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EFFECT OF ZERO CALORIE DRINKS ON SENSORY-SPECIFIC SATIETY

WPŁYW NAPOJÓW TYPU "ZERO" NA SYTOŚĆ SPECYFICZNĄ SENSORYCZNIE

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Authors' contribution
Wkład autorów:
A. Study design/planning
zaplanowanie badań
B. Data collection/entry
zebranie danych
C. Data analysis/statistics
dane – analiza i statystyki
D. Data interpretation
interpretacja danych
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F. Literature analysis/search
wyszukiwanie i analiza literatury
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Summary

Background. Both the problem of obesity and the fashion for being 'fit' are prompting food manufacturers to reduce the calorie content of products by replacing sugar with substitutes, among others. It is unclear whether these treatments actually reduce the total energy intake. The aim of the study was to determine whether having a meal with a zero calorie sweet drink would induce sensory-specific satiety and lead to a reduced appetite for dessert.
Material and methods. Forty-eight students of the University of Life Sciences in Poznań took part in the study. To determine the significance of the difference in the amount of chocolate consumed when pairing a meal with a zero calorie sweet drink versus sparkling water, a T-test was employed.
Results. The results of the T-test proved that pairing a meal with a zero calorie sweet drink, compared to having it with sparkling water, leads to a lower consumption of chocolate for dessert.
Conclusions. The results of the study would suggest that people who tend to reach for sugary snacks after a meal can reduce their cravings for sweets by drinking a zero calorie drink with their meal. More research is needed to answer the question of whether this type of satiety persists between meals and whether it leads to a later compensation of energy intake, causing a so-called rebound effect. There is also a risk that the side effects of using certain sweeteners in the long term may outweigh the benefits of temporary appetite suppression.

Keywords: sensory specific satiety, appetite regulation, artificial sweeteners, diet drinks

Streszczenie

Wprowadzenie. Zarówno problem otyłości, jak i moda na bycie „fit", skłaniają producentów żywności do obniżania kaloryczności produktów, min. poprzez zastępowanie cukru jego zamiennikami. Nie ma jasności czy zabiegi te rzeczywiście przyczyniają się do zredukowania sumarycznej ilości pobieranej energii. Celem badania było określenie czy popijanie posiłku słodkim napojem typu „zero" wywoła zjawisko sytości specyficznej sensorycznie i przełoży się na obniżenie apetytu na deser.
Materiał i metody. W badaniu wzięło udział 48 studentów Uniwersytetu Przyrodniczego w Poznaniu, w wieku 17-23 lat. Do określenia istotności różnicy w ilości spożytej czekolady, w przypadku popijania dania głównego słodkim napojem typu zero a popijania go wodą gazowaną, wykorzystano test T.
Wyniki. Wyniki testu T dowiodły, że popijanie posiłku słodkim napojem typu „zero", w porównaniu do popijania go wodą gazowaną, prowadzi do mniejszego spożycia deseru w postaci czekolady.
Wnioski. Wyniki badania sugerowałyby, że osoby, które mają tendencję do sięgania po słodkie przekąski po posiłku mogą zredukować apetyt na słodycze pijąc do posiłku napój typu „zero". Potrzebna jest większa ilość badań, które odpowiedziałyby na pytanie, czy ten rodzaj sytości utrzymuje się między posiłkami i czy nie prowadzi do późniejszej kompensacji spożycia energii, wywołując tzw. efekt odbicia. Istnieje ryzyko, że efekty uboczne stosowania pewnych substancji słodzących mogą przewyższać korzyści wynikające z chwilowego hamowania apetytu.

Słowa kluczowe: sytość specyficzna sensorycznie, regulacja apetytu, sztuczne substancje słodzące, napoje dietetyczne

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Introduction

The sensation of satiety following the consumption of food is conditioned by numerous physiological processes. In the early 1990s, John Blundell distinguished four phases of this phenomenon, occurring over a period of time (Figure 1), which he called the satiety cascade [1]. As a result of the stimulation of the motor receptors of the masseter muscle and the taste receptors of the tongue, a sensory phase, also known as the early phase, is initiated. It can begin even before food intake, at the moment of perception of olfactory stimuli [2]. From the moment a bite of food is swallowed, sensory information is sent to the brain mainly via the vagus nerve. The most important component of the cascade is the degree of gastric wall distension. The second phase, the cognitive phase, is related to the cognitive evaluation of the food consumed - its calorific value, sensory properties or portion size. The third phase, called the post-ingestive or middle phase, begins with the digestion of the food and is related to the activity of the hormones of the small intestine, including incretin hormones. In the last phase of satiety, known as the post-absorptive or late phase, blood concentrations of insulin and nutrients play a major role [3]. Behavioral interventions to reduce appetite may address each of the levels listed, e.g. the late phase is dependent on dietary fiber content [4], the middle phase on the speed of food intake [5], the cognitive phase on the size of the portion served [6], and the sensory phase on the chewing quality and sensory properties of the food [7]. Pharmacological interventions may, for example, be directed at modifying the phase 3 incretin response, as in the use of drugs that are analogues of glucagon-like peptide-1 (GLP-1) [8].

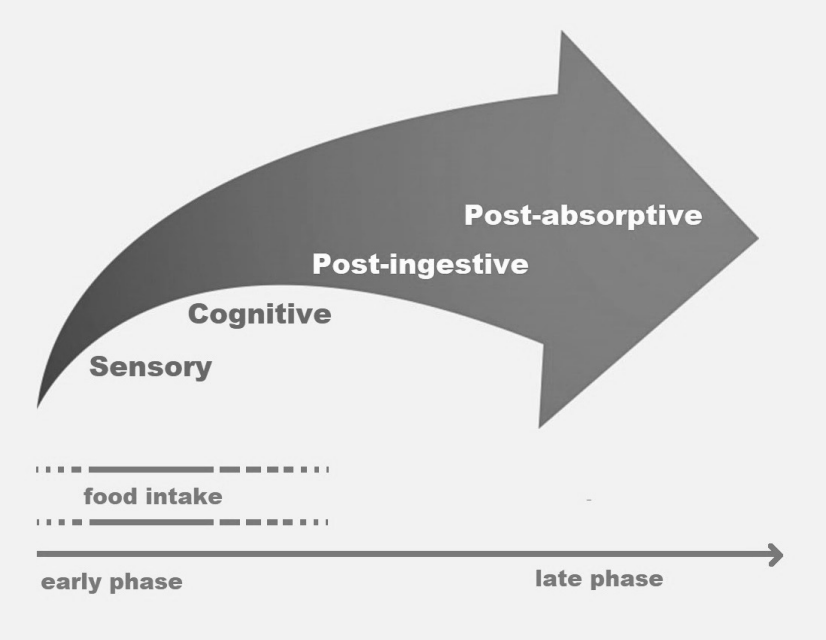

Figure 1. Phases of the satiety cascade

Sensory-specific satiety

Sensory-specific satiety (SSS) is defined as "a progressive decrease in the pleasure experienced as a result of responding to the sensory properties of the currently consumed food as it is eaten, with no change or an increase in interest in foods with different sensory characteristics" [7]. During food consumption, there is a gradual attenuation of the response of neurons responsible for the affective evaluation of the characteristics of the food, while maintaining the sensitivity of neurons responsible for the perception of qualitatively different sensory signals. This results in food with different sensory properties being perceived as the same or more attractive

than before consumption of the product in question [7]. The most commonly studied property of food in the context of this phenomenon is taste, but characteristics such as viscosity or texture are also subject to it [9]. Studies carried out on macaques, in which the organization of the cortical centers is similar to that of humans, have shown that the orbitofrontal cortex (which takes into account olfactory and visual information about food), in cooperation with the primary gustatory cortex (representing the taste and texture of food regardless of their gratifying values) and the amygdala (whose activation, e.g. under the influence of eating bitter food, evokes negative feelings), plays a major role in the evaluation of the rewarding properties of food [9]. The body's response to sensory-specific satiety is not limited to the affective appraisal of food, but includes activation of the autonomic nervous system, which can be observed in subtle changes in alertness and facial expression [10]. The conditioning of satiety perception on the sensory properties of food is thought to be an innate adaptive mechanism that, throughout the history of our species, has contributed to an increase in the variety of food consumed and, thus, a better balance of dietary nutritional properties [11]. This hypothesis would be supported by the observation that the diet tends to have little variety in the elderly, who have impaired or declined SSS as a result of impaired chemoreceptive sensory function [7].

The perception of the sweet taste as "pleasant" is innate [7]. It is believed that for thousands of years fruit was the only dietary source of this taste. Being a rich source of easily assimilable energy and essential vitamins and minerals, fruit was highly useful, which translated into the development of preferences for its most distinguishing characteristic. The innate predilection for sweet taste, important for the survival of early representatives of the human species, in an era of over-supply of food, promotes the development of diseases such as tooth decay, obesity and diabetes [7]. This problem is exacerbated by the aforementioned phenomenon of sensory-specific satiety. The tendency, for example, to reach for a high-calorie dessert after a filling meal leads to energy overconsumption and promotes the development of civilization diseases [11]. It is worth noting that the opposite phenomenon has also been reported – manifested in an increased desire to continue consuming food with currently identified sensory attributes. It is induced by stimulation of the gastrointestinal taste receptors by glucose. This mechanism may be related to conditioning of the association between the taste of food and its nutritional value [12].

Ways are sought to reduce the adverse effects of phenomena such as sensory-specific satiety on energy intake. People on a reduction diet are advised to reduce the variety of undesirable foods (e.g. sweets) kept in the home and increase the variety of desirable foods. In order to increase children's vegetable intake, it is advisable to serve the vegetables whole, rather than in chopped form [13]. In this case, a psychological 'closure' mechanism is probably at work, which motivates them to finish the meal they have started. It seems that it is always a good habit to eat in a slow and attentive manner. Chewing thoroughly and keeping the food in the mouth longer contributes to satiety when less energy is taken in than when eating 'fast' [14].

One way of satisfying the appetite for flavors with different modalities is to provide a sweet drink with a meal with different flavor characteristics. The hypothesis that drinking beverages before and during a meal interferes with nutrient digestion has been debunked [15]. Apart from certain conditions, such as gastroesophageal *reflux* disease [16], there is no basis for recommending that fluids be provided only between meals. Furthermore, it has been shown that drinking water before meals can be an effective tool for reducing energy intake [17]. Research indicates that an overall increase in water intake may have a preventive effect against the development of obesity, as well as promoting weight loss [18]. And while it is known that this effect is not achieved by providing sugar-sweetened beverages [19], reports on the effect of consuming sugary drinks devoid of energy on further energy intake are inconclusive [20]. When used appropriately, zero calorie drinks (those that provide little or no energy) can be a useful tool in the fight against obesity.

The aim of this study, which used an intervention aimed at modifying the sensory phase (Figure 1), was to determine whether beverages sweetened with intense sweeteners can reduce the effect of sensory-specific

satiety on energy intake by attenuating the desire to reach for a sweet snack after the main course. It was hypothesized that zero calorie sweet drinks consumed while having lunch would reduce the amount of chocolate eaten after the meal. To test the hypothesis, a two-stage study was designed in which students were given lunch, a drink and a sweet snack. In the first stage, participants were given a sparkling zero calorie drink to consume, and in the second stage, they were given sparkling water. Due to the relatively small study sample (n=48), this trial should be seen as preliminary to further, larger-scale analyses.

Material and methods

Participants

Forty-eight students of the University of Life Sciences in Poznań (Poland) participated in the study: 6 men (BMI: 17.60-28.40, mean: 23.27, standard deviation: 4.16) aged 19-22 years and 42 women (BMI: 16.07-33.08, mean: 21.51, standard deviation: 3.29) aged 17-23 years. Respondents were part of 4 groups (according to the division of the class into lab groups) of 9-15 participants. During recruitment, participants were informed that only those who were not on a special diet (vegan, gluten-free, etc.) could take part in the study. All those who decided to participate completed the study.

Meals, drinks and sweet snack

The main meal consisted of 300 g cooked wheat pasta (130 kcal/100 g) and 100 g cheese sauce (170 kcal/100 g). The dish was chosen so that its flavor contrasted with the sweetness of the snack. The meals were provided by a catering company and were pre-packed in disposable packaging. The calorie content of the meal was approximately 560 kcal/portion. A 500 ml drink (1 bottle) was served with the meal – during the first meeting it was an orange-flavored, sparkling, zero calorie drink, while during the second meeting it was sparkling water. Unlike, for example, diet coke or "energy drinks", the orange drink served did not contain substances that can affect the appetite (e.g. caffeine, taurine). As it was sparkling, carbonated water was chosen for the second trial. All drinks served were labelled, so in the case of the orange drink, participants were aware they were drinking a zero calorie drink. After the meal, participants were encouraged to treat themselves to milk chocolate (530 kcal/100 g), broken into 2-piece portions. Chocolate was served as a dessert due to its tastiness and high fat content, which meant that the difference between the main course and dessert was mainly focused on taste (salty and fatty vs. sweet and fatty). The chocolate was served on 4 platters, 500 g on each, amounting to a total of 2000 g. This excess ensured that decline in the amount of chocolate was not particularly noticeable, reducing the likelihood of being guided by the 'moderation' standard rather than appetite.

Course of the study

Recruitment of participants took place during one of the lectures. A class representative was asked to create a group using a popular instant messaging app, in order to facilitate communication between the researcher and the participants. The study took place in the seminar room at the beginning of the practical class, on a specific day of the week, between 11:30 and 12:00 p.m.

The second stage, in which water was served instead of a zero calorie drink, took place two weeks after the first stage. Just before stage 1, participants were given a description of the study and signed a consent to participate. They also completed a short, anonymous questionnaire indicating their gender, age, height and weight. One day before the study, the researcher sent a brief reminder to participants via the instant messaging app, asking them to eat breakfast (of a generous amount like every day) at around 8.30 am and to refrain from

eating until the study. During the study, disposable forks were handed out first, followed by a bottle of drink and then the meal. The researcher repeated a brief instruction stating that he would return in 15 minutes, at which time he asked the subjects to drink the entire contents of the bottle and to eat enough of the meal to feel moderately satiated (according to their own assessment). After 15 minutes, chocolate was served with a request to consume it according to appetite. The participants were also asked not to take the chocolate for later, but to eat as much as they felt like at the time. Participants were left for a further 10 minutes, after which they proceeded to another room for the activities scheduled in the timetable. In the final stage, the chocolate platters were weighed to determine the average amount consumed per person.

Statistical analysis

The choice of statistical tool to verify the research hypothesis was preceded by performing the Shapiro-Wilk test, which showed that the distribution of the dependent variable did not differ significantly from a normal distribution (W=0.978, p=0.952). In order to verify the hypothesis regarding the effect of sugary zero calorie drinks on sensory-specific satiety, a dependent-samples Student's T-test was used to compare the effect of drinking sparkling water vs. a sparkling zero calorie drink with the main meal on subsequent chocolate consumption.

Ethics

The study received a favorable opinion from the Bioethics Committee of the Karol Marcinkowski University of Medical Sciences in Poznań (application decision no. 52/23).

Results

A statistically significant (T=-3.8713, df=2, p=0.0305) difference was observed between the amount of chocolate eaten after a meal consumed with a sparkling, sweet, zero calorie drink, compared to when consumed with sparkling water. In the former case, study participants consumed an average of 20.45 g of chocolate per person, while in the latter they consumed 35.18 g per person. The difference in chocolate consumption between the two stages was 14.7 g/person (2-3 cubes) on average, meaning that having a meal with a zero calorie drink translated into a reduction in energy intake in the form of a sweet snack by an average of 78 kcal/person. The results obtained in each group are presented in Table 1.

Table 1. Chocolate consumption according to the type of drink consumed with the main meal

Group	Zero calorie drink	kcal/person	Water	kcal/person
	Average chocolate consumption/person (g)		Average chocolate consumption/person (g)	
1 (9 persons)	14.3	75.79	40.4	214.12
2 (11 persons)	19.5	103.35	30.7	162.71
3 (13 persons)	22.5	119.25	32.6	172.78
4 (15 persons)	25.5	135.15	37	196.1
average:	**20.45**	**108.39**	**35.18**	**186.43**
difference:			**14.725**	**78.04**

Discussion

The results obtained may indicate some utility of zero calorie sweet drinks in reducing appetite. Although the study is not conclusive on this issue, it is assumed that the reduction relates to foods with a taste similar to that of the drink and is due to a sensory-specific satiety phenomenon. This issue was addressed by one study to date [21], in which participants consumed 500 ml of 'coke zero' just before and during unlimited consumption of a variety of snacks. Compared to water, a beverage sweetened with intense sweeteners led to a reduction in intake of snacks characterized by a sweet taste, but not those that were, for instance, salty [21]. In the author's opinion, a certain limitation of the cited study was the use of coke, instead of a decaffeinated beverage, due to the fact that caffeine – by exerting an effect on the sympathetic nervous system – may itself enhance the feeling of satiety [22].

When discussing the usefulness of zero calorie drinks in reducing energy intake, their overall consumption is often taken into account, making the results inconclusive [20]. The model proposed in the above study is a targeted intervention and addresses a specific trend – reaching for dessert after the main course. Although the observed effect was relatively small (chocolate consumption was reduced by a few tens of kilocalories) and a recommendation based on it would probably not translate into weight reduction on its own, in combination with other modifications, it could have a supportive effect. It can be assumed that all substances that intensely stimulate the sweet taste receptor will have a similar effect, but to be sure, the study should be repeated for beverages in which other sweeteners are used. In addition, it has been shown that certain compounds, e.g. sucralose, can induce an 'energy debt' in the neurons of the hypothalamic nuclei that will be overcompensated in the same day, thus nullifying the effect of temporary appetite reduction. This phenomenon is referred to as the 'rebound effect' [23]. It should also be borne in mind that the effects of long-term use of drinks sweetened with intense sweeteners are not fully understood and often vary depending on the substance used. The need for more detailed research in this area is indicated [20,24]. Both diet drinks and calorie-reduced foods are gaining consumer interest, resulting in an increasing supply. Products such as erythrol-sweetened ketchups, sugar-free dessert sauces and sugar-free protein puddings are available on the market. Unless further research shows that the side effects of their long-term use outweigh the benefits, they could play a role in making reduction diets more palatable.

Data from both animal and human studies suggest that the phenomenon of sensory-specific satiety is relatively constant in relation to gender, body weight and age (it only weakens in old age) [25,26]. However, some caution should be exercised in drawing conclusions regarding obese individuals from studies conducted, similarly to the one discussed above, on healthy individuals. Furthermore, despite significant similarities in the neural response to satiety in men and women, there are some differences that would warrant a separate assessment for the two sexes. At the neural level, women, in response to satiety, are characterized by greater stimulation of the association areas of the occipital and parietal lobe cortex and areas of the dorsolateral prefrontal cortex. Men, on the other hand, are characterized by stronger activation of ventral-parietal areas of the prefrontal cortex [27]. In one study, the addition of flavor intensifiers to a meal increased the occurrence of sensory-specific satiety, with this effect being significantly greater in women than in men [28]. Regarding the order of consumption, it has been proven that a sweet drink has an effect on the phenomenon of sensory-specific satiety regardless of whether it is consumed just before, during or after a meal [29]. In contrast, the volume and flavor intensity of the drink may be a factor. With regard to solid food, it was noted that doubling the energy content of a food with the desired taste characteristics without increasing its volume did not translate into an increase in sensory-specific satiety, whereas increasing the volume of the food without changing its calorie content had an additional satiating effect [30]. In the study in question, a 500 ml beverage was used with the

meal. It would be worthwhile to conduct future studies to determine the minimum amount of beverage with an appropriate level of sweetness that would elicit a sufficient effect.

Conclusions

The results of the study would suggest that people with a tendency to reach for sweet snacks after the main meal could reduce their appetite for sweets by drinking a zero calorie sweet drink with their meal (with different sensory properties). Such intervention, as a tool to aid weight reduction, could be relevant especially for obese individuals. However, more research is needed to answer the question of whether this type of satiety persists between meals and whether it leads to a subsequent compensation of energy intake, causing a so-called rebound effect. Furthermore, the long-term consequences of the regular consumption of sugar substitutes need to be determined. There is a risk that the side effects of using certain sweeteners may outweigh the benefits of temporary appetite suppression [24].

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