



Comment

Trustworthy satiety claims are good for science and society. Comment on ‘Satiety. No way to slim’[☆]

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ABSTRACT

In their short communication against satiety claims, Booth and Nouwen (2010) neglect dozens of well designed studies that show consistent relations between satiety, energy intake and body weight. Satiety, intake and weight are separate concepts, that need different claims and evidence to support them. Satiety can be measured reliably. A repeated higher satiety response to a specific food compared to an appropriate control food may be valuable to consumers who want to avoid hunger. This is good for society. The development of the psycho-biological knowledge to achieve this is good for science. The lawmaker should provide the frame of reference for trustworthy satiety claims. It is then up to the consumer to decide the value of these claims.

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Introduction

Booth and Nouwen argue on several grounds that an increased satiety, delivered by specific foods, cannot be considered as an aid to weight reduction/maintenance. In their strong worded short communication, an unidentifiable part of recent research studies on satiety is qualified as “unscientific”, “damaging”, “fundamentally flawed”, “misleading” and “deceptive”. Booth and Nouwen paint a picture of ignorant scientists and policy makers, who work together with a deceitful food industry in a conspiracy to promote deceptive satiety claims.

If I understand the paper well, one of their major concerns is that a higher satiety in itself does not produce a lower energy intake or weight loss. Another issue is that we should not consider satiety properties of foods in isolation, but we need to take habitual eating patterns into account. Repeated reductions in food and energy intake are no guarantee for a better body weight management. Also, “the concept of biological markers of satiety is fundamentally flawed by its neglect of the mechanisms of satiety”. In some way, the “low-fat” debacle and the “low sugar” nonsense are also implicated in this discussion.

Overall, the paper makes a number of sensible points, on which every scholar in the field would agree upon. However, the paper neglects the existence of a large number of studies with appropriate rigorous methodologies that connect satiety with

food intake and studies that connect changes in food/energy intake with changes in body weight. This makes the paper unnecessarily destructive. This also makes the paper a missed chance for a field that is moving in the direction of trustworthy satiety claims. The building of trustworthy satiety claims requires fundamental knowledge on the psycho-biological mechanisms that are involved in the control of food intake and body weight. I think that this is good for the science in this field.

In the response below, it is argued that satiety, food/energy intake and body weight are connected to each other in a meaningful way. Hunger is an unpleasant feeling which consumers want to avoid; hunger and satiety can be measured reliably. Higher consumption of foods with a low satiety value per calorie has been shown to result in overconsumption and a higher body weight. Informing consumers about foods with a higher satiety value may help consumers to select foods that yield more satiation/satiety per calorie. This promotes a healthier food choice, and this is good for society.

Satiety, food intake and body weight: three different but connected constructs

Satiety refers to a subjective feeling of an absence of the motivation to eat. Rated satiety is the golden standard in this respect (Blundell et al., 2010). Food intake (in grams) is a behavioural measure, which is connected to energy intake, by means of the energy density of the food. Changes in body weight are physical measures that are the result of changes in the balance between energy intake and energy expenditure. It is obvious that satiety, food intake, and body weight/body composition are different measures,

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which need to be studied in different types of studies. However, these three constructs are connected to each other in a meaningful way.

Of course, [Booth and Nouwen \(2010\)](#) are right in their observation that satiety in itself does not produce weight loss. However, I do not know of any scholar in the field who has argued that satiety per se leads to weight loss. Subjective satiety and food intake have been shown to be related to each other in dozens of studies. A similar argument applies for the energy intake → body weight relationships. Of course, [Booth and Nouwen \(2010\)](#) are also right in their observation that food/energy intake reductions at some specific occasions do not necessarily lead to overall lower energy intakes and body weight. However, dozens of studies have shown close relationships between changes in energy intake and changes of body weight. These arguments are substantiated below.

Hunger is unpleasant and involved in loss of control with dietary regimes

Hunger is an unpleasant sensation that drives people to search for food ([Castonguay, Applegate, Upton, & Stern, 1983](#)). With humans, the unpleasant sensation of hunger is most clearly visible in crying infants, who often look miserable from hunger. When you give milk to a crying infant, this results in a remarkable transformation within a few minutes, from an infant miserable from hunger to a pleasantly satiated/comfortable baby. The difference between the discomfort and comfort related to food slowly get less pronounced when children get older. However, also for most adults hunger is an uncomfortable feeling, for which eating food is the quickest solution in most circumstances.

Hunger plays an important role when adhering to diets that aim control energy intake ([Burton, Smit, & Lightowler, 2007](#); [Gilhooly et al., 2008](#); [Krupa Das et al., 2009](#); [Martin, O'Neil, & Pawlow, 2006](#); [Wing et al., 2008](#)). To mention a few examples of the relevance of hunger (satiety) for adhering to dietary regimes, [Wing et al. \(2008\)](#) showed that increase in reported hunger after weight loss were involved in subsequent weight gain. [Gilhooly et al. \(2008\)](#) showed that the use of cereal fibre facilitated adherence to a caloric restriction program through a greater satisfaction with the amount of food consumed.

For most of the people, satiety is a pleasant state. This is already apparent in the instructions in many studies that look at food intake. Very often, subjects are instructed to eat until they are pleasantly/comfortably satiated ([Blundell et al., 2010](#)).

Hunger and satiety can be measured reliably

Hunger and satiety are feelings that human subjects are able to quantify on different types of scales, which reflect different slightly different aspects regarding the motivation to eat. Self report scales include hunger, fullness, prospective consumption, and the desire to eat. Since the end of the 1970s the scales developed by [Rogers and Blundell \(1979\)](#) have been used in dozens and dozens of studies. In this context satiety can be considered as the opposite of hunger.

Satiety scales are generally responsive to properties of foods, such as texture, weight, volume, fibre and macronutrient content ([Blundell et al., 2010](#)). Under appropriate experimental conditions, these scales have been shown to have good repeat-reliability with regard to mean response to particular foods ([Blundell et al., 2010](#)). Analyses by [Flint, Raben, Blundell, and Astrup \(2000\)](#) indicate that 8–35 subjects would be required to identify a 10 mm (10%) difference in 4.5 h mean appetite ratings for a comparison of two foods. The recent paper of [Blundell et al. \(2010\)](#) gives an extensive overview on the current state of the art regarding the methodology regarding the measurement of satiety.

Hunger and satiety relate to food/energy intake

It is clear that changes in satiety do not relate to changes in food intake on a one to one basis. Hunger therefore cannot serve as a proxy measure of food intake ([Mattes, 1990](#)). Sometimes people do not eat when they are hungry, and they do eat when they are satiated. Eating or not eating depends on a large number of factors related to the food, the person, and the physical and socio-cultural environment. For example, in a long term (6 months) meal-ambiance study, we showed that family style dinners in a Dutch nursing home led to higher food and energy intakes, higher body weights, and a better quality of life ([Nijs, de Graaf, Kok, & van Staveren, 2006](#)). The effect of the social environment has been shown in dozens of studies.

Notwithstanding the fact that there are many reasons why hunger, satiety and energy intake are disconnected, there are dozens of studies whose results show that hunger ratings do relate to food intake. This is more so in laboratory studies than in field studies (see [Blundell et al., 2010](#)). In the 1980s and the 1990s, the studies of de Castro (e.g. [Bellisle, Dalix, & de Castro, 1999](#); [de Castro, 1988](#); [de Castro & de Castro, 1989](#); [de Castro, 1996](#); [Feunekes, de Graaf, & van Staveren, 1995](#)) show that self report hunger ratings before a meal have a correlation of about 0.4 with the actual energy intake during a meal. In a review on biomarkers of satiety ([De Graaf, Blom, Smeets, Stafleu, & Hendriks, 2004](#)), in which about 80 studies were evaluated with respect to ratings of satiety and actual energy intake, almost all studies showed similar effects of foods and/or satiety hormones on satiety on the one hand and energy intake on the other hand.

Satiety, energy intake and body weight with liquid calories

Numerous studies have shown that solid foods lead to a stronger satiety response than liquid foods with equivalent weight and energy levels. This work started with a study of [Haber \(1977\)](#), with raw apples, apple sauce and apple juice. The study of [Haber \(1977\)](#) showed that the raw apples were more satiating than the apple juice. Later [Bolton, Heaton, and Burroughs \(1981\)](#) showed a similar finding for other solid fruits and fruit juices. Studies of [Hulshof, de Graaf, and Weststrate \(1993\)](#), [Mourao, Bressan, Campbell, and Mattes \(2007\)](#), and [Martens, Lemmens, Born, and Westerp-Plantenga \(2011\)](#) confirmed these observations.

In 1996, [Mattes](#) wrote a review article that showed that liquid calories (from carbohydrates) lead to lower energy intake compensation behaviour than solid calories. This observation was later confirmed in various other studies. In a four-weeks study [DiMeglio and Mattes \(2000\)](#) showed that a solid preload led to a lower energy intake during the remainder of the day, whereas a liquid preload did not. [Raben, Vasilaras, Moller, and Astrup \(2002\)](#) showed in a 12 wks study that energy supplementation in the form of liquid calories was added to the other calories of the diet, and not compensated by a lower intake of other foods. [Tordoff and Alleva \(1990\)](#) made a similar observation with the energy from high fructose corn-syrup drinks.

The body weight data of [DiMeglio and Mattes \(2000\)](#), [Raben et al. \(2002\)](#) and [Tordoff and Alleva \(1990\)](#) were in line with the energy intake data. Subjects with higher energy intakes (mainly from liquid calories) had on average higher body weights. In the 18 months RCT from [Chen et al. \(2009\)](#), it was found that removal of liquid calories from the diet led to a loss of body weight, whereas removal of solid calories did not. There was a dose–response relationship between the amount of liquid calories removed and the amount of body weight lost ([Chen et al., 2009](#)). These data are in line with the results of a number of large scale prospective epidemiological studies that show a positive association between

sugar-sweetened beverage consumption and weight gain and obesity (Hu & Malik, 2010; Malik et al., 2010; Schulze et al., 2004).

In a series of recent papers, we showed that the stronger satiating effect of solids can be explained for a large extent by the duration of the oro-sensory exposure time (De Graaf, 2011; De Graaf & Kok, 2010; Weijzen, Smeets, & de Graaf, 2009; Zijlstra, de Wijk, Mars, Stafleu, & de Graaf, 2009; Zijlstra, Mars, de Wijk, Westerterp-Plantenga, & de Graaf, 2008; Zijlstra, Mars, Stafleu, & de Graaf, 2010). Sensory signals make an important contribution to satiety, probably through their learned association with post-ingestive consequences. This idea is in line with the idea of the taste system as a nutrient sensing system. With fast foods and liquid foods, this system is bypassed, making it difficult for the human body to sense the energy content of foods.

Overall, these data suggest that foods with liquid calories results in a low satiety response, they lead to higher energy intakes, lower energy intake compensation, and on the long term, this translates into higher body weights. Taken together, these data show that satiety, energy intake and long term changes in body weight are connected to each other in a meaningful way.

Satiety, energy intake and body weight with low- and high energy dense foods

In a similar fashion as with liquid calories, it has been shown in numerous studies that food with a low energy density lead to a higher satiety values than foods with a high energy density (e.g. Rolls et al., 1998; Rolls, Bell, & Thorwart, 1999). This is related to the observation that the volume or weight of foods contribute to satiety. Also, low energy density foods take a longer time to consume than higher energy density foods, leading to a longer oro-sensory exposure times. A longer sensory exposure time has also been shown to lead to a lower *ad libitum* food/energy intake (De Graaf, 2011; De Graaf & Kok, 2010; Zijlstra, de Wijk, et al., 2009; Zijlstra et al., 2008; Zijlstra et al., 2010).

The effects of energy density on satiety are in line with the effects of energy density on energy intake. From numerous short and longer term studies it is clear that foods or diets with a high energy density lead to higher energy intakes than foods with a low energy density (e.g. Kendall, Levitsky, Strupp, & Lissner, 1991; Lissner, Levitsky, Strupp, Kalkwarf, & Roe, 1989). For two decisive and comprehensive review on this subject matter, the reader is referred to Poppit and Prentice (1996) and Prentice and Jebb (2003).

The effects of the energy density of the diet on body weight are in line with the effects of energy density on energy intake. For example, Rolls, Roe, Beach, and Kris-Etherton (2010) showed that providing low energy dense foods led to better longer term weight loss than providing high energy dense foods. Diets with higher energy densities lead to higher body weight (Prentice & Jebb, 2003).

Overall, these data suggest that foods with a high energy density results in a low satiety response, they lead to higher energy intakes, lower energy intake compensation, and on the long term, this translates into higher body weights. Taken together, these data show that satiety, energy intake and long changes in body weight are connected to each other in a meaningful way.

The “low fat” debacle and the “low sugar” nonsense

Fat is a macronutrient that has an energy density of 9 kcal/g compared to 4 kcal/g for protein and carbohydrates, implying that the energy density of foods is strongly correlated to their fat content. Fat content has been shown to be difficult to detect by the human senses (Drewnowski & Schwartz, 1990). It is therefore no surprise that fat has been shown to have a low satiating value per

calorie delivered (e.g. Blundell, Lawton, Cotton, & Macdiarmid, 1996). Fat may therefore lead to a passive overconsumption of energy (e.g. Blundell et al., 1996; Kendall et al., 1991; Lissner et al., 1989; Viskaal-van Dongen, Kok, & de Graaf, 2009). Fat intake is highly variable and may easily vary without being noticed (De Graaf et al., 1997).

As fat is difficult to sense and easily over consumed, it makes sense to lower the fat content of foods in order to lower the energy content of the diet. The food industry is doing its best to deliver foods with lower fat content without compromising on taste, texture, mouthfeel or flavour. I do not understand why Booth and Nouwen (2010) see a conspiracy of the food industry in the making of attractive low fat alternatives. Low fat foods may be helpful for consumers to enjoy foods without ingesting too much energy. In this way, food technologists make our life more enjoyable.

The story with sugar is slightly different from the story with fat. Attitudes towards sugar have varied greatly during history (Mintz, 1986). In the middle ages, sugar was conceived to be healthy (Mintz, 1986); at the beginning of the 1970s Yudkin came out with the book “pure, white and deadly” (Yudkin, 1988). This was followed by a large number of publications that were fanatically opposed to the use of sugar (Fischler, 1987). I agree with Booth and Nouwen that the fanatic rejection of sugar is not helpful in the discussion.

However, it is undeniable that sugar contributes to the energy content of foods. Sugar can be replaced with intense sweeteners without too much sacrifice on its taste/pleasantness. Therefore, it also makes sense to (partly) replace sugar with intense sweeteners in order to lower the energy content of the diet. Low sugar foods that still taste sweet may be helpful for consumers to enjoy foods without ingesting too much energy. Just as with low fat, it should not be communicated that the consumption of diet foods per se leads to weight loss.

The issue of replacing sugars with artificial sweeteners is complicated by the argument that artificial sweeteners disconnect the signal sweet from the signal energy (Blundell & Hill, 1986). In this way the congruency between sensory signals and metabolic consequences from foods gets lost. Davidson and Swithers (2004) and Swithers and Davidson (2008) have shown in animal studies that the use of artificial sweetener may disrupt the normal regulation of appetite, energy intake and body weight. We have recently shown in humans that consumption of sugar and artificial sweeteners differentially affects taste activation during tasting (Smeets, Weijzen, de Graaf, & Viergever, 2011). The efficacy of the use of artificial sweeteners may also depend on the food matrix where it is used (solid, liquid, presence of other calories). This is an area that needs further study.

Despite these drawbacks, there is quite some empirical evidence that lowering sugar concentrations using intense sweeteners helps in body weight control. Four papers that reviewed the empirical data on the usefulness of artificial sweeteners for weight control all came to the conclusion that artificial sweeteners may be useful in this respect (Benton, 2005; De la Hunty, Gibson, & Ashwell, 2006; Bellisle & Drewnowski, 2007; Gougeon, Spidel, Lee, & Field, 2004). This issue relates to the notion that artificial sweeteners are mainly used as a replacement for sugar in sweetened beverages. Energy intake compensation is low with sugar sweetened beverages. This implies that sugar reduction is difficult to denounce as nonsense.

Fundamental flaws with the concept of biomarkers of satiety

Booth and Nouwen (2010) argue that the concept of a biological marker of satiety is fundamentally flawed by its neglect of the mechanisms of satiety. This argument denies the numerous observations in many studies that various physiological processes

have been implicated in satiety and the regulation of food intake. If short transient declines in glucose have been associated with meal requests, or if higher CCK levels in blood have been associated with higher satiety ratings and earlier meal termination, then these measures can be considered as biological markers of satiety (Delzenne et al., 2010). In a previous paper (De Graaf et al., 2004), we defined biomarkers of satiety as specific physiological measures that relate to subjective rated appetite, actual food intake or both. I see no fundamental flaw in this definition.

The question whether or not biological markers are necessary for legal claims on satiety is a different discussion. As argued earlier in this paper and elsewhere, satiety is a psychological construct that can be measured reliably. Satiety claims do not need physiological data as a part of claim substantiation (Blundell et al., 2010).

In our 2004 paper (De Graaf et al., 2004) on biomarkers of satiety it was proposed/thought that biological markers of satiety could help to explain the differential satiating effects of different foods. Later data show that relating satiating efficiencies of foods to differences in biological markers is difficult (e.g. Delzenne et al., 2010; Zijlstra, Mars, et al., 2009). The investigation of properties of foods on satiety is usually carried with foods that have about equal weight, energy density, nutrient content or other food components depending on the purpose of the study (Blundell et al., 2010). As a consequence there are small and multiple differences in physiological responses to foods, which are not correlated to any differences in the satiety value from foods. It may well be that we need patterns of physiological responses instead of single physiological markers in order to find a relationship between physiology and behaviour. I see no principle reason, why there would not be a relationship between physiological parameters involved in the regulation of appetite and subjective ratings of satiety.

The making of foods with higher satiety values requires knowledge on the fundamental sensory and physiological mechanisms that have an impact on the regulation of food intake. As it may be that the satiety response on the first exposure with a food may be different from the satiety response on later occasions, we also need to know the learning/conditioning mechanisms involved in satiety responses. It is highly likely that the studies on the mechanisms involve the communication between the gut and the brain. This is good for the science involved in this field.

Discussion

Conclusion

The last 30 years there has been a dramatic increase in the prevalence of obesity. Changes in the food environment with the wide availability of high energy dense foods and foods that can be ingested quickly are partly responsible for this. These foods will not go away. There is a need to reverse this trend, and to deliver foods that are palatable, but which are also designed in such a way that they lead to early satiation, and/or they deliver longer lasting satiety. This should be achieved not only at one exposure, but also after repeated exposure, allowing for incorporation into a habitual eating pattern.

Subjectively rated satiety, food intake and body weight are different constructs measured through different methodologies. Therefore, claims that are focused on satiety are different from claims that focused on food intake. Similarly, claims on food intake are different from claims on body weight management. Communication about these issues should not go beyond the scientific evidence proven. Claims about satiety should not implicitly refer to food intake, and food intake claims should not implicitly refer to body weight management (cf. Blundell, 2010).

Currently, there are quite a number of food products in the European market place with unfounded satiety, and food intake reduction claims. Some of these claims come from small food industries operating in the grey field of alternative medicine and “magical” supplements. However, also more serious and larger food companies have operated, and still operate in this field. This is bad practice, and undermines trustworthiness of this field on the long term. Booth and Nouwen (2010) are right to argue against these ill founded claims, which have no sound scientific basis.

In Europe and the USA, the lawmaker (EFSA, FDA) should provide the framework of evidence required for trustworthy claims with respect to the effects of foods on health related parameters. The food industry and/or independent knowledge institutes should deliver the scientific evidence required for these claims within the appropriate legal framework. It is then up to the consumer to decide the value of these satiety claims.

Hunger is an unpleasant sensation which is strongly involved in the drive of hundreds of millions of people to eat too much. Therefore it makes sense for a food industry to inform consumers about products that deliver an added value with respect to satiety. Recent papers give ample information on how to conduct reliable and scientifically credible research with respect to satiety (Blundell et al., 2010). The informed and responsible consumer may use the information of a trustworthy increased satiety claim to help him/her to maintain a desired level of food intake. This promotes a healthy food choice. This is good for society.

It is reasonable to assume that a single increased satiety response towards a particular food does not necessarily leads to a repeated increased satiety response. It is well known on the food domain that people may learn about the satiating effect of particular properties of foods. Booth was among the first who realized that satiety is a conditioned response (Booth, 1977). A satiety claim on a food is probably only meaningful to consumers if it delivers its higher satiety value in comparison to an appropriate control food, not on a single occasion, but also after repeated exposures. The number of exposures necessary is of course arbitrary and subject to the opinions of experts and/or policy makers.

One of the basic questions is this discussion is, whether or not a product with a higher satiety value at a single exposure leads to sustained satiety after repeated exposure. For example, Lluch et al. (2010) showed that adding 4–6 g of protein and 2.5–3 g of fibre to a 85–120 g/70–85 kcal yoghurt product (holding calories equal), led to higher satiety ratings and a lower food intake in a later test-meal. Can this product to be expected to lead to sustained satiety and a lower food intake and body weight in the long term? I do not think that you can expect this to be the result of a single product. Adding a few grams of proteins and fibre to a product that makes up only a very small proportion of our food supply will probably not lead to sustained lower energy intakes and better weight control. There are no magic bullets. Can this be a meaningful product for enhanced satiety? I think that such a product can be meaningful to consumer, IF the enhanced satiety effect is clearly demonstrated over repeated exposure with a sound methodology (cf. Blundell et al., 2010). Then I think that it is reasonable to inform consumer about this benefit.

The making of foods with a high satiety value after repeated exposure is not a sinecure. As far as I know, there is currently not a single food on the market that would qualify for, say a 10% increase in satiety response compared to an appropriate control for a period of 4 weeks. This would be a major achievement. The achievement of such a product requires fundamental knowledge on the mechanism how foods impact on satiety after repeated exposures. This requires fundamental knowledge how foods are digested, and how components/ingredients of food lead to satiety responses.

As Booth (1977) argued earlier, satiety is a conditioned response. However, data from liquid calories and data with high energy density foods show that these foods deliver a low satiety value, and they continue to do this also after repeated exposure. Apparently, for some foods people do not learn to estimate the satiety value of foods in proportion to their energy content after repeated exposure. This is also clear from the work of Brunstrom and colleagues (e.g. Brunstrom, Shakeshaft, & Scott-Samuel, 2008), that shows that familiar foods greatly differ in their expected satiety value per calorie delivered.

The knowledge required for an increased satiety per calorie includes the timing and the physiology of the digestion of food in response to the texture and nutrient content. It also involves the study on the physiological signals from the gut that are communicated to the brain, especially to the areas that are involved in hedonics and satiety. This field is expected to expand rapidly in the coming years.

One could argue that our current food environment already contains foods with a high satiety value. Raw vegetables, raw fruits, foods with a low energy density and a high fibre content are foods with a high satiating efficiency. A high consumption of these foods is in line with current nutritional recommendations, and can be expected to result in an eating pattern with a moderate energy intake. If people would adhere to a high fibre, low energy density diets, energy intake and obesity prevalence would go down.

To end, most of the bigger food companies in the world have missions that include consumer health, wellness, and/or vitality. Our current food environment is characterized by an overwhelming supply of foods with a high energy density that can be eaten quickly. This food supply undermines a healthy control of satiety and energy intake. Without any changes in our food supply, obesity prevention is mopping with the tap open. A mission that takes health seriously includes the development of food products that help to control satiety and energy intake on a long term basis.

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