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Olfactory and gustatory functions and its relation to body weight

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HIGHLIGHTS

- Data were obtained using the "Sniffin' Sticks" test and "Taste Strips" test.
- Odor thresholds, discrimination and identification were determined.
- Taste thresholds of sweet, sour, salty, or bitter taste were measured.
- Olfactory thresholds which increased with increasing BMI.
- Gustatory thresholds for "salty" were significantly higher with higher BMI.
- Increasing BMI is associated with an increase in olfactory and taste threshold.

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ABSTRACT

In the present study we investigated the influence of body weight as defined by BMI on gustatory and olfactory perception. A total of 66 healthy adults (41 females; 25 males) participated in psychophysical measurements using the "Sniffin' Sticks" test and "Taste Strips" test. Odor thresholds as well as discrimination and identification performance were determined. Tests of gustatory function involved the identification and thresholds of sweet, sour, salty, or bitter taste. In this study, all subjects were healthy participants in a middle age range (between 20 and 56 years of age). Persons with an extreme BMI value were excluded.

Subjects were classified according to their BMI in four groups: (1) 15–19.9 kg/m, (2) 20–24.9 kg/m, (3) 25–29.9 kg/m, and (4) >30 kg/m. We did not observe an overall effect of BMI on general sensory sensitivity. There was a significant influence of BMI on olfactory thresholds ($F(3,62) = 2.79$; $p < 0.047$) which increased with increasing BMI. In a similar line, the gustatory thresholds for "salty" were significantly higher with higher BMI ($F(3,62) = 3.06$; $p < 0.035$). Olfactory discrimination and identification was not affected by BMI. Thresholds for odor and sweet or salty taste were also correlated.

Our data show that body weight influences gustatory and olfactory perception in healthy adults. Increasing BMI is associated with a decrease in olfactory and taste sensitivity. These findings may have implications for the understanding of pathophysiological mechanisms in patients.

1. Introduction

Olfactory and gustatory functions are a key prerequisite in order to judge the quality of food. Thus, the choice of nutrition of humans depends on the individual sensitivity to odor and taste stimuli. It has been suggested that alternated perception is related to nutritional behavior and consequently to body weight (or to the Body Mass Index, BMI). Many of earlier studies were performed on clinical populations [1] or on patients with extreme deviation from normal [2] (BMI exceeding 45 kg/m). From these studies conflicting results arise. For example, Richardson et al. [2] found that subjects with a BMI larger than 45 kg/m were more likely to have olfactory dysfunction than subjects with a BMI smaller than 45 kg/m. These patients suffer from extreme obesity since persons with a BMI value of 25 kg/m or higher are considered overweight, and a BMI larger than 30 kg/m indicates obesity. In a different study Obrebowski et al. [1] reported on a group of 30 children suffering from simple obesity. About 20% of them showed significantly lowered odor detection thresholds which implies that in these children, there was a higher sensitivity to odor stimuli. On the other hand, in patients with eating disorders Aschenbrenner et al. [3] described an opposite effect for the relationship between BMI and gustatory and olfactory functions. In anorexia nervosa or bulimia nervosa patients both overall olfactory function and taste test scores correlated significantly with body weight and BMI. All these data suggest that both pathologically high and low BMI are associated with reduced sensory capability.

In addition to BMI, the subjects' age, health condition, and hunger play a role in the relationship between body weight and olfactory

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sensitivity. A prevalence of olfactory impairment has been repeatedly reported for geriatric patients and persons older than 70 years of age [4–6]. Some of these changes might also be caused by the general health condition of the subjects tested since reduced taste sensitivity is often accompanied by underweight in aged persons [7].

It has been shown that hunger and satiation influence sensitivity to olfactory stimuli in normal subjects. Stafford and Welbeck [8] examined the influence of hunger on the perception of neutral odors and of food-related odors. The authors report that persons in a so-called high BMI group had higher acuity to food odors in the satiated versus non satiated state while no such differences were found for the low BMI group. In a similar line, Cameron et al. [9] showed how fasting for 24 h improved olfactory function and these changes were related to body weight. Griffioen-Roose et al. [10] describe how the taste of a 24-h diet subsequently affects food preferences according to their taste properties. Thus, not only hunger and satiation but also dietary characteristics influence taste. In summary, these findings illustrate a complex interaction between olfactory or taste sensitivity and variables such as hunger state, the relatedness of a given odor to food, and BMI or body weight.

Massive obesity also affects taste function: Pasquet et al. [11] examined the taste sensitivity and the hedonistic responses of adolescents who were severely obese (mean BMI: 39.5 kg/m) or normal weight (mean BMI: 21 kg/m). The obese subjects displayed a significantly higher sensitivity to sugar and salt than non-obese subjects.

Such results demonstrate that the relation between sensory functions and body weight (or BMI) is complex. In the present study we will present psychophysical data on a large group of healthy adults who participated in extensive sensory testing. Both olfactory function and taste sensitivity were quantified. In order to measure olfactory sensitivity we determined thresholds for detection and discrimination and performance on an odor identification task. For taste the thresholds for identification of sweet, salty, sour, and bitter were determined. In order to obtain generalizable results, we decided to study (1) only healthy adults in (2) a middle age range between 19 and 56 years of age (as mentioned above the literature reports mainly effects of high age on sensory thresholds), and (3) persons with an extremely high BMI value (38 kg/m) were excluded from the experiments. We will show in this group of subjects how odor and taste are influenced by BMI, and how these sensory modalities interact in healthy persons.

2. Material and methods

2.1. Subjects

A group of 66 healthy adults (41 females and 25 males) between 19 and 56 years of age (mean: 27.4 years) participated in the study. Twenty five subjects (13 females, 12 males) had a BMI larger than 24.9 kg/m while five females had a BMI smaller than 18.5 kg/m. Thus, 36 persons (13 males, 26 females) can be considered "normal". The mean BMI of all subjects was 24.29 kg/m with a standard deviation of 4.77 kg/m. There were four (occasional) smokers whose data did not deviate from the others. As described below, these persons were asked not to smoke within 1 h before the examination. According to a questionnaire, all subjects were healthy and not under medical treatment. In addition, subjects had no significant weight changes within two months before the examination.

Most of the subjects were recruited from the University of Giessen (students or employees). In order to avoid biased values of the BMI, athletes with a BMI larger than 25 kg/m were excluded from the study [12]. The experimental procedures were explained in full detail to the participants who provided written informed consent. The investigations were performed according to the *Guidelines for Biomedical Studies Involving Human Subjects* (Helsinki Declaration), and were approved by the local ethics committee.

For each subject we determined the BMI (body weight in kilograms divided by height in meters squared). Weight and height measurements were conducted immediately before testing. Body weight was obtained on a calibrated scale (TCM, No. 261038), recorded to the nearest 0.1 kg. All measurements were performed in the dressed state, without shoes. Owing to the weather conditions in the test month (June) an estimate of 1 kg for clothes was subtracted from the measured weight value.

2.2. Procedure

All tests were performed in a bright and ventilated research room; the mean temperature was 23.5 °C with a mean humidity of 40.6%. The subjects were requested not to eat, drink or smoke within 1 h before the test session.

Olfactory function was assessed by the "Sniffin' Sticks" test (Burghart Messtechnik GmbH, Germany; for details see [13]) where odorants are presented in pen-like odor dispensing devices. We employed subtests for odor threshold, discrimination, and identification (see details in [13]). For the determination of odor thresholds 16 sticks with n-Butanol were used. Concentrations ranged from 4% (number 1) to 1.22 ppm (number 16). Control sticks contained distilled water. The subjects were blindfolded and stimuli were presented according to a psychophysical staircase method. Two consecutive correct answers were considered as correct. Discrimination performance was tested with 16 triplets of odors. In each trial subjects were presented three odors, and were asked to identify the sample that had a different smell. Odor identification was assessed by means of common odors. Sixteen odors were chosen (orange, leather, cinnamon, peppermint, banana, lemon, licorice, turpentine, garlic, coffee, apple, clove oil, pineapple, rose, anise, fish). For discrimination and identification the number of correct answers constituted the subject's score on these tests.

Gustatory function was determined by "Taste Strips" test. Paper strips of sweet (saccharose), sour (citric acid), salty (sodium chloride) or bitter taste (quinine hydrochloride) of four different concentrations were presented to the test person (Burghart Messtechnik GmbH, Germany; for details refer to [14]). The subjects received the taste strips in a pseudo-randomized sequence. Before assessment of each strip the mouth was rinsed with mineral water. The number of correct identifications was noted.

The relation between test performance and BMI or other subject parameters was determined by correlation coefficients. We also compared the threshold data obtained from males and females. In addition, we computed analyses of variance (ANOVA) with BMI class as independent factor. For this purpose subjects were classified according to their BMI in four groups: (1) 15–19.9 kg/m (mean: 18.81 kg/m; $n = 11$; mean age = 22.6 years); (2) 20–24.9 kg/m (mean: 22.13 kg/m; $n = 30$; mean age = 27.0 years); (3) 25–29.9 kg/m (mean: 27.32 kg/m; $n = 18$; mean age = 27.7 years); and (4) >30 kg/m (mean: 34.38 kg/m; $n = 7$; mean age = 35.5 years). We note that the uneven number of subjects in the groups is considered as source of variation in the ANOVAs. It turned out that only the mean age of groups 1 and 4 were different. Due to the wide range of odor test concentrations, the threshold values of the subjects differed markedly from a normal distribution (negatively skewed), and the data were converted by a simple logarithmic transformation as $T = \log(1 - \textit{stick-number})$. This yielded normally distributed data as the skewness changed from −1.25 to 0.17.

3. Results

Typically, the data obtained with the "Sniffin' Sticks" test are presented as "TDI-score" which is computed as the sum of results obtained for threshold (T), discrimination (D), and identification (I). In our data this global descriptor of olfactory performance appeared to be not very sensitive. We found a non-significant correlation of the "TDI-score" and BMI with $r = -0.18$ (NS). In a similar line, the global score for taste sensitivity also showed only a weak relation with the BMI ($r = -0.21$, NS). This indicates that there is probably a more complex relationship between perceptual sensitivity and body weight.