

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

Minatsu Kobayashi, Satoshi Sasaki, and Shoichiro Tsugane

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.

Several epidemiological studies have provided the evidence for an inverse association of vegetable and fruit intake with certain cancers.^{1,3} The beneficial effect of vegetable and fruit could be partly due to antioxidant nutrients such as carotenoids or vitamin C, which might protect biological structures from oxidative damage and reduce lipid peroxidation.⁴ In Japan, until recently no comprehensive food composition database for individual carotenoids has been available, making it difficult to assess the possible relationship between specific carotenoid intake and the risk of disease.

In the present study, we estimated the alpha-carotene, beta-carotene and lycopene intake from both our 138-item food frequency questionnaire (FFQ) and 28-day weighed dietary records (DR) among a subgroup of JPHC Study Cohort I using our newly-developed food composition database for individual carotenoids.⁵ We compared the carotenoid intake and vitamin C intake estimated from both the FFQ and DR with the corresponding serum carotenoid level or plasma vitamin C level.

MATERIALS AND METHODS

The study design and subject characteristics have been reported elsewhere in this Supplement.⁶ The methods for surveying dietary records and for computing nutrient intakes from FFQ have also been described therein.^{7,8}

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.⁹ The daily intakes of specific carotenoids, such as alpha-carotene, beta-carotene and lycopene, were calculated using our new carotene database.⁵

Laboratory Measurements

The details of blood collection have been presented elsewhere in this report.⁶ 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.

¹ Epidemiology and Biostatistics Division, National Cancer Center Research Institute East.

Address for correspondence: Shoichiro Tsugane, Epidemiology and Biostatistics Division, National Cancer Center Research Institute East, 6-5-1 Kashiwanoha, Kashiwa, Chiba 277-8577, Japan.

Serum carotenoids were quantified by high-performance liquid chromatography (HPLC) using a previously-described modified method.¹⁰ Briefly, the components were extracted by shaking and mixing for 30 min after addition of each of the following: 250 μ L of water, 500 μ L of ethyl alcohol, 4 mL of *n*-hexane, and 400 μ L 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 μ L of dichloromethane and 200 μ L of the mixed solvent. Then, 200 μ L 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.¹¹ Briefly, 450 μ L 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.¹²

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 (μ g/day) and vitamin C intakes (mg/day) assessed with DR¹ for 28 or 14 days by area

	Ninohe PHC			Yokote PHC			Saku PHC			Ishikawa PHC			ANOVA p-value
	Mean \pm SD	Median	n	Mean \pm SD	Median	n	Mean \pm SD	Median	n	Mean \pm SD	Median	n	
Men (n=102)	n=24			n=28			n=23			n=27			
Carotene	3564 \pm 1330	3304		2503 \pm 798	2441		3174 \pm 874	2972		3902 \pm 1616	3919		0.0003
Alpha-carotene	507 \pm 251	446		286 \pm 115	271		352 \pm 152	308		669 \pm 333	652		0.0001
Beta-carotene	2726 \pm 1055	2476		2021 \pm 697	1919		2578 \pm 724	2516		3111 \pm 1310	3007		0.0011
Lycopene	4336 \pm 4230	3042		2515 \pm 1551	1966		2456 \pm 1342	2292		2622 \pm 2531	1844		0.0414
Vitamin C	122 \pm 38	115		122 \pm 34	123		139 \pm 40	134		134 \pm 45	130		0.3083
Women (n=113)	n=27			n=30			n=28			n=28			
Carotene	3314 \pm 1471	3126		2773 \pm 941	2658		3109 \pm 972	2837		3573 \pm 1505	3746		0.1000
Alpha-carotene	446 \pm 236	359		337 \pm 169	288		358 \pm 142	319		581 \pm 260	571		0.0001
Beta-carotene	2597 \pm 1218	2386		2241 \pm 766	2038		2514 \pm 807	2332		2860 \pm 1241	2888		0.1537
Lycopene	395 \pm 3004	3241		2832 \pm 1894	2125		3243 \pm 2262	2628		3261 \pm 3412	2085		0.4721
Vitamin C	128 \pm 44	114		133 \pm 36	127		146 \pm 46	138		139 \pm 71	117		0.5870

¹ DR, dietary records.

or women.

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 esti-

mated 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 2. Carotenoid intakes ($\mu\text{g}/\text{day}$) and vitamin C intakes (mg/day) assessed with FFQ¹ by area

	Ninohe PHC			Yokote PHC			Saku PHC			Ishikawa PHC			ANOVA
	Mean \pm SD	Median	n	Mean \pm SD	Median	n	Mean \pm SD	Median	n	Mean \pm SD	Median	n	p-value
Men (n=102)	n=24			n=28			n=23			n=27			
Carotene	3722 \pm 2816	3588		3719 \pm 4606	2346		4120 \pm 1818	3551		3736 \pm 2450	3308		0.9643
Alpha-carotene	607 \pm 661	491		449 \pm 636	228		523 \pm 382	403		669 \pm 441	618		0.4754
Beta-carotene	2891 \pm 2168	2762		3015 \pm 3923	2022		3365 \pm 1444	3126		2935 \pm 1965	2377		0.9230
Lycopene	3288 \pm 5203	816		4543 \pm 5368	2761		3407 \pm 3478	2345		2254 \pm 4075	437		0.3424
Vitamin C	146 \pm 95	115		198 \pm 182	170		192 \pm 65	196		130 \pm 68	111		0.0910
Women (n=113)	n=27			n=30			n=28			n=28			
Carotene	3670 \pm 2787	2669		3867 \pm 4194	2549		4638 \pm 2664	4268		4247 \pm 2007	3928		0.6496
Alpha-carotene	513 \pm 485	350		486 \pm 627	241		563 \pm 421	471		759 \pm 377	635		0.1515
Beta-carotene	2906 \pm 2261	2187		3140 \pm 3524	2176		3769 \pm 2129	3515		3342 \pm 1605	2986		0.6215
Lycopene	2762 \pm 2566	1439		4262 \pm 6796	2502		4212 \pm 5993	2049		1261 \pm 1743	535		0.0676
Vitamin C	172 \pm 106	143		208 \pm 229	141		244 \pm 164	203		142 \pm 71	115		0.0915

¹ FFQ, food frequency questionnaire.

Table 3. Serum carotenoid level¹ (mg/ml) and plasma vitamin C level¹ (mg/dl) by area

	Ninohe PHC			Yokote PHC			Saku PHC			Ishikawa PHC			ANOVA
	Mean \pm SD	Median	n	Mean \pm SD	Median	n	Mean \pm SD	Median	n	Mean \pm SD	Median	n	p-value
Men (n=86)	n=22			n=25			n=18			n=21			
Alpha-carotene	0.06 \pm 0.04	0.05		0.05 \pm 0.02	0.05		0.05 \pm 0.02	0.05		0.07 \pm 0.03	0.06		0.2226
Beta-carotene	0.30 \pm 0.2	0.21		0.26 \pm 0.1	0.24		0.37 \pm 0.23	0.32		0.21 \pm 0.07	0.20		0.0230
Lycopene	0.08 \pm 0.03	0.08		0.10 \pm 0.03	0.09		0.10 \pm 0.04	0.09		0.09 \pm 0.02	0.08		0.2307
Vitamin C	1.36 \pm 0.27	1.38		1.07 \pm 0.24	1.01		1.24 \pm 0.22	1.24		1.08 \pm 0.22	1.08		0.0002
Women (n=100)	n=26			n=26			n=24			n=24			
Alpha-carotene	0.06 \pm 0.02	0.06		0.07 \pm 0.03	0.07		0.08 \pm 0.04	0.08		0.11 \pm 0.05	0.11		0.0001
Beta-carotene	0.40 \pm 0.16	0.38		0.46 \pm 0.27	0.36		0.68 \pm 0.45	0.55		0.42 \pm 0.19	0.35		0.0037
Lycopene	0.10 \pm 0.03	0.09		0.10 \pm 0.04	0.08		0.11 \pm 0.04	0.10		0.10 \pm 0.02	0.10		0.3502
Vitamin C ²	1.53 \pm 0.33	1.54		1.16 \pm 0.29	1.22		1.40 \pm 0.22	1.36		1.17 \pm 0.21	1.13		0.0001

¹ Serum carotenoid level, mean measurements of Feb. and Aug.; Plasma vitamin C level, measured in Feb.

² for Ishikawa PHC, n=23

Table 4. Carotenoid intakes ($\mu\text{g}/\text{day}$) and vitamin C intakes (mg/day) assessed with DR¹ for 28 or 14 days and FFQ² in 4 areas and correlations

Sex	DR			FFQ			%	Spearman correlation	
	Mean \pm SD	Median		Mean \pm SD	Median			difference	Crude
Men (n=102)									
Carotene	3274 \pm 1305	2885		3814 \pm 3126	3320		16	0.38	0.36
Alpha-carotene	454 \pm 273	357		561 \pm 545	398		23	0.47	0.47
Beta-carotene	2601 \pm 1052	2314		3044 \pm 2582	2556		17	0.40	0.41
Lycopene	2965 \pm 2715	2121		3386 \pm 4636	1296		14	0.18	0.19
Vitamin C	129 \pm 39	127		166 \pm 118	157		29	0.44	0.42
Women (n=113)									
Carotene	3184 \pm 1262	2870		4105 \pm 3029	3358		29	0.31	0.33
Alpha-carotene	429 \pm 226	348		579 \pm 495	433		35	0.46	0.50
Beta-carotene	2547 \pm 1037	2344		3290 \pm 2493	2789		29	0.30	0.32
Lycopene	3309 \pm 2689	2450		3148 \pm 4942	1438.86		-5	0.22	0.11
Vitamin C	137 \pm 50	127		192 \pm 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	Quintile of carotenoids and vitamin C intake according to FFQ														
	Lowest			Second			Third			Fourth			Highest		
Carotenoids	Mean \pm SD		Mean \pm SD	ratio ³		Mean \pm SD	ratio ³		Mean \pm SD	ratio ³		Mean \pm SD	ratio ³		
Men															
	n=20		n=21			n=20			n=21			n=20			
Carotene	2541 \pm 950		3067 \pm 1185	1.21		3528 \pm 1591	1.39		3365 \pm 1115	1.32		3877 \pm 1329	1.53		
Alpha-carotene	320 \pm 197		331 \pm 147	1.04		477 \pm 266	1.49		538 \pm 349	1.68		608 \pm 260	1.90		
Beta-carotene	2073 \pm 692		2329 \pm 954	1.12		2796 \pm 1292	1.35		2602 \pm 791	1.26		3219 \pm 1140	1.55		
Lycopene	2423 \pm 1812		2801 \pm 2895	1.16		2626 \pm 1761	1.08		2823 \pm 2080	1.16		4115 \pm 4140	1.70		
Vitamin C	103 \pm 30		130 \pm 42	1.26		120 \pm 27	1.17		134 \pm 36	1.30		158 \pm 41	1.54		
Women															
	n=22		n=23			n=23			n=23			n=22			
Carotene	2604 \pm 1012		3021 \pm 1092	1.16		3142 \pm 1169	1.21		3581 \pm 1624	1.37		3561 \pm 1151	1.37		
Alpha-carotene	319 \pm 197		356 \pm 169	1.12		456 \pm 227	1.43		450 \pm 220	1.41		565 \pm 243	1.77		
Beta-carotene	2092 \pm 822		2489 \pm 841	1.19		2556 \pm 1200	1.22		2732 \pm 1189	1.31		2860 \pm 983	1.37		
Lycopene	3329 \pm 3641		2726 \pm 2303	0.82		3617 \pm 3065	1.09		3068 \pm 2109	0.92		3831 \pm 2102	1.15		
Vitamin C	122 \pm 44		127 \pm 65	1.04		138 \pm 43	1.13		145 \pm 44	1.20		151 \pm 52	1.24		

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 FFQ¹ with DR² 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 DR¹ and FFQ²

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 FFQ¹

Carotenoid	Quintile of serum carotenoid and plasma vitamin C level														
	Lowest			Second			Third			Fourth			Highest		
	Mean	± SD	ratio ²	Mean	± SD	ratio ²	Mean	± SD	ratio ²	Mean	± SD	ratio ²	Mean	± SD	ratio ²
Men (n=86)															
Total carotene	2677	± 1598	1.50	4023	± 2277	1.76	4718	± 6072	1.76	3655	± 1804	1.37	6847	± 4212	2.56
Alpha-carotene	348	± 243	1.24	432	± 337	1.24	793	± 811	2.28	543	± 296	1.56	1221	± 1219	3.51
Beta-carotene	2283	± 1791	1.34	3060	± 1544	1.34	4172	± 5109	1.83	2450	± 994	1.07	5366	± 3007	2.35
Lycopene	1819	± 2763	1.49	2702	± 3618	1.49	2441	± 3151	1.34	4687	± 5732	2.58	3973	± 4520	2.18
Vitamin C	191	± 192	0.87	165	± 96	0.87	175	± 70	0.92	125	± 55	0.66	168	± 97	0.88
Women (n=100)³															
Total carotene	3844	± 2388	0.80	3070	± 1817	0.80	4865	± 4549	1.27	3900	± 2553	1.01	4152	± 2633	1.08
Alpha-carotene	402	± 336	0.95	380	± 285	0.95	604	± 717	1.50	725	± 532	1.81	622	± 406	1.55
Beta-carotene	2783	± 2004	1.07	2978	± 2010	1.07	3819	± 3885	1.37	2984	± 1766	1.07	3377	± 2144	1.21
Lycopene	2166	± 2027	1.09	2361	± 2988	1.09	3801	± 7273	1.76	4697	± 7399	2.17	2798	± 2440	1.29
Vitamin C	156	± 61	0.99	154	± 57	0.99	185	± 84	1.18	264	± 282	1.69	184	± 107	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 FFQ¹ for intakes of carotenoids and vitamin C based on joint classification by quintile (%)

Carotenoids	Men (n=86)			Women (n=100) ²		
	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	$\mu\text{g/day}$	Cumulative ² percent
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 ¹	Description ¹	µg/day	Cumulative ² percent
Men (n=102)			
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
Women (n=113)			
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).^{13,14} 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 0.36.¹³⁻¹⁹ 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,²⁰ 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.

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