Interrelationship of Some Selected Nutritional Parameters Relevant to Taste for Salt in a Group of College-Aged Women

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Summary
Students in a women's college were investigated for taste acuity for salt, discrimination of salt concentrations in food, and anthropometrical (the body mass index, and systolic and diastolic blood pressures) and biochemical nutritional parameters (blood hemoglobin, plasma zinc, plasma copper, plasma vitamin A, plasma retinol-binding protein, urinary sodium, urinary potassium, urinary magnesium, urinary calcium and urinary zinc).

Among 95 students who participated in the test for discrimination of salt concentrations, which was repeated 6 times with 5 different test samples, only 43 (45.3%) committed no mistakes. The detection threshold for taste of salt was significantly associated with neither the discriminability of salt concentrations nor any biochemical parameters.

Levels of plasma zinc (PZn), urinary zinc (UZn) and plasma vitamin A (VA) were lower in the present subjects than in those reported previously. The rate of correct discrimination (RCD) was significantly correlated with PZn and VA positively, and with urinary sodium (UNa) and urinary potassium (UK) negatively. In the factor analysis to investigate the interrelationship of nutritional parameters, 6 factors with significance were extracted, among which factors 3 and 4 were related to RCD. Factor 3 had large loadings on VA, plasma retinol-binding protein (RBP) and RCD, and factor 4 was positively loaded on UNa and UK and negatively on UZn and RCD. In the stepwise multiple regression analysis (RCD being the dependent variable), significant independent
variables selected were VA, UK, PZn, systolic blood pressure and UNa. From these results, the college-aged women's failure in discriminating salt concentrations in food was likely to be related to (1) vitamin A inadequacy, (2) mild Zn deficiency and (3) excessive intakes of Na and K.

**Key Words** discrimination of salt concentrations in food, detection threshold for taste of salt, plasma vitamin A, plasma zinc, urinary sodium, urinary potassium, urinary zinc, college-aged women.

It is well recognized that zinc (Zn) status is closely associated with taste functions (1), and that vitamin A depletion is accompanied by loss of normal taste preference in rats (2) and decreased taste acuity in man (3). Moreover, Zn seems to be essential in vitamin A metabolism in man (4) and rats (5). However, taste acuity testing does not necessarily reveal the extent of Zn deficiency and some researchers rather expect that other aspects of gustatory sense, such as taste intensity perception or taste preference, will prove to be more reproducibly related to Zn nutrition than is the taste acuity threshold (6).

In recent times in Japan, young adult female populations aged in the low 20s have tended to be leaner than those in the high teens and of 25 years and over (7), which suggests that those females approaching age 20 are likely to make special efforts to become leaner. This may result in erroneous dieting and marginal or definite deficiencies for some nutrients in some cases: In actuality, a considerable percentage of new students in a women's college, who were apparently healthy and not showing any clinical signs, were not able to discriminate two levels (0.6 and 0.7%) of salt concentration in food (8). Therefore, assessment of nutritional status with reference to taste functions, especially Zn and vitamin A status, is of urgent necessity for such young women. If they were under the condition of marginal deficiency of vitamin A or Zn, the levels of vitamin A or Zn in plasma or in urine should be below the normal value or in the lower range of normal variation without giving rise to any apparent clinical signs of vitamin A or Zn deficiency. Thus, several nutritional parameters were selected for assessment of nutritional status and analysis of relationship to taste functions.

**SUBJECTS AND METHODS**

*Subjects.* One hundred and eighteen new students, studying dietetics in a women's college and aged 18 years in 1983, were studied for their taste acuity and discriminability of salt concentrations and other nutritional status with informed consent in a period from November 1983 to March 1984. The number of students participating in most of the biochemical examinations was 63.

*Detection threshold for the taste of NaCl.* A detection threshold, defined as the lowest concentration of test solution that can be distinguished from distilled water, was measured by presenting each test solution (6, 12 or 30 mmol NaCl/liter) to the student together with two solutions of distilled water (with precautions described by...
Henkin et al. (9) in March 1984).

**Discrimination of NaCl concentrations in food.** Five kinds of test samples (water solution, Japanese-style consomme soup, miso soup, boiled rice and boiled potato) were prepared so as to contain NaCl at a level of 0.6 or 0.7%. After preparation, samples randomly selected were measured for Na by atomic absorption spectrometry (the sample was oxidized before measurement when needed) to check actual concentration. The student was requested to state which of two samples of each foodstuff (served at room temperature) was more salty after tasting. This test was conducted on three different occasions from November to December 1983, and at any one time, two kinds of test sample were presented.

**Biochemical examinations.** Blood and urine were collected on a single occasion (two hours or more after lunch) in February, 1984. Hemoglobin concentration in blood was determined by the cyan-methemoglobin method. The blood taken into a heparinized tube from the cubital vein was separated into red blood cells and plasma by centrifugation and stored in a freezer in the dark until analysed. Zinc (Zn) and copper (Cu) concentrations in plasma were measured by flame atomic absorption spectrometry (Nikon Jarell Ash, Model AA-845) after appropriate dilution with distilled water. Retinol-binding protein (RBP) in plasma was estimated by radial immunodiffusion (10) using Partigen plates (Hoechst), and vitamin A was measured by fluorometry (11).

For singly voided urine samples, creatinine was colorimetrically measured using Jaffe's reaction (12), and urinary elemental concentrations were expressed as related to creatinine. Elements measured for urine were sodium (Na), potassium (K), magnesium (Mg), calcium (Ca) and Zn: All were measured by flame atomic absorption spectrometry.

Anthropometric data were obtained from the college's health examination records for 1983 and 1984.

**Statistical analysis.** Some parameters such as urinary Na, Mg, Ca and Zn concentrations expressed as related to creatinine and the individual's rate of correct discrimination in repeated tests for NaCl concentration in food showed skewness in their distribution; therefore, such urinary elemental concentrations were converted to the logarithm and the rate of correct answers was subjected to arcsine transformation for statistical analysis. Correlation analysis, factor analysis (the factoring method was the principal factor method without iteration, with varimax rotation), and stepwise regression analysis were applied to examine the interrelationship of nutritional parameters (13).

**RESULTS**

**Discrimination of NaCl concentrations and detection thresholds**

In six tests, rates of correct discrimination on a group basis varied from 74% for boiled rice to 92% for miso soup (Table 1). The extent of consistency of individual students' discriminability for different tests was low, the largest point
Table 1. Results of salt concentration discrimination.

| Test sample              | No. of students tested | Rate of correct discrimination (%) |
|-------------------------|------------------------|------------------------------------|
| Japanese-style consommé soup No.1 | 94                    | 81                                 |
|                         | No.2<sup>a</sup>        | 70                                 |
| Miso soup               | 99                    | 92                                 |
| NaCl water solution     | 94                    | 85                                 |
| Boiled rice             | 94                    | 74                                 |
| Boiled potato           | 98                    | 81                                 |

<sup>a</sup> Conducted on a different occasion from test of No. 1.

Table 2. Distribution of students by rate of correct discrimination.

| No. of correct discriminations | No. of tests participated in | No. of students |
|--------------------------------|-----------------------------|-----------------|
| 6/6                            | 6                           | 16              |
| 5/6                            | 5                           | 14              |
| 4/6                            | 4                           | 6               |
| 3/6                            | 3                           | 1               |
| 2/6                            | 2                           | 1               |
| 1/6                            | 1                           | 1               |
| 5/5                            | 5                           | 20              |
| 4/5                            | 4                           | 15              |
| 3/5                            | 3                           | 7               |
| 2/5                            | 2                           | 2               |
| 4/4                            | 4                           | 7               |
| 3/4                            | 3                           | 2               |
| 2/4                            | 2                           | 1               |

correlation coefficient between the results of two different tests being 0.385 ($p<0.001$) in the case of the test with boiled rice vs. the 2nd test using Japanese-style soup. The trials conducted on the same occasion only yielded weak but statistically significant correlations (coefficients: 0.226–0.385). The status of students in relation to menstruation, i.e., during, after, and just prior to menstruation, did not show any significant association with the correctness of discrimination, in every test done (data are not shown).

The number of subjects participating in all six tests was 41; in 5 tests, 44; and in 4 tests, 10. Among the 95 participants in 4 tests and more, the number of subjects...
Table 3. Detection threshold of taste for salt and discrimination of salt concentrations in food. Figures in the table show number of students belonging to each group, who participated in 4, 5 or 6 tests of discrimination and the threshold test.

| Detection threshold | Group by rate of correct discrimination |
|---------------------|----------------------------------------|
|                     | I(100%) | II(100 > 80%) | III(80 > 50%) | IV(50%) | Total |
| 6 mmol/liter        | 24      | 18            | 10           | 4       | 56    |
| 12 mmol/liter       | 7       | 3             | 3            | 2       | 15    |
| 30 mmol/liter       | 5       | 3             | 0            | 1       | 9     |
| Total               | 36      | 24            | 13           | 7       | 80    |

$\chi^2 = 3.172 \text{ (d.f.} = 6, \text{ } p > 0.05) \text{.}$

Table 4. Anthropometric data in 1983.

| Item                  | Group by salt discrimination | n  | Mean | Standard deviation | Range | ANOVA\(^a\) |
|-----------------------|------------------------------|----|------|--------------------|-------|-------------|
| Body mass index \((W, \text{ kg}/H^2, \text{ m}^2)\) | I 26 21.0 2.6 | 16.1 | 26.8 | 0.293 |
|                       | II 21 21.4 2.3 | 18.3 | 28.5 | $p = 0.830$ |
|                       | III 10 21.1 2.2 | 18.5 | 25.7 |
|                       | IV 7 21.8 2.1 | 19.8 | 25.9 |
|                       | Total 64 21.2 2.4 | 16.1 | 28.5 |
| Systolic blood pressure \((\text{mmHg})\) | I 26 110 13 | 90 | 136 | 0.855 |
|                       | II 21 109 12 | 90 | 132 | $p = 0.469$ |
|                       | III 10 113 7 | 98 | 120 |
|                       | IV 7 116 14 | 96 | 136 |
|                       | Total 64 111 12 | 90 | 136 |
| Diastolic blood pressure \((\text{mmHg})\) | I 26 70 9 | 56 | 80 | 1.303 |
|                       | II 21 68 9 | 58 | 80 | $p = 0.282$ |
|                       | III 10 75 11 | 60 | 86 |
|                       | IV 7 72 12 | 58 | 84 |
|                       | Total 64 70 9 | 56 | 86 |

\(^a\) ANOVA, analysis of variance. Rate of correct discrimination for salt concentrations is 100% in group I, 100 > 80% in group II, 80 > 50% in group III, and 50% in group IV.

who did not commit any mistakes was only 43 (45.3%). In Table 2, the distribution of subjects by the number of correct answers is shown, and there are several students who failed to discriminate different NaCl concentrations in more than half
of the trials.

In 69% of 90 tested students the detection threshold was concentrated at the level of 6 mmol/liter, though in 19% the level was 12 mmol/liter and in 11% the level was 30 mmol/liter. No significant association was found between the detection threshold and the rate of correct discrimination (Table 3).

**Anthropometrical parameters**

The body mass index (BMI), and systolic and diastolic blood pressures (SBP and DBP) of the students whose blood was examined are shown in Table 4, in which

| Item                  | Group by discrimination | n  | Mean | Standard deviation | Range min. | Range max. | ANOVA F-value |
|-----------------------|-------------------------|----|------|--------------------|------------|------------|---------------|
| Hemoglobin (g/dl)     | I                       | 26 | 13.3 | 0.8                | 11.0       | 14.8       | 0.172         |
|                       | II                      | 21 | 13.1 | 1.1                | 10.5       | 14.8       | p = 0.915     |
|                       | III                     | 10 | 13.2 | 0.3                | 12.8       | 14.0       |               |
|                       | IV                      | 7  | 13.1 | 0.6                | 12.6       | 14.4       |               |
|                       | Total                   | 64 | 13.2 | 0.8                | 10.5       | 14.8       |               |
| Plasma Zn (ng/ml)     | I                       | 26 | 743  | 86                 | 614        | 912        | 1.462         |
|                       | II                      | 21 | 732  | 85                 | 531        | 876        | p = 0.234     |
|                       | III                     | 10 | 682  | 72                 | 603        | 841        |               |
|                       | IV                      | 7  | 696  | 116                | 591        | 936        |               |
|                       | Total                   | 64 | 725  | 88                 | 531        | 936        |               |
| Plasma Cu (ng/ml)     | I                       | 26 | 814  | 127                | 605        | 1,166      | 0.652         |
|                       | II                      | 21 | 856  | 120                | 678        | 1,086      | p = 0.585     |
|                       | III                     | 10 | 834  | 113                | 690        | 1,016      |               |
|                       | IV                      | 7  | 867  | 78                 | 712        | 958        |               |
|                       | Total                   | 64 | 837  | 118                | 605        | 1,166      |               |
| Plasma RBP* (mg/dl)   | I                       | 26 | 4.8  | 0.7                | 3.4        | 5.9        | 0.603         |
|                       | II                      | 21 | 4.7  | 0.8                | 3.2        | 6.6        | p = 0.615     |
|                       | III                     | 10 | 4.5  | 0.7                | 3.5        | 5.6        |               |
|                       | IV                      | 7  | 4.8  | 1.1                | 2.9        | 6.6        |               |
|                       | Total                   | 64 | 4.7  | 0.8                | 2.9        | 6.6        |               |
| Plasma vitamin A (µg/dl) | I                     | 19 | 41.7 | 6.6                | 30.0       | 54.2       | 1.900         |
|                       | II                      | 17 | 39.6 | 5.9                | 26.2       | 50.8       | p = 0.143     |
|                       | III                     | 9  | 36.8 | 5.2                | 27.3       | 42.9       |               |
|                       | IV                      | 6  | 35.8 | 8.8                | 22.3       | 47.1       |               |
|                       | Total                   | 51 | 39.4 | 6.6                | 22.3       | 54.2       |               |

* RBP, retinol-binding protein.
only the data for 1983 are presented. BMI stayed almost unchanged from 1983 to 1984 and the correlation coefficient between 1983 and 1984 values was 0.886 ($p<0.001$). SBP fluctuated to some extent between the two examinations (correlation coefficient: 0.519, $p<0.001$), but DBP fluctuation had a non-significant correlation between 1983 and 1984 (correlation coefficient: 0.212, $p>0.05$). As is shown in the table, the breakdown of students according to the rate of correct discrimination of salt concentrations (RCD) does not reveal any significant differences among the groups in both BMI and blood pressures. However, the

Table 6. Urinary biochemical parameters.

| Item            | Group by salt discrimination | n | Mean | Standard deviation | Range min. | Range max. | ANOVA F-value |
|-----------------|------------------------------|---|------|--------------------|------------|------------|---------------|
| Urinary Na$^a$  | I                            | 25 | 3.2  | 1.4                | 1.7        | 6.1        | 2.088         |
| (g/g cr)        | II                           | 21 | 4.0  | 1.4                | 1.5        | 6.2        | $p=0.112$    |
|                 | III                          | 10 | 3.5  | 1.4                | 2.5        | 6.0        |               |
|                 | IV                           | 7  | 4.3  | 1.6                | 2.5        | 8.2        |               |
|                 | Total                        | 63 | 3.6  | 1.4                | 1.5        | 8.2        |               |
| Urinary K       | I                            | 25 | 1.7  | 0.6                | 0.5        | 2.8        | 2.650         |
| (g/g cr)        | II                           | 21 | 1.8  | 0.7                | 0.7        | 3.1        |               |
|                 | III                          | 10 | 1.7  | 0.4                | 1.0        | 2.3        | $p=0.057$    |
|                 | IV                           | 7  | 2.4  | 1.0                | 1.4        | 3.9        |               |
|                 | Total                        | 63 | 1.8  | 0.7                | 0.5        | 3.9        |               |
| Urinary Mg$^a$  | I                            | 25 | 70   | 1.5                | 32         | 122        | 0.733         |
| (mg/g cr)       | II                           | 21 | 77   | 1.3                | 49         | 167        |               |
|                 | III                          | 10 | 83   | 1.5                | 47         | 181        | $p=0.537$    |
|                 | IV                           | 7  | 77   | 1.4                | 53         | 133        |               |
|                 | Total                        | 63 | 75   | 1.4                | 32         | 181        |               |
| Urinary Ca$^a$  | I                            | 25 | 112  | 1.5                | 48         | 176        | 0.559         |
| (mg/g cr)       | II                           | 21 | 125  | 1.5                | 63         | 249        | $p=0.644$    |
|                 | III                          | 10 | 139  | 2.0                | 29         | 444        |               |
|                 | IV                           | 7  | 127  | 1.7                | 56         | 226        |               |
|                 | Total                        | 63 | 122  | 1.6                | 29         | 444        |               |
| Urinary Zn$^a$  | I                            | 25 | 203  | 1.9                | 55         | 683        | 0.276         |
| (μg/g cr)       | II                           | 21 | 176  | 2.2                | 26         | 438        | $p=0.843$    |
|                 | III                          | 10 | 207  | 2.4                | 56         | 795        |               |
|                 | IV                           | 7  | 228  | 2.5                | 88         | 844        |               |
|                 | Total                        | 63 | 197  | 2.1                | 26         | 844        |               |

$^a$To rectify the skewness of their distribution, the values were converted to the logarithm. Thus, the geometric mean and its standard deviation are shown in the table. cr, creatinine.
breakdown of students by detection threshold for salt taste showed a significant difference between the lowest threshold (6 mmol NaCl/liter) group and others in BMI; i.e., the average in the former was 21.7 and that in the latter 19.9 (t = 2.48, two-tailed probability: 0.016), but this was not the case for SBP and DBP.

**Biochemical parameters**

Among blood biochemical parameters examined, the items with decreasing levels paralleling the worsening of salt concentration discrimination were plasma Zn (PZn) and plasma vitamin A (VA), although no significant variations were detected among the groups by one-way analysis of variance (ANOVA) (Table 5).

Except for urinary K (UK), urinary elemental concentrations were transformed to the logarithm for statistical purposes as already mentioned. By ANOVA, the variation among the different discrimination rate groups seems not to be negligible in the case of UK, in which the group of the worst discrimination (group IV) had the highest UK level (Table 6). In urinary Na (UNa), the level tended to increase in the groups of worse discrimination without showing a significant variation in ANOVA. No results worthy of note were obtained for other elements such as Mg, Ca and Zn.

For all the biochemical parameters, the breakdown of students by detection threshold did not show any significant difference between the groups.

**Results of correlational analysis**

Significant, but not very strong, correlations with RCD were found for PZn and VA, positively, and for UNa and UK, negatively (Table 7). In this correlation matrix, other interesting correlations of significance were recognized in such pairs as SBP vs. BMI, PZn vs. HB, PZn vs. RBP, PZn vs. UZn, RBP vs. HB, RBP vs. VA, UCa vs. UNa and UCa vs. UZn. These indicate the interrelationship of nutritional status regarding protein, Zn and vitamin A on the one hand, and the intimacy of Ca, Mg and Na in their urinary excretion on the other.

**Results of factor analysis**

Using the correlation matrix of Table 7, factor analysis was conducted (Table 8). There were 6 extracted factors with an eigenvalue of over 1.0: Factor 1 had the largest loadings on UCa and UMg, then on UZn; factor 2 was the factor of blood pressures; the third had the largest loading on vitamin A, then next on RBP and RCD; the fourth had large positive loadings on UNa and UK and relatively large negative loadings on UZn and RCD; the fifth had large loadings on HB, PZn, UZn and RBP; and finally, the sixth had large loadings on BMI and PCu. Among these items, a small communality was observed for both UNa and PZn, which indicates their relative uniqueness among the items examined.

Factors 3 and 4 were those which loaded to a fairly great extent on RCD. Thus, the calculated factor scores for the individual students in terms of factors 3 and 4 are shown in Fig. 1. When the students are broken down into 4 groups according to
Table 7. Correlation matrix between nutritional parameters.

|     | BMI   | SBP   | DBP   | HB    | PZn   | PCu   | RBP   | VA    | UNa   | UK    | UMg   | UCa   | UZn   |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| BMI | -0.122| -0.122| -0.084| 0.082 | 0.268*| -0.158| 0.123 | 0.309*| -0.255*| -0.269*| -0.174| -0.116| -0.020|
| SBP | 0.312*| -0.007| 0.048 | -0.071| 0.500*| -0.055| -0.096| -0.034| -0.024 | -0.256*| -0.046| -0.185|       |
| DBP |       |       | 0.633***| 0.019 | -0.026| 0.156 | 0.103 | 0.234 | 0.123 | -0.079 | -0.129 | 0.052 | 0.025 |
| HB  |       |       |       | 0.116 | 0.014 | 0.094 | 0.113 | 0.163 | 0.070 | -0.175 | -0.081 | -0.027 | 0.125 |
| PZn |       |       |       |       | 0.325**| 0.063 | 0.283*| -0.011| -0.016 | -0.010 | -0.076 | -0.096 | 0.195 |
| PCu |       |       |       |       |       | 0.167 | 0.255*| -0.058| 0.036 | -0.106 | -0.054 | 0.262*|       |
| RBP |       |       |       |       |       |       | 0.116 | 0.136 | 0.166 | 0.048 | 0.063 | 0.145 | 0.183 |
| VA  |       |       |       |       |       |       |       | 0.581***| 0.178 | 0.213 | -0.059 | -0.085 | 0.074 |
| UNa |       |       |       |       |       |       |       |       | 0.129 | 0.217 | 0.059 | 0.077 | 0.142 |
| UK  |       |       |       |       |       |       |       |       |       | 0.223 | 0.233 | 0.331**| -0.172 |
| UMg |       |       |       |       |       |       |       |       |       |       | 0.147 | 0.198 | -0.259*|
| UCa |       |       |       |       |       |       |       |       |       |       |       | 0.507***| 0.143 |
| UZn |       |       |       |       |       |       |       |       |       |       |       |       | 0.074 |

RCD, rate of correct discrimination (arc sine converted); BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HB, hemoglobin; PZn, plasma Zn; PCu, plasma Cu; RBP, plasma retinol-binding protein; VA, plasma vitamin A; UNa, urinary Na (log converted); UK, urinary K; UMg, urinary Mg (log converted); UCa, urinary Ca (log converted); UZn, urinary Zn (log converted). *,**,***: p<0.05, p<0.01, p<0.001, respectively.
Table 8. Results of factor analysis after varimax rotation.

| Item | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Communality |
|------|----------|----------|----------|----------|----------|----------|-------------|
| RCD  | -.215    | -.239    | .633     | -.467    | .001     | -.115    | .736        |
| BMI  | -.310    | .093     | -.129    | .059     | -.130    | .803     | .787        |
| SBP  | -.059    | .843     | .112     | .025     | -.089    | .271     | .809        |
| DBP  | -.014    | .896     | .039     | -.076    | .091     | -.071    | .824        |
| HB   | -.168    | .090     | -.068    | .102     | .785     | -.029    | .669        |
| PZn  | -.038    | -.140    | .226     | -.111    | .703     | .113     | .592        |
| PCu  | .286     | .074     | .074     | .023     | .231     | .766     | .734        |
| RBP  | -.097    | .135     | .647     | .369     | .401     | -.026    | .743        |
| VA   | .139     | .198     | .882     | .130     | .005     | .022     | .854        |
| UNa  | .347     | .193     | .027     | .608     | -.034    | .044     | .531        |
| UK   | .089     | -.214    | .130     | .777     | .024     | .024     | .675        |
| UMG  | .809     | -.089    | -.049    | .114     | -.046    | -.158    | .706        |
| UCa  | .765     | -.009    | .023     | .157     | -.134    | .133     | .646        |
| UZn  | .419     | .147     | .036     | -.494    | .516     | -.008    | .708        |

Eigenvalue: 2.24 2.13 1.83 1.47 1.32 1.03
Rate of contribution (%): 16.0 15.2 13.1 10.5 9.4 7.3

Table 9. Results of stepwise regression analysis.

| Dependent variable | Independent variables | R    | Beta   | F-value |
|--------------------|-----------------------|------|--------|---------|
| RCD                | VA                    | .309 | .514   | 17.6*** |
|                    | UK                    | .463 | -.443  | 12.6*** |
|                    | PZn                   | .528 | .313   | 7.1*    |
|                    | UZn                   | .587 | -.324  | 6.7*    |
|                    | SBP                   | .638 | -.232  | 3.9#    |
|                    | UNa                   | .675 | -.232  | 3.9#    |

*R*, multiple correlation coefficient.

**Beta**, standardized partial regression coefficient.

***, *p* < 0.001; *, *p* < 0.05; #, *p* < 0.1.

Other abbreviations, see Table 7.

RCD, the distribution of each group on the plane formulated by factors 3 and 4 gradually shifts in the direction of quadrant II to quadrant IV: Most of the students in group I are uniformly distributed in quadrant II, and group IV is mainly located in quadrant IV. The pattern of scattering of students who belong to group IV on
Results of stepwise multiple regression analysis

As an additional approach to reveal the details of the interrelationship of nutritional parameters, stepwise regression analysis was conducted by adopting RCD as a dependent variable and other parameters as independent variables. Independent variables selected as being significant were VA, UK, PZn, UZn, SBP and UNa (Table 9). The standardized regression coefficient took positive values in VA and PZn and negative ones in UK, UZn, SBP and UNa.

DISCUSSION

Most of the parameters except for PZn, UZn and VA had levels in the range described in the literature on the group basis. The present levels of PZn and UZn seem to be either slightly or greatly lower than the reported values; e.g., Yamane stated that normal plasma Zn levels in female Japanese were $779 \pm 40 \text{ ng/ml}$ (14) and
According to Okada (15) normal daily urinary Zn excretion was in the range of 300 to 800 µg. Thus, it is probable that some subjects with low levels of PZn or UZn in the present study may have had mild Zn deficiency.

According to Muto (16), the level of plasma retinol concentrations, 15–30 µg/dl, may reflect the condition of marginal vitamin A deficiency, and the present average, about 40 µg/dl, is not far from this upper margin. Further, of interest was the fact that the minimum value of plasma vitamin A in the group of RCD 100%, was 30 µg/dl. When a subject showed the VA level above this value, they were judged as normal in their vitamin A status in the human experiment conducted in Iowa, U.S.A. (3), and from the results of dosing of vitamin A in Brazilian children, the serum levels of vitamin A from 20 to 30 µg/dl were considered to suggest inadequate vitamin A status (17).

By correlation analysis, RCD (arcsine transformed value) was significantly correlated with each of VA, PZn, UK and UNa; in the factor analysis, RCD kept a close position to RBP in the factor 3 loading and was close to UZn at a contrastingly reverse position from UK and UNa in the factor 4 loading; and stepwise multiple regression analysis revealed that the significant partial regression coefficients were VA, UK, PZn, UZn, SBP and UNa in the equation (dependent variable: RCD). From these results, it is likely that students' failure to discriminate salt concentration in food is related to (1) inadequate vitamin A status, (2) mild Zn deficiency and (3) relatively excessive intakes of Na and K, and that these three exert an effect independently of each other. The low levels of VA and Zn, which were previously discussed, also support the above thinking. Of incidental note is that neither RCD nor any of the biochemical parameters showed an association with the detection threshold for salt taste; therefore, we are tempted to say that RCD is more sensitive than the detection threshold to marginal deficiencies of Zn or VA. However, the detection threshold was tested one to three months after the conclusion of the discrimination test and biochemical examinations. Only after evaluating the influence of such time-lag, we can definitely compare the detection threshold with the discrimination for sensitivity to Zn or VA deficiencies. In relation to this, Pangborn and Pecore (18) claimed that discrimination and intensity of perception for salt concentrations were independent behavioral measures. Their findings, if related to nutritional status of Zn and VA, may be useful for interpreting the present results.

In interpreting the Zn values in plasma and urine, the results of the stepwise multiple regression analysis give rise to an interesting suggestion. There was a significant positive correlation between UZn and PZn, but the partial regression coefficient of PZn had a positive value and that of UZn, on the contrary, a negative value, meaning that the increase of urinary Zn excretion is parallel with a worsening of discrimination when the level of PZn is constant. Thus, we have to be careful in interpreting the UZn value as an index of Zn nutrition. It must be evaluated simultaneously with PZn.

The relationship of VA and RBP in plasma and its implication to RCD is also
of interest. The correlation coefficient between VA and RBP was 0.581, not as high as described in the literature (19, 20), presumably because the present subjects were apparently healthy and the range of RBP and VA values was very narrow compared to literature cases including patients with low RBP and VA values. As the determinant of RCD in the regression analysis, VA, but not RBP, was significant. Since the biological half-life of VA (154 days) is far longer than that of RBP, 12–16 h (16), the VA status at the testing of discrimination which was conducted two to three months before the biochemical examination might have been better reflected on the level of VA rather than that of RBP. Aside from its role as an indicator of vitamin A status, RBP showed a significant correlation with HB, which suggests role of RBP as an indicator of protein nutrition index.

Finally, we discuss the test condition of salt concentration discrimination in relation to the effect of excessive intake of Na and K. This may also relate to the validity of our discriminability testing. The salt concentrations in test food were set at 0.6 and 0.7%, which must have been less than those encountered in normal meals (27). The students who prefer salty food might be liable to fail on discrimination of less salty foods, since changes in salt taste were recognized in the subjects who maintained a low sodium diet artificially for 5 months (22). However, the reason why the excessive intake of K, presented as elevated UK excretion, was related to RCD is obscure. Coincidental intakes of Na and K, a deficit of Zn supply by high K diet, or some direct effect on taste functions for salt by different levels of K intake should be examined in further studies. The present discrimination test was conducted using only two test-batches, each having a different salt concentration. The result obtained using this test condition is certainly liable to be influenced by examinees’ psychological states. Thus, the lack or weakness of individuals’ consistency in discrimination may have partly resulted from this test procedure, and therefore we repeated the test six times changing the kind of test sample. If we use three, instead of two, batches, two of which have identical concentrations as in the detection threshold test, for the test of discrimination, it may increase the precision and the reproducibility of results. This is now under examination in our laboratory.

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REFERENCES

1) Henkin, R. I. (1984): Zinc in taste function, A critical review. Biol. Trace Element Res., 6, 263–280.

2) Bernard, R. A., and Halpern, B. P. (1968): Taste changes in vitamin A deficiency. J. Gen. Physiol., 52, 444–464.

3) Sauberlich, H. E., Hodges, R. E., Wallace, D. L., Kolder, H., Canham, J. E., Hood, J., Vol. 31, No. 6, 1985
Raica, N., Jr., and Lowry, L. K. (1974): Vitamin A metabolism and requirements in the human studied with the use of labeled retinol. *Vitam. Horm.*, **32**, 251–275.

4) Smith, J. C., Jr., McDaniel, E. G., Fan, F. F., and Halsted, J. A. (1973): Zinc: A trace element essential in vitamin A metabolism. *Science*, **181**, 954–955.

5) Smith, J. C., Jr., Brown, E. D., McDaniel, E. G., and Chan, W. (1976): Alterations in vitamin A metabolism during zinc deficiency and food and growth restriction. *J. Nutr.*, **106**, 569–574.

6) Solomons, N. W. (1979): On the assessment of zinc and copper nutriture in man. *Am. J. Clin. Nutr.*, **32**, 856–871.

7) Koseisho Koshueiseikyoku Eiyoka (eds.) (1984): *Kokumin Eiyono-Genjo, Showa 59 nen Ban, Showa 57 nen Kokumin Eiyo Chosa Seiseki* (in Japanese). Daichi Shuppan, Tokyo.

8) Takahashi, H., Ishida, H., and Suzuki, H. (1984): Instable discriminability for the salt taste in young female adults. Abstracts of the 38th General Assembly of Japanese Society of Nutrition and Food Science in Kyoto (Abstract in Japanese).

9) Henkin, R. I., Gill, J. R., Jr., and Bartter, F. C. (1963): Studies of taste thresholds in normal man and in patients with adrenal cortical insufficiency: The role of adrenal cortical steroids and of serum sodium concentration. *J. Clin. Invest.*, **42**, 727–735.

10) Mancini, G., Carbonara, A. O., and Heremans, J. F. (1965): Immunochemical quantitation of antigens by single radial immunodiffusion. *Immunochemistry*, **2**, 235–254.

11) Thompson, J. N., Erdody, P., Brien, R., and Murray, T. K. (1971): Fluorometric determination of vitamin A in human blood and liver. *Biochem. Med.*, **5**, 67–89.

12) Bonsnes, R. W., and Taussky, H. H. (1945): On the colorimetric determination of creatinine by the Jaffe reaction. *J. Biol. Chem.*, **158**, 581–591.

13) Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., and Bent, D. H. (1975): *Statistical Package for the Social Sciences*, 2nd Ed., McGraw-Hill, Inc., New York, pp. 276–508.

14) Yamane, Y. (1982): Metabolism and functions of essential metals, (b) Zinc. *Rinshoi (Med. Clin. Jpn.)*, **8**, 1544–1546.

15) Okada, J. (1982): Measurements of trace metals in blood and urine and interpretation of data, (b) Zinc. *Rinshoi (Med. Clin. Jpn.)*, **8**, 1627–1630.

16) Muto, Y. (1982): Metabolic characteristics in marginal vitamin A deficiency and its countermeasures. *Nihon Rinsho Eiyo Gakkai Zasshi (Jpn. J. Clin. Nutr.)*, **3**, 9–17.

17) Flores, H., Campos, F., Araujo, C. R. C., and Underwood, B. A. (1984): Assessment of marginal vitamin A deficiency in Brazilian children using the relative dose response procedure. *Am. J. Clin. Nutr.*, **40**, 1281–1289.

18) Pangborn, R. M., and Pecore, S. D. (1982): Taste perception of sodium chloride in relation to dietary intake of salt. *Am. J. Clin. Nutr.*, **35**, 510–520.

19) Vahlquist, A., Sjolund, K., Norden, A., Peterson, P. A., Stigmar, G., and Johansson, B. (1978): Plasma vitamin A transport and visual dark adaptation in diseases of the intestine and liver. *Scand. J. Clin. Lab. Invest.*, **38**, 301–308.

20) Kashiwazaki, O., Kubo, H., and Nagao, F. (1982): Pathophysiological status, surgical insults and vitamin A in surgery. *Nihon Rinsho Eiyo Gakkai Zasshi (Jpn. J. Clin. Nutr.)*, **3**, 23–30.

21) Sasaki, N., and Kikuchi, R. (1980): *Shokuen to Eiyo (Salt and Nutrition)*. Dai Ichi Shuppan, Tokyo, pp. 145–175.

22) Bertino, M., Beauchamp, G. K., and Engelman, K. (1982): Long-term reduction in dietary sodium alters the taste of salt. *Am. J. Clin. Nutr.*, **36**, 1134–1144.