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Note

Factors Associated with Dietary Habits and Mood States Affecting Taste Sensitivity in Japanese College Women

Kanae KARITA[1], Matsuko HARADA[2], Masao YOSHIDA[1] and Akatsuki KOKAZE[3]

[1] *Department of Public Health, Kyorin University School of Medicine, Mitaka, Tokyo 181–8611, Japan*
[2] *Department of Living Science, Teikyo Junior College, Shibuya-ku, Tokyo 151–0071, Japan*
[3] *Department of Public Health, Showa University School of Medicine, Shinagawa-ku, Tokyo 142–8555, Japan*

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Summary We conducted a cross-sectional survey to evaluate the factors associated with dietary habits and mood states affecting taste sensitivity in 127 Japanese college women with a mean age of 19.2 y. Differential thresholds for the four basic tastes on the tongue were determined by the filter paper disc method, while dietary intake was assessed using a food frequency questionnaire. Psychological mood states were evaluated by the Profile of Mood State (POMS) questionnaire. Differential thresholds for saltiness and bitterness in alcohol drinkers were higher than those in alcohol non drinkers, whereas differential thresholds for the other tastes did not differ significantly between any of the stratified groups. Canonical correlation analysis revealed that among the five POMS mood states, POMS fatigue scores showed relatively stronger association with combined variables of taste thresholds. Logistic regression analysis revealed significant involvement of zinc and iron intake, and that POMS fatigue and anger scores affected the differential threshold for sourness. Specific mood and dietary factors were shown to be associated with sensitivity to sourness and bitterness. Among the five POMS mood states, high POMS fatigue scores and low POMS anger scores appeared to be associated with decreased taste sensitivity.

Key Words taste sensitivity, differential threshold, dietary habits, mood state, college women

Sensitivity of gustatory functions is affected by age and some habitual factors such as smoking and alcohol consumption (*1–3*). Decrease in taste sensitivity has been reported to be associated with zinc deficiency and intake of some minerals and vitamins (*4–7*). Other studies have suggested that taste intensities are associated with food preference and consumption patterns (*8*,*9*). For instance, taste perception for bitterness may be affected by intake of food and beverages containing alcohol, caffeine, and other bitter compounds. However, there are many differences between individuals in taste acceptability, with some subjects showing no association between differential threshold and preference for bitterness (*8*, *10*).

Physiological and psychological conditions such as mood and temper have been demonstrated to affect food preference and taste sensory function. According to a Greek epidemiological study, anxiety is a factor affecting food choice in healthy adults (*11*). Christensen and Brooks reported that women were more likely to consume sweet foods after a sad event (*12*), while human interventional studies showed mental and physical stress may alter bitter, sour and sweet taste perceptions (*13*). In contrast, Scinska et al. showed in a non-clinical human population that symptoms of depression may not determine taste responses (*14*).

Recently, there has been increased concern regarding dietary problems such as excessive dieting and unbalanced dietary intake in young women in Japan. Gustatory functions may be adversely altered by inappropriate dietary habits, and mental health may play an important role in taste perception. To date, only a small number of studies have demonstrated the effect of mood states on the sensitivity of gustatory functions in healthy young women. The aim of this cross-sectional study was to examine preliminarily the effect of dietary habits, nutrient intake, and mental and mood states on taste sensitivity in a homogeneous population of non-smoking healthy young women.

Methods

Subjects. The study included 127 students from a women's junior college in Tokyo, aged 18 to 29 y with a mean age of 19.2 y. All participants were non-smokers and did not use pills. None suffered from neurological disorders or depression.

All subjects agreed to participate and provided informed consent. The study was approved by the Teikyo Junior College Ethics Committee (date of approval: December 25, 2009) and was conducted in accordance with the Declaration of Helsinki (*1989*) of the World Medical Association.

E-mail: kanae@ks.kyorin-u.ac.jp

Table 1. Distribution of differential thresholds for the four basic tastes on the tip of the tongue and the soft palate (SP) among the subjects.

Taste (Solvent)		Distribution for detected concentrations[1] (*n*, number)					*n* for those higher than mode value	*n* for low-sensitivity group
		Level l	Level 2	Level 3	Level 4	Level 5		
Sweetness	Tip	10	47	**54**	12	4	16	49
(Sucrose)	SP	22	**66**	30	8	1	39	
Saltiness	Tip	52	**55**	18	1	1	20	32
(Sodium chloride)	SP	48	**59**	18	2	0	20	
Sourness	Tip	15	36	**65**	11	0	11	35
(Tartaric acid)	SP	23	**70**	29	5	0	34	
Bitterness	Tip	24	**72**	24	7	0	31	42
(Quinine hydrochloride)	SP	39	**67**	20	1	0	21	

[1] The mode value is indicated by a boldface number.

Taste threshold measurement. Differential thresholds for the four basic tastes were determined by a forced-choice, staircase procedure using filter paper discs (*15*). Materials used for testing included 5-mm diameter filter paper discs and taste solutions, which were diluted sequentially with distilled water to produce five dilutions of each basic taste, i.e., sucrose for sweetness, sodium chloride for saltiness, tartaric acid for sourness, and quinine hydrochloride for bitterness. Concentrations (%) used for testing differential thresholds from Level 1 to Level 5 were 0.3, 2.5, 10, 20, 80 for sucrose, 0.3, 1.25, 5, 10, 20 for sodium chloride, 0.02, 0.2, 2, 4, 8 for tartaric acid, and 0.001, 0.02, 0.1, 0.5, 4 for quinine hydrochloride. Differential thresholds for the four basic tastes were determined by testing increasing concentrations of each solution in four locations of the mouth (on the right and left sides of the tip of the tongue and the soft palate), followed by rinses with water between tests. Incorrect identification of the solution led to administration of the next higher concentration, while correct identification led to administration of a taste sample at the next lower concentration, until all four tastes had been examined.

Dietary assessment. All subjects were requested to answer a "meal menu and intake time-based semi-quantitative food frequency questionnaire" (MMITQ). MMITQ includes all major food groups, dishes, sweets, drinks, and alcoholic beverages that contribute to over 90% of the energy and macronutrients present in the Japanese diet (*16*). In particular, consumptions of 161 food items and their portion sizes were recorded as averages per week over the previous year.

Psychological assessment. The Profile of Mood States (POMS) questionnaire (*17*) was used to evaluate the mood states of the participants. Reliability and validity of POMS have been established in the Japanese population (*18*). The subjects answered 65 questions using a five-point category scale and the composite score was computed by summing the subscale scores of tension-anxiety (anxiety), depression-dejection (depression), anger-hostility (anger), fatigue-inertia (fatigue), and confusion-bewilderment (confusion). The positive POMS scale of vigor-activity was eliminated from analysis to avoid multicollinearity.

Table 2. Characteristics, nutrient intake and dietary habits of the subjects (n=127).

	Mean±SD
Characteristics	
Age (y)	19.2±1.6
Height (cm)	158.1±5.2
Weight (kg)	51.0±6.4
Body mass index (kg/m^2)	20.4±2.3
Nutrient and mineral intake	
Protein (g)	71±36
Carbohydrate (g)	262±130
Sodium (mg)	4,983±2,622
Potassium (mg)	2,492±1,284
Magnesium (mg)	256±130
Calcium (mg)	525±262
Phosphorus (mg)	1,043±522
Iron (mg)	7.9±4.1
Zinc (mg)	9.4±4.8
Copper (mg)	1.2±0.7
Dietary habits	% (*n*)
Alcohol consumption; >1 d/wk	13.4 (17)
Dining out; >1 d/wk	57.5 (73)
Bedtime snack; >10 pm, regularly	29.1 (37)
Supplement user[1]	23.6 (30)
Skipping breakfast every day	10.2 (13)
Unbalanced diet[2]	34.6 (44)
Sufficient energy intake[3]	56.7 (72)
Sufficient vitamin intake[3]	48.9 (62)

[1] Subjects taking supplements such as vitamins, DHA or minerals regularly.
[2] Subjects scored more than 7 in a 10-point unbalanced diet scale [1 (excellent) to 10 (worst)].
[3] Subjects satisfied the Japanese dietary recommended allowance for women aged 18 to 29 y.

Statistical analysis. Differential thresholds of the right and left sides of the tongue and the soft palate

Table 3. Comparison of differential thresholds for the four basic tastes on the tip of the tongue between non-drinkers and drinkers.[1]

Taste (Solvent)	Group (*n*)	Median	Mean	S.D	Mann-Whitney *U*-Test	
					Z score	*p*-value
Sweetness (Sucrose)	Non-drinker (110)	2.5	2.6	0.8	0.022	0.9823
	Drinker (17)	3	2.6	0.7		
Saltiness (NaCl)	Non-drinker (110)	2	1.8	0.7	−2.585	0.0097
	Drinker (17)	2	2.3	0.5		
Sourness (Tartaric acid)	Non-drinker (110)	2.5	2.5	0.7	−0.919	0.3581
	Drinker (17)	3	2.6	0.5		
Bitterness (Quinine hydrochloride)	Non-drinker (110)	2	2.1	0.7	−3.187	0.0014
	Drinker (17)	3	2.7	0.7		

[1] Habitual alcohol consumption >1 d/wk.

Table 4. Mean±SD of POMS scores and daily mineral intakes in the low-sensitivity groups for sweetness, saltiness, sourness, and bitterness.

	Sweetness (*n*=49)	Saltiness (*n*=32)	Sourness (*n*=35)	Bitterness (*n*=42)
POMS scores (point)				
Anxiety	14.4±7.5	15.0±6.7	15.1±8.3	14.5±8.1
Depression	21.8±11.9	23.4±11.3	22.3±13.3	21.3±12.9
Anger	14.7±8.7	15.7±8.4	13.9±9.5	14.8±10.1
Fatigue	15.2±6.7	15.0±6.0	15.9±7.0	14.6±7.3
Confusion	14.3±5.6	14.3±5.4	13.7±5.9	14.1±6.2
Mineral intake (mg)				
Sodium	5,224±2,463	5,286±2,789	4,669±2,469	5,016±2,402
Potassium	2,658±1,213	2,634±1,262	2,366±1,156	2,554±1,153
Magnesium	271±124	272±133	244±119	264±119
Calcium	529±240	538±263	515±25.6	547±234
Phosphorus	1,071±472	1,068±515	992±470	1,050±446
Iron	8.4±3.8	8.4±4.1	7.4±3.8	8.3±3.7
Zinc	9.7±4.1	9.8±4.8	9.2±4.5	9.3±3.8
Copper	1.3±0.6	1.3±0.7	1.1±0.6	1.2±0.6

were averaged, and the study subjects were classified into two groups for each of the four basic tastes. The high-sensitivity group included subjects whose differential thresholds of either tongue location were equal or lower than the total mode value of each threshold test. The low-sensitivity group included the remaining subjects whose differential thresholds of either or both locations were higher than the mode value. In other words, the low-sensitivity group included those who identified tastes even at the mode level on one location but the higher level than mode on the other location. Semi-quantitative information obtained from MMITQ was transformed into quantitative data using the median of the food-intake classes.

To evaluate how mood factors were associated with the sensitivity of the four basic tastes, data sets were compared using canonical correlation analysis (CCA), a technique used for analyzing associations between two sets of variables that uses partial least square regression for each separate attribute (*19*). Backward multiple logistic regression analysis was used to evaluate the effect of dietary and mood factors on decreased sensitivity of each taste by calculating the multiple adjusted odds ratio (OR) and 95% confidence interval (CI). The exclusion criterion was set at 20% and 95% CIs was based on likelihood test statistics. Analysis was performed using the Statistical Package for the Biosciences (SPBS ver. 9.5) (*19*).

Results

Distribution of differential thresholds of the four basic tastes in the study subjects is shown in Table 1, along with the number in each low-sensitivity group. The respective mode and median threshold concentrations for the taste solutions were 1.25% for sodium chloride and 0.02% for quinine hydrochloride on both the tip of the tongue and the soft palate, and 2.5% and 0.2% for sucrose and tartaric acid on the soft palate and 10% and 2% on the tip of the tongue. The percentage of subjects in the low-sensitivity group was 39% for sweetness, 25%

for saltiness, 28% for sourness and 33% for bitterness.

Table 2 summarizes the characteristics of the study participants. Intake of minerals below the Japanese dietary recommended allowance was observed for calcium and iron in all subjects. The physical characteristics, major nutrient intakes and dietary habits of the subjects did not differ significantly between the high- and low-sensitivity groups. As shown in Table 3, subjects who habitually consumed alcohol more than once a week ($n=17$) were less sensitive to saltiness and bitterness on the tip of the tongue ($p=0.0097$, and 0.0014 respectively calculated by Mann-Whitney U-test). No differences in median thresholds were noted at any location of the tongue for sweetness or sourness between non-drinkers and drinkers.

Table 4 shows the mean values and standard deviation (SD) of POMS scores and daily mineral intakes in the low-sensitivity groups for sweetness, saltiness, sourness, and bitterness. To examine sensitivity of gustatory functions for the four basic tastes with POMS negative outcomes consisting of five variables, the combined canonical variables and correlations were analyzed by CCA. A summary of results on the association between taste and POMS variables is shown in Table 5. Significant canonical correlations were synthetically presented using multi-correlation between differential thresholds of the four basic tastes and scores of the five POMS categories. For the first solution, the canonical correlation coefficient was 0.448 with a p value of 0.007. This showed that the taste variables within one set were associated with POMS variables within the other. The significant structure coefficients of thresholds listed in order from the highest to lower were for sourness, bitterness and saltiness. For the predictor variables, POMS fatigue score showed relatively stronger cross loadings.

As shown in Table 6, results of backward multiple logistic regression analyses indicated that factors contributing to the low-sensitivity group for sourness included dietary intake of iron and zinc and POMS anger and fatigue scores. Low sensitivity for sourness was affected by higher POMS fatigue scores and lower POMS anger scores as well as less dietary intake of iron and zinc. Another model for analysis showed alcohol consumption and unbalanced diet as factors with a positive predictive score in the low-sensitivity group for bitter taste (Table 6). There were no clear explanatory factors observed in models for the low-sensitivity group for either sweetness or saltiness (data not shown).

Table 5. Canonical correlations between differential thresholds for the four basic tastes and scores of the five POMS categories.

	Variables	
	First	Second
Taste thresholds		
Sweetness	0.102	−0.662**
Saltiness	0.510**	0.034
Sourness	0.961**	−0.057
Bitterness	0.594**	−0.680**
POMS scores		
Anxiety	−0.248**	−0.468**
Depression	−0.112	−0.385**
Anger	0.224*	−0.322**
Fatigue	−0.448**	−0.692**
Confusion	0.028	−0.826**
Canonical correlation: R	0.448**	0.258

** $p<0.01$, * $p<0.05$.

Discussion

Since taste sensitivity may depend to some degree on the mental and physical state, we used CCA in this study to examine the independent statistical associations that existed between the sets of variables. The results of CCA suggested that psychological factors including anxiety, anger and fatigue may affect the differential thresholds for the four basic tastes. In addition, results of our logistic regression analyses indicated that taste sensitivity for sourness was related to intake of two minerals and two POMS scores, while no independent variable other than alcohol consumption and an unbalanced diet was associated with decreased sensitivity for bitterness.

Taste perception changes are a function of varia-

Table 6. Results of the multiple logistic regression model in the low-sensitivity groups for sourness and bitterness[1] associated with significant dietary and psychological factors.

	Odds ratio (95% confidence interval)	p-value
Criterion: Low-sensitivity group for sourness		
Explanatory variable: Iron intake	0.742 (0.579–0.949)	0.018
Zinc intake	0.722 (0.561–0.929)	0.011
POMS fatigue score	1.093 (1.123–1.969)	0.006
POMS anger score	0.935 (0.880–0.993)	0.029
Criterion: Low-sensitivity group for bitterness		
Explanatory variable: Habit of alcohol consumption	3.644 (1.254–10.59)	0.018
Unbalanced diet score	1.087 (1.009–1.171)	0.028

[1] Only the results of the criterion for the low-sensitivity groups for sourness and bitterness are shown, as no other factors were found to be statistically significant.

tions in mood states (*20*), with a person's sense of taste responding to changes at the neurotransmitter level during different mood states (*21*). In this study, mood states of fatigue, anxiety, and anger assessed by POMS appeared to have the potential to affect taste sensitivity. Heath et al. demonstrated that mood states of depression or anxiety altered serotonin and noradrenaline concentrations, which changes may be associated with taste disturbances (*21*). Glendinning showed that proline-rich proteins (PRPs) in human saliva carry lipophilic proteins of compounds such as bitter compounds. An experimental study in mice showed PRPs were increased in the saliva of mice who had received chronic treatment with a β-agonist (*22*). Therefore, mental stress may possibly increase the concentration of bitter compound carriers in saliva. Further investigations into the biochemical mechanisms involved in the association between taste sensitivity and moods are required in the future.

A higher threshold for the bitterness of quinine hydrochloride was associated with frequent alcohol consumption in our study. It has been reported that receptors for bitterness belong to the G protein-coupled receptors, and there is evidence that the taste receptors, TAS2Rs, coupled to G proteins are responsible for the ability of humans to taste bitter compounds (*23*). Guinard et al. reported that intake of bitter substances was higher in people who often consumed beer than that in people who did not, although it was not a major determinant for the taste response to bitter isohumulones (*8*). Previous reports in children and middle-aged women (*24*, *25*) showed that sensitivity to the bitterness of 6-*n*-propylthiouracil was also affected by body mass index (BMI) after adjustment for demographic characteristics. However, we found no such tendencies in our study, probably as a consequence of the narrow range of BMIs in the subjects.

This study had several limitations. First, women in this study attended a single college in Tokyo and the results were obtained from measurements performed in day in a limited population. The cross-sectional nature of the study does not permit us to draw any conclusions about any causal associations between mood status and taste sensitivity. Second, CCA was conducted to interpret synthetically the multi-correlation between POMS outcomes and sensitivities of the four basic tastes in multiple dimensions; however, the canonical coefficient expressed as *R* was rather small. Since POMS scores alone may be insufficient to evaluate mood states, other scales or biochemical indicators may be required to confirm the potential associations. With regard to the taste sensitivity test, the filter paper disc method provides a constant intensity and range of stimulation. Nevertheless, other methods such as the whole-mouth method or electrogustometry should be used to examine the accuracy and reliability of the filter paper disc method. Finally, because there may be associations between genetic taste markers and eating habits (*26*), the reproducibility of our results need to be examined in further studies that consider other essential confounders, such as genetic variations and hormonal effects.

In conclusion, it is possible that dietary habits and mood states may affect the differential thresholds for sourness and bitterness. Further precise information on factors that affect taste perception would contribute to the maintenance of a good quality of life in women.

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