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# Is the energy balance explanation of the obesity epidemic wrong?

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ABSTRACT

There is a striking discrepancy in both U.S and the U.K data between obesity rates, which are increasing, and self-reported food consumption rates, which are decreasing. There are two possible explanations for this discrepancy, namely that the widely accepted energy balance interpretation of obesity is wrong or that food consumption data are somehow biased. In a comment entitled "Obesity-an unexplained epidemic", Mozaffarian (2022) challenged the Energy Balance Model (EBM) and argued for a need to replace it with a novel biological theory. This challenge is premature, because there are psychological explanations for this discrepancy, namely that individuals with overweight and obesity underreport their food consumption and that this tendency has increased in recent years. To support these hypotheses, U.S and U.K data are reviewed that used the Doubly Labelled Water method (DLW), which is the gold standard for estimating energy expenditure. Such studies find not only consistent evidence of underreporting, but also that the discrepancy between measured energy expenditure and reported calorie consumption increased over time. Two psychological explanations for this pattern are discussed.

## 1. Introduction

Mozaffarian (2022) recently highlighted the apparent discrepancy between the Energy Balance Model (EBM) explanation of the obesity epidemic and the self-reported food consumption data that fail to support an increase in energy intake assumed by the EBM. According to this model, overweight and obesity are the result of a chronic imbalance between energy intake and energy expenditure. People with overweight or obesity consume more calories than their bodies need for physical exercise and to maintain bodily functions (Hall et al., 2022; Stroebe, 2023). The historical increase in obesity rates is therefore caused by overeating, with this overeating being driven by intensive marketing of hyperpalatable food.

In his critique of this explanation, Mozaffarian (2022) points to an important inconsistency, namely that U.S national data on food consumption do not support this interpretation.[1] Rather, the U.S National data on energy intake, report a *decrease* in calorie consumption during a time, when there was a clear increase in U.S obesity rates (Ford & Dietz, 2013; Fryar, Kruszan-Moran, Gu, & Ogden, 2018). According to data from the U.S National Health and Nutrition Examination Survey (NHANES), which is based on food consumption self-reports of nationally representative samples (24h dietary recall), the adjusted mean energy intake of U.S adults decreased in the period between 2003 and 2004 to 2009–2010 from 2269 kcal/d to 2195 kal/d (Ford & Dietz, 2013). During the same period, obesity rates increased from 32.2% to 35.7% (Fryar et al., 2018).[2]

A similar pattern can be observed in the U.K. According to the U.K National Diet and Nutrition Survey (NDNS), which is a continuous cross-sectional survey that assesses the nutrient intake of the general population based on interviews and a 4-day estimated diet diary, energy intake declined from 1972 kcal/d in 2000–2001 to 1862 kcal/d in 2011–2012 (Harper & Hallsworth, 2016). During this period, the U.K obesity rates increased steadily and rather rapidly from 15% in 1993 to 28% in 2019 (UK Parliament, 2023).

How can we explain these discrepancies? Mozaffarian (2022) developed a "complex biological explanation between the types, quality,

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[1] Mozaffarian (2022) also draws on the loss adjusted US. food availability data to support his argument. However, as Archer et al. (2016), who compared the presumed energy requirements for a nationally representative sample for the years 1971–2010 demonstrated, the loss adjusted food availability data underestimated the presumed energy requirements and this discrepancy increased over the 39-year period.

[2] One could argue that the average energy intake of a country should be related to average weight of a population rather than obesity rates, which are extreme scores (i.e., percentage of people with a BMI 30 and above). However, as average weight also increased in the USA during this period, even though less steeply [nine pounds; (Fryar, Kruszan-Moran, Gu, Ogden)], this does not solve the puzzle.

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and processing of foods and population shifts in our gut microbiome" (p. 1448). There are other models such as the carbohydrate-insulin model (CIM; Ludwig et al., 2021) that also challenge the EBM (but see Hall, 2017; Hall et al., 2022). However, these models have been (or need to be) assessed in experimental research and have been discussed elsewhere (Stroebe, 2023). In this article, it will be argued that the discrepancy between obesity rates and self-reported energy intake data cannot be used to challenge the EBM, because people have a tendency to underreport their food consumption in dietary recall questionnaires. Furthermore, this tendency has increased in recent years, probably as the result of the increasing number of popular diets and the increased stigmatization of people with overweight or obesity (Stroebe, 2023).

## 2. Underreporting of energy intake in self-report of energy intake

There is a great deal of empirical evidence that dietary recall questionnaires result in an underestimation of actual energy intake (e.g., Archer et al., 2013; Briefel et al., 1997; Burrows et al., 2019; Freedman et al., 2014; Harper & Hallsworth, 2016; Johansson et al., 1998; Livingstone & Black, 2003; Watanabe et al., 2019) for both genders (McKenzie et al., 2021). Two techniques have been used to assess the validity of these recall measures (Livingstone & Black, 2003). One compares the energy intake data with the minimum level of calorie consumption that would be required to maintain the current weight of the individuals reporting their energy intake (energy requirement is a function of basal metabolic rate multiplied by physical activity level). Using this method to evaluate the validity of NHANES data collected between 1971 and 1974 to 2009–2010, Archer et al. (2013) reported evidence of significant underreporting ranging from 281 kcal/d to 365 kcal/d. They further concluded that the degree of underreporting increased over time and was considerably greater in the more recent NHANES surveys. Finally, they found the greatest degree of underreporting among men and women with obesity. Subtracting total energy expenditure from (estimated) actual energy expenditure, the degree of underreporting ranged from 41% to 20% in women and from 25% to 15% in men. Studies using biological indicators for energy intake (Doubly Labelled Water technique; DLW)[3] arrived at the same conclusion. One systematic review that pooled the results of five such validation studies conducted on U.S samples reported substantial degrees of underreporting that ranged from 24% to 32% (Freedman et al., 2014).

Using both these methods to evaluate the validity of the data of the U.K NDNS, a review by Harper and Hallsworth (2016) [4] arrived at the same conclusion. The calculation of the presumed energy requirement (BMR) used data on national average height, age and weight for adults in 2013. This estimated BMR was then multiplied with the lowest plausible level of physical activity (assuming a sedentary lifestyle). This resulted in an estimate of the average energy requirement to maintain current weight of around 2446 kcal/d (2755 kcal/d for men and 2138 kcal/d for women). This estimate was substantially larger than the estimates based on self-reported consumption. Furthermore, a study using the DLW technique on a subsample of respondents included in the 2011 NDNS estimated the degree of underreporting to be approximately 32%.

## 3. The increase in underreporting of energy intake

### 3.1. Empirical findings

There is ample evidence that underreporting increased in recent years. As mentioned earlier, in their evaluation of the validity of NHANES data, Archer et al. (2013) found not only significant underreporting, but also that the degree of underreporting increased over time and was considerably greater in the more recent NHANES surveys. Similar increases in underreporting of weight between 1998 and 2007 were found in a study in Ireland that compared self-reported weight with measured weight in small subsamples of their survey participants (Shiely et al., 2013). British studies reviewed by Harper and Hallsworth (2016) found a similar increase in underreporting. DLW studies on subsamples of respondents included in the NDNS conducted in 1993, 2000 and 2011 show that underreporting increased from 19% in 1993 to 25% in 2000.

### 3.2. Psychological interpretations

This leaves a last question, namely why underreporting increased substantially over this period of time. One plausible reason is the combined effect of health messages emphasizing dieting and weight loss (e.g., Archer et al., 2013; Stroebe, 2023) and the prejudice against individuals with overweight and obesity (Brown et al., 2022; Latner & Stunkard, 2003; Sikorski et al., 2016; Spahlholz et al., 2016) which has substantially increased during recent decades (e.g., Andreyeva et al., 2008; Latner & Stunkard, 2003). The image of the ideal body shape projected by mass media is that of a slim person. Mass media reinforce standards of the ideal body and provide models for social comparison. This motivates individuals to continually assess the extent to which their body conforms to culturally valued ideals (Möri et al., 2022; Paterna et al., 2021; Rollero, 2022). This can lead to body dissatisfaction and attempts to lose weight in order to conform to culturally valued ideals.

Governments in many countries have engaged in obesity prevention campagaigns emphasizing the health impact of obesity and providing advice on weight loss (Stroebe, 2023). For example, LiveLighter mass media campaign that ran during August to October 2012 in Western Australia, presented graphic anatomical images of visceral fat in their first campaign message to motivate individuals to consider obesity a serious health risk (Morley et al., 2016). In subsequent messages it informed viewers how to prevent becoming obese by making changes in their behavior (e.g., reduce amount of high calorie food, drink fewer sugar sweetened drinks). Similar messages were provided by the Fighting Fat, Fighting Fit campaign of the British Broadcasting Corporation, which was specifically targeted at individuals with obesity (Miles et al., 2001). To help people with their weight control, a recent U.S law requires all chain restaurants to provide calorie information on their menus (Stroebe, 2023). Although it is debatable whether any of these campaigns resulted in actual weight loss (Stroebe, 2023), they are likely to have increased the motivation to lose weight among persons with overweight or obesity.

Given these pressures towards weight loss, it is hardly surprising that dieting and weight-loss attempts have increased in many countries. For example, data from NHANES covering the period from 1999 and 2000 to 2015–2016 indicated an increase in the percentage of adults who attempted to lose weight during the previous year from 34.3% to 42.2% (Han et al., 2019). Similarly, data of the Health Survey for England indicated an increase in the rate of dieting between 1997 and 2013 of from 39% to 49% (Piernas et al., 2016). There is also a strong association between the desire to lose weight and weight underreporting (e.g., Johansson et al., 1998; Maurer et al., 2006), even though it is unclear whether such underreporting is conscious or merely a result of wishful

[3] The doubly labelled water method (DLW) is the gold standard for the assessment of total energy expenditure (TEE). It does not restrict individual behavior and therefore does not interfere with the daily activities of individuals whose TEE is being measured (Speakman, 1998). All it requires is for individuals to drink a measured amount of doubly labelled water, that is water in which both the hydrogen and the oxygen have been partly or completely replaced (i.e., labelled) with stable isotopes deuterium ($^2$H) and oxygen-18 ($^{18}$O). Saliva-, or urine samples, collected at the start and end of the observation interval, allow researchers to assess the difference between the apparent turnover rates of the hydrogen and oxygen of body water and thus to infer $CO_2$ production.

[4] Harper and Hallsworth (2016) review of great deal of U.K government research, which has not been published in scientific journals. References for these reports can be found in their review.

thinking. Because individuals with overweight or obesity are aware that their weight is often attributed to overeating, they are most likely to experience pressure to underreport their food consumption.

This pressure towards underreporting of consumption and weight loss should be stronger, the more individuals with overweight or obesity feel discriminated against. There is evidence that prejudice towards individuals with overweight and obesity has increased during recent decades. For example, Latner and Stunkard (2003) replicated in 2001 a study 5th and 6th grade children by Richardson et al. (1961) that has been conducted half a century earlier, and found that stigmatization of children with obesity had increased substantially during that period. Similarly, a study by Andreyeva et al. (2008) which examined the presence of prejudice towards individuals with overweight and obesity in two representative U.S samples in 1995–1996 and 2004–2006 found an increase in prejudice towards these individuals. During both periods respondents reported experiences of prejudice and also gave the perceived reasons for the prejudicial treatment. They found a significant increase in weight/height discrimination of from 7.3% to 12.2% during this ten-year period.

In contrast to the explanation above, which assumes that underreporting is a motivated process, Waterworth et al. (2022) recently suggested that individuals with obesity do not underreport their food consumption to a greater extent than do normal weight individuals, if data are scaled to body mass. This does not contradict the psychological interpretation presented above, however, because that explanation assumes that the tendency to underreport is correlated with bodyweight. In addition, because individuals with obesity consume more food at any given meal, they have a greater opportunity to forget certain items in their dietary self-report, suggesting a novel explanation that does not rely on motivational assumptions. If one assumes that individuals – asked to respond to dietary recall questionnaires – underreport their calorie intake by a fixed percentage due to forgetting, it would result in a greater degree of underreporting in absolute terms among individuals with obesity than among individuals with normal weight. This would also explain why the discrepancy between consumption assessed with the DLW method and with dietary intake questionnaires increased in recent years.

However, the predictions derived from such a theory do not quite fit the data. As mentioned earlier, according to the NHANES the adjusted mean energy intake of U.S adults decreased in the period between 2003-2004 and 2009–2010 from 2269 kcal/day to 2195 kcal/day (Ford & Dietz, 2013). Similarly, according to the U.K NDNS, self-reported energy intake of the population has decreased from 1972 kcal/d in 2000–2001 to 1862 kcal/d in 2011–2012 (Harper & Hallsworth, 2016). In contrast, the assumption that – with increasing portion size - individuals with obesity underreport more of the food they consume – does not explain the decrease in reported calorie consumption.

## 4. Conclusions

Although one cannot exclude the possibility that the increasing discrepancy between self-reported energy intake and obesity rates is at least partly due to changes in biology (Mozzafarian, 2022), such biological explanations need to be tested in experimental studies rather than with problematic data from self-reported energy intake. Furthermore, the evidence on underreporting of total energy intake in reports on food questionnaires particularly by individuals with overweight or obesity offers sufficient support for the traditional explanation of the obesity epidemic in terms of an imbalance in energy intake and energy expenditure. However, the question why individuals with obesity underreport their food consumption, whether this is a motivated process or at least partly the result of fact that the risk of reporting errors increases with portion size, requires further investigation.

## Ethical statement

Not applicable, because this is a review paper.

## Declaration of competing interest

There is no conflict of interest for this paper.

## Data availability

No data was used for the research described in the article.

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