46), in their study published in 1986, showed that greater numbers of nonnutritive sweetener users than nonusers reported weight gain. It was noted that the nonnutritive sweetener users were more likely to be overweight than the nonusers. However, the study was unable to show that this related to altered food intake in the users compared with the nonusers.

Rogers et al. (47) have attempted to uncouple the effects of sweet taste and energy content on hunger and food intake and have suggested that intense sweeteners, by comparison with glucose and water, can produce significant delayed increases in appetite and hunger over 60 min with no decrease (or increase) in energy intake at 60 min. Glucose did reduce energy intake at 60 min against a background of sustained decrease in appetite and hunger. However, further scrutiny of the data indicates that the combined energy intakes for preload and 60 min meal choices would not have been significantly different. This agrees with the observations of Rolls et al. (48), who have studied the impact on a second meal 1 or 2 hours later of consumption of foods sweetened with either aspartame or sucrose inasmuch as combined energy intakes were not different. These studies lend support to the view that weight or volume of food is a significant factor in food choice. The role of sweetness alone in the overall maintenance of energy intake is less clear. In the Rolls study, there were no differences in appetite or hunger ratings between sucrose-fed and aspartame-fed subjects.

Porikos et al. (49) have made longer-term observations over 15 days in obese subjects, using sucrose or aspartame to achieve a change in energy density. There was an initial reduction for 3 days to 77% of baseline energy intake, which then increased to 86% of baseline, but this was not statistically significant. Over 12 weeks, Kanders et al. (50) placed 59 men and women on a balanced deficit diet (BDD) alone or supplemented with aspartame. Both groups achieved significant reduction in BMI, with men losing more weight than women. However, only women showed a significant difference between the control and aspartame-supplemented groups.

Prospective studies in obese, nonobese, and other subjects, especially diet-conscious adolescents, are required over extended periods of time. End points must include not only energy intake but also weight and body compositional analysis.

Eating pattern

A recent study (51) comparing the metabolic effects of nibbling (17 snackes per day) as opposed to 3 meals per day has suggested a role in meal frequency on serum

lipid concentrations and carbohydrate tolerance. The nibblers were demonstrated to significantly reduce their mean blood glucose levels, serum insulin, and serum C-peptide despite ingesting the equivalent amount of food. Implications of this finding in affecting cardiovascular risk profiles or obesity are yet to be examined. It is conceivable that a combination of snacking, but of low fat foods, would be conducive to less obesity and less tissue lipid deposition.

Adjuvant Drug Therapy

To reduce appetite or hunger

If obesity were simply an eating disorder whereby increased appetite or overwhelming hunger led to overeating and obesity, treatment with anorectic (appetite suppressant) or satiety-inducing drugs would be useful. Unfortunately, this appears to be not always so, and eating behavior can be influenced by a number of psychosocial factors. Thus, the effectiveness of pharmacotherapy alone is questionable. Furthermore, many drugs used in the past have been abandoned because of their sympathomimetic and psychostimulant effects. D-Fenfluramine is the first satiety-inducing drug that appears to be purely serotoninergic (releases serotonin and inhibits uptake) and, therefore, has the potential for long-term use. It may offer effective therapy adjuvant to diet and maintain weight loss in obese patients, particularly in those with uncontrolled hyperphagia or stress-induced compulsive feeding behavior (52).

To alter food choices

Carbohydrate craving, with subsequent increase in total fat intake (because of the common association of high-carbohydrate, high-fat snack foods), has been thought to contribute to obesity. D-Fenfluramine with its ability to alter carbohydrate intake selectively (53) may be of great benefit in these patients.

To increase metabolic rate

The use of thyroxine as an adjuvant therapy for obesity management has, on the whole, been discontinued. Many potential problems and serious side effects could be anticipated form its use due to precipitation of ischemic heart disease or preferential loss of lean body mass. The search for a drug to increase metabolic rate continues with D-fenfluramine being one of the more recent contenders. D-Fenfluramine has been shown to increase the thermic effect of feeding (but not the resting metabolic rate) in rats (54). However, application of this finding to humans is less clear.

Surgically-induced intervention

Techniques, such as gastric reduction via either stapling or vertical banding, are drastic measures, which nonetheless may benefit a morbidly obese patient (55). With

the limitations on physical exercise imposed by morbid obesity as well as considerations of morbidity and mortality associated with it, surgery occasionally is the preferred method of achieving adequate weight reduction (56). It must be combined with long-term maintenance therapy that is based on a low-energy, nutritionally complete diet as well as behavioral therapy, which can be provided by either the treating physician, the surgeon, or a psychiatrist.

Jejuno-ileal bypass, which was performed in the past, has been shown to have an unacceptably high incidence of complications, such as liver cirrhosis. Gastric balloons have been shown to be no better in controlling food intake than a placebo effect (gastroscopy with no balloon insertion) and are no longer in use. Jaw wiring, if acceptable to the patient, is one method to surgically achieve a reduction in food intake, particularly solids. However, if not combined with adequate dietary advice, the energy content of the food ingested can easily be increased to the usual intake by use of high-fat liquid meals, such as chocolate milk shakes.

CONCLUSION

Since abdominal obesity is the form with the greatest health consequences, its determinants are of the greatest health importance. Diet may be only one of these, along with gender, genetic predisposition, physical activity, cigarette smoking, and alcohol consumption. Nevertheless, food intake features prominently in any discussion on obesity, whether it is on prevention or management.

The priority in management actually may not be the obesity *per se* but may relate more to overall well-being and physical fitness (Table 7). There are many diets available. An individual protocol, however, must take into account the degree of obesity as well as individual food habits, opportunity for physical activity, and health status. In patients with mild to moderate stable obesity, the best diet actually may be one in which the total energy content does not change. Such strategies as food behavioral modification and increased physical exercise have a large role to play and must be included wherever possible. Reduced energy intake down to about 800 calories per day (low-energy diets) and down to about 500 calories per day with the use of nutritionally complete meal replacements (very low-energy diets) are useful in certain situations, such as where a demonstration to the patient that fat loss is possible is required. Another situation exists where there is a degree of clinical urgency for weight loss or where physical activity is limiting.

TABLE 7. *Priorities*

Obesity or other health outcome?
Life expectancy
Morbidity
Fitness
Wellness

The food compositional change of most defined importance is a reduction to less than 25% of energy intake as fat, with less than 10% of the 25% as saturated fat. The intake of carbohydrate is likely to be appropriate for energy needs if it is not accompanied by saturated fat and if regular physical activity is achieved. It may be possible and useful to reduce the contribution of nutritive sweetener intakes, such as sucrose, as a source of excess energy intake by substitution with nonnutritive sweeteners, such as aspartame, and for a related reduction in adiposity to be achieved, but long-term prospective studies of body compositional change are required. Currently, the thermal effects of nonnutrient components of food are being investigated for both prevention and management of obesity. Newer drugs for appetite suppression, snacking behavior modification, and effects on metabolic rate may be adjuncts to dietary maneuvers. Gastric surgery is reserved for morbidly obese patients as a way to reduce energy intake in individuals at considerable risk from their obesity and in whom increases in physical activity can be difficult.

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DISCUSSION

Dr. Hers: You barely mention the role of insulin. In my opinion, carbohydrate will stimulate insulin secretion and may be more effective even than the lipid.

Dr. Wahlqvist: We suspect that glucose consumption alters insulin secretion and that insulin secretion is important.

Dr. O'Dea: Some carbohydrates stimulate insulin secretion much more than others.

Dr. Truswell: I wonder if you could explain the correlation of phospholipids and polyunsaturated fatty acids with weight change.

Dr. Wahlqvist: We examined fatty acid patterns in plasma as a determinant of body mass index in hyperlipidemic men. We studied phospholipid, triglyceride, and cholesterol-ester fatty acid patterns, at 3-month intervals, in relation to BMI. Phospholipid fatty acid was a very significant determinant of degree of fatness as measured by the BMI (1). I am advisedly using the term "determinant" because, quite clearly, there are various ways in which the fatty acid patterns themselves may be determined, and there is an interplay between fatness, presumably, and fatty acid transport in blood.

Dr. Zimmet: I am not sure that the question of the role of hyperinsulinemia and obesity is such a closed case. I agree with Dr. Hers that one needs to keep it up front.

Dr. Wahlqvist: But it was carbohydrate in hyperinsulinemia and obesity.

Dr. Zimmet: Yes, but perhaps the carbohydrate is potentiating a preexisting hyperinsulinemia. There are a number of animal models where this is the case. But I share your concern about applying animal models to humans.

Dr. Hers: My opinion was that eating carbohydrates will stimulate insulin secretion and cause obesity. That looks obvious to me, but of course I know that hyperinsulinemia occurs in obese people. That is another problem about which I have no opinion.

Dr. Storlien: I was interested in information about obesity and fatty acid composition. I think that a great deal of focus in this workshop has been on different types of sugars, as is appropriate to the title of the workshop, but it is becoming clearer that the different types of fats in the diet also are important (2). I take slight exception to Dr. Hers' comment that

adipose tissue is the most insulin-responsive tissue in the body. Muscle, particularly oxidative muscle, is much more insulin responsive than white adipose tissue.

Dr. Gracey: I want to ask a simple question about body composition. You mentioned the waist/hip ratio and its usefulness. You are aware that different groups of people have different body shapes. Australian Aborigines, for example, have a relatively long limb/trunk ratio, and Aboriginal women tend to have a central or android distribution of fat. How does that affect the assessment of obesity and the development of risk factors? In addition, I would like to know what is the best method of anthropometric assessment of obesity in children.

Dr. Wahlqvist: My responses have to be somewhat speculative. I would expect that the data in Caucasians on waist/hip ratio could be extrapolated to Aboriginal Australians, but I have no data to confirm or deny that. I think it ought to be examined. On the question of children, I wonder whether the same significance applies in childhood given the recoverability of a good deal of childhood obesity. Its long-term implications are uncertain.

Dr. O'Dea: If I could perhaps comment on Aborigines. Most Aboriginal women studied have a central distribution of obesity and a waist/hip ratio above 0.8, which confirms that earlier comment by Michael Gracey. These same populations have the metabolic abnormalities that we are interested in: hyperinsulinemia and impaired glucose tolerance, a high rate of diabetes, and hypertriglyceridemia. However, those conditions are not related to body fat distribution in these populations because everybody has a central distribution of fat, and yet not everybody has these metabolic abnormalities.

Dr. Guesry: When discussing diet and obesity, we should pay more attention to satiety and its two components: the immediate satiety that is linked to the quantity of food in the stomach and the secondary satiety that is probably linked to the gastric emptying and to the osmolarity of the food, but also to the level of glycemia. Would you elaborate a little bit on these factors?

Dr. Wahlqvist: They are many, as you rightly say, and those factors do operate on both hunger and appetite. We need to study those variables and their relative importance to open the way for prospective intervention studies, where we seriously examine such questions as the relative value of nonnutritive sweeteners, the relative value of changing macronutrient composition, or the relative value of stress management or of exercise.

Dr. Hollenbeck: I would like to ask which free fatty acids were associated with the increased BMI?

Dr. Wahlqvist: They are not free fatty acids; they are combined or esterified-lipid fatty acid patterns. The amounts of omega 3 fatty acid in these subjects are not really enough for us to make any statement about the role of omega 3 fatty acid. We would need to have done platelet-phospholipid fatty acid patterns to have addressed that question more adequately. Dr. Storlien's point is well taken about the potential relative importance of omega 3 and omega 6 fatty acids.

Dr. Schiffman: One of the things that we find is that overweight people want more taste, smell, and texture in their foods, and if you ask them why they are overweight, they say that they like to eat. So that is one of the problems in lowering fat content in food. Most odorants are fat-soluble, and if you take the fat out of the food, you are taking out most of the flavor, so you have to put it back in. Lettuce leaves and cottage cheese don't work.

Dr. Shafrir: I want to return to the remarks of Dr. Hers on insulin. Although adipose tissue is very sensitive to insulin, there is one limitation in that human adipose tissue is a poor lipid synthetizer and most of human fat synthesis occurs in the liver. The effect of insulin on adipose tissue would facilitate the entry of triglycerides by increasing the activity of lipoprotein lipase, but most of the effect would be on hepatic lipogenesis. Furthermore, carbohydrate

is not as efficient for lipid storage as preformed lipid itself because exogenous lipid, by forming chylomicrons directly posited in adipose tissue, requires much less energy than synthesis of fatty acids in the liver, their secretion as VLDL, and entry into adipose tissue, which may all cost 30 to 35% of the energy of the molecule of triglyceride. The deposition of preformed fat may cost only 5 to 10% per triglyceride molecule.

Dr. Truswell: Can I support what was said about the importance of studying satiety? This is very difficult. It is highly subjective, but my colleagues are trying to use a 7-scale, visual analogue scale and seem to get some reproducibility. Subjective satiety is recorded every half-hour after different test meals, and plasma cholecystokinin also is measured. Early satiety and cholecystokinin levels did seem to correlate very well with the subjective measure of satiety. Not all foods are equally satisfying for the same number of calories, and it would be a major tool in the management of obesity if we could say, "These 12 foods will make you feel much more full than those 12 foods."

Dr. Wahlqvist: Could I ask Susan to resolve a paradox? There is a view that increasing the variety of foods predisposes toward obesity, whereas Susan Schiffman argues that by increasing the range and intensity of flavors, and also avoiding flavor fatigue, one ought to have a favorable impact on weight management.

Dr. Schiffman: If you increase flavor, say in one meal, there are some data that suggest you will eat more, but over the long-term, if you have only bland food for 6 or 7 days or more, most people will go off a liquid diet, they will go off cottage cheese and lettuce leaves because they have to have a certain amount of taste, smell, and texture. Unfortunately for overweight people, because they have been eating so much, they are not able to go back to lettuce leaves and cottage cheese.

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