The calorie: myth, measurement, and reality[1-3]

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ABSTRACT Few dietary components are surrounded by more misinformation and myths than the calorie. This confusion can be attributed in part to a lack of accurate and practical methods for assessing energy intake and thus requirements in humans over periods extending beyond several days. The availability of modern respiratory-chamber indirect calorimetry systems and results from human studies with doubly labeled water are now helping to clarify uncertainties surrounding energy requirements. We describe studies of patients with endogenous obesity as an example of how these research methods are resolving long-standing questions regarding energy requirements. The results of these investigations reveal some of the flaws in estimating energy requirements by self-report methods. Advances in accurately measuring energy expenditure are making important contributions to the study of human energy requirements and are providing new and important research opportunities. *Am J Clin Nutr* 1995;62(suppl): 1034S–41S.

KEY WORDS Energy requirements, food records, obesity, doubly labeled water

INTRODUCTION

Few dietary components are surrounded by more myths than the calorie. For example, consider the case of Therese Neumann, a German woman who in the 20th century reportedly survived 35 y and even gained weight with a daily intake of only a communion wafer (1–3). Such myths or incomplete understandings of energy requirements pervade not only the lay community but the research establishment as well. Why has it been so difficult to firmly establish concepts relating to energy expenditure in humans that are apparent in vitro and in animals? Part of the answer may be that energy requirements in humans have been, until recently, extraordinarily difficult to measure. New measurement techniques, introduced or developed for human use over the past decade, are now finally allowing investigators to accurately determine energy requirements.

The purpose of this review is twofold. First we give a general overview of how energy intake and requirements are established by traditional and new methods. Second, we show how an old myth relating to energy intake can be systematically examined using modern methods of quantifying thermogenesis.

QUANTIFYING ENERGY REQUIREMENTS

A simple diagram of energy flow in humans is shown in **Figure 1**. According to the first law of thermodynamics, energy intake as shown in the figure is equal to energy losses plus or minus somatic or stored energy. Generally, energy stores are equated with body mass. When body mass and energy stores are constant, energy intake must exactly balance energy output.

This diagram helps one to consider the definition of dietary energy requirements. These requirements can be examined at two different levels. The first, and perhaps most important, is the "desirable" intake level, which we will define for adults as the energy intake required by an individual that maintains cellular mass and function and promotes optimum health and longevity. This is clearly the intake level that needs to be established in the long term. However, the database of information needed to make such recommendations is now so limited that we cannot answer this question with any reasonable amount of accuracy. Instead, we might consider a second and more pragmatic question: what is an individual's current energy intake? Once we can answer this question by using presently available methods, we may then begin to address the more complex issue of desirable intake.

Establishing the energy intake of an individual is not a simple task. In fact, the very complexity of estimating intake has led to many uncertainties and myths surrounding the question of what an individual eats. To probe this topic further, we expanded our diagram of energy flow in humans, as shown in **Figure 2**. Energy intake as shown in the figure consists of carbohydrate, protein, and fat. Complete utilization of nutrient energy requires oxygen, which is transported to cells by the circulatory system. After fuel oxidation, the end products of metabolism are eliminated through evaporation (water), respiration (water and carbon dioxide), and urination (water and urea). There are also energy losses in feces (eg, undigested foods, desquamated mucosal cells, and bacteria) and from miscellaneous sources such as hair, skin, and menstrual flow. The gross intake of energy must exactly balance these losses for energy stores and body mass to remain constant.

There are many ways of estimating energy intake and losses in humans (**Table 1**), and energy stores can be readily measured using currently available body composition methods (15). The two primary stores considered most frequently are fat

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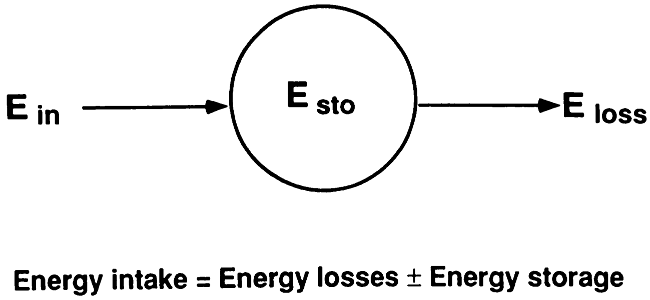

FIGURE 1. Flow of energy through the human body. The difference between energy intake (in) and losses is somatic or storage (sto) energy.

and protein. The small but difficult-to-measure glycogen component is generally ignored. Only rough estimates of change in energy stores are possible over short time periods (eg, several days or weeks) because current body composition methods are not sufficiently accurate or reproducible enough to detect small changes in fat or protein balance. Two strategies can be used to estimate a subject's energy intake under conditions of approximate energy equilibrium: directly evaluating intake or indirectly evaluating intake through total losses through the use of methods outlined in Table 1.

The problem with relying on self-reported food intake is that subjects may misreport and this leads to questions of data validity (16–26). Nevertheless, much of what is known today about food intake is based on self report because, until recently, accurate methods of estimating total energy losses were unavailable. Very accurate estimates of fecal, urinary, and miscellaneous losses could be made using bomb calorimetry and chemical analytic techniques (Table 1). Portions of total thermal energy losses, such as metabolic rate at rest over several hours and the thermic effect of food, could also be accurately measured (8).

A major gap, however, remained because methods of accurately evaluating total energy expenditure were lacking. Over the past decade this measurement limitation was largely eliminated by the introduction of modern respiratory-chamber indirect calorimeters (8, 10), the doubly iabeled water method (11), and bicarbonate dilution methods (12) of quantifying energy expenditure over several days or weeks. In particular, the doubly labeled water method allows measurement of energy expended in free-living subjects over 10–14 d (27, 28). The importance of the doubly labeled water method is that it allows measurement of metabolizable energy intake (gross energy intake minus losses in feces and as urea) in subjects who are unencumbered by the constraints of a laboratory setting or of being under direct observation.

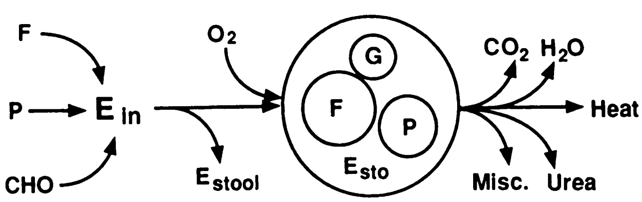

FIGURE 2. Expanded diagram of energy flow through the human body. CHO, carbohydrate; E_{sto}, somatic or stored energy; E_{stool}, energy lost through stool; F, fat; G, glycogen; P, protein; Misc, miscellaneous energy losses.

This brief overview shows that we can now evaluate an individual's energy intake and expenditure by using various methodologies ranging from self-report to unobtrusive measures such as doubly labeled water.

SELF-REPORTED ENERGY INTAKE

Therese Neumann reportedly survived for 35 y by consuming nothing but a daily communion wafer (1–3). Some religious figures are alleged to have ingested little or no food without ill effect for long periods of time. Similar reports, mainly in the lay press, suggest that the widespread belief persists today that individuals can survive and even maintain their body weight on little or no food.

This of course would imply that energy losses in subjects such as Therese Neumann were negligible or very low. Otherwise, energy stores and body weight would by necessity decrease over time. The unlikely possibility that the laws of thermodynamics need reconsideration or that humans can generate energy by photosynthesis can probably be discounted. For the remainder of our discussion we will examine the possibility that some subjects have a markedly reduced rate of energy loss.

Is there an endogenous obesity syndrome?

As far-fetched as a very low energy expenditure may seem, the belief prevails today that some subjects are endowed with a remarkably low metabolic rate and thus a low requirement for food energy. One of the best examples of this belief is the occasional obese subject who claims to eat very little and at the same time is maintaining consistently large adipose tissue stores. Of similar concern is the patient who gains weight, without evidently increasing food intake, over a period of several years. Patients such as these are challenges for physicians and dietitians who, without adequate measuring techniques in the past, found themselves unable to objectively quantify food intake and/or energy losses in these patients and thus could not establish a conclusive diagnosis.

In 1906 Allchin (29) classified subjects such as those discussed above as suffering from "intrinsic" obesity. Four years later in 1910 von Noorden (30) coined the term "endogenous" obesity, which would appear for the next seven decades in medical texts. These patients were individuals, mainly women, who ingested relatively little food but, by virtue of their "weak" or "deficient" metabolism, remained obese (31). The concept of endogenous obesity prevailed even after the discovery of thyroid hormones and the effective treatment of hypothyroidism. The overuse of thyroid hormone preparations to augment a slow metabolism evidently compelled Newburgh and Johnston (32) to carry out a classic experimental study of obesity that was published in 1938. Obese subjects placed into negative energy balance were invariably shown to lose body weight as predicted by the first law of thermodynamics. A proviso was that some subjects failed to lose weight on low-energy diets for brief periods of time because fat loss was counterbalanced by fluid retention. Hence, the final chapter appeared closed on the clinical diagnosis of endogenous obesity.

Despite Newburgh and Johnston's conclusive findings, investigators today continue to report the existence of endogenous obesity or at least they suggest that obese eat no more than do nonobese persons. No doubt their reasoning is based on the

TABLE 1
Methods of evaluating energy exchange components

Component	How measured and reference
Energy intake	Food records, subject observation in confined setting (4), and bomb calorimetry of selected food items (5)
Energy losses	
Fecal and miscellaneous	Bomb calorimetry (6)
Urinary	
Total	Bomb calorimetry (6)
Urea	Urea nitrogen analysis (7)
Thermal	Direct calorimetry: *1*) gradient-layer (8) and *2*) thermography (9)
Thermal	Indirect calorimetry: *1*) combinations of oxygen consumption, carbon dioxide production, and urea excretion (8), for example, face mask or ventilated hood, respiratory chambers (10), doubly labeled water (11), and bicarbonate dilution (12); *2*) insensible water losses (13); and *3*) heart rate counting (14)

multitude of studies suggesting that obese and nonobese persons eat similar amounts. Many of these studies, some of which are summarized in **Table 2**, are based on either self-reported food intake or on relatively brief observations of obese and nonobese subjects. The table presents studies that provide self-reported energy intake data that give sufficient information to calculate body mass index. The correlation coefficient (r), calculated using meta-analytic techniques, is given for reported intake versus body mass index. As shown in the last column of the table, most studies reported negative associations between reported energy intake and body mass index. Homogeneity tests indicated that results could be pooled for the interview data resulting in a weighted r for self-reported energy intake by interview versus body mass index of -0.1145 ($P < 0.0001$). The homogeneity test for questionnaire data was not statistically significant, mainly because the first two studies heavily weighted the pooled data. However, similar to other questionnaire studies, these two investigations both showed negative associations between intake estimates by questionnaire and body mass index. The weighted r for pooled questionnaire studies of intake versus body mass index ($r = -0.1633$, $P < 0.0001$) was similar to that for the interview data.

A reasonable conclusion based on this self-reported data is that, on average, obese persons eat slightly less than do nonobese persons. Presumably, it was this type of information that led Rothblum (49) to conclude in 1989, "I have presented evidence that the following aspects of weight are myths rather than reality: . . . obese people take in more calories than the nonobese." Shah and Jeffrey (50) suggested in 1991 that "recent research with improved methodologies generally confirms earlier conclusions that habitual overconsumption of food energy is not a consistent characteristic of obesity." Dattilo (51) in 1992 reported that "total calories were not related to body weight or body fat in most studies" and "in addition, national data from Germany, the Netherlands, and the United States indicates that total caloric intake is not related to obesity."

TABLE 2
Studies of self-reported energy intake

Study	Subjects	r
By interview[1]		
Johnson et al, 1956 (33)	High school girls (n = 56)	−0.5584
Stefanik et al, 1959 (34)	Adolescent boys (n = 65)	−0.4237
Kromhout, 1983 (35)	Middle-aged men (n = 809)	−0.2065
Braitman et al, 1985 (36)	Adults, NHANES II[3] (n = 6219)	−0.1087
Greco et al, 1990 (37)	Children aged 7–11 y (n = 305)	−0.1170
Kulesza, 1982 (38)	Adult women in Warsaw (n = 150)	0.0648
Young and Sevenhuysen, 1989 (39)	Adult Cree and Ojibwa (n = 704)	−0.0622
Story et al, 1986 (40)	Adolescent Cherokee aged 13–17 y (n = 180)	0.0357
By questionnaire[2]		
Dreon et al, 1988 (41)	Obese men aged 30–59 y (n = 155)	−0.1101
Maxfield and Konishi, 1966 (42)	Adult females (n = 50)	−0.0723
McCarty, 1966 (43)	Premenopausal women (n = 89)	−0.0821
Bandini et al, 1990 (18)	Children aged 12–18 y (n = 55)	−0.1888
Meyers et al, 1988 (44)	Female undergraduates (n = 40)	−0.0
Keen et al, 1979 (45)	Adults (n = 3394)	−0.1713
Prentice et al, 1986 (46)	Adult females (n = 21)	−0.2974
Furukawa and Harris, 1986 (47)	Elderly whites and Hispanics (n = 56)	−0.20
Romieu et al, 1988 (48)	Female nurses (n = 141)	−0.11

[1] $n = 8488$; homogeneity test $\chi^2 = 39.3$, df = 7, $P = 0.00002$; weighted mean $r = -0.1145$, $P < 0.0001$.
[2] $n = 4001$; homogeneity test $\chi^2 = 3.55$, df = 8, $P > 0.05$; weighted mean $r = 0.1633$, $P < 0.0001$.
[3] Second National Health and Nutrition Examination Survey.

Even in 1994, after publication of many respiratory chamber and doubly labeled water studies of lean and obese subjects, Melnyk and Weinstein (52) stated that "individuals who are overweight and obese may not consume more energy on average than persons who are lean." Such terms as "small" and "large" eaters no doubt add further support to the notion that individuals of greatly different body weights ingest similar amounts of food (53, 54).

Studies emerging in the 1980s began to resolve some of the confusion surrounding energy requirements of obese persons. Modern respiratory-chamber indirect calorimetry systems, growing in number around the world, were showing increasingly that either body weight or fat-free body mass were strongly correlated with both resting metabolic rate and total energy expenditure (10). By virtue of their increased body mass, obese persons were extremely likely to have greater energy expenditure and thus, energy intake.

These studies failed to address the specific question of whether or not there is a subset of obese individuals with endogenous obesity. A theory prevailed that a portion of individual differences in either resting metabolic rate or total energy expenditure was secondary to genetic factors (55, 56). These familial factors, however, could only explain a small portion of between-individual differences in energy requirements. What about the obese subject who reports a very low energy intake ($< \approx$5.02 MJ/d, or 1200 kcal/d) and yet fails to lose weight or even gains weight over time?

An example of such a patient is presented in **Figure 3** (57). This 33-y-old mother of two was referred to us after she attempted unsuccessfully to lose weight. Approximately 19 mo before referral she lost 20.4 kg over 20 wk by consuming a formula diet containing 2.18 MJ/d (520 kcal/d). The patient was gradually switched to 5.02 MJ/d (1200 kcal/d) of regular foods. She then experienced gradual weight gain (15 kg) over the next 36 wk despite "strict" adherence to her prescribed diet. She was placed on the very-low-energy diet again and lost several kilograms of weight over the next 2 wk. The patient was then returned to a restricted food intake of 4.18 MJ/d (1000 kcal/d) and she began to gain weight again. Does this patient merit the diagnosis of endogenous obesity? Or alternatively, does a complex case such as this one reveal the unreliability of self-reported food intake?

We examined this question in 17 patients referred to us at the Obesity Research Center over a 4-y period. All subjects reported energy intakes of < 5.02 MJ/d (< 1200 kcal/d) on the basis of 3-d food records. In addition, the patients had one of the following medical histories at baseline: *1*) obese [body mass index (kg/m^2) ≥ 28], weight-stable (± 3 kg over 3 mo), in good health, and ambulatory (n = 10); *2*) unexplained weight gain over time (n = 3); and *3*) relapse after low- or very-low-energy diet treatment, despite persistent low energy intake (n = 4). Additional details describing these patients are presented in references 20 and 57.

All patients were euthyroid at the time of study as judged by serum concentrations of thyroid hormones. Control results were derived from obese subjects enrolled at the clinic who had no history of weight loss failure, who had unexplained weight gain over time, or who relapsed from previous diets without a clear corresponding report of increased food intake (20).

Self-reported food intake and energy expenditure were monitored using conventional food records and doubly labeled water, respectively. Resting metabolic rate and the thermic effects of food and exercise were evaluated by indirect calorimetry (20). Only 1 of the 17 patients was found to have a low resting metabolic rate (23.2% below that predicted) and total energy expenditure (25.0% below that predicted) (57). This hypometabolic patient had a history of hyperthyroidism treated with radioiodine and she was taking moderate doses of antidepressant and other centrally acting medications. The specific underlying basis of her low metabolic rate was not established. All of the remaining patients had normal thyroid hormone concentrations and resting metabolic rates within ± 15% of those predicted on the basis of the patients' body composition. Thus they were eumetabolic according to traditional criteria.

The eumetabolic subject pool comprised 1 man and 15 women with an average age of 45.6 ± 11.2 y and body mass index (kg/m^2) of 33.1 ± 5.0. The thermic effects of food and exercise were similar between the eumetabolic group and the control group (20, 57).

Self-reported energy intake over the 14-d study period is shown plotted against actual energy intake as determined by doubly labeled water and body composition estimates in **Figure 4**. The results are striking. A marked disparity is present between self-reported and actual energy intake. The patients reported an intake of 1054 ± 211 kcal/d (4.41 ± 0.88 MJ/d)

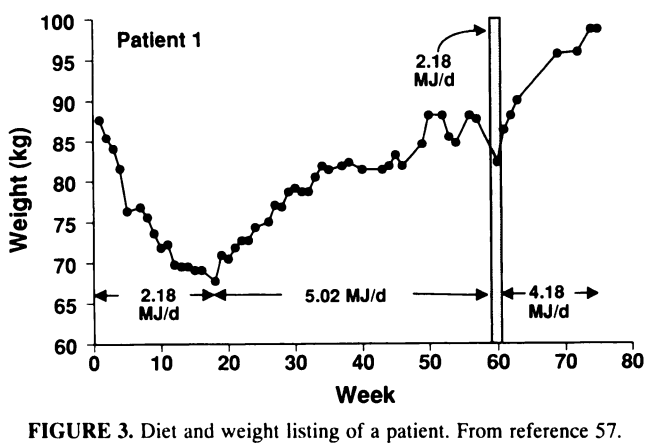

FIGURE 3. Diet and weight listing of a patient. From reference 57.

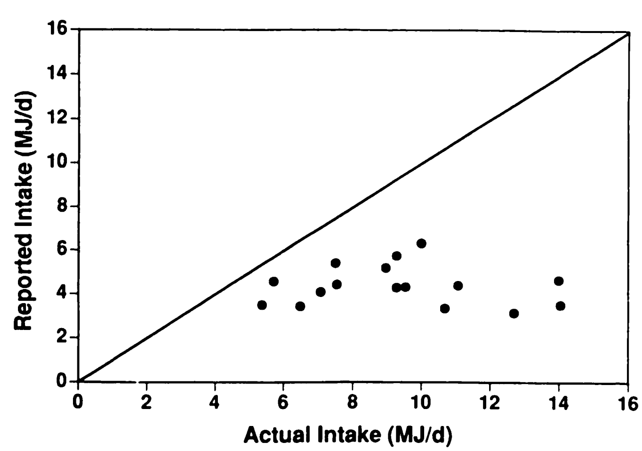

FIGURE 4. Reported intake on the abscissa with actual meal intake on the ordinate in 16 obese subjects with unexplained disturbances in body weight regulation. The diagonal line is the line of identity.

whereas their actual intake was 2227 ± 647 kcal/d (9.32 ± 2.71 MJ/d), a difference of > 1000 kcal/d (> 4.18 MJ/d). In contrast, the patients' total energy expenditure as estimated by doubly labeled water was within ± 15% of that predicted in 15 patients and slightly low (−19%) for body composition in one patient. We concluded that these patients were substantially misreporting their food intake despite thorough instructions on how to maintain diet records, and therefore were not suffering from a "slow" metabolism. Obese control subjects (n = 6) also tended to underreport their energy intake from food (−19 ± 38%), although to a smaller degree than observed in the patient group; the result of this underreporting was unexplained disturbances in body weight regulation (−48.9 ± 16.3%).

It appears from these studies that, in general, obese persons have a higher metabolic rate and greater energy intake than do nonobese persons. This study, and others like it (10, 16, 20, 25, 26, 46, 58–61) dispel the myth that obese persons on average eat the same or less than nonobese persons. Moreover, this study reaffirms the calorie as a constant unit of energy. Other than a single patient with a history of thyroid disease and who was taking several centrally acting psychoactive medications, we could find no evidence of a substantially reduced energy requirement in our patients.

POTENTIAL CAUSES OF UNDERREPORTING OF ENERGY INTAKE

What possible mechanisms could help explain such serious misreporting? Are there other studies that question the validity of food records as a measure of quantifying energy intake or requirements? The possible causes of food intake underreporting that we will discuss include the following: inadequate education, inaccurate food-size estimates, memory disturbance, psychosocial motivation, and inaccurate food labeling.

Inadequate education

Inadequate education in our patients is an unlikely explanation for misreporting because we provided each patient with a comprehensive instruction period before the 2-wk doubly labeled water evaluation phase. This does not negate the usefulness of educational methods in improving the validity of food records. On the contrary, Howat et al (62) recently showed the usefulness of various educational strategies in enhancing food record accuracy.

Inaccurate food-size estimates

We were able to rule out the likelihood that underreporting of food intake was due to a systematic misperception of food size. A previously reported approach was used to evaluate our patients' ability to judge food portion sizes (20, 63). Overall, patients misreporting food intake were able to accurately report the size of various food objects (20). Again, this does not imply that some patients were not accurately estimating portion sizes. Rather, our patients were capable of judging portions accurately for size and volume.

Memory disturbance

To test memory and other cognitive processes, we developed a test-meal protocol. Fifteen of the subjects were provided with a smorgasbord lunch in which they were asked to eat an amount that filled them to 80% capacity (20, 64). Twenty-four hours after the meal we asked the patients during a telephone conversation to recall the previous day's meals. The results of this experiment are shown in **Figure 5**. Overall, most patients recalled with reasonable accuracy their energy intake of the test meal. This stands in sharp contrast with the underreporting of food intake over the 14-d doubly labeled water study as depicted in Figure 4. Again, our results should not be interpreted as dismissing the role of memory in how accurately food records are prepared. We suggest that our patients, with the exception of a few, could recall with reasonable accuracy their previous day's test meal.

Memory disturbances may indeed account for a failure to recall food intake in the general population. Cognitive methods may be useful in recalling ingested nutrients (65–67). Elderly subjects may be particularly prone to forgetting foods ingested (68). Some patients may suffer dissociative, amnestic, or fugue states. The night eating syndrome provides another explanation for underreporting (69). Some subjects may eat excessively during "sleep" and thus fail to recall their food intake the next day.

Psychosocial motivation

One possible explanation for the greater accuracy found in the test meal reporting is that subjects were motivated to be more accurate because they believed the researcher would be able to check the accuracy of their reporting. This tentatively suggests that when given an incentive to report more accurately, subjects were able to be more accurate.

Consistent with this notion, we examined whether patients tended to engage in socially desirable responding with respect to their intake reports. That is, did patients fill out their food records in a way that made them appear in a socially favorable light. Socially desirable responding is generally believed to consist of two components (70–74). The first component is impression management, which is thought to be associated with a more deliberate conscious process. It involves the purposeful tailoring of one's responses to display a positive image to others. The second is the more hypothetical process of self-deception, which is thought to be associated with the unconscious process of denial (70–74). It

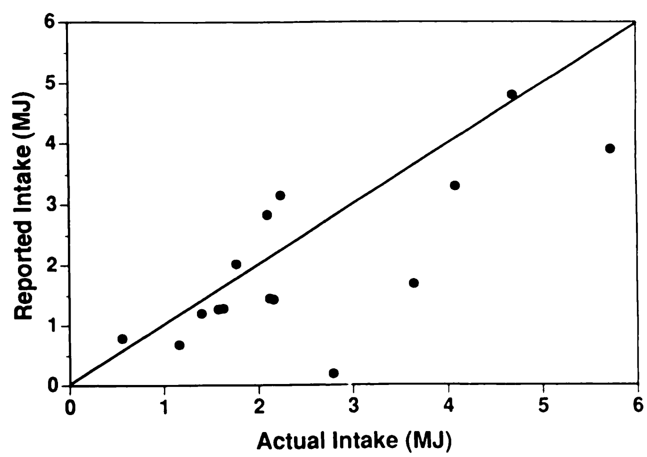

FIGURE 5. Reported meal intake on the abscissa and actual meal intake on the ordinate in 15 obese subjects with unexplained disturbances in body weight regulation. The diagonal line is the line of identity. Subjects reported their food intake on questioning 24 h after ingesting a meal of known amount and composition.

involves the use of psychologic techniques to preserve a favorable view of the self (75).

The 16 patients with disturbances in body weight regulation and low self-reported intake, who were described earlier, and control subjects were administered the Minnesota Multiphasic Personality Inventory (MMPI) (75). The MMPI has two validity scales that correspond with the two elements of socially desirable responding (74). The L (lie) scale measures a subject's attempt to create a positive social image. It is generally considered to be a measure of unsophisticated impression management that primarily picks up naive attempts to appear favorable to others (74). The patient group's t score (53.8 ± 8.8) was significantly higher than that of an archived group of 118 obese control subjects (47.0 ± 6.4, $P = 0.0002$). These results suggest that the group as a whole tended to present an exaggerated favorable impression. It is possible that this style of self-presentation carried over to the subjects' completion of the food diaries, and that the patients reported less food than was actually consumed out of fear of being seen as gluttonous and thus, blamed for their obesity.

The K scale on the MMPI is a more subtle measure and tends to quantify what some have referred to as self deception (74). The patients in this investigation also scored significantly higher on the K scale (59.2 ± 7.2) than did the obese control group (52.6 ± 7.8, $P = 0.0017$). This suggests that patients who underreport their energy intake may have a biased view of themselves and may downplay their negative qualities and behaviors. It is possible that patients in this study had a greater tendency to distort information on how much they had eaten to preserve the virtuous self-image of a stringent dieter and to avoid the shame and guilt that they feel after eating fattening foods.

These preliminary results suggest that some patients with unexplained disturbances in body weight regulation display interpersonal patterns of responding that go beyond simple forgetfulness or poor judgment of portion sizes. There appears to be a conscious or unconscious attempt by these patients to present themselves in a favorable light. These findings also help to explain other self-reported characteristics of these subjects such as their high dietary restraint, low disinhibition and hunger, and their statements that genetic and metabolic causes are the basis of their obesity rather than overeating and lack of exercise (20).

Results from both the L and K scales differed significantly in the patients from the control group, although the group means for these tests were not distinctly abnormal. The relevance of these observations awaits future follow-up studies that make use of additional measures of socially desirable responding on a larger subject pool.

Although further research into the psychologic characteristics of these patients is needed, a clear finding emerging from these results is that food records provide a less-than-objective measure of energy intake in most patients who have unexplained disturbances in body weight regulation.

We describe these subjects only as an example of how a myth about persons who survive on remarkably low energy intake can be fully explored and paradoxes resolved using modern techniques for studying energy exchange. Our results in these subjects contributes to a rapidly expanding literature that challenges the accuracy of self-reported food intake. Schoeller et al (25, 26), Bandini et al (18), and others (16, 17, 19–24) have reported discrepancies between self-reported intake and energy expenditure measured by doubly labeled water. Mertz et al (76) trained 266 healthy volunteers to keep 7-d food records. The volunteers were then fed a weight-maintenance diet for ≥ 45 d. On average, the group underreported their maintenance energy intake by 18%. In a recent comprehensive review, Black et al (21) reported their extensive experience using doubly labeled water to estimate actual energy requirements in various subject groups. Subjects under direct observation or highly motivated volunteers gave very accurate reports of food intake. Reports from men and women revealed intakes of 82% and 81% of actual intake, respectively. Men and women in the lowest tertile of reported intake transcribed only 69% and 61% of their respective actual energy intakes. The investigators also found that obese and postobese women reported 73% and 64% of their actual intake estimated by doubly labeled water. A reasonable conclusion is that underestimation of energy intake is a widespread phenomenon that varies in magnitude between different subject groups.

Inaccurate food labeling

A further cause of underestimation of energy intake worthy of mention is ingestion of foods that contain more energy than that reported in textbooks or on package labels. For example, many obese subjects in New York report eating a bagel on their food records. The textbook weight of a bagel is ≈65 g (2.3 oz). We found that bagels brought to us by patients typically weighed ≈99–128 g (3.5–4.5 oz), in some cases almost twice that of textbook values. A typical New York bagel might therefore have ≈1.7–2.1 MJ (400–500 kcal) and not the 840 kJ (200 kcal) tabulated in food charts. Our own observations were confirmed in a recent article in the *New York Times* that reported representative bagel weights and energy contents of up to ≈198 g (7 oz) and ≈2.3 MJ (552 kcal), respectively ($n = 9$; $\bar{x}$ ± SD, 5.3 ± 1.3 oz, 413 ± 97 kcal) (77).

Another hypothesis explored by us was that patients were misled by unrealistically low energy estimates on food labels. To examine this possibility, we purchased "diet" and "health" foods in stores throughout Manhattan. Energy content of foods was measured by bomb calorimetry and then adjusted to approximate metabolizable energy (78). We found that all locally prepared foods ($n = 8$) had higher energy contents than what was labeled. The mean percentage of actual energy greater than labeled energy was 85 ± 78% per item ($P = 0.01$). Regionally distributed foods ($n = 12$) also had significantly more energy per item than reported (25 ± 16%, $P = 0.001$). Nationally advertised foods ($n = 20$) did not have significantly more actual than reported energy per item ($P = 0.37$). These results suggest that a tendency for some diet or health foods to systematically provide more actual energy than stated on their labels or in textbooks contributes to a low self-reported intake by some subjects.

At this point it is worth reflecting on the question of how such large and systematic biases in self reports of food intake could remain unproven for so long. Although there may be several explanations, the most probable is that accurate reference methods for estimating actual energy intake in free-living subjects were unavailable until the introduction of the doubly labeled water method for use in humans by Schoeller and van Santen (11) in 1982. Although there is immediate concern surrounding the validity of food intake records, particularly in subjects such as those with unexplained disturbances in body weight regulation, there exists an important opportunity for research that probes the causes of misreporting. A food intake history is central to patient evaluation and is a routine part of behavioral treatment for obesity. Therefore, every effort should be made to find approaches that improve the veracity of food intake records.

Although our results strongly indicate that patients referred to us for disturbances in body weight regulation were underreporting their food intake, we did observe one patient with a resting and total energy expenditure ≈25% below that predicted based on body composition. It is thus possible to have a modest reduction in energy requirements, and more research is needed to explore the underlying causes of a low resting metabolic rate in the presence of normal serum thyroid hormones.

CONCLUSION

The purpose of this symposium was to explore in-depth issues relating to human energy requirements. We have shown how new methods of estimating energy expenditure can finally dispel myths surrounding energy requirements and in turn open new areas of scientific inquiry. In particular, our results and those of many other research groups suggest that the population as a whole underestimates energy intake by self report and that the degree of underestimation is severe in selected subject groups. These significant biases in self report have hampered our understanding of energy requirements and energy balance. Thus, it is important to turn elsewhere for energy intake data.

There is a definite need to firmly establish individual and population energy requirements that will allow for the maintenance of a constant body weight while fostering a healthy and long life span. These are challenging and vital issues for future research.

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