Validity of a Self-administered Food Frequency Questionnaire Used in the 5-year Follow-up Survey of the JPHC Study Cohort I to Assess Carotenoids and Vitamin C Intake: Comparison with Dietary Records and Blood Level

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We compared carotene and vitamin C intake assessed with our 138-item food frequency questionnaire (FFQ) against 28-day weighed dietary records among a subgroup of JPHC Study Cohort I (102 men and 113 women), and the corresponding serum carotenoid levels or plasma vitamin C levels (86 men and 100 women). Correlation coefficients between carotenoids or vitamin C intake estimated from FFQ and intakes estimated from DR were as follows in men and women, respectively: alpha-carotene, $r=0.47$ and $r=0.46$; beta-carotene, $r=0.40$ and $r=0.30$; lycopene, $r=0.18$ and $r=0.22$; vitamin C, $r=0.44$ and $r=0.31$. Correlation coefficients between carotenoids or vitamin C intake estimated from FFQ and the corresponding serum carotenoids levels or plasma vitamin C levels were as follows: alpha-carotene, $r=0.38$ and $r=0.30$; beta-carotene, $r=0.28$ and $r=0.11$; lycopene, $r=0.30$ and $r=0.19$; vitamin C, $r=-0.07$ and $r=0.06$; in men and women, respectively. These data indicated carotenoid and vitamin C intakes estimated from FFQ were associated with intake from DR, although the association was weak for lycopene. Carotenoid intake estimated from FFQ were associated with corresponding serum carotenoid levels in men, but the correlation was weak in women except for alpha-carotene. Both in men and women, no association was observed for plasma vitamin C levels. J Epidemiol 2003;13(Suppl):S82-S91.

Key words: carotenoid, vitamin C, validity, food frequency questionnaire, dietary record, blood.

MATERIALS AND METHODS

The study design and subject characteristics have been reported elsewhere in this Supplement. The methods for surveying dietary records and for computing nutrient intakes from FFQ have also been described therein.

Carotenoid and Vitamin C Intake Calculations

The daily intakes of total carotenoids and vitamin C were calculated using the Standard Tables of Food Composition in Japan. The daily intakes of specific carotenoids, such as alpha-carotene, beta-carotene and lycopene, were calculated using our new carotene database.

Laboratory Measurements

The details of blood collection have been presented elsewhere in this report. Briefly, the blood was collected just before winter or just after summer 7-day DR. The plasma and serum samples were stored in separate tubes and stored at -80°C until analysis. Plasma collected in February, was stabilized by metaphosphoric acid for ascorbic acid measurement.

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Serum carotenoids were quantified by high-performance liquid chromatography (HPLC) using a previously-described modified method. Briefly, the components were extracted by shaking and mixing for 30 min after addition of each of the following: 250 μL of water, 500 μL of ethyl alcohol, 4 mL of n-hexane, and 400 μL of serum. After centrifugation, the n-hexane layer was dried with N2 gas. To determine carotenoids (alpha-carotene, beta-carotene, lycopene), the residue was dissolved in 30 μL of dichloromethane and 200 μL of the mixed solvent. Then, 200 μL of the solution was applied to a HPLC (Waters, Milford, Mass) with the following conditions: C18 reverse phase column, Wakopak (Wako, Osaka, Japan); mobile phase, methanol: acetonitrile: water=60:40:1; UV wavelength, 450; flow rate, 1.0 ml/min.

Plasma ascorbic acid was measured by spectrophotometer using a modified method described previously. Briefly, 450 μL of the samples was sequentially mixed with 0.15 mL of 0.15% dithiothreitol, 0.15 mL of 0.5% N-ethylmaleimide, and 0.75 mL of trichloroacetic acid. After centrifugation, the supernatant was mixed with 0.75 mL of a chromogen (phosphate: water: 1.8%FeCl3: 4%dipyridyl=1:1:1:2), incubated at 37°C for 30 min, and then the optical density at 525 nm was measured with a UV/Vis spectrophotometer (V-550, Nihon Bunko, Tokyo, Japan).

Statistical Analysis

The subjects of this study were 215 persons (102 men and 113 women). Both their FFQ for the validation study and the complete DR (14-day records in Ishikawa PHC area and 28-day records on other 3 areas) were included in this analysis. As for the analysis using the serum carotenoid level, 186 subjects (86 men and 100 women) were measured twice (Feb. and Aug.). For their plasma ascorbic acid use, 185 subjects (86 men and 99 women) were measured (Feb.).

The mean, SD and median intakes for carotenoids (alpha-carotene, beta-carotene, lycopene) and vitamin C from the FFQ and DRs were calculated by sex and area. The Spearman rank correlation was used to assess the association between carotenoid and vitamin C intake from FFQ and from DR. Serum carotenoids and plasma vitamin C were presented as mean, SD and median by sex and area. The Spearman correlation was again used, this time to examine the association between intakes (carotenoids and vitamin C assessed by FFQ or DR) and blood levels (serum carotenoids and plasma ascorbic acid). The mean intake of carotenoids and vitamin C assessed by DR and the mean biochemical indicator concentrations were calculated according to quintile of intake assessed with FFQ. All statistical analyses were performed using the SAS statistical software package.

RESULTS

Table 1 shows carotenoid and vitamin C intakes by sex and area estimated from the DR. In men, alpha-carotene and beta-carotene intakes were highest in the Ishikawa PHC area. Lycopene intakes were highest in the Ninohe PHC area. In women, no apparent area-difference was observed for carotenoid intake except that alpha-carotene intake was the highest in the Ishikawa PHC area. No apparent area-difference was observed for vitamin C intakes both in men and women.

Table 2 shows carotenoid and vitamin C intakes by sex and area estimated from FFQ. No apparent area-difference was observed for any carotenoid and vitamin C intakes in either men

| Table 1. Carotenoid intakes (μg/day) and vitamin C intakes (mg/day) assessed with DR1 for 28 or 14 days by area |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                 | Ninohe PHC | Yokote PHC | Sakura PHC | Ishikawa PHC | ANOVA |
|                                 | Mean ± SD  | Median         | Mean ± SD  | Median         | Mean ± SD  | Median         | Mean ± SD  | Median         | Mean ± SD  | Median         | p-value |
| Men (n=102)                     |             |                |             |                |             |                |             |                |             |                |        |
| Carotene                        | 3564 ± 1330 | 3304           | 2503 ± 798 | 2441           | 3174 ± 874 | 2972           | 3902 ± 1616 | 3919           | 0.0003     |             |
| Alpha-carotene                  | 507 ± 251   | 446            | 286 ± 115  | 271            | 352 ± 152  | 308            | 669 ± 333   | 652            | 0.0001     |             |
| Beta-carotene                   | 2726 ± 1055 | 2476           | 2021 ± 697 | 1919           | 2578 ± 724 | 2516           | 3111 ± 1310 | 3007           | 0.0011     |             |
| Lycopene                        | 4336 ± 4230 | 3042           | 2515 ± 1551| 1966           | 2456 ± 1342| 2292           | 2622 ± 2531 | 1844           | 0.0414     |             |
| Vitamin C                       | 122 ± 38    | 115            | 122 ± 34   | 123            | 139 ± 40   | 134            | 134 ± 45   | 130            | 0.3083     |             |
| Women (n=113)                   |             |                |             |                |             |                |             |                |             |                |        |
| Carotene                        | 3314 ± 1471 | 3126           | 2773 ± 941 | 2658           | 3109 ± 972 | 2837           | 3573 ± 1505 | 3746           | 0.1000     |             |
| Alpha-carotene                  | 446 ± 236   | 359            | 337 ± 169  | 288            | 358 ± 142  | 319            | 581 ± 260  | 571            | 0.0001     |             |
| Beta-carotene                   | 2597 ± 1218 | 2386           | 2241 ± 766 | 2038           | 2514 ± 807 | 2332           | 2860 ± 1241 | 2888           | 0.1537     |             |
| Lycopene                        | 395 ± 3004  | 3241           | 2832 ± 1894| 2125           | 3243 ± 2262| 2628           | 3261 ± 3412 | 2085           | 0.4721     |             |
| Vitamin C                       | 128 ± 44    | 114            | 133 ± 36   | 127            | 146 ± 46   | 138            | 139 ± 71   | 117            | 0.5870     |             |

1 DR, dietary records.
Table 3 shows mean and median serum carotenoid and plasma vitamin C levels by sex and area. In men, the serum beta-carotene level was highest in the Saku PHC area. In women, the serum alpha-carotene level was highest in the Ishikawa PHC area and the serum beta-carotene level was highest in the Saku PHC area. Both in men and women, the plasma vitamin C level was highest in the Ninohe PHC area.

Table 4 shows intake levels of carotenoids and vitamin C estimated from DR and FFQ in 4 areas. Both in men and women, total carotene, beta-carotene, lycopene and vitamin C intakes estimated from FFQ were higher than intake from DR except for lycopene in women. Table 4 also presents the relation between carotenoid and vitamin C intake estimated from FFQ, and carotenoids and vitamin C intake estimated from DR. Spearman rank correlation coefficients between carotenoid or vitamin C intake estimated from FFQ and intakes estimated from DR were as follows: alpha-carotene, r=0.47 and r=0.46; beta-carotene,
Table 4. Carotenoid intakes (µg/day) and vitamin C intakes (mg/day) assessed with DR¹ for 28 or 14 days and FFQ² in 4 areas and correlations

| Sex         | DR Mean ± SD | Median | FFQ Mean ± SD | Median | % difference | Spearman correlation | Energy-adjusted¹ |
|-------------|--------------|--------|---------------|--------|--------------|----------------------|------------------|
| Men (n=102) |              |        |               |        |              |                      |                  |
| Carotene    | 3274 ± 1305  | 2885   | 3814 ± 3126   | 3320   | 16           | 0.38                 | 0.36             |
| Alpha-carotene | 454 ± 273   | 357    | 561 ± 545     | 398    | 23           | 0.47                 | 0.47             |
| Beta-carotene | 2601 ± 1052 | 2314   | 3044 ± 2582   | 2556   | 17           | 0.40                 | 0.41             |
| Lycopene    | 2965 ± 2715  | 2121   | 3386 ± 4636   | 1296   | 14           | 0.18                 | 0.19             |
| Vitamin C   | 129 ± 39      | 127    | 166 ± 118     | 157    | 29           | 0.44                 | 0.42             |
| Women (n=113)|             |        |               |        |              |                      |                  |
| Carotene    | 3184 ± 1262  | 2870   | 4105 ± 3029   | 3358   | 29           | 0.31                 | 0.33             |
| Alpha-carotene | 429 ± 226    | 348    | 579 ± 495     | 433    | 35           | 0.46                 | 0.50             |
| Beta-carotene | 2547 ± 1037  | 2344   | 3290 ± 2493   | 2789   | 29           | 0.30                 | 0.32             |
| Lycopene    | 3309 ± 2689  | 2450   | 3148 ± 4942   | 1438.86| -5           | 0.22                 | 0.11             |
| Vitamin C   | 137 ± 50      | 127    | 192 ± 159     | 156    | 41           | 0.31                 | 0.22             |

¹ DR, dietary records.
² FFQ, food frequency questionnaire.
³ Energy was adjusted by residual model for intake.
For n=102, r>0.20 = p<0.05, r>0.26 = p<0.01, r>0.33 = p<0.001.
For n=113, r>0.19 = p<0.05, r>0.25 = p<0.01, r>0.31 = p<0.001.

Table 5. Mean intake of carotenoids and vitamin C from DR¹ within quintile of intake determined by FFQ²

| Sex         | Lowest Carotenoids | Second Carotenoids | Third Carotenoids | Fourth Carotenoids | Highest Carotenoids | Vitamin C |
|-------------|--------------------|--------------------|-------------------|--------------------|---------------------|-----------|
|             | Mean ± SD          | Mean ± SD          | Mean ± SD         | Mean ± SD          | Mean ± SD           | Mean ± SD |
| Men         |                    |                    |                   |                    |                     |           |
| Carotene    | 2541 ± 950         | 3067 ± 1185        | 3528 ± 1591       | 3365 ± 1115        | 3877 ± 1329         | 103 ± 30  |
| Alpha-carotene | 320 ± 197          | 331 ± 147          | 477 ± 266         | 538 ± 349          | 608 ± 260           | 130 ± 42  |
| Beta-carotene | 2073 ± 692         | 2329 ± 954         | 2796 ± 1292       | 2602 ± 791         | 3219 ± 1140         | 120 ± 27  |
| Lycopene    | 2423 ± 1812        | 2801 ± 2895        | 2626 ± 1761       | 2823 ± 2080        | 4115 ± 4140         | 134 ± 36  |
| Vitamin C   | 103 ± 30            | 130 ± 42           | 120 ± 27          | 134 ± 36           | 158 ± 41            | 158 ± 41  |
| Women       |                    |                    |                   |                    |                     |           |
| Carotene    | 2604 ± 1012        | 3021 ± 1092        | 3142 ± 1169       | 3581 ± 1624        | 3561 ± 1151         | 2604 ± 1012|
| Alpha-carotene | 319 ± 197          | 356 ± 169          | 456 ± 227         | 450 ± 220          | 565 ± 243           | 319 ± 197 |
| Beta-carotene | 2092 ± 822         | 2489 ± 841         | 2556 ± 1200       | 2732 ± 1189        | 2860 ± 983          | 2092 ± 822|
| Lycopene    | 3329 ± 3641        | 2726 ± 2303        | 3617 ± 3065       | 3068 ± 2109        | 3831 ± 2102         | 3329 ± 3641|
| Vitamin C   | 122 ± 44            | 127 ± 65           | 138 ± 43          | 145 ± 44           | 151 ± 52            | 122 ± 44  |

¹ DR, dietary records.
² FFQ, food frequency questionnaire.
³ Ratio compared to lowest quintile.
r=0.40 and r=0.30; lycopene, r=0.18 and r=0.22; vitamin C, r=0.44 and r=0.31; in men and women, respectively. No improvement in the correlation coefficient was observed when intakes were expressed as energy-adjusted value.

Table 5 shows the mean carotenoid and vitamin C intake estimated from DR within quintiles of corresponding carotenoid and vitamin C intake estimated from FFQ. In men, the mean intake in the highest quintile was 1.5 times higher or more than in the lowest quintile for any carotenoid and vitamin C. In women, only alpha-carotene was more than 1.5 times higher. A steady increase in mean intake from the lowest to the highest quintile was observed for alpha-carotene in men and beta-carotene in women. The result of cross-classification of the subjects by quintiles from carotenoids and vitamin C intake from DR and carotenoids and

Table 6. Comparison of FFQ\(^1\) with DR\(^2\) for carotenoids and vitamin C based on joint classification by quintile (%)  

| Carotenoids       | Men (n=102) | Women (n=113) |
|-------------------|-------------|---------------|
|                   | Same category | Adjacent category | Extreme category | Same category | Adjacent category | Extreme category |
| Carotene          | 30          | 71             | 4              | 24          | 63             | 3              |
| Alpha-carotene    | 29          | 71             | 3              | 25          | 70             | 2              |
| Beta-carotene     | 30          | 69             | 5              | 24          | 60             | 4              |
| Lycopene          | 17          | 61             | 6              | 27          | 62             | 5              |
| Vitamin C         | 36          | 73             | 1              | 26          | 66             | 4              |

\(^1\) FFQ, food frequency questionnaire.  
\(^2\) DR, dietary records.

Table 7. Serum Carotenoid (mg/ml) and plasma vitamin C (mg/dl) in 4 areas and correlations with carotenoid intakes, vitamin C intakes assessed with either DR\(^1\) and FFQ\(^2\)  

| Sex     | Carotenoids | Mean | SD | Median | Spearman correlation |
|---------|-------------|------|----|--------|----------------------|
|         |             |      |    |        | DR | FFQ  |
|         |             | crude | energy-adjusted\(^3\) | crude | energy-adjusted\(^3\) |
| Men (n=86) | Total carotene | 0.35  | 0.25 | 0.27 | 0.25 | 0.25 | 0.30 | 0.21 |
|         | Alpha-carotene | 0.06  | 0.03 | 0.05 | 0.38 | 0.38 | 0.38 | 0.34 |
|         | Beta-carotene | 0.29  | 0.23 | 0.22 | 0.21 | 0.20 | 0.28 | 0.18 |
|         | Lycopene     | 0.09  | 0.03 | 0.08 | 0.28 | 0.34 | 0.30 | 0.26 |
|         | Vitamin C    | 1.17  | 0.27 | 1.13 | -0.01 | -0.13 | -0.07 | -0.20 |
| Women (n=100)\(^4\) | Total carotene | 0.57  | 0.33 | 0.50 | 0.25 | 0.26 | 0.12 | 0.08 |
|         | Alpha-carotene | 0.08  | 0.04 | 0.07 | 0.40 | 0.43 | 0.30 | 0.30 |
|         | Beta-carotene | 0.49  | 0.31 | 0.41 | 0.26 | 0.25 | 0.11 | 0.03 |
|         | Lycopene     | 0.10  | 0.04 | 0.09 | 0.34 | 0.37 | 0.19 | 0.10 |
|         | Vitamin C    | 1.31  | 0.31 | 1.32 | 0.07 | -0.02 | 0.06 | -0.14 |

\(^1\) DR, dietary records.  
\(^2\) FFQ, food frequency questionnaire.  
\(^3\) Energy was adjusted by residual model for intake.  
\(^4\) For vitamin C, women (n=99).  
For n=86, r>0.22 = p<0.05, r>0.28 = p<0.01, r>0.35 = p<0.001.  
For n=100, r>0.20 = p<0.05, r>0.26 = p<0.01, r>0.33 = p<0.001.
vitamin C intake from FFQ are shown in Table 6. Both in men and women, more than 60% of them were classified in the adjacent quintiles and less than 6% of them were classified in the extreme quintiles.

Table 7 shows the mean, SD and median serum carotenoid levels and plasma vitamin C level in 4 areas. All serum carotenoid and plasma vitamin C levels were higher in women than in men. Table 7 also presents the relation between serum carotenoid level or plasma vitamin C level and corresponding carotenoids or vitamin C intakes estimated from FFQ and DR. In men, serum carotenoid levels were moderately correlated with the respective intake estimated from both the DR and FFQ. Correlation coefficients were as follows: alpha-carotene, both r=0.38; beta-carotene, r=0.28 and r=0.21; lycopene, r=0.30 and r=0.28; from FFQ and DR, respectively. In women, a moderate correlation was observed between serum carotenoid levels and the respective intake estimated from DR: alpha-carotene, r=0.40; beta-carotene, r=0.26; lycopene, r=0.34. However, this correlation was not observed with intake estimated from FFQ except for alpha-carotene: alpha-carotene, r=0.30; beta-carotene, r=0.11; lycopene,

**Table 8. Serum carotenoid and plasma vitamin C within quintile of carotenoid and vitamin C intake from FFQ**

| Carotenoid       | Quintile of serum carotenoid and plasma vitamin C level | Men (n=86) | Women (n=100)$^1$ |
|------------------|--------------------------------------------------------|-----------|-------------------|
|                  | Lowest Mean ± SD | Second Mean ± SD | Third Mean ± SD | Fourth Mean ± SD | Highest Mean ± SD | Ratio 1 | Ratio 2 |
| Total carotene   | 2677 ± 1598      | 4023 ± 2277      | 4718 ± 6072      | 3655 ± 1804      | 6847 ± 4212      | 1.50    | 1.76    |
| Alpha-carotene   | 348 ± 243        | 432 ± 337        | 793 ± 811        | 543 ± 296        | 1221 ± 1219      | 1.24    | 2.28    |
| Beta-carotene    | 2283 ± 1791      | 3060 ± 1544      | 4172 ± 5109      | 2450 ± 994       | 5366 ± 3007      | 1.34    | 1.83    |
| Lycopene         | 1819 ± 2763      | 2702 ± 3618      | 2441 ± 3151      | 4687 ± 5732      | 3973 ± 4520      | 1.49    | 1.34    |
| Vitamin C        | 191 ± 192        | 165 ± 96         | 175 ± 70         | 125 ± 55         | 168 ± 97         | 0.87    | 0.92    |

| Carotenoid       | Quintile of serum carotenoid and plasma vitamin C level | Men (n=86) | Women (n=100)$^1$ |
|------------------|--------------------------------------------------------|-----------|-------------------|
|                  | Lowest Mean ± SD | Second Mean ± SD | Third Mean ± SD | Fourth Mean ± SD | Highest Mean ± SD | Ratio 1 | Ratio 2 |
| Total carotene   | 3844 ± 2388      | 3070 ± 1817      | 4865 ± 4549      | 3900 ± 2553      | 4152 ± 2633      | 0.80    | 1.27    |
| Alpha-carotene   | 402 ± 336        | 380 ± 285        | 604 ± 717        | 725 ± 532        | 622 ± 406        | 0.95    | 1.50    |
| Beta-carotene    | 2783 ± 2004      | 2978 ± 2010      | 3819 ± 3885      | 2984 ± 1766      | 3377 ± 2144      | 1.07    | 1.37    |
| Lycopene         | 2166 ± 2027      | 2361 ± 2988      | 3801 ± 7273      | 4697 ± 7399      | 2798 ± 2440      | 1.09    | 1.76    |
| Vitamin C        | 156 ± 61         | 154 ± 57         | 185 ± 84         | 264 ± 282        | 184 ± 107        | 0.99    | 1.18    |

$^1$ FFQ, food frequency questionnaire.

$^2$ Ratio compared to the lowest quintile.

$^3$ For vitamin C, women (n=99).

**Table 9. Comparison of serum carotenoids and plasma ascorbic acid with FFQ$^1$ for intakes of carotenoids and vitamin C based on joint classification by quintile (%)**

| Carotenoids | Same category | Adjacent category | Extreme category | Same category | Adjacent category | Extreme category |
|-------------|---------------|-------------------|------------------|---------------|-------------------|------------------|
| Total carotene | 24            | 60                | 1                | 23            | 52                | 6                |
| Alpha-carotene | 23            | 63                | 1                | 28            | 64                | 4                |
| Beta-carotene  | 23            | 64                | 2                | 23            | 57                | 8                |
| Lycopene       | 29            | 65                | 1                | 22            | 61                | 3                |
| Vitamin C      | 21            | 53                | 9                | 20            | 53                | 6                |

$^1$ FFQ, food frequency questionnaire.

$^2$ For vitamin C, women (n=99).
Table 10. Cumulative % contribution of the top 20 foods for alpha-carotene assessed by DR

| Food code ¹ | Description ¹                      | μg/day | Cumulative ² % |
|------------|------------------------------------|--------|----------------|
| Men (n=102)                                      |        |                |
| 12-94a     | Carrot/Root/Raw                    | 400.1  | 88.1           |
| 12-85      | Tomatoes/Fruit                     | 19.1   | 92.3           |
| 12-19a     | Leaf mustard/stems and leaves/Raw  | 13.8   | 95.4           |
| 13-79      | Mangos/Raw fruit                   | 5.5    | 96.6           |
| 12-92a     | Bitter gourd/Fruit/Raw             | 3.9    | 97.4           |
| 12-6a      | Kidney beans, Snap beans/Pods, immature/Raw | 2.3 | 97.9           |
| 13-64      | Bananas/Raw fruit                  | 1.8    | 98.3           |
| 12-19b     | Leaf mustard/stems and leaves/Boiled | 1.4 | 98.6           |
| 13-17b     | Satsuma mandarins/Raw fruit, sections with membranes/Normal ripening type | 1.2 | 98.9           |
| 13-26a     | Kaki, Japanese Persimmons/Raw fruit/Hard type | 1.0 | 99.1           |
| 13-88      | Apples/Raw fruit                   | 0.9    | 99.3           |
| 12-83a     | Maize, Corn/Sweet corn, immature/Raw | 0.7 | 99.5           |
| 12-35a     | Sweet pepper/Fruit/Raw             | 0.6    | 99.6           |
| 12-84b     | Maize, Corn/Canned/Whole-kernel style | 0.4 | 99.7           |
| 16-20      | Green tea/Maccha, finely ground    | 0.2    | 99.7           |
| 12-36      | Perilla/Leaves                     | 0.2    | 99.8           |
| 13-24b     | Oranges/Raw fruit, sections without membranes/Valencia | 0.2 | 99.8           |
| 13-80b     | Melons/Raw fruit/Hybrid melons     | 0.2    | 99.9           |
| 13-54      | Natsumikan, Japanese summer orange/Raw fruit, sections without membranes | 0.2 | 99.9           |
| 13-50      | Tangors/Raw fruit                  | 0.1    | 99.9           |
| Women (n=113)                                   |        |                |
| 12-94a     | Carrot/Root/Raw                    | 369.8  | 86.3           |
| 12-85      | Tomatoes/Fruit                     | 25.9   | 92.4           |
| 12-19a     | Leaf mustard/stems and leaves/Raw  | 8.7    | 94.4           |
| 13-79      | Mangos/Raw fruit                   | 7.1    | 96.1           |
| 12-92a     | Bitter gourd/Fruit/Raw             | 2.8    | 96.7           |
| 12-6a      | Kidney beans, Snap beans/Pods, immature/Raw | 2.1 | 97.2           |
| 13-64      | Bananas/Raw fruit                  | 1.9    | 97.6           |
| 13-17b     | Satsuma mandarins/Raw fruit, sections with membranes/Normal ripening type | 1.7 | 98.0           |
| 12-19b     | Leaf mustard/stems and leaves/Boiled | 1.7 | 98.4           |
| 13-26a     | Kaki, Japanese Persimmons/Raw fruit/Hard type | 1.3 | 98.7           |
| 13-88      | Apples/Raw fruit                   | 1.1    | 99.0           |
| 12-83a     | Maize, Corn/Sweet corn, immature/Raw | 1.0 | 99.2           |
| 16-20      | Green tea/Maccha, finely ground    | 0.6    | 99.3           |
| 12-84b     | Maize, Corn/Canned/Whole-kernel style | 0.5 | 99.4           |
| 13-24b     | Oranges/Raw fruit, sections without membranes/Valencia | 0.4 | 99.5           |
| 12-35a     | Sweet pepper/Fruit/Raw             | 0.4    | 99.6           |
| 13-54      | Natsumikan, Japanese summer orange/Raw fruit, sections without membranes | 0.3 | 99.7           |
| 12-36      | Perilla/Leaves                     | 0.2    | 99.8           |
| 13-80b     | Melons/Raw fruit/Hybrid melons     | 0.2    | 99.8           |
| 13-27      | Kaki, Japanese Dried fruit         | 0.2    | 99.8           |

¹ Food codes and descriptions correspond to those of the Standard Tables of Food Composition, 4th revised edition in Japan by Science and Technology Agency.
² Data on subjects in Ishikawa PHC (14-day data) were counted twice for 28-day data.
Table 11. Cumulative % contribution of the top 20 foods for beta-carotene assessed by DR

| Food code | Description | µg/day | Cumulative percent |
|-----------|-------------|--------|--------------------|
| 12-94a    | Carrot/Root/Raw | 1138.6 | 39.2               |
| 12-117a   | Spinach/Leaves/Raw | 355.1  | 51.5               |
| 12-93a    | Chinese chive/Leaves/Raw | 112.0  | 55.3               |
| 12-98b    | Nozawana/Leaves/Salted | 103.4  | 58.9               |
| 12-32a    | Komatsuna/Leaves/Raw | 92.6   | 62.1               |
| 12-18a    | Pumpkin and squash/Squash/Raw | 74.3   | 64.6               |
| 12-39a    | Garland chrysanthemum/Leaves/Raw | 57.5   | 66.6               |
| 12-85     | Tomatoes/Fruit | 49.3   | 68.3               |
| 12-55a    | Daikon,Japanese radish/Leaves/Raw | 43.9   | 69.8               |
| 12-77a    | Basella/Leaves/Raw | 33.1   | 71.0               |
| 13-79     | Mangos/Raw fruit | 31.1   | 72.0               |
| 12-74a    | Chingentsuai/Leaves/Raw | 27.4   | 73.0               |
| 12-72     | Lettuce/Head lettuce,butter head type | 26.0   | 73.9               |
| 12-114a   | Broccoli/Head/Raw | 26.0   | 74.8               |
| 12-19a    | Leaf mustard/stems and leaves/Raw | 25.6   | 75.7               |
| 13-45     | Watermelon/Raw fruit | 23.5   | 76.5               |
| 12-76     | New Zealand spinach/stems and leaves | 23.2   | 77.3               |
| 12-25a    | Cucumber/Fruit/Raw | 22.6   | 78.1               |
| 12-113a   | Chard,Swiss chard/Leaves/Raw | 21.6   | 78.8               |
| 13-80b    | Melons/Raw fruit/Hybrid melons | 14.8   | 79.3               |

Men (n=102)

| Food code | Description | µg/day | Cumulative percent |
|-----------|-------------|--------|--------------------|
| 12-94a    | Carrot/Root/Raw | 1052.4 | 41.4               |
| 12-117a   | Spinach/Leaves/Raw | 361.4  | 55.6               |
| 12-93a    | Chinese chive/Leaves/Raw | 102.7  | 59.6               |
| 12-18a    | Pumpkin and squash/Squash/Raw | 93.5   | 63.3               |
| 12-32a    | Komatsuna/Leaves/Raw | 92.5   | 66.9               |
| 12-98b    | Nozawana/Leaves/Salted | 86.9   | 70.3               |
| 12-85     | Tomatoes/Fruit | 66.7   | 72.9               |
| 12-39a    | Garland chrysanthemum/Leaves/Raw | 54.5   | 75.1               |
| 12-77a    | Basella/Leaves/Raw | 43.1   | 76.8               |
| 12-55a    | Daikon,Japanese radish/Leaves/Raw | 42.6   | 78.4               |
| 13-79     | Mangos/Raw fruit | 40.3   | 80.0               |
| 13-45     | Watermelon/Raw fruit | 29.0   | 81.2               |
| 12-114a   | Broccoli/Head/Raw | 28.7   | 82.3               |
| 12-74a    | Chingentsuai/Leaves/Raw | 26.6   | 83.3               |
| 12-113a   | Chard,Swiss chard/Leaves/Raw | 24.1   | 84.3               |
| 12-25a    | Cucumber/Fruit/Raw | 22.5   | 85.2               |
| 12-72     | Lettuce/Head lettuce,butter head type | 21.9   | 86.0               |
| 12-76     | New Zealand spinach/stems and leaves | 19.3   | 86.8               |
| 13-80b    | Melons/Raw fruit/Hybrid melons | 18.6   | 87.5               |
| 13-17b    | Satsuma mandarins/Raw fruit,sections with membranes/Normal ripening type | 18.6   | 88.2               |

1 Food codes and descriptions correspond to those of the Standard Tables of Food Composition, 4th revised edition in Japan by Science and Technology Agency.

2 Data on subjects in Ishikawa PHC (14-day data) were counted twice for 28-day data.
r=0.19. As for the plasma vitamin C, no significant correlation was observed either in men (r=0.07, r=0.01 for FFQ and DR, respectively) or women (r=0.06, r=0.07 for FFQ and DR, respectively). No improvement in the correlation coefficient was observed when intakes were expressed as an energy-adjusted value.

Table 8 shows the mean serum carotenoid and plasma vitamin C levels within quintiles of corresponding carotenoid and vitamin C intake estimated from FFQ. The ratio of the mean intake in the highest to the lowest quintile in men was higher than in women. The result of cross-classification of the subjects by quintiles from serum carotenoid level or plasma vitamin C level and carotenoids and vitamin C intake from FFQ are shown in Table 9. Both in men and women, more than 50% of the subjects were classified in the same or adjacent quintiles, and less than 10% of the subjects were classified in the extreme quintiles.

Table 10 and Table 11 show the cumulative % contribution of the top 20 foods for alpha-carotene and beta-carotene assessed by DR. Carrots and tomato contributed more than 92% of the total alpha-carotene intake in both sexes. Carrots were the greatest contributor, and many kinds of leafy green vegetables were important contributors of beta-carotene.

DISCUSSION

In the present study, we examined the correlation between dietary alpha-carotene, beta-carotene, lycopene and vitamin C intakes estimated from FFQ and DR. We also examined the possible correlation between the carotenoid and vitamin C intake and blood levels of carotenoid and vitamin C. Both in men and women, dietary alpha-carotene, beta-carotene, and vitamin C intakes estimated from FFQ were significantly correlated with intake from DR. However, the association between dietary lycopene intakes estimated from FFQ and DR was weak. Dietary carotenoid intake was associated with serum carotenoid level in men. However, there was no association in women except for alpha-carotene. Both in men and women, no significant correlation was observed for the plasma ascorbic acid level.

The correlation between dietary alpha- or beta-carotene intake estimated from the FFQ and DR was moderate. The alpha-carotene correlation coefficient was within the range of reported correlations (0.34-0.49) in earlier studies as was the beta-carotene correlation coefficient (0.20-0.50). Because carotenoids are not energy-provided nutrition, the correlation between carotenoid intakes estimated from FFQ and both intake from DR and serum carotenoid level was not improved when expressed as an energy-adjusted value.

The correlations between carotenoid intake estimated from FFQ and the corresponding serum carotenoid levels were higher in men than in women. Also, in men, correlations between carotenoid intake estimated from FFQ and corresponding serum carotenoid levels were higher than between intakes from DR and the corresponding serum carotenoid levels. In many previous studies, the correlations between dietary alpha-carotene intakes and the corresponding serum or plasma levels ranged from 0.25 to 0.53, while dietary beta-carotene intakes and the corresponding serum or plasma levels ranged from 0.15 to 0.36. Our observed correlation for men was within the range of these reported correlations. These results suggest that the data on carotenoid intake assessed with FFQ used in the JPHC study might be valid for men. However, it seemed reasonable to think that the bioavailability of carotenoids was different in men and women.

A low correlation was observed between dietary lycopene intake estimated from FFQ and those estimated from DR. This might be due to the inadequate portion size of tomatoes which contribute to more than 50% for the cumulative percentage of lycopene intake. In addition, because the lycopene database was quotation from the Department of Agriculture (USDA) food composition tables, it may be difficult to estimate lycopene intake in Japanese.

No meaningful correlation was observed between Vitamin C intake estimated from both DR and FFQ and plasma vitamin C levels. It is considered that vitamin C intake may vary in response to the availability of seasonal foods, and also the plasma vitamin C levels do not reflect habitual intake because of its short half-life. In addition, the estimated vitamin C intake in this study did not take account of cooking loss, and this is another reason for no meaningful correlation.

In summary, we observed a moderate correlation between dietary carotenoids and vitamin C intake estimated from the FFQ and DR. A moderate correlation was also found between dietary carotenoid intake and the corresponding serum carotenoid level for men; the correlation, however, was weak for women except for alpha-carotene. No significant correlation was observed with the plasma ascorbic acid level. These results suggest that carotenoid intake estimated from the FFQ is more valid in men than in women.

REFERENCES

1. Steinmetz KA, Potter JD. Vegetables, fruit, and cancer. I. Epidemiology: Cancer Causes Control 1991;2:325-57.
2. van't Veer P, Jansen MC, Klerk M, Kok FJ. Fruits and vegetables in the prevention of cancer and cardiovascular disease. Public Health Nutr 2000;3:103-7.
3. La Vecchia C. Diet and human cancer: a review. Eur J Epidemiology: Cancer Causes Control 1991;2:325-57.
4. Steinmetz KA, Potter JD. Vegetables, fruit, and cancer. II. Mechanisms. Cancer Causes Control 1991;2:427-42.
5. Takahashi Y, Sasaki S, Tsugane S. Development and validation of specific carotene food composition tables for use in nutritional epidemiologic studies for Japanese populations. J Epidemiol 2001;11:266-75.
6. Tsugane S, Sasaki S, Kobayashi M, Tsubono Y, Akabane M. Validity and reproducibility of the self-administered food frequency questionnaire in the JPHC Study Cohort I: study
7. Sasaki S, Kobayashi M, Ishihara J, Tsugane S. Self-administered food frequency questionnaire used in the 5-year follow-up survey of the JPHC Study: questionnaire structure, computation algorithms, and area-based mean intake. J Epidemiol 2003;13(Suppl):S13-S22.

8. Sasaki S, Takahashi T, Iitoi Y, Iwase Y, Kobayashi M, Ishihara J, et al. Food and nutrient intakes assessed with dietary records for the validation study of the self-administered food frequency questionnaire in the JPHC Study Cohort I. J Epidemiol 2003;13(Suppl):S23-S50.

9. Science and Technology Agency. Standard Tables of Food Composition in Japan. The fourth revised edition. Tokyo: Printing Bureau, Ministry of Finance; 1982. (in Japanese)

10. Ito Y, Sasaki R, Minohara M, Otani M, Aoki K. Quantitation of serum carotenoid concentrations in healthy inhabitants by high-performance liquid chromatography. Clin Chim Acta 1987;169:197-207.

11. Zannoni V, Lynch M, Goldstein S, Sato P. A rapid micromethod for the determination of ascorbic acid in plasma and tissues. Biochem Med 1974;11:41-8.

12. SAS/STAT User's Guide, version 6.4, Vol 2. Cary, NC, 1989.

13. Forman MR, Lanza E, Yong L-C, Holden JM, Graubard BI, Beecher GR, et al. The correlation between two dietary assessments of carotenoid intake and plasma carotenoid concentrations: application of a carotenoid food-composition database. Am J Clin Nutr 1993;58:519-24.

14. Yong LC, Forman MR, Beecher GR, Graubard BI, Campbell WS, Reichman ME, et al. Relationship between dietary intake and plasma concentrations of carotenoids in pre-menopausal women: application of the USDA-NCI carotenoids food-composition database. Am J Clin Nutr 1994;60:223-30.

15. Bingham AS, Gill C, Welch A, Cassidy A, Runswick SA, Oakes S, et al. Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. Int J Epidemiol 1997;26(Suppl.1):S137-S151.

16. Coates RJ, Eley JW, Block G, Gunter EW, Sowell AL, Grossman C, et al. An evaluation of a food frequency questionnaire for assessing dietary intake of specific carotenoids and vitamin E among low-income black women. Am J Epidemiol 1991;134:658-71.

17. Ascherio A, Stampfer MJ, Colditz GA, Rimm EB, Litin L, Willett WC. Correlations of vitamin A and E intakes with the plasma concentrations of carotenoids and tocopherols among American men and women. J Nutr 1992;122:1792-801.

18. Romieu I, Parra S, Hernandez JF, Madrigal H, Willett W, Hernandez M. Questionnaire assessment of antioxidants and retinol intakes in Mexican women. Arch Med Res 1999;30:224-39.

19. Michaud DS, Giovannucci EL, Ascherio A, Rimm EB, Forman MR, Sampson L, et al. Associations of plasma carotenoid concentrations and dietary intake of specific carotenoids in samples of two prospective cohort studies using a new carotenoid database. Cancer Epidemiol Biomarkers Prev 1998;7:283-90.

20. U.S. Department of Agriculture, Agricultural Research Service. 1977. USDA Nutrient Database for Standard Reference, Release 11-1.