ORIGINAL ARTICLE

Differences in taste detection thresholds between normal-weight and obese young adults

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Abstract
Conclusion: Compared with normal-weight individuals, obese young adults exhibited a significantly higher taste threshold for salty taste. Smoking also affected taste functions in this population. Objective: The aim of this study was to investigate the differences in taste detection thresholds between normal-weight and obese young adults. Methods: Taste threshold was measured using electrogustometry (EGM) and chemically with sucrose, NaCl, citric acid, and quinine hydrochloride in 41 volunteers in their twenties, 23 with body mass index (BMI) < 23 kg/m² (normal-weight group) and 18 with BMI > 25 kg/m² (obese group). Results: BMI was significantly higher in the obese than in the normal-weight group (p < 0.05). The obese group exhibited significantly higher EGM thresholds than the normal-weight group on the right (p < 0.05) and left (p < 0.05) posterior tongue. In chemical taste tests, the obese group had higher thresholds for sweet, salty, sour, and bitter tastes than the normal-weight group, although the difference in threshold was significant only for salty taste (p < 0.05). Smoking had an impact on taste threshold, with smokers having higher thresholds than non-smokers, with significantly higher EGM thresholds on the right anterior and posterior and the left anterior tongue (p < 0.05 each).

Keywords: Electrogustometry, salty taste, smoking, chemical taste test

Introduction

Obesity is defined as a condition in which excess body fat has accumulated because energy intake exceeds energy consumption. Obesity is regarded as one of the leading worldwide threats to human health in the 21st century. Worldwide, the number of obese people has doubled since the 1980s. In 2008, 1.4 billion adults were overweight and over 200 million men and nearly 300 million women were obese. In 2011, more than 40 million children aged 5 years or under were overweight. Thus the population that is overweight and obese is increasing every year [1].

Obesity is a multifactorial disorder, induced by the combined effects of eating habits, a lack of physical activity, genetic factors, abnormalities in the central nervous system, hormonal factors, psychological disorders, and socioeconomic factors. Women are prone to obesity after pregnancy and during and after menopause. Men tend to become obese due to drinking alcohol, age-associated inactivity, and frequent work-related dining. Students may become overweight due to stress, overeating, and the lack of exercise [2].

Obesity-associated diseases include hypertension, coronary artery disorders, cerebrovascular accident, cardiac disorders, hyperlipidemia, non-insulin-dependent (type 2) diabetes, osteoarthritis, metabolic syndrome, gout, breathing difficulties, respiratory dyspnea, sleep disorders, eating disorders, emotional disorders, low back pain, gallbladder disease, cancers (breast, uterus, prostate, and colon), and sudden death [6–8].

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Differences in taste detection thresholds may affect taste preferences and food intake. Sensitivity to taste is associated with various factors, including age, diseases, medication, head trauma, and taste training. Obesity may also affect taste detection thresholds. This study aimed to identify differences in taste detection thresholds between obese and normal-weight young adults. To minimize factors affecting taste, only subjects with healthy sensory functions, with no history of olfaction or taste disorders, were assessed.

Material and methods

A total of 41 individuals, 24 men and 17 women, aged 20–29 years (mean age, 24.65 ± 3.51 years), who visited the otorhinolaryngology clinic at Kyung Hee University voluntarily participated in this study and underwent taste tests. Of these 41 subjects, 23 had a body mass index (BMI) <23 kg/m² (normal-weight group) and 18 had a BMI >25 kg/m² (obese group). The normal-weight group consisted of 12 men and 11 women, ranging in age from 20 to 29 years (mean age, 23.68 ± 3.04 years) and in BMI from 18.5 to 22.9 kg/m². The obese group consisted of 12 men and 6 women, ranging in age from 20 to 28 years (mean age, 24.81 ± 2.45 years). Obesity was defined based on World Health Organization (WHO) standards for Asia Pacific subjects, with BMIs <18.5 kg/m², 18.5–22.9 kg/m², 23–24.9 kg/m², 25–29.9, and ≥30 kg/m² defined as underweight, normal weight, overweight, obese, and severely obese, respectively [9]. Subjects with disturbances in smell and taste, head and/or neck malformation, systemic diseases, suspected immune deficiency, a recent history of upper airway infection, and head and neck trauma were excluded.

Each subject was administered a questionnaire before undergoing any taste tests, which included questions such as ‘What do you think about your sense of taste?’, ‘What tastes do you like most?’, ‘What are your eating habits?’, ‘Do you drink alcohol or not?’, ‘Do you smoke or not?’.

Taste was assessed by electrogustometry (EGM) and chemical taste tests. Researchers were unaware of whether subjects belonged to the obese or normal-weight group, and subjects randomly underwent taste tests without knowing the type of taste to be administered. Subjects were instructed not to eat or drink anything except for water for 1 h before the start of testing. EGM was performed first using an electrogustometer (EG-IIIB, Nagashima Medical Instrument Co., Tokyo, Japan). EGM thresholds were measured on both sides of the anterior and posterior tongue bases. In EGM, a current is delivered to areas of the tongue containing taste buds using a stimulus probe.

Before the test, a stimulus over the threshold current was administered to subjects to help them recognize the stimulus. The minimal amount of output current at which a metallic or sour sensation was recognized was defined as the threshold. The electrogustometer was designed to measure 22 different thresholds, ranging from 3 μA (−8 dB) to 400 μA (34 dB), in a manner similar to pure-tone audiometry.

In chemical taste tests, the taste thresholds for sweet (sucrose), salty (NaCl), bitter (quinine hydrochloride), and sour (citric acid) tastes throughout the entire mouth were measured. Solutions of each at 10 different concentrations were administered, and the minimum concentration at which taste was detected was defined as the threshold for that taste (Table I). Each solution was applied to the tongue of subjects using a sterile cotton swab, and they were asked whether they sensed a taste and what taste they perceived. Subjects rinsed their mouths with water and took a break of 1–2 min before starting the next test.

After taste tests, BMI was measured, and subjects were grouped into a normal-weight group, with BMI <23 kg/m², and an obese group, with BMI ≥25 kg/m², as described above. SPSS version 18.0 was used for statistical analysis. Continuous variables were compared with the Mann–Whitney U test and categorical variables with the chi-squared test. A p value < 0.05 was considered statistically significant.

Results

BMI was significantly higher in the obese than in the normal-weight group (27.62 ± 2.57 kg/m² vs 20.52 h 1.06 kg/m², p < 0.05). EGM showed that taste thresholds on the right (20.11 higher in the obese analysis

Table I. Concentrations of taste test solutions used in the study (g/ml).

<table>
<thead>
<tr>
<th>Suite</th>
<th>NaCl</th>
<th>Quinine hydrochloride</th>
<th>Citric acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.016</td>
<td>0.00001</td>
<td>0.05</td>
</tr>
<tr>
<td>0.1</td>
<td>0.025</td>
<td>0.00003</td>
<td>0.09</td>
</tr>
<tr>
<td>0.2</td>
<td>0.1</td>
<td>0.0001</td>
<td>0.165</td>
</tr>
<tr>
<td>0.4</td>
<td>0.3</td>
<td>0.0003</td>
<td>0.3</td>
</tr>
<tr>
<td>0.5</td>
<td>0.4</td>
<td>0.0006</td>
<td>0.35</td>
</tr>
<tr>
<td>0.6</td>
<td>0.5</td>
<td>0.0012</td>
<td>0.4</td>
</tr>
<tr>
<td>0.8</td>
<td>0.6</td>
<td>0.003</td>
<td>0.45</td>
</tr>
<tr>
<td>0.9</td>
<td>0.7</td>
<td>0.006</td>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
<td>0.8</td>
<td>0.012</td>
<td>0.55</td>
</tr>
<tr>
<td>2.0</td>
<td>0.9</td>
<td>0.03</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Sucrose, sweet; NaCl, salty; Citric acid, sour; Quinine hydrochloride, bitter.
$p < 0.05$) and left (20.44, 11 higher in the obese analysis $p < 0.05$) posterior regions of the tongue were significantly higher in the obese than in the normal-weight group (Figure 1). Taste thresholds were also higher on the right (20.77 dB vs 12.43 dB) and left (18.33 dB vs 13.47 dB) anterior tongue in the obese group, but those differences were not statistically significant compared to the normal-weight group ($p > 0.05$).

The results of the chemical taste tests revealed higher thresholds in the obese than in the normal-weight group for sweet (0.70 n in t g/ml vs 0.33 (0.70 g/ml), salty (0.45 in 0. g/ml vs 0.28 (0.70 g/ml), bitter (0.03 n i g/ml vs 0.01. 03 70 g/ml), and sour (0.22 n n in l vs 0.18 ± 0.15 g/ml) tastes. However, only the threshold for salty taste was significantly higher in the obese than in the normal-weight group ($p < 0.05$) (Figure 2).

In response to the questionnaire item asking what subjects thought of their taste sensitivity, 12 subjects (54.5%) in the normal-weight group described it as fine and 10 subjects (45.5%) as blunt; in the obese group, 4 subjects (23.5%) described it as fine and 13 (76.5%) as blunt (23.5%). On the question asking, “what taste do you like most?”, sweet was the most frequent in the normal-weight group (11 subjects, 50%), followed by salty (2 subjects, 9.1%), sour (2 subjects, 9.1%), and bitter (0 subjects, 0%). Sweet was also the most frequent in the obese group (seven subjects, 41.2%), followed by salty (four subjects, 23.5%), sour (one subject, 5.9%) and bitter (0 subjects, 0%). On the item asking subjects to describe the taste of foods that they usually eat, 11 subjects (50.0%) in the normal-weight group said bland, followed by salty (6 subjects, 27.3%), spicy (3 subjects, 13.6%) and sweet (2 subjects, 9.1%). In the obese group, 10 subjects (58.8%) answered salty, followed by spicy (4 subjects, 23.5%), bland (2 subjects, 11.8%), and sweet (1 subject, 5.9%).

In analyzing the effects of alcohol intake, lower EMG thresholds on the right (6.5 ± 17.49 dB vs 18.77 ± 13.31 dB) and left (10.25 ± 15.94 dB vs 17.03 ± 13.52 dB) anterior tongue and on the right (11.50 ± 19.70 dB vs 14.51 ± 12.53 dB) and left (13.00 ± 17.03 dB vs 15.87 ± 12.13 dB) posterior tongue were observed in the 31 subjects who drank alcohol than in the 8 who did not, but none of these differences was statistically significant, compared with the non-drinking group of 8 subjects ($p > 0.05$) (Figure 3a). In the chemical taste test, detection thresholds were lower for sweet (0.43 st, de g/ml vs 0.52 t (0.4 g/ml) and salty (0.35 alt (g/ml vs 0.36 t (0.4 g/ml) in the drinking group, while thresholds for sour (0.19 hresho g/ml vs 0.19 eshold g/ml) and bitter (0.01 ur (01 g/ml vs 0.02 bitte g/ml) were similar, compared with the non-drinking group, but none of these differences was statistically significant (Figure 3b).

When the subjects were divided into those who smoked ($n = 14$) and those who did not ($n = 25$), the detection thresholds were significantly lower in non-smokers than in smokers on the right (11.92 right dB vs 24.00 rs old dB, $p < 0.05$) and left (11.52 24.00 dB vs 23.00 rs old dB, $p < 0.05$) anterior tongue and on the right (10.56 right dB vs 19.85 ± 11.07 dB, $p < 0.05$) posterior tongue. The threshold was also lower on the left posterior tongue (12.48 eshold dB vs 20.28 was al dB), but that difference was not significant (Figure 4a). Chemical taste tests showed that thresholds were lower in the non-smoking group for sweet (0.39 weet (g/ml vs 0.71 (up eg/ml), salty (0.31 lty (g/ml vs 0.43 (up eg/ml), and sour (0.17 d

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**Figure 1.** Mean ± SD electromyography (EMG) threshold of each part of the tongue in the normal-weight group (body mass index (BMI) 18.5–23.0 kg/m²) and obese (BMI >25 kg/m²) group.

**Figure 2.** Mean ± SD specific taste thresholds of the whole mouth in the normal-weight group (BMI 18.5–23.0 kg/m²) and obese (BMI >25 kg/m²) group. The sensitivity to salty taste was significantly lower in the obese group ($p < 0.05$).
sour g/ml vs 0.22 ur (eg/ml) tastes, but higher for bitter taste (0.02 (ter g/ml vs 0.01 ± 0.01 g/ml), although none of these differences was statistically significant (Figure 4b).

Discussion

Obesity is a risk factor for various diseases and it has emerged as a growing health, socioeconomic, and national problem. Many studies have sought to identify the causes of obesity; however, less is known about the association of taste sensitivity with obesity. Although taste is considered less critical than the other four human senses, taste sensitivity has been associated with quality of life [10,11].

Sensitivity to taste varies among individuals and with age. Although studies have reported that taste detection thresholds increased with age, other studies have found no differences in capsaicin sensitivity or two-point distinguishable thresholds in different age groups. Low sensitivity to food in elderly individuals may be due more to decreased taste sensitivity rather than somatosensory sensations such as tactile or pain sense. Detection thresholds for four tastes and the perception threshold for salt were significantly higher in older than in younger subjects [12]. In a study involving teenagers aged ≤18 years, those who were obese exhibited a lower ability to identify correct test qualities, as determined by total score, and a decreased rate of detection of salty and bitter tastes. Thus the ability to identify taste qualities was lower in obese than in normal-weight children and adolescents. Taken together, these results suggest that taste is affected by aging [13].

Using EMG and chemical taste tests, we found that taste thresholds were higher in obese than in normal-weight young adults. This finding was consistent with previous results in other age groups. Although many studies have addressed the causes of taste disorders...
and the relationship between taste disorders and obesity, it is difficult to exclude all variables associated with taste sensitivity. Our study was conducted in healthy young adults to minimize factors associated with taste disorders and taste sensitivity, including aging, comorbid conditions, medication history, chronic diseases, systemic diseases, and history of upper airway infection. Children were not included due to their difficulties in expressing themselves and difficulties in testing.

Although it was unclear why the obese group had higher taste thresholds than the normal-weight group, several possibilities should be considered. First, sensitivity to sensory-based termination signals is lower in obese than in normal-weight subjects. This decreased sensitivity increases motivation for food sensitivity, reducing the activity of food reward circuits and leading to excess energy intake and eventually obesity. Second, the activity of brain tissue in each part of the brain differs in obese and normal-weight subjects. Application of gustatory stimulus solutions of sucrose (pleasant), quinine HCl (aversive), vanilla flavor (complex taste with high palatability), followed by scanning of brain activity by functional MRI (fMRI) showed increased activity in cortical structures of obese individuals, including the anterior cingulate cortex, insular and opercular cortices, and orbitofrontal cortex, as well as in subcortical structures such as the amygdala, nucleus accumbens, putamen, and pallidum, suggesting that the brain tissue of obese individuals shows various activities in response to pleasant and unpleasant gustatory stimuli. Third, the expression in taste buds of the tongue of CD36, a receptor associated with taste sensitivity, has been found to differ in obese and normal-weight subjects. In rats, decreased CD36 expression on the taste buds of obese rats reduces mouth sensitivity to long chain fatty acids; thus rats must consume greater amounts of fat to satisfy oral fat taste responses, resulting in gains in body weight [14]. In humans, individuals with genetic variations in CD36 are less sensitive to fat, consume greater quantities of fat, and become overweight or obese [15].

We assessed taste sensitivity by both EGM and chemical taste tests, as well as administering questionnaires to all subjects. The advantages of EGM include its ease of performance, high reproducibility, and short testing time. However, EGM is of limited use in tracking changes in taste disorders [16]. Whole mouth taste tests using subjective taste assessment and chemical agents are effective and correlate with each other [17].

Obesity is usually caused by a combination of factors. Obese individuals like to consume sweet and fatty foods, with a preference for these foods resulting in overweight and obesity [18]. In the present study, both the obese and normal-weight groups preferred sweet foods, a finding inconsistent with the results of earlier studies in this age group. However, the two groups were distinguished by the foods they usually eat. Subjects in the normal-weight group regarded themselves as having high taste sensitivity and reported that their usual foods tasted bland, whereas those in the obese group regarded their taste sensitivity as blunt and reported that their usual foods tasted salty. Thus, their respective eating habits may explain, at least in part, the higher taste thresholds in the obese group.

Smoking and drinking have also been reported to affect taste sensitivity. Smokers had lower sensitivity to 6-n-propylthiouracil (PROP) than non-smokers, with fewer of the former able to perceive its bitter taste [19]. In addition, studies have shown that fewer smokers than non-smokers were able to perceive the bitter taste of phenylthiocarbamide (PTC), and that a higher percentage of individuals who smoke or drink were unable to taste PTC than was observed in a cohort who neither smoke nor drink [20]. We also found that taste thresholds were significantly higher in smokers than in non-smokers, suggesting a significant association between smoking and taste thresholds.

One important limitation of our study was its small sample size, which may have introduced a selection bias. The small sample size also did not allow comprehensive investigation of a wide variety of socioeconomic variables associated with obesity, including age, gender, amounts of smoking and alcohol intake, dependence on nicotine and alcohol, preferred foods, maximum daily intake, age starting smoking and/or drinking, and subdivision by BMI into underweight, normal weight, overweight, and obese.

In conclusion, the obese group exhibited higher taste thresholds than the normal-weight group, with the eating habits of the former inclined toward salty foods. Smoking was also found to affect taste thresholds, whereas drinking did not.

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References


