

Taste Function in Healthy Taiwanese Adults

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ABSTRACT

OBJECTIVE: In this work, our aim was to measure the taste function of healthy Taiwanese adults using 2 commonly used taste tests.

METHODS: The taste function of 102 healthy Taiwanese adults was evaluated using the whole-mouth suprathreshold taste test and the taste quad test. In the whole-mouth taste test, 5 concentrations of sweet, bitter, sour, and salty solutions were sipped and swished in the mouth twice in a counterbalanced order. A total of 40 tests were done to give a maximum score of 40 for correct quality identification of tastant solutions. In the taste quad test, the 4 quadrants of the tongue were tested using high concentration drops of sweet, bitter, sour, and salty solutions 6 times. A total of 96 tests were done to give a maximum score of 96 for correct quality identification of tastant solutions.

RESULTS: The score of the whole-mouth taste test ranged from 33 to 40 with a mean of 38.6 for men and from 31 to 40 with a mean of 38.9 for women. The score of the taste quad test ranged from 40 to 91 with a mean of 75 for men and from 38 to 96 with a mean of 78 for women. Sex was shown not to affect the taste function.

CONCLUSIONS: Our result showed that sex did not affect the taste function of healthy Taiwanese adults.

KEYWORDS: Taiwanese, taste function, taste test

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Introduction

According to a nationwide survey of US population in 2016, the estimated prevalence of taste impairment in the United States was 26.3 million (17.3%).¹ Nevertheless, physicians often overlook taste disorders. Loss of taste function strongly affects quality of life. Taste disorders affect the ability to detect toxic or spoiled foods. In addition, it might change food preference and cause malnutrition. Subjects with taste dysfunction might suffer from anxiety, depression, or nutritional deficiencies.² Currently, the taste function of Asian people remains little explored.

Diagnosis of taste disorders is challenging. Taste function is closely related with olfactory function. An estimated 95% of patients who complain of taste dysfunction are caused by olfactory impairment rather than loss of taste.³ Many causes can result in loss of taste function including aging, smoking, neurodegenerative diseases, medication, trauma, ear surgery, or radiotherapy.^{2–6} To perform a correct diagnosis and arrange adequate management for individuals with taste dysfunction, it is necessary to conduct a comprehensive assessment of taste function.

Taste function has been measured using chemical stimuli or electric stimuli.⁷ Chemical stimuli are presented to testers in several ways including ‘sipping & spitting’, tastant strips, taste tablet, cotton swabs, or discs.^{2,7,8} Solution-based taste tests have been shown to be reliable.⁹ Solution-based taste tests

developed by Smell & Taste Center of University of Pennsylvania include a whole-mouth suprathreshold taste test and a taste quad test (regional test).⁷ The whole-mouth test could reflex the patients’ actual taste experience. The regional test provides further evaluation of nerve innervation in different regions of tongue.⁷ The objective of this work was to measure the taste function of healthy Taiwanese adults using solution-based taste tests developed by Smell & Taste Center of University of Pennsylvania.

Methods

Study subjects

Healthy Taiwanese adults with normal self-rated taste function whose ages ranged from 20 to 49 years were enrolled. Any subject who had undergone oral or middle ear surgery or had suffered from an acute oral infection was excluded from the study. All eligible volunteers received a whole-mouth suprathreshold taste test and a taste quad test to evaluate their taste function. All test procedures were performed in the same examination room with air conditioner.

This work was approved by the Ethics Committee of Taichung Veterans General Hospital (IRB TCVGH No.: CE15137A). Informed consents were written by all subjects. The authors assert that the procedures contributing to this study comply with the ethical requirement of the relevant national and



institutional guidelines on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Taste tests

In this study, we used the taste tests developed by Smell & Taste Center of University of Pennsylvania.⁷ In the whole-mouth suprathreshold taste test, 4 basic tastant solutions (sweet, bitter, sour, and salty) were prepared by dissolving each powder of sucrose, citric acid, sodium chloride (I Chan chemical Ltd., Taipei, Taiwan), and caffeine (Uni-Onward Corp., New Taipei City, Taiwan) in distilled water. Five different suprathreshold concentrations were prepared for the 4 tastant solutions (the concentrations of sucrose: 0.08, 0.16, 0.32, 0.64, 1.28 molar; the concentrations of caffeine: 0.0026, 0.0051, 0.0102, 0.0205, 0.0410 molar; the concentrations of citric acid: 0.0026, 0.0051, 0.0102, 0.0205, 0.0410 molar; the concentrations of sodium chloride: 0.032, 0.064, 0.128, 0.256, 0.512 molar). The subjects were instructed not to smoke or eat within 1 hour before the test. At the beginning of the test, 10 mL of each solution were presented to the subjects in small cups in a counterbalanced order. The solution in the first cup was sipped, swished in the mouth for 10 seconds, and expectorated. In a forced-choice paradigm (the subject is forceful to choose which one was the correct option even though he or she was uncertain), the subject indicated which taste the solution was, and rated the intensity and unpleasantness/pleasantness of the solution on 9-point rating scales. The intensity of the solution was selected using the following scale: 1, not present at all; 2, very slight; 3, slight; 4, definitely present; 5, moderate; 6, moderately strong; 7, strong; 8, very strong; and 9, extremely strong. The pleasantness of the solution was selected using the following scale: 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; and 9, like extremely. After expectorating the solution, they rinsed their mouths with distilled water. Each of 4 tastant solutions was tasted by the subject at the 5 concentrations given above twice. Thus, for each subject, a total of 40 tests (4 tastants \times 5 concentrations \times 2 trials) were done to give a maximum score of 40 for correct quality identification of tastant solutions, and the intensity and unpleasantness/pleasantness of the solution were rated on 9-point rating scales.

In the taste quad test, the 4 basic tastant solutions were prepared by dissolving 83.86 g sucrose in 500 mL distilled water, by dissolving 3.88 g caffeine in 500 mL distilled water, by dissolving 1.58 g citric acid in 500 mL distilled water, and by dissolving 9.04 g sodium chloride in 500 mL distilled water, respectively. This produced 0.49 molar sucrose solution, 0.31 molar sodium chloride solution, 0.015 molar citric acid solution, and 0.04 molar caffeine solution. When beginning the test, the subjects were asked to protrude his or her tongue and the examiner then visually divided the tongue

into 4 quadrants (quadrant 1: right posterior quad, quadrant 2: right anterior quadrant, quadrant 3: left anterior quadrant, and quadrant 4: left posterior quadrant). Next, 15 μ L of the first tastant solution was dripped onto one of the quadrants using a micropipette. In a forced-choice paradigm, the subjects indicated which taste the dripped solution was, and rated the intensity of the solution on the same 9-point rating scale as that for the whole-mouth taste test. After reporting the answer, they rinsed their mouth with distilled water. Each tastant solution was tested on each quadrant a total of 6 times, and the tests were performed in a counterbalanced order. Therefore, in total, 96 tests were done in the taste quad test to give a maximum score of 96 for correct quality identification of tastant solutions, and the intensity of the solution was rated on 9-point rating scales. There was a 10-minute break between the whole-mouth suprathreshold test and taste quad test.

Statistical analyses

The ages, scores, and correct quality identification percentages of these 2 taste tests were compared between men and women using the Mann–Whitney *U* test. The score of correct quality identification at the 10th percentile was defined as the normative data.^{9,10} The percent correct quality identification of the 4 tastant solutions in 2 taste tests were compared by the Friedman test and were compared between 2 tastant solutions by the Wilcoxon signed rank test. All calculation was done using SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA). Two-tailed *P*-values $<.05$ were used to mean statistically significant.

Results

Study subjects

There were 40 male and 62 female volunteers included in the study. The ranges of ages were between 21 and 41 years old with a mean of 27.4 years in men and between 20 and 45 years old with a mean of 28.5 years in women. The age was not significantly different between the male and female volunteers ($P=.341$).

Whole-mouth suprathreshold taste test

The total scores of correct quality identification of tastant solution ranged from 33 to 40 with a mean of 38.6 (SD: 2.11) in men and from 31 to 40 with a mean of 38.9 (SD: 1.61) in women. The score was not significantly different between men and women ($P=.982$). The score for men at the 10th percentile was 35, and the score for women at the 10th percentile was 37.3.

The correct quality identification percentages of the 4 tastant solutions are shown in Tables 1 and 2. The correct quality identification percentage of each of the 4 tastant solutions was not significantly different between male and female subjects, but the correct quality identification

Table 1. Correct quality identification percentage of whole-mouth suprathreshold taste test and taste quad test.

	MEN (40) ^a	WOMEN (62)	P VALUE
Whole-mouth suprathreshold taste test			
Sweet tastant	99.25 (0.42) ^b	99.52 (0.28)	0.579
Bitter tastant	96.50 (1.50)	97.58 (1.07)	0.641
Sour tastant	95.75 (1.71)	95.48 (1.35)	0.373
Salty tastant	94.25 (1.68)	96.45 (0.86)	0.403
4 tastants	96.44 (0.83)	97.26 (0.51)	0.982
Taste quad test			
Quadrant 1			
Sweet tastant	81.67 (3.76)	89.78 (2.31)	0.054
Bitter tastant	77.92 (3.70)	86.29 (2.67)	0.022
Sour tastant	75.00 (3.82)	83.33 (2.94)	0.026
Salty tastant	74.17 (4.00)	69.89 (3.73)	0.571
4 tastants	77.19 (2.94)	82.33 (2.25)	0.081
Quadrant 2			
Sweet tastant	88.33 (3.22)	91.67 (2.02)	0.310
Bitter tastant	81.67 (3.52)	87.63 (2.81)	0.042
Sour tastant	77.08 (4.37)	74.19 (3.46)	0.608
Salty tastant	68.75 (3.92)	69.89 (3.49)	0.680
4 tastants	79.27 (2.67)	80.85 (1.76)	0.807
Quadrant 3			
Sweet tastant	87.08 (3.50)	90.86 (2.65)	0.160
Bitter tastant	85.42 (3.39)	89.52 (1.89)	0.515
Sour tastant	76.25 (4.13)	72.85(3.17)	0.323
Salty tastant	62.08 (4.22)	60.48 (3.48)	0.770
4 tastants	77.50 (2.57)	78.43 (1.94)	0.896
Quadrant 4			
Sweet tastant	85.00 (3.81)	89.25 (2.37)	0.480
Bitter tastant	82.08 (3.45)	84.41 (2.79)	0.489
Sour tastant	76.67 (3.81)	84.14 (2.55)	0.097
Salty tastant	70.42 (5.05)	75.00 (2.34)	0.691
4 tastants	78.44 (2.91)	83.20 (2.11)	0.114

^aNumber of subjects.^bMean (mean standard error).

percentage of the sweet solution was significantly higher than those of the sour and salty solutions in male subjects ($P=.036, .005$, respectively) as well as in female subjects ($P=.001, .001$, respectively). The intensity and pleasantness

scores of each concentration of the 4 tastant solutions are shown in Table 3.

Taste quad test

The total score of correct quality identification of tastant solutions ranged from 40 to 91 with a mean of 75.0 (SD: 13.55) in men and from 38 to 96 with a mean of 78.0 (SD: 12.99) in women. The score was not significantly different between men and women ($P=.195$). The score of men at the 10th percentile was 55, and the score of women at the 10th percentile was 57.

The correct quality identification percentages of the 4 tastant solutions in each quadrant are shown in Table 1. The correct quality identification percentage of all 4 tastant solutions in each quadrant was not significantly different between male and female subjects ($P=.081, .807, .896, .114$, respectively), but female subjects had a significantly higher correct quality identification percentage of sour solution in quadrant 1 ($P=.026$) and bitter solution in quadrants 1 and 2 ($P=.022, .042$, respectively) than male subjects. When the correct quality identification percentage of the 4 quadrants was compared, there was no significant difference in male subjects ($P=.913$), but in female subjects, the correct identification percentage of quadrant 3 was significantly lower than those of quadrants 1 and 4 ($P=.008, .004$, respectively). Regardless of sex and quadrant, sucrose solution had the highest correct identification percentage, followed by caffeine solution, citric acid solution, and sodium chloride solution, which had the lowest correct identification percentage. The intensity scores of the 4 tastant solutions in each quadrant are shown in Table 4.

Discussion

There are many causes underlying gustatory dysfunction.¹¹ To correctly diagnose and treat taste dysfunction, it is essential to first assess taste function.⁹ Although solution-based taste tests have been employed to evaluate taste function for more than 30 years,¹⁰ only 1 study which used solution-based taste tests was reported in Asian population.¹² In this study, we used solution-based taste tests to test taste function in healthy Taiwanese adults. Our results showed that they had quite good and consistent performance in the whole-mouth taste test, but a wide range of results was yielded in the taste quad test. It has previously been shown that sex differences exist with respect to olfactory function,¹³ but sex did not seem to influence taste function in the present study.

Welge-Lussen et al¹⁴ found that women are lightly better than men in identifying different tastes in their investigation of 761 healthy subjects, but Doty et al¹⁵ employed the same procedures of whole-mouth suprathreshold taste test and taste quad test as ours to evaluate the taste function of 29 healthy Western volunteers. They did not find a sex difference in most tests, except for intensity ratings in the taste quad test. They

Table 2. Correct quality identification percentage of whole-mouth suprathreshold taste test as a function of tastant concentration.

	C1 ^a	C2	C3	C4	C5
Men (40) ^b					
Sweet tastant	96.25 (2.11) ^c	100.00 (0.00)	100.00 (0.00)	100.00 (0.00)	100.00 (0.00)
Bitter tastant	93.75 (3.20)	95.00 (3.49)	97.50 (1.75)	97.50 (1.75)	98.75 (1.25)
Sour tastant	90.00 (3.67)	95.00 (2.40)	97.50 (1.75)	97.50 (1.75)	98.75 (1.25)
Salty tastant	88.75 (4.56)	93.75 (2.65)	92.50 (3.82)	98.75 (1.25)	97.50 (1.75)
Women (62)					
Sweet tastant	97.58 (1.37)**	100.00 (0.00)	100.00 (0.00)	100.00 (0.00)	100.00 (0.00)
Bitter tastant	98.39 (1.61)	95.97 (1.74)	96.77 (1.57)	96.77 (1.95)	100.00 (0.00)
Sour tastant	90.32 (2.53)	93.55 (2.15)	99.19 (0.81)	97.58 (1.79)	96.77 (1.95)
Salty tastant	95.97 (1.74)	96.77 (1.57)	92.74 (2.26)	99.19 (0.81)	97.58 (1.79)

^aTastant concentrations were as follows: sucrose=0.08, 0.16, 0.32, 0.64, 1.28 molar; caffeine=0.0026, 0.0051, 0.0102, 0.0205, 0.0410 molar; citric acid=0.0026, 0.0051, 0.0102, 0.0205, 0.0410 molar; sodium chloride=0.032, 0.064, 0.128, 0.256, 0.512 molar.

^bNumber of subjects.

^cMean (mean standard error).

Table 3. Intensity and pleasantness rating of whole-mouth suprathreshold taste test as a function of tastant concentration.

	C1 ^a	C2	C3	C4	C5
Intensity rating					
Men (40) ^b					
Sweet tastant	3.20 (0.17) ^c	4.34 (0.16)	6.14 (0.14)	6.70 (0.12)	7.20 (0.15)
Bitter tastant	4.25 (0.25)	4.90 (0.21)	5.34 (0.21)	6.23 (0.22)	7.34 (0.15)
Sour tastant	4.94 (0.16)	5.66 (0.18)	6.19 (0.19)	6.98 (0.20)	7.52 (0.15)
Salty tastant	3.22 (0.23)	4.28 (0.21)	5.19 (0.20)	6.12 (0.18)	6.94 (0.17)
Women (62)					
Sweet tastant	3.56 (0.18)	4.53 (0.14)	6.06 (0.13)	6.66 (0.14)	7.27 (0.15)
Bitter tastant	4.06 (0.16)	4.90 (0.19)	5.51 (0.18)	6.48 (0.15)	7.34 (0.15)
Sour tastant	4.73 (0.15)	5.55 (0.15)	6.04 (0.15)	7.07 (0.15)	7.71 (0.12)
Salty tastant	3.84 (0.17)	4.62 (0.14)	5.19 (0.15)	6.04 (0.16)	7.13 (0.14)
Pleasantness rating					
Men (40)					
Sweet tastant	5.35 (0.13)	5.88 (0.13)	5.76 (0.18)	5.55 (0.23)	5.33 (0.29)
Bitter tastant	3.90 (0.14)	3.76 (0.13)	3.35 (0.16)	2.90 (0.16)	2.33 (0.17)
Sour tastant	4.54 (0.16)	4.19 (0.19)	3.64 (0.21)	3.05 (0.23)	2.74 (0.22)
Salty tastant	4.84 (0.10)	4.68 (0.13)	4.36 (0.16)	3.80 (0.17)	3.00 (0.17)
Women (62)					
Sweet tastant	5.44 (0.10)	5.79 (0.12)	5.60 (0.16)	5.10 (0.20)	4.75 (0.24)
Bitter tastant	3.94 (0.11)	3.56 (0.14)	3.14 (0.13)	2.77 (0.15)	2.16 (0.12)
Sour tastant	4.62 (0.11)	4.39 (0.14)	3.94 (0.17)	3.31 (0.21)	2.88 (0.19)
Salty tastant	5.01 (0.52)	4.89 (0.76)	4.52 (0.11)	4.15 (0.13)	3.31 (0.18)

The intensity of the solution was selected using the following scale: 1, not present at all; 2, very slight; 3, slight; 4, definitely present; 5, moderate; 6, moderately strong; 7, strong; 8, very strong; 9, extremely strong. The pleasantness of the solution was selected using the following scale: 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; 9, like extremely.

^aTastant concentrations were as follows: sucrose=0.08, 0.16, 0.32, 0.64, 1.28 molar; caffeine=0.0026, 0.0051, 0.0102, 0.0205, 0.0410 molar; citric acid=0.0026, 0.0051, 0.0102, 0.0205, 0.0410 molar; sodium chloride=0.032, 0.064, 0.128, 0.256, 0.512 molar.

^bNumber of subjects.

^cMean (mean standard error).

Table 4. Intensity rating of taste quad test as a function of quadrants.

	QUADRANT 1	QUADRANT 2	QUADRANT 3	QUADRANT 4
Men (40) ^a				
Sweet tastant	4.02 (0.24) ^b	4.16 (0.22)	4.04 (0.21)	4.05 (0.27)
Bitter tastant	3.90 (0.30)	3.94 (0.24)	3.99 (0.22)	3.81 (0.28)
Sour tastant	4.12 (0.26)	4.20 (0.19)	3.92 (0.21)	4.29 (0.24)
Salty tastant	4.27 (0.25)	4.32 (0.19)	4.24 (0.18)	4.19 (0.24)
Women (62)				
Sweet tastant	3.98 (0.20)	4.24 (0.20)	4.19 (0.20)	4.27 (0.19)
Bitter tastant	4.21 (0.21)	4.10 (0.22)	4.26 (0.19)	4.04 (0.22)
Sour tastant	4.23 (0.26)	3.94 (0.20)	3.79 (0.18)	4.12 (0.20)
Salty tastant	4.19 (0.19)	4.16 (0.19)	4.32 (0.17)	4.23 (0.19)

The intensity of the solution was selected using the following scale: 1, not present at all; 2, very slight; 3, slight; 4, definitely present; 5, moderate; 6, moderately strong; 7, strong; 8, very strong; 9, extremely strong.

^aNumber of subjects.

^bMean (mean standard error).

found women gave significantly larger intensity ratings to caffeine than did men. Our results showed a similar phenomenon (Table 4). Nevertheless, the 2 populations were not matched for other potentially confounding factors.

In the whole-mouth suprathreshold taste test, the sucrose solution had the highest correct identification percentage, followed by the caffeine solution, the citric acid solution, and the sodium chloride solution in our study, but in the study by Doty et al,¹⁵ the sucrose solution had the highest correct identification percentage, followed by the sodium chloride solution, the caffeine solution, and the citric acid solution. It has been assumed that cultural or diet differences between populations might affect the results of taste tests.^{12,16} Regarding the intensity ratings, the ratings increased with increased concentration of all tastant solutions in our study. For the pleasantness ratings, the ratings decreased with increased concentration of caffeine, citric acid, and sodium chloride solutions. The pleasantness of the sucrose solution increased with increased concentration, but this trend was reversed at the third concentration. These rating results were consistent with those reported by Doty et al.¹⁵

In the taste quad test, the order of correct identification percentage was the same as that in the whole-mouth suprathreshold taste test in our study. The sucrose solution had the highest correct identification percentage, followed by the caffeine solution, the citric acid solution, and the sodium chloride solution. In the study by Doty et al,¹⁵ the order of correct identification percentage in the taste quad test was also the same as that in the whole-mouth suprathreshold taste test. The sucrose solution had the highest correct identification percentage, followed by the sodium chloride solution, the caffeine solution, and the citric acid solution.

However, their Western volunteers demonstrated spatial differences in identification performance and intensity rating. The anterior tongue (quadrants 2 and 3) had higher correct identification percentage and larger intensity ratings than the posterior tongue (quadrants 1 and 4), but our results did not show that tendency (Tables 1 and 4).

Conclusions

This study used the whole-mouth suprathreshold taste test and taste quad test to evaluate the taste function of healthy Taiwanese adults. Our result showed that sex did not affect the taste function of healthy Taiwanese adults. Further study is required to understand the prevalence and impact of taste dysfunction in Taiwanese population.

Authors' Note

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Author Contributions

RSJ contributed to the data collection and WJL contributed to the manuscript preparation.

Availability of Data

The data used to support the findings of this study are available from the first author on request.

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