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PRESS RELEASE

Differences in taste sensitivity between obese and non-obese children and adolescents

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ABSTRACT

Background Taste sensitivity varies between individuals. Several studies describe differences between obese and non-obese subjects concerning their taste perception. However, data are partly contradictory and insufficient. Therefore, in this study taste sensitivity of obese and non-obese children/adolescents was analysed.
Methods In a cross-sectional study gustatory sensitivity of n=99 obese subjects (body mass index (BMI) >97th percentile) and n=94 normal weight subjects (BMI <90th percentile), 6–18 years of age, was compared. Sensitivity for the taste qualities *sweet*, *sour*, *salty*, *umami* and *bitter* was analysed by means of impregnated 'taste strips' in different concentrations. A total score was determined for all taste qualities combined as well as for each separately. Furthermore, the possible influence of sex, age and ethnicity on taste perception was analysed. An intensity rating for *sweet* was performed on a 5-point rating scale.
Results Obese subjects showed—compared to the control group—a significantly lower ability to identify the correct taste qualities regarding the total score ($p<0.001$). Regarding individual taste qualities there was a significantly lower detection rate for *salty, umami* and *bitter* by obese subjects. Furthermore, the determinants age and sex had a significant influence on taste perception: older age and female sex was associated with better ability to identify taste qualities. Concerning the sweet intensity rating obese children gave significantly lower intensity ratings to three of the four concentrations.
Conclusions Obese and non-obese children and adolescents differ in their taste perception. Obese subjects could identify taste qualities less precisely than children and adolescents of normal weight.

What is already known on this topic

Taste sensitivity varies between individuals. Several studies describe differences between obese and non-obese subjects concerning taste perception. However, data on infants and adolescents are insufficient.

What this study adds

- Obese children can identify taste qualities less precisely than non obese.
- A better taste differentiation with increasing age is thought to be the normal development.

INTRODUCTION

Prevalence of childhood obesity is increasing worldwide. Obesity is considered as a disease caused by a multifactorial aetiology that has a genetic basis, but requires lifestyle influences to manifest.[1] Diet constitutes an important part of such environmental influences.

Taste is a primary aspect by which children determine food acceptance. It plays an essential role in eating behaviour.[2 3] In an evolutionary context taste has an important function in the identification of valuable nutrition: sweet tastes promise readily available calories whereas bitter often indicates toxic substances.

Sensitivity for different taste qualities differs between individuals.[4] This has been investigated best for the bitter compound propylthiouracil (PROP) which tastes bitter to some whereas others cannot taste it at all or require higher concentrations.[5] Taste blindness for the bitter compound PROP has been shown to be associated with a more pleasant rating of bitter taste as found in some vegetables.[6 7] This lacking aversion is hypothesised to have an implication on long-term health outcomes. Relating thereto, several authors have observed differences in taste sensitivity between obese and non-obese adults[8–10] as well as children.[8 11] In these studies individuals with a higher body mass index (BMI) showed reduced taste sensitivity and were significantly more often taste blind for the bitter compound PROP. PROP tasters are supposed to be more sensitive not only to bitter taste, but also to other taste qualities and the taste of fat.[12] As a result they need to consume less to have the same taste sensation. This is believed to be related to a larger number of fungiform papillae in tasters. Data concerning a correlation of obesity and taste sensitivity is inconsistent and based mainly on the PROP taster status.[8] Analyses of other taste qualities are rare especially for the savoury tastes *salty* and *umami*. Several studies on PROP taster status and BMI have been conducted in infants and adolescents, but very little is currently known about other taste qualities than *bitter*.

This study aimed to compare taste sensitivity between obese and normal weight children and adolescents for all five taste qualities. Furthermore the influence of sex, age and ethnicity on taste sensitivity was subject of this investigation.

SUBJECTS AND METHODS

Subjects

In a cross-sectional study we examined n=99 obese and n=94 normal-weight children and adolescents, 6–18 years of age, of multiethnic origin in the Paediatric Obesity Centre of

Charité—Universitätsmedizin Berlin (Germany). Obese subjects were patients of the Obesity Centre, subjects of the control group were recruited from other departments of the clinic. Both groups had neither disease nor did they take drugs that are known to affect smell or taste. Patients with acute or chronic diseases disturbing smell or taste function (eg, upper airway infections, lesions of cranial nerves VII, IX, X after trauma or middle ear operation) were excluded from participation. Subjects with diseases affecting weight, such as Cushing's syndrome or hypo-/hyperthyreosis, or those treated with medications affecting weight, such as corticosteroids, were also excluded. The study was approved by the Research Ethics Committee of Charité—Universitätsmedizin Berlin (EA2/037/10).

A complete medical history including the family history, as well as bodyweight and height of each parent was obtained from all subjects. Ethnicity was defined by native country of both parents and language spoken at home.[13 14]

Body weight was measured with a digital scale (Soehnle, Germany) to the nearest 0.1 kg. Height was measured using a wall-mounted stadiometer (Keller, Stuttgart, Germany). BMI was calculated (weight in kilograms divided by the square of the height in meters). German reference data were used for the definition of obesity (BMI >97th percentile) and normal weight (BMI 10th to 90th BMI-Percentile).[15]

Taste test

'Taste strips' were used for gustatory testing.[16] Taste strips made from filter paper were impregnated with different taste solutions. Four different concentrations for *sweet*, *sour*, *salty*, *umami* and *bitter* (sweet: 0.4, 0.2, 0.1, 0.05 g/ml sucrose; sour: 0.3, 0.165, 0.09, 0.05 g/ml citric acid; salty: 0.25, 0.1, 0.04, 0.016 g/ml Sodium Chloride; umami: 0.25, 0.1, 0.04, 0.016 g/ml monosodium glutamate; bitter: 0.006, 0.0024, 0.0009, 0.0004 g/ml quinine-hydrochloride) plus two blank strips resulted in a total number of 22 paper strips. Concentrations were chosen in such a way that the lowest concentrations of each taste quality should be identified by half of healthy subjects, whereas the highest concentration should be identified by approximately 100% of the participants.[16–18]

The taste strip method is characterised by a good acceptance especially by children and adolescents and has been applied in several clinical and research contexts.[17–21] The test–retest-reliability compares well to other taste tests.[16]

Participants were asked not to eat, to drink nothing but water and not to chew chewing gum at least 1 h before testing.

In a first experiment the taste strips (plus two blank strips without taste) were presented in increasing concentrations. At each level of concentration the taste quality order was randomised. Taste strips were placed on the tongue and subjects were asked to identify the taste quality by choosing one of six possible answers on a form (*sweet*, *sour*, *salty*, *umami*, *bitter*, *no taste*). Before the experiment started, taste qualities were explained to the participants (ie, *sour* like lemon, *umami* like chips). Before assessment of each taste strip the mouth was rinsed with water.

In a second test, participants were asked to rank the different concentrations of the taste quality *sweet* according to its intensity. The same type of strips as before were used and ranked on a 5-point rating scale, with 1, representing *No Taste*, and 5 representing *Very Strong Taste*.[22]

Once more taste strips were presented to the subjects in a randomised order. Again, children rinsed their mouths with water before every sample. Before the testing began the intensity scale was explained to the subjects. Participants were asked to indicate their chosen intensity on the scale or tell the number to the investigator.

Statistical methods

Statistical analyses were performed using SPSS V.14.0 (SPSS Inc., Chicago, Illinois, USA). Data are presented as mean±SD or median and IQR. Frequency is given in percentage (%).

For the first taste test all correctly identified taste strips of the qualities *sweet*, *sour*, *salty*, *umami* and *bitter* were summarised in a total score giving a maximum score of 20 points. For every single taste quality we also calculated a score with a maximum of four points. Normality was tested by the Shapiro-Wilks test. Differences in medians were tested using non-parametric tests (Mann-Whitney-U-test); differences in means were tested using parametric tests (t-test). To analyse the influence of the independent variables sex, age and ethnicity multiple linear regression analysis was performed. A probability value of less than 0.05 was considered significant.

RESULTS

Median age of the n=99 obese subjects was 13.1 (range: 6.2–17.7) and 12.2 (range: 6.1–18.0) years in the control group (n=94). In the obesity group 48% were boys, in the control group 40%. As children and adolescents with Turkish migration background were by far the second largest ethnic group after German participants, they were analysed separately. Obese children and adolescents were 55% German, 24% Turkish and 17% of other ethnicities; subjects of the control group were 73% German, 13% Turkish and 14% others. Obese subjects had a mean BMI of 29.9±4.9, normal-weight participants of 18.2±2.4. Obese participants' parents also had significant higher BMI scores than parents of the control group (p<0.001) (table 1).

Taste sensitivity for all taste qualities and taste qualities separately

The sum of all five possible taste qualities in the four different concentrations resulted in a maximum total score of 20. The two blank strips were not added to the total score. The total scores obtained in the present study ranged between 2 and 19. *Sweet* and *salty* were the two qualities most often identified

Table 1 Clinical characteristics

	Obesity group (n=99)	Control group (*n*=94)	p Value
Age (years)†	13.1 (10.6; 14.6)	12.2 (9.7; 14.8)	0.573*
Range	6.2–17.7	6.1–18.0	
Sex			
Male	48%	40%	0.202**
Female	52%	60%	
Ethnicity			
German	57%	73%	0.05**
Turkish	25%	13%	
Other	18%	14%	
BMI (kg/m^2)‡	29.9±4.9	18.2±2.4	<0.001***
Mothers' BMI (kg/m^2)†	27.1 (23.5; 32.0)	23.8 (21.7; 25.4)	<0.001*
Fathers' BMI (kg/m^2)†	28.0 (25.2; 31.5)	25.3 (22.9; 26.9)	<0.001*

*Mann-Whitney-U-test; **χ^2-test, ***t-test.
†Data shown as median (1st quartile; 3rd quartile).
‡Data shown as mean±SD.
BMI, body mass index.

correctly. Participants mostly confounded *salty* with *sour* as well as *salty* with *umami*.

Obese subjects had significantly more difficulties in correctly identifying the different taste qualities compared to normal weight children resulting in a lower total score.

Whereas obese children and adolescents' medium total score was 12.6±3.0, non-obese participants reached a significantly higher score of 14.1±3.0 ($p<0.001$; figure 1).

When considering taste qualities separately, the four different concentrations added to a maximum score of 4. Some qualities were identified significantly less often by obese subjects. This proved to be significant for *salty* ($p=0.002$) *umami* ($p<0.001$) and *bitter* ($p=0.018$). Regarding the qualities *sweet* and *sour* no significant differences between the study groups were observed (table 2).

Influence of weight status, sex, age and ethnicity on taste sensitivity

A multiple linear regression model was fitted to the total score as a function of test group, sex, age, and ethnicity in order to determine the influence of these variables on taste sensitivity. Test group, sex and age had a significant influence on taste sensitivity, with obese subjects displaying a mean total score 1.5 points lower than that of the control group ($p<0.001$).

Girls could identify taste qualities significantly better than boys, their mean total score being 0.92 points higher ($p=0.036$). Likewise increasing age was shown to influence taste sensitivity, with older children scoring higher than younger participants ($p=0.004$).

There were no significant differences in total score by ethnicity (table 3).

Intensity rating for the taste quality *sweet*

In the sweetness intensity rating, obese (n=93) and normal-weight (n=75) children and adolescents rated sweet taste strips according to their intensity. Subjects of both test groups rated higher concentrations of *sweet* higher on the sweetness scale. However, the obese subjects rated all concentrations lower on the intensity scale when compared to the control group. For the concentration levels 1–3 these differences were significant (table 4).

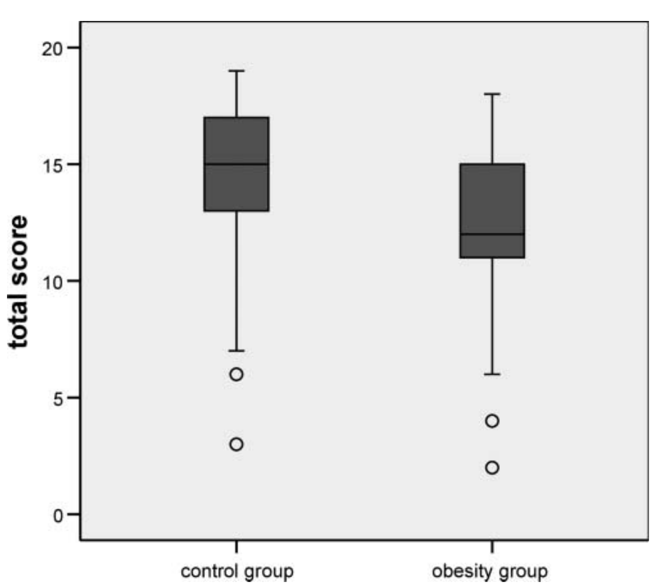

Figure 1 Relationship between total score and study group. Boxplot: median, 1st–3rd quartile.

Table 2 Scores of different taste qualities

	Mean ±SD	1st quartile	Median	3rd quartile	p Value*
Score 'sweet'					
Control group (n=94)	3.7±0.6	4	4	4	0.834
Obesity group (n=99)	3.7±0.7	4	4	4	
Score 'sour'					
Control group (n=94)	1.9±0.8	2	2	2	0.457
Obesity group (n=99)	1.9±0.9	1	2	3	
Score 'salty'					
Control group (n=94)	3.2±1.0	3	4	4	0.002
Obesity group (n=99)	2.8±1.0	2	3	4	
Score 'umami'					
Control group (n=94)	2.3±1.3	1	3	3	<0.001
Obesity group (n=99)	1.6±1.3	1	2	2	
Score 'bitter'					
Control group (n=94)	3.0±1.2	2	3	4	0.018
Obesity group (n=99)	2.6±1.4	2	3	4	

*Mann-Whitney-U-test.

DISCUSSION

The purpose of this study was to analyse taste sensitivity of obese and non-obese children and adolescents. In contrast to the majority of studies concerning taste and weight status, in this study taste sensitivity for all five taste qualities was analysed. The hypothesis that obese and non-obese children and adolescents differ in their taste sensitivity was confirmed in the present investigation.

Reasons for differences in taste sensitivity are poorly understood. Findings about genetic, hormonal and learning effects suggest a multifactorial cause. Polymorphisms of the genes coding for taste are supposed to cause inter-individual differences in taste sensitivity.[4 23] This has been investigated best for the sensitivity towards the bitter compound PROP, which is influenced by a polymorphism in the TAS2R38 gene. Several authors assume that this polymorphism is responsible for the reduced taste perception in obese subjects.[8–11] However, others did not confirm this difference in taste sensitivity according to PROP taster status.[24–26] Furthermore age and sociocultural

Table 3 Regression analysis of the dependent variable total score ($R^2=0.12$)

	Regression coefficient	95% CI	p Value
Influence factors			
Test group (reference: control group)			
Obesity group	−1.51	−2.37 to 0.65	<0.001
Sex (reference: male)			
Female	0.92	0.06 to 1.78	0.036
Age	0.22	0.07 to 0.36	0.004
Ethnicity (reference: German)			
Turkish	−0.07	−1.19 to 1.06	0.908
Other	0.60	−0.59 to 1.79	0.322

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Table 4 Intensity rating for 'sweet'

	Mean ±SD	1st quartile	Median	3rd quartile	p Value*
Blank					
Control group (n=75)	1.1±0.4	1	1	1	0.625
Obesity group (n=93)	1.1±0.4	1	1	1	
Level 1					
Control group (n=75)	1.8±0.9	1	2	2	0.002
Obesity group (n=93)	1.4±0.8	1	1	2	
Level 2					
Control group (n=75)	2.2±0.9	2	2	3	0.007
Obesity group (n=93)	2.0±0.8	1	2	2	
Level 3					
Control group (n=75)	2.7±1.0	2	3	3	<0.001
Obesity group (n=93)	2.0±0.9	1	2	3	
Level 4					
Control group (n=75)	4.4±0.7	4	4,5	5	0.132
Obesity group (n=93)	4.2±0.8	4	4	5	

*Mann-Whitney-U-test.

factors influence taste sensitivity and are believed to be responsible for variation in taste sensitivity during lifetime. Mennella *et al*[27] showed that mothers and children with the same genotypes differ in their taste sensitivity which is supposed to be an effect of learning and sociocultural influences. With regard to this learning effect, the exposure to a variety of distinct taste stimuli in early childhood appears to be essential.[28]

Hormonal influence of leptin and insulin on weight regulation is well known.[29] Recent work has also shown an immediate stimulation of taste receptors by several hormones. Kawai *et al*[30] identified leptin receptors on taste buds in mice. Obese animals with a defect in the leptin receptor presented elevated neural responses and higher behavioural preferences for sweet stimuli. The work of Umabiki *et al*[31] showed a relation between serum leptin level and weight status: women undergoing a weight-loss programme showed decreasing serum leptin levels as well as lower detection levels for sweet taste. Furthermore other hormones like GLP-1, protein YY and the neurotransmitters serotonin and noradrenalin are said to influence taste sensitivity.[32–34] These recent findings suggest a modulation of the taste apparatus itself by endocrine and paracrine mechanisms and show the gustatory apparatus to be less static than it has been assumed before. However, detailed regulation of the gustatory system is still not understood. Results from the current study support the idea that obese and non-obese children differ in their taste sensitivity, with a multifactorial genesis appearing to be most likely.

Concerning the single taste qualities, obese subjects in our study showed a significantly lower sensitivity for *salty*, *umami* and *bitter*. Little is known so far about the savoury taste qualities *salty* and *umami* and variation in body weight.[8] Recent work by Pepino *et al*[35] suggested a lower sensitivity for *umami* in obese women. For children, reference data concerning *umami* sensitivity do not exist. One study in obese children showed—in contrast to our data—a higher sensitivity for salty tastes in obese subjects.[36] Obese children have been shown to eat significantly more savoury snacks than normal-weight children, supporting the hypothesis that savoury taste sensitivity could be important in children's weight status and eating behaviour.[37] Bitter sensitivity and body weight was mainly tested for the synthetic bitter compound PROP. Data in scientific literature about the sensitivity of children towards the bitter compound quinine-hydrochloride appears to be insufficient.[8]

Regarding the intensity rating, the four sweet concentrations were all rated lower by the obese subjects. In three of four concentrations this difference was significant. Other authors describe a similar difference in obese subjects' intensity rating.[22 38] These results also support the hypothesis that taste sensitivity differs between obese and non-obese subjects.

In this study, girls identified taste qualities significantly better than boys. This effect is in line with the current scientific literature.[7 17 18 39] Women of all ages are said to be able to identify taste qualities better than their male peers.[17 18] Women are more often classified as PROP 'supertasters'[7] and exhibit a higher number of fungiform papillae on their tongues.[39] The gustatory system of women appears to be more sensitive because of a protection against toxic and teratogenic substances, at least during pregnancy,[40] or because of a higher interest in the chemosensory signals of smell and taste.

In our study, normal weight subjects could identify taste qualities significantly better with increasing age. This effect was not observed in obese subjects. A better taste differentiation with increasing age is thought to be the normal development. The absence of an increase of taste sensitivity in obese children and adolescents supports the hypothesis that the taste system is affected in obese subjects.

An influence of ethnicity on taste sensitivity was not observed in our study. This is supported by the work of Mennella *et al*.[3 27] Although a difference in taste sensitivity caused by cultural influences on nutrition is conceivable, according to our data in children with migration background living in Germany this effect was not significant.

LIMITATIONS AND CONCLUSION

Limitations of our study were the differences between study-group and control-group in regard to the composition of ethnicity and sex, as well as the cross-sectional study design. Also participants' socioeconomic status could be a confounding factor, as obesity is known to be associated with low socioeconomic status—in the obesity cohort of our clinic 85% of all patients have a low socioeconomic status.

In conclusion, the results of this study support the hypothesis that obese and non-obese children and adolescents differ in their taste perception. However, longitudinal studies are required to confirm these cross-sectional results. Recent findings suggest a remarkable modulation of taste sensitivity by endocrine and paracrine processes. The gustatory system seems to be much more susceptible than originally thought. However, to date these modulations are only marginally understood. Therefore, further studies on taste sensitivity and hormonal status in obese subjects are required. Eventually, this could help develop further strategies of obesity prevention and therapy in childhood. Nutritional education could already focus on taste preferences.

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Contributors JO performed the taste testing, documentation and data collection. She was intensively involved in the statistical analysis as well as in patients' recruitment and furthermore prepared the manuscript. TH prepared the test strips for taste testing. He developed and has previously described and validated the test procedure. He was involved in designing the study. He reviewed the manuscript. HK was involved in the development of the hypothesis, aims of the study and the study design. He reviewed the manuscript. SW was responsible for the study design, patients' recruitment, study performance and statistical analysis. She prepared and reviewed the manuscript.

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