Minerals and Vitamin-A Status in Relation to Gustatory Functions for Salt in Healthy Female College Students

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Summary Twenty-five healthy female college students were studied for the gustatory function tests for salt (NaCl) and some selected biochemical parameters including plasma retinol and plasma retinol-binding protein (PRBP). Plasma zinc (PZn) and retinol levels were comparable with those of good responders in tests of discrimination between two levels of NaCl in the previous report, but PRBP was lower in the present subjects. From the results of correlation analysis and stepwise multiple regression analysis, the individual students' discriminability of NaCl concentrations was related to the parameters regarding metabolic status of calcium (Ca), magnesium (Mg), sodium (Na), and selenium (Se). The detection threshold of NaCl concentration ranged from 1 to 60 mmol/liter and was related to PRBP. Plasma Zn was significantly positively correlated with both plasma retinol and PRBP, but significantly negatively correlated only for the detection threshold of NaCl concentration. On the basis of these results, the importance of vitamin-A nutrition and the relation of minerals such as Na, Ca, Mg, and Zn to the gustatory functions of NaCl was confirmed and a possible participation of Se to the functions was suggested.

Key Words discrimination between NaCl concentrations, detection threshold for taste of salt, minerals in plasma and urine, sodium, potas-

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sium, calcium, magnesium, zinc, selenium, plasma retinol-binding protein, retinol

Gustatory function tests of the taste for salt (NaCl) were twice studied in our laboratories in different subject: the first for female college students (1) and the second for male college students (2). The results of two studies were somewhat dissimilar: in the female students, the discriminability of NaCl concentrations in foods was related positively to plasma zinc (PZn) and plasma retinol levels and negatively to urinary potassium (UK) and sodium (UNa) levels without showing a significant association with the detection threshold for NaCl (1); in the male students, no significant parameters were found for the discriminability of NaCl concentration, but the detection threshold for NaCl was associated with the ratio of urinary calcium (Ca) to magnesium (Mg), plasma Ca (PCa), plasma sodium (PNa), and discriminability between NaCl concentrations (2). The differences between the two groups in PZn and PRBP (these were higher in the male than in the female students) as well as in the Ca, Mg, and Na metabolism (male students would have engaged in hard physical exercise almost every day and had elevated plasma levels of these minerals) might be the cause of this dissimilarity. However, the minerals Na, K, Ca, Mg, and Se, which were studied in plasma for the male students, were not included in the study on female students. Therefore, it was necessary to study the female students again, adding the minerals in plasma as the items for examination.

In the previous studies, the discrimination test was conducted using only two test-batches, each having a different NaCl concentration. This mode of testing may be influenced by the examinees' psychological states; therefore, in this study, a "two-batch" mode was compared with a "three-batch" mode in which two of the batches had identical concentrations of NaCl. The lowest NaCl concentration in the previous threshold testing was 6 mmol/liter, and the threshold in 70% of female students was at this level, indicating the possible existence of more sensitive responders. Thus, the lowest concentration tested is 1 mmol/liter in the present study.

SUBJECTS AND METHODS

Subjects. Twenty-five volunteers (age: 18–19 years old) from among the new students at a women's college in 1985 participated in this study. They volunteered for participation after listening to an explanation of the scope, objectives, and methodologies of the study.

Study schedule. The schedule of the study is presented in Fig. 1. In October 1985, the two-batch mode discrimination test was compared with the three-batch mode, and additional three-batch mode tests were conducted in May and June 1986.

	1985					1986				
	O	N	D	J	F	M	A	M	J	J
Discrimination	*							*	*	
Detection threshold								*		
Blood and urine sampling									*	

Fig. 1. Schedule of the study: letters represent months, asterisks show the examination dates.

The detection threshold for salt concentration was tested May 29, 1986. Blood and urine were collected at the occasion of the three-batch test in June 1986.

Gustatory function tests. The detection threshold for NaCl concentration was tested as in the previous study (1), and the levels of concentration tested were 1, 3, 6, 12, 30, and 60 mmol/liter. In the repetition of tests (8 times) with a 4-day interval for selected 5 students, the detection threshold had fluctuated in a narrow range (results will be published elsewhere); thus, errors due to the time-lapse between the threshold test and the blood and urine sampling was expected to be not so large.

As the matrix for discrimination between two levels of NaCl concentration (0.6 and 0.7%), water and Japanese-style consommé soup were selected because other matrices tested in the previous two studies yielded low rates (e.g., boiled rice: 50–74%) or high rates (*Miso* soup: 92–100%) of correct discrimination. The two-batch mode of testing was similar to that in the previous studies; for the three-batch mode, it was randomly decided which of two combinations—i.e., two 0.6% batches and one 0.7% batch, or one 0.6% batch and two 0.7% batches—would be applied to each examinee.

Blood and urine collection. Blood was veni-punctured into a heparinized tube in the afternoon (at least two hours after lunch) of June 2, 1986. Urine samples were collected over a 24-h period in a week from June 3 to June 9, with instructions for careful collection.

Biochemical analysis. Hemoglobin concentration in blood was measured by the cyan-methemoglobin method. Hematocrit was determined by centrifugation using capillary tubes. Plasma total protein (TP), albumin (ALB), triglycerides (TG), cholesterol (CHO), and activities of plasma enzymes such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), lactate dehydrogenase (LDH), and creatine phosphokinase (CK) were determined using an auto-analyzer (Abbott Bichromatic Analyzer, ABA 200) with clinical chemical reagents supplied by Abbott Laboratories. To ensure the accuracy of determination, a standard serum (Moni-Trol I, American Dade) was measured on every occasion of determination.

Retinol, α -carotene, β -carotene, and α -tocopherol in plasma were determined as follows: HPLC (column: YMC-PACK A-302 ODS, 4.6 $\times$ 150 mm; eluent: methanol/butanol = 80/20 containing 0.1% (v/v) 10 mM acetate buffer, pH 3.6; flow

rate: 1.0 ml/min, back pressure 60 kgf/cm²; detector: UV/visible detector; wavelength: 325 nm for retinol, 292 nm for α -tocopherol and α -tocopheryl nicotinate, 450 nm for carotenes) after extraction of plasma with ethanol and *n*-hexane. Calibration was conducted by an external standard method with a computer-aided data system, and α -tocopheryl nicotinate was used only as a standard for volume-correction and recovery. Authentic samples of retinol, carotenes, α -tocopherol and α -tocopheryl nicotinate were purchased from Sigma Chemicals.

Minerals (Na, K, Ca, Mg, and Zn) in plasma and urine were measured by flame atomic absorption spectrometry (Nippon Jarell Ash, Model AA-845); for Ca, lanthanum chloride was added to prevent interference due to phosphate. Selenium (Se) in plasma and erythrocytes was measured by Watkinson's method (3). To check the accuracy of mineral measurements, a reference serum (Natl. Inst. Environ. Studies of Japan, NIES No. 4) was simultaneously measured.

Retinol-binding protein (RBP) in plasma was estimated by radial immunodiffusion (4) using Partigen plates (Hoechst). Creatinine in urine was colorimetrically measured using Jaffe's reaction (5). From the 24-h excretion of creatinine and stature, creatinine height index (CHI) was calculated.

Anthropometry. Height and weight were measured on the occasion of testing the detection threshold; using these, the body mass index—(weight, kg)/(height², m²)—was calculated.

Statistical analysis. Variables whose distribution deviated from the normal distribution for the values of skewness and kurtosis in basic statistics were subjected to logarithm conversion, *e.g.*, the detection threshold. Correlation analysis and stepwise multiple regression analysis were applied to reveal the interrelationship between the variables and to select the variables which may be relevant to gustatory functions (6). To compare the results of discrimination tests for different test modes and different occasions, Fischer's exact probability method or Wilcoxon's matched pairs signed-rank test was used (7).

RESULTS

Anthropometry, plasma proteins, and some biochemical parameters

Nothing noteworthy was seen in the stature, weight and body mass index measurements, and no anemic students were found (Table 1). TP, ALB, and CHO in plasma were all in the normal range, but plasma triglycerides (TG) were elevated in two students (404 and 236 mg/dl, respectively; the normal range: 50–130 mg/dl). Levels of PRBP were low: the average, 4.0 mg/dl, was lower than those in the previous two samples (female college students: 4.7, and male college students: 5.8 mg/dl). Activities of plasma enzymes were all in the normal range except for a single case with very marginal elevation of LDH activity (data not shown).

Gustatory functions

Discrimination between two levels of NaCl concentration. Discrimination tests

Table 1. Anthropometric data and some biochemical parameters.

	<i>n</i>	Mean	SD
Stature (cm)	25	158.4	4.2
Weight (kg)	25	53.2	6.8
Body mass index (kg/m ²)	25	21.2	2.6
Hemoglobin (g/dl)	25	13.5	0.8
Hematocrit (%)	25	40.6	2.2
Plasma total protein (g/dl)	25	8.0	0.5
Plasma albumin (g/dl)	25	4.3	0.15
Plasma RBP ^a (mg/dl)	25	4.0	0.7
Plasma triglycerides (mg/dl)	25	114	71
Plasma cholesterol (mg/dl)	25	200	31

^a RBP, retinol-binding protein.

Table 2. Results of salt concentration discrimination.

Test matrix	No. of students tested	No. of correct discriminators	(%)
Water solution 2-batch (Oct. '85)	24	23	(95.8)
3-batch (Oct. '85)	24	18	(75.0)
3-batch (May '86)	24	11	(45.8)
Japanese-style consommé soup			
2-batch (Oct. '85)	24	19	(79.2)
3-batch (Oct. '85)	24	15	(62.5)
3-batch (May '86)	24	14	(58.3)

Results of "two-batch" and "three-batch" test modes were compared for the data obtained in October 1985, and no significant difference between two modes was found by Fischer's exact probability: $p=0.596$.

in October 1985 compared the two-batch mode and the three-batch mode using water solution and Japanese-style consommé soup (Table 2). The proportion of correct discriminators was slightly—albeit not statistically significantly ($p>0.05$ by Fischer's exact probability method)—decreased in the three-batch mode of tests. Consistency of discrimination was compared between the results obtained in October 1985 and those obtained in May and June 1986, both using three-batches: the discrepancy between two occasions was not significant (Wilcoxon's test, $p>0.05$). However, the proportion of correct discriminators varied from 46 to 96% with test matrices, occasions, and test modes (Table 2); and the individual student's rate of correct discrimination (RCD) in repeated tests (one student completed 5 tests; two, 4 tests; 22, 6 tests) ranged from 0 to 100% (Fig. 2). The present average rate was 70% which was slightly lower than the previous result (83.2%) (Table 3).

Fig. 2. Relationship between the detection threshold and individual's rate of correct discrimination between NaCl concentrations. Detection threshold as mm of NaCl concentration is on abscissa, and individual's correct discrimination rate in repeated tests (the perfect discrimination: 1.0) is on ordinate. Number of subjects: 24, because one student failed to attend the detection threshold examination.

Table 3. Gustatory functions and vitamins in plasma.

	<i>n</i>	Mean	SD
RCD ^a : Salt (%)	25	70.2	22.7
Detection threshold for salt (mmol/liter) ^b	24	12.5	14.0
Retinol (μg/ml)	25	0.42	0.066
α-Carotene (μg/ml)	22	0.11	0.036
β-Carotene (μg/ml)	25	0.41	0.25
α-Tocopherol (μg/ml)	25	7.68	1.12

^a RCD, rate of correct discrimination. ^b Geometric mean and its standard deviation: 7.4×2.9 mmol/liter.

Detection threshold for NaCl concentration. The level of detection threshold scattered from 1 to 60 mmol/liter, and the log-converted values did not correlate with the individual's rate of correct discrimination (correlation coefficient, $r=0.137$, $p>0.05$) (Fig. 2). In this correlogram, a single subject who completely failed in discrimination tests occupied a position far from the general trend. This subject had elevated PCa and PMg levels as mentioned later, but the levels of PCa and PMg in other subjects were all in the normal range. Then, if this subject with complete failure in discrimination tests is excluded, and the subjects with normal PCa and PMg levels are analyzed, the correlation coefficient will be significant as $r=0.434$ ($p<0.05$).

Biochemical analysis concerning minerals and vitamins

Plasma retinol, carotenes, and tocopherol. The levels of plasma retinol, which was measured by fluorometry in the previous study and by HPLC with UV detector in the present study, were in good agreement, *i.e.*, the previous average was 0.39 and the present average was 0.42 $\mu\text{g/ml}$. However, these values were lower than the average for 10 healthy adult males in our laboratory (0.57 $\mu\text{g/ml}$, also measured by HPLC) (8), presumably reflecting a gender-related difference. Beta-carotene levels were higher and α -tocopherol levels were lower in the present subjects than in the adult males, but there are no comparable data for α -carotene.

Plasma and erythrocyte minerals. In contrast to the previous result, low levels of PZn were not found: the present average, 0.75 $\mu\text{g/ml}$, corresponded to the level observed in the excellent discriminators in the previous study. The levels of PSe and ESe were comparable with those reported in ordinary Japanese and in our previous male subjects (9, 10).

Table 4. Plasma and erythrocyte minerals.

	<i>n</i>	Mean	SD
PZn ($\mu\text{g/ml}$)	25	0.75	0.09
PSe ($\mu\text{g/ml}$)	25	0.13	0.011
ESe ($\mu\text{g/g}$)	25	0.31	0.04
PCa ($\mu\text{g/ml}$)	25	98.7	4.7
PMg ($\mu\text{g/ml}$)	25	25.7	2.8
PCa/Mg (mol/mol)	25	2.31	0.23
PNa (mg/ml)	25	3.29	0.17
PK (mg/ml)	24	0.17	0.01

P, plasma; E, erythrocyte.

Table 5. Daily urinary excretion of minerals and creatinine.

	<i>n</i>	Mean	SD
Na (g/day)	25	2.36	0.85
K (g/day)	25	1.55	0.57
Na/K (mol/mol)	25	2.88	1.22
Ca (mg/day)	25	93.0	35.6
Mg (mg/day)	25	93.1	34.9
Ca/Mg (mol/mol)	25	1.20	2.23
Zn ($\mu\text{g/day}$)	25	366	107
Se ($\mu\text{g/day}$)	25	42.8	10.7
Creatinine (g/day)	25	0.95	0.19
Creatinine height index (mg/cm)	25	6.01	1.09

Table 6. Correlation matrix between various parameters examined.

ALB	CHO	TG	PZn	PSe	ESe	PCa	PMg	PNa	PK	AST	ALT	LDH	CK	UZn
—	—	—	—	.443	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		—	—	—	—	—	—	—	.508	—	.516	.444	—	—
			—	—	—	—	—	—	—	—	—	—	—	—
				—	—	—	—	—	—	—	—	—	—	—
					—	.542	—	—	—	—	—	—	—	—
						—	—	.435	—	—	—	—	—	—
							—	—	.489	—	—	—	—	—
								—	—	—	.513	—	—	—
									—	—	—	—	—	—
										—	—	—	—	—
											—	—	—	—
												—	—	—
													—	—
														.438

Figures in the table are statistically significant correlation coefficients ($p < 0.05$). ALB, albumin; CHO, cholesterol; TG, triglycerides; PZn, plasma zinc; PSe, plasma selenium; ESe, erythrocyte selenium; PCa, plasma calcium; PMg, plasma magnesium; PNa, plasma sodium; PK, plasma potassium; AST, aspartate aminotransferase; ALT, alanine aminotransferase; LDH, lactate dehydrogenase; CK, creatine phosphokinase; UZn,

A single case had elevated levels of PCa (115 $\mu\text{g/ml}$) and PMg (33.4 $\mu\text{g/ml}$), who completely failed in discrimination tests as mentioned; others were all in the normal range, and no elevation of PNa and PK levels was observed (Table 4).

Urinary excretion of minerals and creatinine. Creatinine height indices in the present subjects were slightly smaller than those we reported in adult Japanese females (11). The difference may have resulted from the age difference. Daily excretions of minerals were all within the normal variation range (Table 5).

Correlation and regression analyses

Correlation analysis revealed that the log-converted detection threshold was negatively correlated with PRBP, plasma retinol, UMg, or PZn, and RCD was

USe	UCa	UMg	UNa	UK	CHI	RBP	Ret	β -C	α -C	Toc	THD	RCD	
—	—	—	-.482	—	—	—	—	—	—	—	—	—	TP
—	—	—	—	—	—	—	—	—	—	—	—	—	ALB
—	-.403	—	-.450	—	-.421	—	—	—	—	.806	—	—	CHO
—	—	—	—	—	—	—	—	—	—	—	—	—	TG
—	—	—	—	—	—	.490	.514	—	-.562	—	-.421	—	PZn
.424	—	—	—	-.399	-.594	—	—	-.406	—	—	—	-.490	PSe
—	—	—	—	—	—	—	—	.506	—	—	—	—	ESe
—	—	—	—	—	—	—	—	—	—	—	—	-.623	PCa
—	—	—	—	—	—	—	—	—	—	—	—	—	PMg
—	—	—	—	—	—	—	—	—	—	—	—	.434	PNa
—	—	—	—	—	—	—	.585	—	—	—	—	—	PK
—	—	—	—	—	—	—	—	—	—	—	—	—	AST
—	—	—	—	—	—	—	—	—	—	.398	—	—	ALT
—	—	—	—	—	—	—	—	—	—	.400	—	—	LDH
—	.439	—	—	—	—	—	—	—	—	—	—	—	CK
—	.480	—	—	—	—	—	—	—	—	—	—	—	UZn
—	—	.399	—	.532	.567	—	—	—	—	—	—	—	USe
—	—	.477	.497	—	—	—	—	—	—	—	—	—	UCa
—	—	—	.425	—	—	—	—	—	—	—	—	—	UMg
—	—	—	—	—	—	—	—	—	—	—	-.470	-.452	UNa
—	—	—	—	—	.471	—	—	.503	—	—	—	—	UK
—	—	—	—	—	—	—	—	—	—	—	—	—	CHI
—	—	—	—	—	—	—	.909	—	—	—	-.580	—	RBP
—	—	—	—	—	—	—	—	—	—	—	-.559	—	Ret
—	—	—	—	—	—	—	—	—	.548	—	—	—	β -C
—	—	—	—	—	—	—	—	—	—	—	—	—	α -C
—	—	—	—	—	—	—	—	—	—	—	—	.402	Toc
—	—	—	—	—	—	—	—	—	—	—	—	—	THD

urinary zinc; USe, urinary selenium; UCa, urinary calcium; UMg, urinary magnesium; UNa, urinary sodium; UK, urinary potassium; CHI, creatinine height index; RBP, retinol-binding protein; Ret, retinol; β -C, β -carotene; α -C, α -carotene; Toc, α -tocopherol; THD, the detection threshold for salt; RCD, rate of correct discrimination of salt concentrations.

negatively correlated with PCa, PSe or UMg and positively with PNa or plasma α -tocopherol (Table 6).

Among other sets of significant correlations, of remarkably high significance ($p < 0.001$) were PRBP vs. plasma retinol ($r = 0.909$) and PCHO vs. plasma α -tocopherol ($r = 0.806$). Plasma Zn was correlated significantly positively with either PRBP or plasma retinol.

Scrutinizing the most highly significant correlation with RCD, that with PCa (Fig. 3), it is apparent that the existence of a single subject who completely failed all the discrimination tests and had an abnormally elevated PCa level contributed to this high level of significance. This same individual also possessed an elevated PMg level, as mentioned. If this case were excluded, the correlation coefficient would be

Table 7. Results of stepwise regression analysis.

Dependent variable	Independent variables	Standardized partial regression coefficient	t-Value
RCD (R=0.883)	PCa	-.613	-5.68***
	UMg	-.481	-4.47**
	PNa	.415	3.85**
RCD' (R=0.821)	PNa	.589	4.30**
	PSe	-.513	-3.75**
	UMg	-.472	-3.49**
THD (R=0.580)	RBP	-.580	-3.27**

RCD, rate of correct discrimination; RCD', the result after exclusion of one case with abnormally elevated PCa and PMg levels; R, multiple correlation coefficient; THD, the detection threshold; RBP, retinol-binding protein. **,***: $p < 0.01$, $p < 0.001$, respectively.

found between PRBP and the threshold ($r = -0.580$) was almost unchanged at -0.587 (Fig. 4); other significant correlations also remained as being significant, and no new significant correlations emerged.

Stepwise multiple regression analysis revealed that the primary variable was PCa, the secondary was UMg, and the tertiary was PNa as significant factors in explaining the variation of RCD in the subjects of this study as a group; but when the single case with elevated PCa and PMg levels was excluded, the significant explanatory factors were PNa, PSe, and UMg. For variation of the detection threshold, PRBP was the only significant factor for the entire group of subjects, and after exclusion of the high-PCa case, UMg and hemoglobin concentration were added as significant factors (data are not shown in the table) (Table 7).

DISCUSSION

The present levels of PZn and plasma retinol were in good agreement with those in good discriminators among the female subjects in the previous study (1), but the level of PRBP was lower in the present subjects. The pattern of interrelation of these three parameters—PZn, plasma retinol, and PRBP—was different between the previous and the present studies: correlation between PRBP and plasma retinol was very strong ($r = 0.909$), and correlations between PZn and plasma retinol and between PZn and PRBP were both positively significant in the present subjects ($r = 0.514$ and 0.490 , respectively), while correlation between PRBP and plasma retinol was moderate ($r = 0.581$), PZn's correlation with plasma retinol was not significant and that with PRBP was significant but weak ($r = 0.255$) in the previous

study (1). Normally, in the blood, plasma retinol and PRBP is understood to circulate in a 1:1 molar complex with little unbound RBP present, and the molar ratio over 1.0 indicates the existence of apo-RBP (12). In the present subjects, the ratio (RBP/retinol) was 1.3 on average and it was 1.6 in the previous study. Despite the methodological difference between the two studies in measuring plasma retinol, the existence of apo-RBP is common. Thus, a question arises from this result: Among the following 4 chemical compounds, retinol, holo-RBP, apo-RBP, and RBP, which is responsible in regulating the detection threshold for salt? The amount of apo-RBP, which can be calculated from the values of retinol and RBP by the formula: $(\text{RBP}/21,000 - \text{retinol}/286) \times 21,000$, only weakly correlated with the threshold ($r = -0.418$, $p = 0.042$). If all retinol exists to be bound to RBP, the amount of retinol will represent the amount of holo-RBP. The correlation coefficient between retinol and the threshold was -0.5592 ($p = 0.005$), being slightly smaller than that between RBP and the threshold ($r = -0.5804$, $p = 0.003$). From this minute difference in the value of coefficients, we hesitate to draw any conclusive statement. This is to be further clarified.

An association between Zn and RBP has been reported in human studies on pathological conditions such as hepatic diseases, malnutrition, and others (12–14). Animal experiments have repeatedly demonstrated the impaired hepatic mobilization of vitamin A and a depression of RBP in the plasma and liver of Zn-deficient animals (13). Nevertheless, an association between PZn, plasma retinol, and PRBP in apparently healthy human populations has not been described as evidently as in the present paper. From this association, we can postulate that even in the normal fluctuation range of Zn nutriture, Zn influences the vitamin A metabolism, although the exact mechanism is not known. Since the turnover rate of RBP is very rapid (biological half-life is 11.1–11.7 h, with a synthesis rate of 190 mg/m²/day in young men) (15) and in contrast, the biological half-life of Zn is as long as 930 d (16), a rapid change of PRBP is liable to occur while PZn is rather stable. Moreover, PZn levels did not change significantly during the menstrual cycle in women (17, 18), though PRBP levels did. Therefore, a follow-up observation with repeated monitorings of vitamin A and Zn nutrition is needed to clarify the changing pattern of interrelation among PZn, plasma retinol, and PRBP.

Ability to discriminate between NaCl concentrations was completely lost in one subject with elevated PCa and PMg (other parameters were all normal) in the present study. This subject's discriminability and plasma minerals were re-examined in January 1987, at which time she discriminated two NaCl concentrations (0.6 and 0.7%) and her plasma mineral values were all in the normal range. Thus, PCa and/or PMg is most likely to be relevant to gustatory functions under normal Zn and vitamin A nutritional conditions. In our previous study of male college students, the detection threshold for NaCl was related to urinary Ca/Mg, PCa, PNa and discriminability also within the normal levels of PZn and PRBP (2). In the present regression analysis, PNa remained unchanged and PSe and UMg appeared as significant independent variables to explain RCD after removal of the high PCa

and PMg subject. Hence, the metabolic status of not only Ca and Mg, but also Na, deserves particular attention in the study of gustatory functions for NaCl. For the unexpected participation of PSe, we cannot find any plausible interpretation. In the document of WHO dealing with "Principles and Methods for the Assessment of Neurotoxicity Associated with Exposure to Chemicals" (19), selenium is listed as an example chemical which induces human taste alteration, but we cannot find the scientific evidence in the text and in the literature cited in this document. An association between Zn and Se was noticed in the previous study of male college students (2), but not in the present subjects; however, there was a significant correlation between PSe and PCa. Thus, it is of further concern to elucidate whether the participation of Se in gustatory functions is merely coincidental.

Finally, the relation of RCD and the detection threshold must be discussed. As already mentioned in the RESULTS section, a significantly positive correlation appeared between these two functions after removal from the sample of a subject with complete failure in discrimination tests, who had elevated PCa and PMg (Fig. 2). This means that a keener detection of NaCl concentration is accompanied by duller discrimination between NaCl concentrations in the subjects within normal ranges of PCa and PMg. The NaCl concentrations used for discrimination were 0.6 and 0.7%, or 100 and 120 mM, respectively; and the lowest concentration detected was 1 mM in the present subjects. Therefore, the neural response to NaCl concentrations in the discrimination tests might have been modified to result in a loss of discriminability in the cases more sensitive to changes in NaCl concentration. For clarification, we need to examine the discriminability using various NaCl concentrations with reference to the detection threshold. The reason we selected 0.6 and 0.7% as the test concentration for discrimination was that in the preliminary results, 70 to 80% of examinees responded correctly at these concentrations. These concentrations have practical significance in ordinary cooking of less salty dishes. If this discrimination test is useful for detecting mild zinc or vitamin-A deficiency, the optimum concentrations of NaCl can be searched for more extensively in relation to meticulous consideration of other nutritional parameters related to gustatory functions.

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