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## Dietary Strategies for Weight Management

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### Abstract

In an 'obesogenic' environment, getting people to eat appropriate amounts is challenging. Several food-based strategies have the potential to promote satiety and moderate energy intake. Components of foods such as macronutrients and functional ingredients can affect satiety; however, for weight management a more comprehensive approach is needed that emphasizes behavioral strategies to improve the overall diet. Research shows that large portions of energy-dense foods facilitate overconsumption and that reductions in portion size and energy density are associated with reduced energy intake. While this suggests that people should eat smaller portions, recent data show that if people lower the energy density of their diet, they can continue to eat their usual amount of food while limiting calories. Furthermore, serving larger portions of low-energy-dense foods can be used strategically to encourage their consumption and reduce dietary energy density, and this has been shown to be associated with decreased energy intake while maintaining satiety. This new understanding of how portion size can be used positively to manage energy intake has the potential to help people achieve sustainable improvements in their energy intake and bodyweight. Science-based strategies that increase the availability of affordable nutrient-rich, lower energy-dense foods are urgently needed.

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In an 'obesogenic' environment characterized by large portions of palatable, inexpensive, energy-dense foods, finding ways to encourage people to eat appropriate amounts is challenging. This paper will consider food-based strategies that have the potential to control hunger and promote satiety in order to moderate energy intake. The available research encompasses: a biological approach aimed at developing foods that affect satiety mechanisms, a behavioral approach

focused on understanding eating behaviors that affect satiety, and an environmental approach that could help to make low-energy-dense foods a more likely choice. In this review, opportunities and challenges related to utilizing these approaches for the management of obesity will be considered.

## **Biological Approach**

### *Macronutrients and Satiety*

Short-term studies have demonstrated that a number of properties of foods can affect satiety and energy intake, including the proportions of macronutrients, various ingredients, and even the physical form. The standard experimental paradigm for assessing satiety is to ask study participants to consume a fixed amount of a food at the start of a meal. Following this preload, changes in ratings of hunger and satiety (fullness), and of biological variables such as glucose, insulin, and gut hormones can be tracked and related to later intake [1]. Such studies have led to the hypothesis that there is a hierarchy for satiety such that protein is the most satiating macronutrient, followed by carbohydrate, with fat the least satiating [2].

While this hierarchy has dominated satiety research, the results of numerous studies comparing the impact of macronutrients on satiety have been inconsistent. One reason for this variability is that each macronutrient category has different types with different physiologic effects. For example, carbohydrates include sugars, starch, and fiber, and it is not clear where they should be considered in the hypothesized hierarchy. Furthermore, macronutrient proportions affect other properties of food that could influence satiety, such as the palatability and energy density (calories per gram). While the hierarchy hypothesis has provided a useful framework for studies of satiety, its utility for weight management has not been established.

The emphasis on macronutrients has dominated the dietary management of obesity; however, the results of randomized controlled trials aimed at determining the effects of diets with different proportions of macronutrients have been mixed [3]. Even when a particular macronutrient was associated with the amount of weight lost during the active treatment phase, significant differences were not sustained during the maintenance phase. The authors of one large, 2-year trial that compared diets with four different macronutrient compositions concluded that: 'Reduced-calorie diets result in clinically meaningful weight loss regardless of which macronutrients they emphasize' [4]. Furthermore, diet composition did not affect satiety, hunger, and satisfaction with the intervention. With similar results coming from several recent large trials, health policy recommendations for weight management have shifted away from macronutrient-based advice to a food-based approach emphasizing control of portion size and total calorie intake [5].

### *Functional Ingredients*

Another major thrust of satiety research is the characterization of functional ingredients that affect hunger and satiety mechanisms. While much of the focus in this area has been on various types of fiber [6] or protein [7], the scope for new products is broad and will continue to grow as the biological bases of hunger and satiety become better understood. However, the utility of such products for weight management remains to be established [8]. Demonstrating that an ingredient or a functional food affects hunger, satiety, or energy intake in the short-term does not indicate that these effects are robust or persistent enough to resist physiological regulatory systems for the maintenance of energy balance. Nor does it show that in the context of an obesogenic environment bodyweight will be affected [9].

A critical question that is raised by studies of food components that enhance satiety is whether any one of these can have an impact on its own. Is it realistic to expect the addition of a few grams of fiber or protein to not only control hunger but also to decrease daily energy intake and reduce bodyweight? Perhaps effects will only be seen if such food components are consumed in combination or as part of a more comprehensive approach to both dietary and behavioral strategies that facilitate weight management.

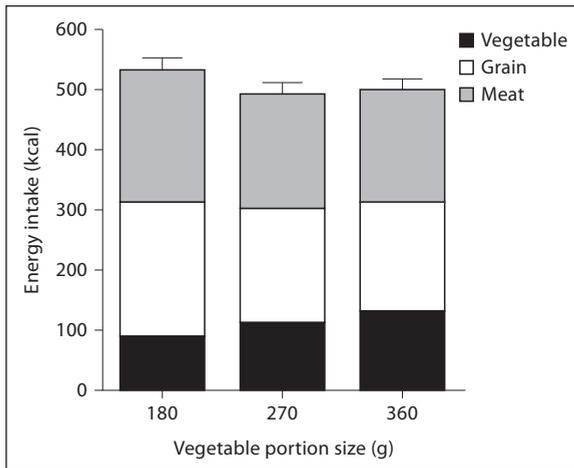
## **Behavioral Approach: Understanding Properties of Foods That Affect Eating Behavior**

While the emphasis in studies of eating behavior has often been on the mechanisms controlling satiety and energy intake, recent data indicate that people readily ignore biological satiety signals when surrounded by large portions of palatable, energy-dense foods. Such overconsumption begins early in life [10] and often becomes a habitual pattern that continues to be reinforced over the lifespan. Dietary interventions that rely on people making changes in established eating patterns to achieve negative energy balance are often unsustainable in an obesogenic environment.

Changing eating behavior represents one of the greatest challenges in obesity prevention and treatment. Ultimately, parental and childhood interventions along with government and food industry initiatives are needed. These initiatives will benefit from sound research that identifies robust behavioral responses to food that could help to moderate intake. Such responses include the effects of portion size and energy density on energy intake.

### *Portion Size*

The goal of much of the research on portion size has been to establish a relationship between large portions of energy-dense foods and overconsumption. It is clear that portion size has a powerful, sustained effect on the amount of food



**Fig. 1.** Portion size can be used positively to increase vegetable intake and decrease energy intake at a meal. As the amount of vegetables served at a meal was increased and the amount of other meal components (meat and grain) was decreased, vegetable intake of 48 adults increased by half a serving (29%) and energy intake decreased by 40 calories (7%). Reprinted from Rolls et al. [13].

consumed. This effect has been demonstrated for different types of foods and beverages in both laboratory and natural environments, and in overweight and normal-weight men and women [11]. Of particular importance is that bouts of overeating associated with large portions are not followed by a compensatory reduction in intake. For example, when the portion size of all foods served over 11 days was increased, there was a persistent and significant effect of portion size on energy intake [12]. Thus, characteristics of the eating environment such as the ready availability of large portions of energy-dense foods can override the regulation of energy balance over prolonged periods.

Since the effects of portion size are robust and sustained, it is possible that they could be used to increase intake of nutritious, low-energy-dense foods such as vegetables. Recent dietary advice relies on this premise. The 2010 Dietary Guidelines for Americans [5] urge people not only to eat less overall and to avoid oversized portions, but also to increase the proportion of vegetables and fruits served at a meal. There is some evidence that this could influence intake. In one study, increasing the proportion of a low-energy-dense vegetable served on a plate by substituting it for the meat and grain significantly increased vegetable intake and reduced energy intake at the meal (see fig. 1) [13]. Other studies show that in both children and adults increasing the portion of vegetables served at the start of a meal increases vegetable intake [14] and can decrease energy intake at a meal. Such findings support the suggestion that variations in portion size can be used beneficially to influence the types and amounts of

foods consumed at a meal, but there are no data on the effects of such strategic manipulations of portion size on sustained changes in intake or bodyweight.

Another portion control strategy that individuals can utilize is to structure their food environment so that exposure to large portions of energy-dense foods is limited during several eating occasions in a day. This can be achieved with pre-portioned foods (PPFs) such as entrées, snack foods, or liquid meals that are packaged individually in portions appropriate for a meal or snack. Existing evidence suggests that the consumption of liquid PPFs helps to limit energy intake and promotes weight loss [15]. There is also limited evidence on the efficacy of solid PPFs for weight management. Providing participants with most or all of their foods as pre-portioned items facilitated weight loss [16]. It is also likely that solid PPFs contributed to weight loss and weight loss maintenance over 2 years in a recent trial that compared a structured weight loss program including free prepared meals to usual care [17]. Although PPFs show promise as a useful tool for weight management, little is known about how characteristics such as their energy content and energy density affect efficacy [18]. Nor is it known if their use leads to better understanding of appropriate portions and whether their consumption will be continued so that they facilitate weight loss maintenance.

More research is needed to determine the impact of specific portion control strategies on body weight regulation. In particular, there is an urgent need for evidence-based strategies to help consumers limit the overconsumption associated with large portions of energy-dense foods. In the current environment, it is difficult for many individuals to eat appropriate amounts of food. Getting intake back in synchrony with energy needs will be challenging since consumers equate large portions with good value and they have a distorted idea of how much food is appropriate. If people were to heed the frequently offered advice simply to 'eat less', and were to reduce the portion size of all the foods consumed, they would probably feel deprived and would not sustain this eating pattern. A promising approach that would allow people to eat satisfying portions would be to reduce the energy density of the diet or at least of selected foods.

### *Energy Density*

Dietary energy density has emerged in recent years as one of the most consistent influences on satiety and energy intake. While the energy density of food is often related to its fat content, the water content can have an even greater effect. The combination of water with the macronutrients in foods determines the energy density, and variations in water can be used to separate the effects of energy density from those of the macronutrients. A number of systematic studies show that when the macronutrient content of foods was varied, but the energy density was kept constant, the effects of fat, carbohydrate, and protein on satiety were similar [19]. On the other hand, the energy density of foods is a robust and significant determinant of satiety and energy intake regardless of macronutrient composition [19].

Most of the studies on the effects of energy density have been relatively short-term, examining individual meals or effects over several days. These studies show that consuming a large low-energy-dense preload of a water-rich food such as soup, salad, or fruit, was associated with reduced energy intake at a meal [2, 19]. In other studies, the energy density of meals was reduced by increasing the proportion of vegetables, and it was found that adults who were offered ad libitum access ate a consistent weight of food. This meant that energy intake varied directly with changes in energy density. Subjects reported similar ratings of hunger and fullness even when reductions in energy density led to a decrease in energy intake of approximately 25% over 2 days [19, 20]. The response to energy density emerges early in life as indicated by studies in preschool children showing they too consumed significantly less energy when the energy density of the available foods was lowered [21]. This suggests the possibility of using reductions in energy density strategically to prevent excess energy intake in young children as well as in adults [10].

While much of the evidence related to energy density comes from short-term studies, reductions in energy density show promise as an effective approach for weight management. In a year-long trial, daily incorporation of a low-energy-dense food into a reduced-energy diet increased the magnitude of the weight loss compared to the incorporation of snack foods higher in energy density [22]. In another year-long trial, obese women who were counseled to reduce dietary energy density by increasing intake of fruits and vegetables along with reducing intake of fat had greater weight loss than those who were advised just to reduce fat intake [23]. Over the course of the year, participants randomly assigned to the lower energy-dense diet (higher in fruits and vegetables) reported consuming an average of 25% more food and reported less hunger than those in the fat reduction group. In the multi-center PREMIER trial that included three different lifestyle interventions, dietary changes that reduced energy density were related to greater weight loss after 6 months [24]. Furthermore, participants with both large and modest decreases in energy density increased the amount of food they consumed. Eating a greater amount of food while decreasing energy intake could contribute to the long-term acceptability of a low-energy-dense eating pattern since it could help to control hunger.

The association between energy density and bodyweight is supported by both longitudinal and epidemiological studies that have tracked dietary patterns. In a 6-year longitudinal study, it was observed that young women who reported a diet higher in energy density gained two and a half times as much weight as those reporting a diet lower in energy density [25]. Longitudinal studies in children have also found an association between dietary energy density and changes in body fatness [10]. Population-based studies in adults provide additional support for associations between energy density and energy intake, the amount of food consumed, diet quality, and weight status. Surveys of self-reported intakes by free-living adults have shown that normal-weight individuals consume diets

with a lower energy density than obese individuals [26]. Furthermore, increases in dietary energy density were associated with greater weight gain in a prospective study of 50,000 middle-aged women over 8 years [27].

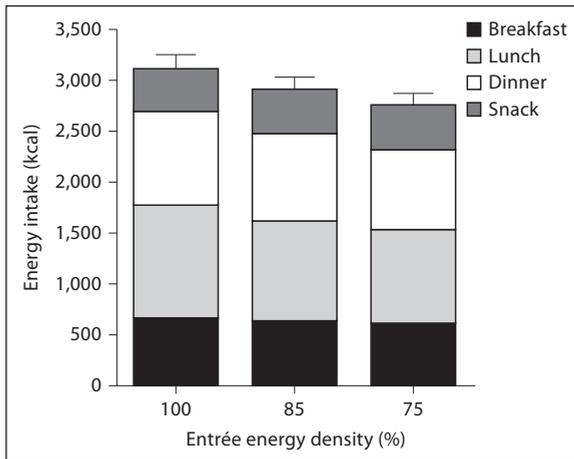
While data suggest that reducing dietary energy density can facilitate weight management, more long-term studies are needed to understand how to implement this approach and facilitate the maintenance of low-energy-dense eating habits. If people were to adopt lower energy-dense eating patterns, they would be able to eat satisfying amounts of foods appropriate to meet both energy and nutrient needs. However, long-term compliance with any diet that requires deliberate and sustained changes in established eating habits is difficult. A key question is whether the food environment can be modified to help people lower the energy density of their diets and to eat appropriate amounts in order to prevent the development of obesity and facilitate weight management.

## **Environmental Approach**

The types of foods that are readily available, affordable, and fit with consumers' preferences and lifestyle can influence energy intake. This suggests the possibility that the eating environment could be strategically designed to encourage consumers to choose more foods that are appropriate in portion size and lower in energy density. A range of strategies has been proposed including education and nutritional information such as menu labeling, increased promotion and availability of low-energy-dense foods such as vegetables and fruits, more opportunities to choose smaller portions of energy-dense foods, and pricing or tax incentives to encourage selection of appropriate portions of nutrient-dense, low-energy-dense foods [28, 29].

At present, there are few data to support the effectiveness of such environmental approaches for weight management, and they have economic ramifications for the food and restaurant industries that could present barriers to implementation. Some of these barriers are evident in surveys asking food providers such as chefs about the items they serve. In one survey, chefs reported the portions served were primarily influenced by the presentation of foods, food cost, and customer expectations [30]. Although most chefs thought that the amount of food they serve influences how much patrons consume, their opinions were mixed about whether it is their responsibility or the customer's to eat an appropriate amount when served a large portion. In another survey, nearly all chefs thought that calories in menu items could be reduced by 10–25% without customers noticing, but they noted low consumer demand as the primary barrier to making such changes [31]. Clearly, innovative marketing strategies that increase the appeal of healthier options are needed – for both consumers and food providers.

The opinions of chefs agree with lab-based studies showing that both the energy content and portion size of foods can be decreased significantly without



**Fig. 2.** Reducing the energy density of entrées served at main meals decreased daily energy intake. When puréed vegetables were incorporated to reduce the energy density of the standard entrées (100%) to 85 and 75%, daily energy intake of 41 adults decreased by 202 (6%) and 357 kcal (11%), respectively. Daily vegetable intake increased by 129 g (50%) in the 85% condition and by 217 g (80%) in the 75% condition. Reprinted from Blatt et al. [32].

people noticing and that these changes will help to moderate energy intake [20]. Energy density can be reduced in a variety of ways such as the addition of vegetables or fruits to recipes or by lowering the fat or sugar content. Herbs and spices can be used to enhance flavors and mask changes in foods. A particularly effective strategy to reduce energy density covertly is to add puréed vegetables. When the energy density of the main dishes served over a day was reduced by the addition of puréed vegetables, both adults and preschool children consumed significantly fewer calories. Large amounts of vegetables were added without affecting the palatability of the foods, even in people who showed a low preference for vegetables (see fig. 2) [32, 33]. Such innovative strategies to lower dietary energy density need to be applied to the development of a range of foods that are palatable, affordable, and readily available.

Changing the food environment in order to have sustained effects on energy intake will be challenging. However, the effects of portion size and energy density on energy intake are robust and should be utilized to develop dietary strategies for weight management and to promote a healthier eating environment.

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## Disclosure Statement

Dr. Rolls has a licensing agreement with Jenny Craig, Inc. for the use of the Volumetrics trademark.

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## Discussion

*Dr. Ard:* Dr. Rolls, you know I am on your side on this. Do you think we shot ourselves in the foot with the diet crazes of the 1980s by going so low fat and being so restrictive that it's going to be really hard to reverse that messaging to get people to understand that they actually need to eat more in order to be successful with managing their weight?

*Dr. Rolls:* Unless we can figure out ways to make the low energy density, reasonable portion approach more accessible and affordable to become almost the default, I think we are going to have a very hard time changing the way people are eating now. For a while, we have had few popular fad diets, but now a couple of best-selling diet books are back to suggesting that changing the proportions of macronutrients or cutting out whole food groups will make weight loss easy. We need to figure out how to make healthy weight management easier and appealing.

*Dr. Finegood:* Why is it that food companies such as those that sell cereal advertise the heavily sugar-sweetened, less nutritious cereals but don't advertise healthier ones? There are data to suggest that in a blinded test kids don't necessarily prefer cereal higher in sugar. Is it that the profit margins are much higher or is it because they don't think the lower sugar product will sell well?

*Dr. Rolls:* I cannot speak for the industry, but one possibility is that they think that they are more likely to get kids to eat cereal in the first place and that kids who eat any

kind of cereal, even if it's sugar sweetened, have a better diet quality than those eating no breakfast or some other less nutritious option.

*Dr. Finegood:* But we can't disentangle that from the advertising efforts.

*Dr. Rolls:* We know that we have to be marketing the healthy foods more effectively. That is why the recent TV ads suggesting that parents have to be secretive about vegetables in foods are so interesting – kids see the message that vegetables are so bad they shouldn't be told about them. Product developers know how to put more vegetables in foods without affecting taste, but marketers have not figured out how to get consumers to buy them. By the way, we have found that 'stealth' vegetables in foods are an effective way to reduce energy density and to get kids to eat their vegetables. We recently published a study showing that we could add large amounts of vegetables to a variety of foods without affecting the palatability. Our problem with the stealth vegetables was with the baked goods – the children liked them better with more vegetables, probably because they were moister. By adding pureed vegetables to main dishes across a day, we got the preschoolers meeting their daily vegetable requirements [1]. If people like vegetables anyway, you don't have to go stealth, but why not try some more innovative ways to get vegetables into the day?

*Dr. Barclay:* The food industry is looking for ways to become increasingly part of the solution rather than only being considered part of the problem; however, we seem to be getting some mixed messages from the science. There is a recent paper from Duffey and Popkin [2] looking at the relative importance of portion size, eating frequency, and energy density. They found that energy density explained less of the increase in energy intake over recent decades in US adults compared to portion size and eating frequency.

*Dr. Rolls:* In that analysis of reported intakes in a population-based data set, a novel algorithm was used to compare the relative importance of those factors. We plan to revisit this issue using more conventional methods of analysis. In our controlled studies, energy density has more robust effects than portion size, but portion size also has significant effects on energy intake. It is clear that the pattern of eating and properties of foods such as energy density and portion size can affect intake, and the food industry should be applying this knowledge to product development.

*Dr. Goran:* I completely buy the energy density argument, but I was wondering if there is more research on the factors that drive choice at the moment of consumption. What are the contextual factors or the intrinsic biological factors that we know about or need to know about that drive individual choice at the moment of consumption?

*Dr. Rolls:* There is a large body of information on the determination of an individual's food choices that we don't have the time to cover. This brings us back to the issue of behavioral phenotypes and personalized approaches. Choice would be something that I would want to put into any weight management plan so up front we can figure out what kinds of foods people are going to be able to eat in a sustainable fashion. I dream of a computer program where people's food preferences are screened before they go into a program. You would then use that information to direct them towards a plan that will accommodate those choices. In the end, maintenance is the issue and that depends on liking the food.

*Dr. Drewnowski:* Designing food patterns based on linear programming in people's existing choices based on 7 days of records is being done by my colleagues in Marseille, France. So, this is something that's absolutely on its way.

*Dr. Rosenbaum:* I was wondering if people can learn to respond visually to portion size. If all foods were packaged so that people could see how much food they would get

for a particular amount or calories – like the 100-calorie packs, but for all foods – would they choose the bigger portions of less calorically dense foods and eat less?

*Dr. Rolls:* I wish we could find a real world setting to do that, but that's part of what we try to educate people to do. If you go lower calorie density you are going to get more food for your calories. But if you ask most people how many calories they should eat in any one occasion they have no idea. You also have the economics of food choice – some people want the most calories for their money.

*Dr. Rosenbaum:* But forget about the economics for a second. If you just walk into a store and you pay by the calorie and you have to buy 500 calories for a meal, if you can see that you would get a lot more food if you choose apples rather than a calorie-dense sandwich, would you buy differently?

*Dr. Rolls:* There is a chain in Britain that has a 'bundled meal' where you pay a flat rate for 500 calories for lunch. They have all kinds of different packages where you can mix and match your sandwich, drink, and snack. This could provide a wonderful opportunity to do research because people could buy items that were different in value as well as energy density and portion size for their 500 calories. Wouldn't it be interesting to look at what they choose?

*Dr. St. Jeor:* I am curious about what your recommendations are regarding high-protein drinks, some of them with as much as 60 g of protein that promotes their satiety-enhancing properties.

*Dr. Rolls:* We will always have a lot of choices, but this goes back to where I began. We don't want people basing their choices on the hope that they will get a boost of satiety that will help them to eat less with little effort. We want people to be eating a diet with a balance of nutrients. We need to think more about how to show people that they can use regular food to enhance satiety and eat less.

*Dr. Drewnowski:* One trend in children's nutrition is to try and replace juices with intact whole fruits. Would that make a difference in satiety or energy density?

*Dr. Rolls:* We have done studies and so have others showing that whole fruit is more satiating than juice even if you add the fiber back into the juice. There is a lot of interesting work on texture and thickness of beverages and how these properties affect satiety. This takes us back to the functional ingredients approach to satiety, which we should continue to pursue, but in the context of a healthier diet overall.

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