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Effect of meal volume on hunger and satiety in obese subjects

Volume of meal and satiety

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Abstract

Objective: The results of several studies showed that energy density of food affects both satiety and food intake. None of them has checked the influence of energy density variation in solid meals in obese subjects. We examined the effect of meal volume on satiety potency of food and its effect on glucose and insulin profiles in obese subjects.

Design: Subjects were served a test meal (milk pudding) equal in energy content and composition (fat, protein, carbohydrate) across two volumes : 250 ml and 500 ml.

Subjects: Study group: 22 obese subjects without additional diseases, BMI: 37.9 + 7.1.

Measurements: The satiety state was assessed on VAS before and after consumption test meal during 180 minutes of observation. During the study every 30 min the blood was taken to determine glucose and insulin profiles.

Results: There were no differences in taste assessment of both test foods on VAS scale. Food consumption results in significant reduction of hunger and increase of satiety feelings independently of food volume. The food volume had no important influence on satiety status of study patients during whole study. Only just after ingestion we observed the significant more satiating efficiency of bigger than smaller volume. We didn't also notice any differences in plasma glucose and insulin levels after ingestion of both food volumes.

Conclusion: Food volume has only limited influence on satiety state directly after meal consumption but not glucose and insulin plasma concentrations.

Keywords: satiation, volume, obesity, food intake

Introduction

Obesity is frequent condition in developed countries [1,2]. It is a major cardiovascular risk factor and the cause of a large number of complications. The epidemic of obesity is probably a result of increasing sedentary lifestyles combined with easily available palatable, energy dense food. The calorie restriction and increase of physical activity are the main methods of obesity treatment. Low calorie diets are very effective in promoting weight loss, but long term results are very disappointing. It may be due to worsening of self control and increased feeling of hunger during the diet [3]. This can be resolved by reduction of daily hunger feelings and increasing satiety after food consumption. One possible method of resolving this problem is a surgical treatment (gastric binding), but it is limited only for very obese subjects. Anorectic drugs are very useful and their efficiency was proven in many clinical trials. The main problem of pharmacotherapy of obesity is safety and lack of evidence that lifelong therapy prevents weight gain. Another issue is high cost of these drugs. On the other hand results of several studies showed that energy density of food affects both satiety and food intake [4].

Studies that compared the effects of fat and carbohydrate on both satiation (the amount eaten in a meal) and satiety (the effect on subsequent intake), revealed little difference between these macronutrients when the palatability and energy density were similar. However, energy density of foods has been proved to have a significant effect on both satiety and satiation, independently of palatability and macronutrient content. It is likely that the high energy density of many high fat foods facilitates the overconsumption of fat. It seems that energy density of foods plays role in the regulation of food intake [5].

Some authors [6, 7, 8, 9] indicate that energy intake was directly related to the energy density and fat content of diet. However, Poppitt et all [10] revealed that macronutrient composition had a significant effect on short-term hunger; subjects were less hungry after the protein preload and the subjects also had a lower energy intake after the protein preload. It seems that only protein has a differential short-term satiating effect when incorporated iso-energetically and at a similar energy density into the diet.

Some investigators have manipulated energy density, by varying the water or air content of food [11]. This manipulation in preload composition had significant influence on subsequent energy intake. Some studies, however, have not revealed any decrease in hunger feelings after the meal with additional amount of water [12, 13]. Most of these studies have examined different energy density variation in liquid test meals. None of them has checked the influence of energy density variation in solid meals. Another limitation of these studies is lack of reliable measurements evaluating important physiological responses such as blood glucose concentration. The present study assessed the influence of energy density of solid food on appetite and subsequent blood glucose and insulin concentration.

Methods

Twenty two obese subjects (19 women and 3 men) without additional diseases aged 42+13 yrs with a mean body mass index (BMI) 37.9 + 7 kg/m^2 were recruited from patients beginning weight loss treatment. None of patients was on a diet to lose weight or was taking any medication during last three months. Informed consent was obtained from all the subjects and the study was approved by the Ethics Committee of Medical University of Silesia.

Subjects were instructed to fast from 8 p.m. the day before the study. Patients came to the laboratory at 8 a.m.; weight and height measurements were taken.

The experiment included 2 conditions in a single blinded, randomized fashion. On two separate days patients eat isoenergetic (310 kcal) breakfast consisting of milk pudding in two different volumes (250 ml and 500 ml).

The milk pudding with greater volume was sweetened with aspartame and thicken by adding gelatin to make a similar taste and consistency to the meal with smaller volume.

Insoluble gelatin was added to the small in volume milk pudding to maintain the similar content. Finally both test meals have similar content, consistence and there was no difference in taste.

The satiety efficiency was examined on VAS scale before consumption of the test meal, after ingestion and then every 30 minutes during 180 min of observation. At the same time points (except directly after consumption) blood samples were collected to determine serum glucose and insulin concentration.

Subjects rated their hunger, fullness and prospective consumption (how much food they thought they could eat) on 100-mm line on VAS [14].

Blood samples were collected in heparinized tubes and immediately centrifuged, and the plasma was stored at -60^{o} C until assayed.

The serum concentration of glucose was assed by using the test kit by colorimetric method (Cormay), insulin concentration was assed by radioimmunoassay (Diagnostic Products Corporation, USA).

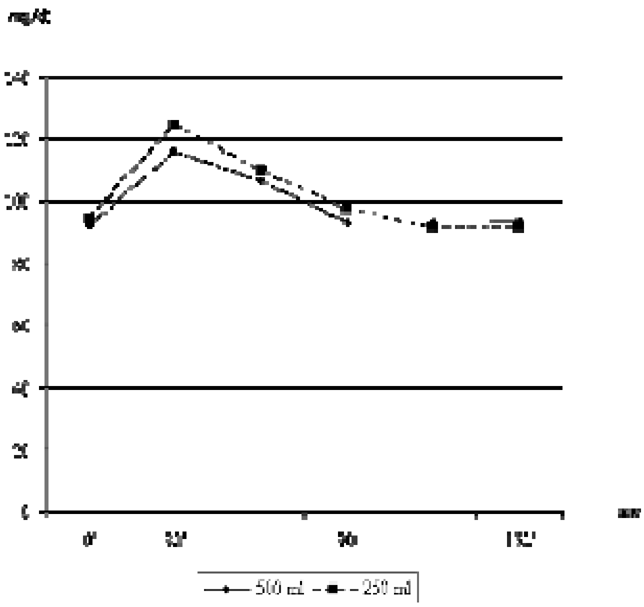
Statistical analyses

Data were analyzed by using Statistica 5.1 for Windows and were shown as mean + SE.

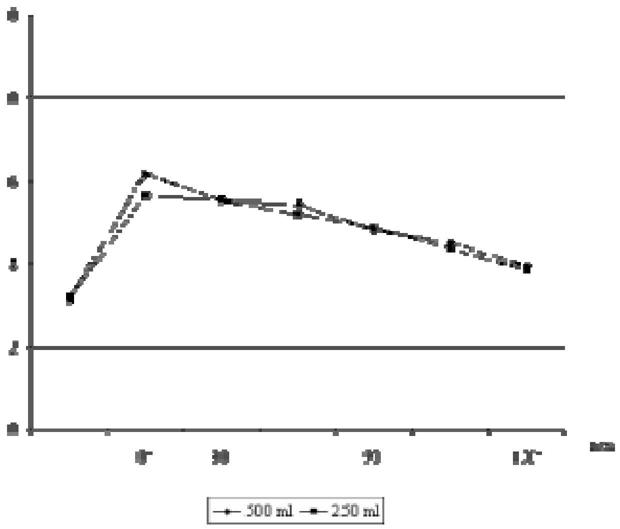
The significance of differences was tested by paired Student`s t-tests. Relationship between glucose, insulin concentration and VAS scoring was assessed using linear regression analysis. P< 0.05 was considered statistically significant.

Results

All of the subjects completed the study. There were no differences in subjects' assessment of taste and appetite of both test meals. On the VAS 100 mm scale the test meals were rated as tasty and were well liked (VAS 78 + 5 mm). Consumption of both volumes of milk pudding resulted in significant reduction in hunger feeling ratings and increase in the satiety ratings. On VAS scale, just after ingestion, we observed the significant more satiating efficiency of bigger than smaller volume. During the rest of the study we didn't notice any differences in hunger and satiety rating between the volumes (Fig.1).



The mean fasting serum glucose and insulin concentrations didn't differ significantly between test days with big and small volume meals (glucose: 92.4 mg/dl vs 94.4 mg/dl, insulin: 16.5 vs. 13.8 UI/l). We observed maximal concentrations of serum glucose and insulin 30 min after consumption of both large and small volume of test meal: glucose 116.2 vs. 124.5 mg/dl, insulin 86.7 vs. 91.4 UI/L, respectively. There was no significant difference in plasma glucose (Fig.2) and insulin concentration during whole period of observation.



We didn't find any correlation between plasma insulin, glucose concentration and hunger and satiety scoring. At the end of observation after 180 min after consumption of test meal there was no significant difference in prospective consumption assessed on VAS for both meals.

Discussion

Our results show that the volume of consumed food had a small and short effect on satiation in group of obese patients.

Only just after ingestion of lower energy density meal (bigger in volume meal) we observed short significant decrease in hunger rating and increase satiation in comparison to small in volume food. This effect was transient and not observed during the rest of the study. The volume of food had also no effect on glucose and insulin plasma concentration, which may suggest that there was no significant influence of food volume on gastric emptying rate [13]. In subjects who digested diluted and concentrated meal there were no differences in intensity and duration of satiety, the amount of energy ingested, ad libitum, 6 h after the test meal. Both the intensity and duration of satiety correlated significantly with the gastric emptying time for solids. These results show that satiety depends on gastric emptying of energy and is not affected by the energy density of food intake [15].

The effect of increased satiation associated with bigger meal volume may also be due to the perception of how much food is being consumed. We served the meals in one or two dishes to ensure that subjects could see that foods differed in volume. It is likely, that seeing the bigger volume led to perception that more energy was consumed. There was no differences in subjects' ratings of pleasantness and taste of both meals. Rolls et al [29] examined whether food volume and energy content affected satiety in lean and obese women, when visual and oral cues were bypassed by infusing food intragastrically. The results showed that increasing the volume of infused food, but not the energy content, affected satiety in both lean and obese women. There was a 13 % mean decrease in energy intake at lunch after the 400-ml preload compared with the iso-energetic 200-ml preload. Increasing the energy content of infused food, but not the volume, did not affect satiety. Thus, when sensory cues were bypassed, the volume of liquid food infused intragastrically affected subsequent energy intake in both lean and obese women. These results suggest that gastric and postgastric mechanisms are involved in the effects of high-volume, low-energy-dense foods on satiety [16].

Another issue is the fact, that larger volume requires more time to consume than smaller meal in volume. The time and amount of oral stimulation varied with volume of food and more effective stimulation may be responsible for short, more satiating effect of larger in volume food in comparison to smaller one. Another explanation of short, more satiating effect of larger in volume milk pudding is that the greater the volume of meal the greater the gastric distension experienced by the subjects. Several studies show that gastric distension effects food intake [17]. On the other hand, several authors didn't find any strong correlation between gastric content (assessed by scintigraphy), hunger and satiety ratings [18,19,20]. Both our meals were isoenergetic and addition of gelatin enables to get the same appearance and form, the only difference between the meals was in aspartame content; larger meal was sweetened by addition of small amount of aspartame. However we cannot rule out the influence of this sweetener on satiation, several studies showed that aspartame alone in beverages does not increase or diminish the intake in comparison to water [21,22]. Moreover, it has been suggested that high carbohydrate foods may influence energy balance by reducing food intake through greater satiety effects, reducing energy density and displacing fat from the diet-the fat-sugar seesaw effect. Some reduced-fat and higher carbohydrate foods are highly energy dense. High carbohydrate foods do not necessarily have a low energy density. Evidence from recent studies suggests that adding carbohydrate, and especially sugar, does not protect against elevated energy intake[23].

We cannot also exclude that satiation effect of increased volume was neutralized by diminished effect of decreased energy density. Meal size and energy density were examined at one time in the study. It was shown that large portions of high-dense first course increased the number of calories consumed during the main meal. Subjects did not differ in hunger and fullness but the difference in consumption of calories was 56 % [24].

The effect of meal size on satiation was examined by several studies. For example Holt et al [25] assessed satiety potency of 38 isoenergetic foods and found that the most important factor affecting satiation is food weight. Another results published by Graaf and Hulsof [26] showed that caloric content of meal more then food weight affects subsequent ingestion. However both studies didn't take into account the nutrients composition of the test meals, appearance, taste and consistency. These variables could have important influence on hunger and satiation and could preclude proper assessment of examined features.

Nutrient composition is thought to be very important feature in food intake control. Barkeling et al [27], Hill and Blundell [28], Rolls et al [29] proved that high protein isoenergetic preload exert more significant satiation effect than fat or carbohydrate preload. However, dietary macronutrients exert differential effects on energy intake. Nutrients exert hierarchical effects on satiety in the order protein >carbohydrate > fat. In short-to-medium term, increases in energy density are more effective at increasing energy intake than at decreasing food intake. In longer term and cross-sectional studies conducted in naturalistic environments, increased energy density appears more effective at decreasing food intake and less effective at elevating energy intake [30].

These studies revealed that the weight of meal is not the most important variable affecting satiation. For example high fat diets lead to over consumption and in part are responsible for development of obesity [31]. Moreover, Green showed that high fat foods (probably due to higher energy density) lead to a passive overconsumption which generates a relatively weak satiety [32].

Several studies indicate the role of food volume in satiation control. Rolls et al [33] showed the results of the study assessing the influence of varying volume of preload on subsequent calorie intake. The addition of water to milk-based preloads affects intake in such pattern that as volume increased less energy was consumed at lunch 15 min later. Another study checked the results of increased volume of food by air incorporation without changing of energy density [34]. This pure effect of increased preload volume significantly increased fullness and reduced hunger and energy intake at lunch. Some studies suggest that subjective appetite after the preloads was reduced by the high-volume preloads relative to low-volume preloads, with no difference between the two at each volume level [35]. Obese persons in contrast to lean subjects may have no adequate satiety response to the test meal and several studies showed that in this population satiety response to the food is inadequate [36, 37]. Study conducted on obese persons revealed that fat in the yoghurts was less effective in reducing subsequent food intake than carbohydrate[38]. However, some studies demonstrated no differences in satiety between obese and nonobese eating high or low density diet [39].

Secondly, in above mentioned study, 300 ml and 600 ml preloads cause only 12% difference in calorie intake at lunch. This value is maybe to small to be detected by VAS rating in obese subjects. For example, in another study Bell and Rolls [40] revealed that 6 % reduction in VAS scale was responsible for 30 % reduction in caloric intake when high calorie food was compared with low calorie. Another issue is the volume of food. In our study we compared 250 and 500 ml volumes which were smaller in comparison to above mentioned studies, and this differences may be to small to reduce significantly hunger 30 min after ingestion.

The results of our study suggest that food volume has only limited influence on hunger and satiety and subsequent calorie intake. Therefore, lowering energy density of food could be a useful tool to help manage obesity.

Conclusions

Food volume has only limited influence on satiety state directly after meal consumption but not on glucose and insulin plasma concentrations.

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