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Supplementary Materials: High Fruit and Vegetable Consumption and Moderate Fat Intake Are Associated with Higher Carotenoid Concentration in Human Plasma

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Table S1. Limits of detection and quantification, concentration range and r of the calibration curves of the different carotenoids (µmol/L).

Analyte	LoD	LoQ	Concentration range	r
astaxanthin	0.009	0.17	0.17 – 5.03	0.9965
lutein	0.023	0.88	0.88 – 8.79	0.9978
zeaxanthin	0.120	0.88	0.88 – 5.27	0.9930
canthaxanthin	0.0005	0.089	0.089 – 5.31	0.9975
E-*β*-apo-8′-carotenal	0.018	0.12	0.12 – 7.20	0.9967
β-cryptoxanthin	0.004	0.02	0.02 – 18.09	0.9982
13-*Z*-*β*-carotene	0.072	0.93	0.93 – 18.63	0.9909
α-carotene	0.037	0.12	0.12 – 1.86	0.9932
β-carotene	0.021	0.19	0.19 – 18.63	0.9927
9-*Z*-*β*-carotene	0.129	0.93	0.93 – 18.63	0.9967
lycopene	0.005	0.09	0.09 – 9.31	0.9974

LoD, Limit of detection; LoQ, limit of quantification; r, correlation coefficient.

Table S2. Main dietary nutrient intake and food consumption by group.

	Low F&V		High F&V		*p*-value*
	Low-to-Moderate fat	Very high fat	Low-to-Moderate fat	Very high fat	
No. of subjects	59	58	60	53	
Mediterranean diet adherence score	7.29 ± 2.33	6.67 ± 2.56	10.0 ± 2.49	9.83 ± 2.79	< 0.001
Total energy, Kcal/day	1701 ± 511	2803 ± 420	2026 ± 373	3161 ± 356	< 0.001
Nutrient intake					
Carbohydrates, g/day	180 ± 77.7	256 ± 74.8	249 ± 66.7	324 ± 67.9	< 0.001
Fiber, g/day	15.5 ± 6.15	19.2 ± 4.79	35.3 ± 6.39	42.5 ± 8.87	< 0.001
Protein, g/day	70.8 ± 18.2	99.1 ± 19.6	89.8 ± 19.5	127 ± 21.7	< 0.001
Total fat, g/day	64.8 ± 15.3	140 ± 14.6	69.7 ± 12.6	142 ± 16.9	< 0.001
SFA, g/day	17.7 ± 4.44	36.9 ± 7.19	17.8 ± 4.66	34.5 ± 7.14	< 0.001
MUFA, g/day	32.4 ± 8.69	72.8 ± 11.0	33.7 ± 7.81	75.5 ± 12.4	< 0.001
PUFA, g/day	9.87 ± 3.56	22.5 ± 6.10	12.2 ± 3.98	25.3 ± 7.75	< 0.001
Cholesterol, mg/day	292 ± 105	437 ± 130	317 ± 97.1	459 ± 134	< 0.001
Alcohol, g/day	16.3 ± 20.9	17.3 ± 18.1	6.08 ± 11.1	11.6 ± 13.4	< 0.001
Food consumption, g/day					
F&V	278 ± 68.7	300 ± 52.7	1265 ± 299	1328 ± 270	< 0.001
Legumes	14.2 ± 7.95	18.3 ± 7.94	24.3 ± 16.4	30.4 ± 17.2	< 0.001
Cereals	140 ± 88.1	170 ± 85.3	129 ± 78.7	177 ± 82.4	0.005
Dairy	244 ± 113	360 ± 226	297 ± 213	380 ± 216	0.001
Meat	117 ± 44.9	151 ± 58.4	120 ± 48.0	171 ± 67.9	< 0.001
Fish	64.6 ± 38.5	92.6 ± 53.8	100 ± 48.0	136 ± 56.5	< 0.001
Nuts	5.11 ± 6.53	20.6 ± 21.4	10.5 ± 10.5	39.1 ± 30.7	< 0.001
Olive oil	23.2 ± 11.1	53.4 ± 15.5	24.0 ± 10.6	48.1 ± 16.4	< 0.001
Sunflower oil	1.40 ± 3.76	2.04 ± 5.72	0.91 ± 3.53	2.34 ± 7.22	0.455
Butter	0.75 ± 2.22	1.87 ± 4.77	0.56 ± 2.18	0.87 ± 2.08	0.092
Margarine	0.68 ± 1.65	1.38 ± 3.44	0.35 ± 0.98	1.34 ± 3.08	0.065
Pastries	18.4 ± 20.2	40.9 ± 43.6	14.6 ± 18.8	31.8 ± 32.1	< 0.001

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; F&V, fruit and vegetables.

Values are percentages for categorical variables and means ± SD for continuous variables.

* *P*-values were calculated by analysis of variance–one factor was used for continuous variables and the χ^2-test for categorical variables, $p < 0.05$.

Table S3. Differences in individual carotenoids plasma concentrations (μmol/L) between F&V consumption groups.

		High F&V vs. Low F&V	***p*-value**	**High F&V vs. Low F&V (low-to-moderate fat)**	***p*-value**	**High F&V vs. Low F&V (high fat)**	***p*-value**
α-carotene	Median	0.19 vs. < 0.12		0.21 vs. < 0.12		0.14 vs. < 0.12	
	ß [CI]-model 1	0.15 [0.058; 0.24]	0.001	0.18 [0.052; 0.30]	0.005	0.11 [-0.017; 0.24]	0.088
	ß [CI]-model 2	0.11 [0.022; 0.20]	0.014	0.13 [0.007; 0.25]	0.038	0.088 [-0.039; 0.21]	0.173
	ß [CI]-model 3	0.10 [-0.006; 0.21]	0.064	0.094 [-0.048; 0.24]	0.197	0.045 [-0.1; 0.19]	0.553
β-carotene	Median	1.78 vs. < 0.02		2.55 vs. < 0.02		0.71 vs. < 0.02	
	ß [CI]-model 1	4.25 [2.27; 6.22]	< 0.001	4.97 [2.33; 7.61]	< 0.001	3.24 [0.40; 6.07]	0.025
	ß [CI]-model 2	3.76 [1.79; 5.73]	< 0.001	4.34 [1.71; 6.98]	0.001	2.93 [0.14; 5.71]	0.039
	ß [CI]-model 3	4.31 [1.98; 6.64]	< 0.001	4.52 [1.40; 7.64]	0.005	3.05 [-0.21; 6.31]	0.066
E-lycopene	Median	< 0.005 vs. < 0.005		< 0.09 vs. < 0.005		< 0.005 vs. < 0.005	
	ß [CI]-model 1	1.00 [-0.10; 2.10]	0.075	1.5 [-0.021; 3.03]	0.053	0.41 [-1.19; 2.00]	0.617
	ß [CI]-model 2	0.82 [-0.29; 1.93]	0.146	1.26 [-0.27; 2.80]	0.107	0.31 [-1.28; 1.89]	0.704
	ß [CI]-model 3	0.72 [-0.59; 2.02]	0.282	1.45 [-0.36; 3.26]	0.115	0.54 [-1.30; 2.37]	0.567
Z-lycopene	Median	< 0.005 vs. < 0.005		< 0.005 vs. < 0.005		< 0.005 vs. < 0.005	
	ß [CI]-model 1	0.63 [-0.41; 1.68]	0.233	1.14 [-0.30; 2.57]	0.120	0.042 [-1.48; 1.56]	0.957
	ß [CI]-model 2	0.48 [-0.57; 1.54]	0.368	0.93 [-0.52; 2.39]	0.207	-0.039 [-1.55; 1.47]	0.959
	ß [CI]-model 3	0.024 [-1.22; 1.27]	0.970	0.35 [-1.34; 2.03]	0.686	-0.58 [-2.33; 1.18]	0.518
Sum lycopene	Median	< 0.09 vs. < 0.09		0.29 vs. < 0.09		< 0.09 vs. < 0.09	
	ß [CI]-model 1	1.63 [-0.17; 3.43]	0.076	2.56 [0.07; 5.05]	0.044	0.55 [-2.06; 3.15]	0.681
	ß [CI]-model 2	1.35 [-0.47; 3.17]	0.145	2.18 [-0.33; 4.70]	0.089	0.39 [-2.20; 2.98]	0.768
	ß [CI]-model 3	0.94 [-1.21; 3.09]	0.393	2.01 [-0.94; 4.97]	0.182	0.30 [-2.71; 3.31]	0.845
astaxanthin	Median	0.44 vs. 0.35		0.42 vs. 0.31		0.48 vs. 0.36	
	ß [CI]-model 1	0.15 [0.038; 0.26]	0.009	0.18 [0.027; 0.34]	0.022	0.12 [-0.044; 0.28]	0.155
	ß [CI]-model 2	0.14 [0.027; 0.26]	0.016	0.17 [0.014; 0.33]	0.033	0.11 [-0.05; 0.27]	0.175
	ß [CI]-model 3	0.12 [-0.015; 0.25]	0.082	0.17 [-0.011; 0.35]	0.066	0.068 [-0.12; 0.25]	0.471
lutein	Median	< 0.88 vs. < 0.02		< 0.88 vs. < 0.88		< 0.88 vs. < 0.02	
	ß [CI]-model 1	0.64 [0.29; 0.99]	< 0.001	0.63 [0.16; 1.10]	0.009	0.65 [0.14; 1.16]	0.012
	ß [CI]-model 2	0.52 [0.18; 0.87]	0.003	0.48 [0.013; 0.94]	0.044	0.57 [0.073; 1.06]	0.025
	ß [CI]-model 3	0.48 [0.076; 0.88]	0.020	0.31 [-0.23; 0.84]	0.259	0.33 [-0.23; 0.90]	0.250
canthaxanthin	Median	0.16 vs. 0.18		0.18 vs. 0.18		0.15 vs. 0.17	
	ß [CI]-model 1	0.001 [-0.062; 0.064]	0.969	0.027 [-0.06; 0.11]	0.542	-0.028 [-0.12; 0.062]	0.538
	ß [CI]-model 2	-0.003 [-0.067; 0.062]	0.937	0.022 [-0.067; 0.11]	0.626	-0.031 [-0.12; 0.06]	0.505
	ß [CI]-model 3	0.039 [-0.037; 0.12]	0.314	0.023 [-0.079; 0.12]	0.663	-0.02 [-0.13; 0.085]	0.710
β-cryptoxanthin	Median	0.72 vs. 0.24		0.78 vs. 0.24		0.69 vs. 0.24	
	ß [CI]-model 1	0.58 [0.42; 0.75]	< 0.00001	0.70 [0.47; 0.93]	< 0.00001	0.45 [0.21; 0.69]	< 0.001
	ß [CI]-model 2	0.58 [0.41; 0.75]	< 0.00001	0.69 [0.46; 0.93]	< 0.00001	0.45 [0.21; 0.69]	< 0.001
	ß [CI]-model 3	0.60 [0.40; 0.81]	< 0.00001	0.70 [0.43; 0.97]	< 0.00001	0.44 [0.16; 0.72]	0.002

ß, difference between groups; CI, confidence interval.

Model 1— adjusted for age and sex. Model 2—adjusted for age, sex and physical activity. Model 3—adjusted for the variables used in model 2 plus energy intake, the modified Mediterranean diet adherence score (subtracting the questions regarding F&V, fat and wine) and alcohol consumption (g/day). *P*-values < 0.05 were considered significant.

Table S4. Differences in individual carotenoids plasma concentrations (μmol/L) between fat intake groups.

		High fat vs. Low-to-Moderate fat	***p*-value**	**High fat vs. Low-to-Moderate fat (low F&V)**	***p*-value**	**High fat vs. Low-to-Moderate fat (high F&V)**	***p*-value**
α-carotene	Median	< 0.12 vs. 0.16		< 0.12 vs. < 0.12		0.14 vs. 0.21	
	ß [CI]-model 1	-0.049 [-0.14; 0.043]	0.295	-0.012 [-0.14; 0.12]	0.858	-0.076 [-0.20; 0.051]	0.241
	ß [CI]-model 2	-0.053 [-0.14; 0.035]	0.239	-0.027 [-0.15; 0.098]	0.671	-0.07 [-0.19; 0.053]	0.265
	ß [CI]-model 3	-0.13 [-0.28; 0.008]	0.064	-0.071 [-0.25; 0.11]	0.437	-0.12 [-0.30; 0.059]	0.189
β-carotene	Median	< 0.02 vs. 0.33		< 0.02 vs. < 0.02		0.71 vs. 2.55	
	ß [CI]-model 1	-1.87 [-3.87; 0.12]	0.066	-0.78 [-3.63; 2.07]	0.592	-2.51 [-5.1; 0.073]	0.057
	ß [CI]-model 2	-1.88 [-3.81; 0.051]	0.056	-0.97 [-3.76; 1.82]	0.496	-2.39 [-4.92; 0.15]	0.065
	ß [CI]-model 3	-3.70 [-6.85; -0.55]	0.021	-0.61 [-4.65; 3.43]	0.767	-2.08 [-5.89; 1.74]	0.287
E-lycopene	Median	< 0.005 vs. < 0.005		< 0.005 vs. < 0.005		< 0.005 vs. < 0.09	
	ß [CI]-model 1	-0.38 [-1.49; 0.73]	0.501	0.23 [-1.35; 1.80]	0.777	-0.87 [-2.41; 0.67]	0.269
	ß [CI]-model 2	-0.42 [-1.51; 0.67]	0.452	0.12 [-1.45; 1.68]	0.884	-0.84 [-2.37; 0.69]	0.281
	ß [CI]-model 3	0.30 [-1.45; 2.06]	0.734	1.39 [-0.90; 3.68]	0.235	0.47 [-1.72; 2.66]	0.672
Z-lycopene	Median	< 0.005 vs. < 0.005		< 0.005 vs. < 0.005		< 0.005 vs. < 0.005	
	ß [CI]-model 1	-0.29 [-1.34; 0.77]	0.595	0.30 [-1.19; 1.79]	0.694	-0.80 [-2.27; 0.68]	0.289
	ß [CI]-model 2	-0.31 [-1.35; 0.73]	0.559	0.21 [-1.27; 1.69]	0.781	-0.76 [-2.22; 0.70]	0.305
	ß [CI]-model 3	-0.31 [-1.97; 1.35]	0.718	0.14 [-2.00; 2.28]	0.896	-0.78 [-2.85; 1.28]	0.458
Sum lycopene	Median	< 0.09 vs. < 0.09		< 0.09 vs. < 0.09		< 0.09 vs. 0.29	
	ß [CI]-model 1	-0.59 [-2.40; 1.23]	0.526	0.52 [-2.05; 3.10]	0.691	-1.49 [-4.02; 1.03]	0.246
	ß [CI]-model 2	-0.65 [-2.44; 1.14]	0.478	0.35 [-2.21; 2.91]	0.79	-1.45 [-3.94; 1.05]	0.257
	ß [CI]-model 3	0.072 [-2.78; 2.93]	0.961	1.69 [-2.04; 5.41]	0.375	-0.029 [-3.59; 3.53]	0.987
astaxanthin	Median	0.37 vs. 0.38		0.36 vs. 0.31		0.48 vs. 0.42	
	ß [CI]-model 1	0.045 [-0.067; 0.16]	0.428	0.078 [-0.08; 0.24]	0.330	0.012 [-0.15; 0.17]	0.887
	ß [CI]-model 2	0.039 [-0.074; 0.15]	0.496	0.075 [-0.083; 0.23]	0.351	0.013 [-0.15; 0.17]	0.875
	ß [CI]-model 3	-0.059 [-0.23; 0.12]	0.511	0.056 [-0.16; 0.28]	0.617	-0.044 [-0.26; 0.18]	0.700
lutein	Median	< 0.88 vs. < 0.88		< 0.02 vs. < 0.88		< 0.88 vs. < 0.88	
	ß [CI]-model 1	-0.32 [-0.67; 0.037]	0.079	-0.33 [-0.83; 0.18]	0.204	-0.31 [-0.78; 0.17]	0.208
	ß [CI]-model 2	-0.33 [-0.67; 0.014]	0.060	-0.37 [-0.86; 0.12]	0.140	-0.28 [-0.74; 0.18]	0.233
	ß [CI]-model 3	-0.68 [-1.22; -0.15]	0.013	-0.52 [-1.21; 0.17]	0.139	-0.49 [-1.16; 0.17]	0.147
canthaxanthin	Median	0.15 vs. 0.18		0.17 vs. 0.18		0.15 vs. 0.18	
	ß [CI]-model 1	-0.041 [-0.10; 0.022]	0.206	-0.014 [-0.10; 0.074]	0.763	-0.069 [-0.16; 0.021]	0.132
	ß [CI]-model 2	-0.041 [-0.10; 0.022]	0.199	-0.015 [-0.10; 0.073]	0.731	-0.068 [-0.16; 0.021]	0.135
	ß [CI]-model 3	-0.12 [-0.22; -0.018]	0.020	-0.096 [-0.22; 0.029]	0.131	-0.14 [-0.27; -0.012]	0.032
β-cryptoxanthin	Median	0.38 vs. 0.51		0.24 vs. 0.24		0.69 vs. 0.78	
	ß [CI]-model 1	-0.18 [-0.36; -7e-05]	0.05	-0.043 [-0.28; 0.19]	0.720	-0.29 [-0.52; -0.058]	0.015
	ß [CI]-model 2	-0.19 [-0.37; -0.006]	0.042	-0.045 [-0.28; 0.19]	0.705	-0.29 [-0.52; -0.057]	0.015
	ß [CI]-model 3	-0.42 [-0.70; -0.13]	0.004	0.035 [-0.30; 0.37]	0.837	-0.23 [-0.56; 0.11]	0.186

ß, difference between groups; CI, confidence interval.

Model 1— adjusted for age and sex. Model 2—adjusted for age, sex and physical activity. Model 3—adjusted for the variables used in model 2 plus energy intake, the modified Mediterranean diet adherence score (subtracting the questions regarding F&V, fat and wine) and alcohol consumption (g/day). *P*-values < 0.05 were considered significant.

Table S5. Differences in individual carotenoids plasma concentrations (μmol/L) between extreme groups.

		Low-to-Moderate fat & high F&V vs. High fat & low F&V	***p*-value**	**High fat & high F&V vs. Low-to-Moderate fat & low F&V**	***p*-value**
α-carotene	Median	0.21 vs. < 0.12		0.14 vs. < 0.12	
	ß [CI]-model 1	0.19 [0.063; 0.31]	0.003	0.10 [-0.028; 0.23]	0.126
	ß [CI]-model 2	0.16 [0.035; 0.28]	0.012	0.061 [-0.066; 0.19]	0.348
	ß [CI]-model 3	0.16 [0.013; 0.32]	0.033	-0.026 [-0.26; 0.20]	0.825
β-carotene	Median	2.55 vs. < 0.02		0.71 vs. < 0.02	
	ß [CI]-model 1	5.75 [3.03; 8.48]	< 0.001	2.46 [-0.30; 5.22]	0.081
	ß [CI]-model 2	5.31 [2.63; 8.00]	< 0.001	1.96 [-0.78; 4.69]	0.161
	ß [CI]-model 3	5.13 [1.82; 8.43]	0.002	2.44 [-2.64; 7.53]	0.347
E-lycopene	Median	< 0.09 vs. < 0.005		< 0.005 vs. < 0.005	
	ß [CI]-model 1	1.28 [-0.24; 2.79]	0.098	0.63 [-0.97; 2.24]	0.438
	ß [CI]-model 2	1.15 [-0.36; 2.65]	0.136	0.42 [-1.18; 2.03]	0.605
	ß [CI]-model 3	0.062 [-1.79; 1.91]	0.948	1.93 [-1.00; 4.85]	0.197
Z-lycopene	Median	< 0.005 vs. < 0.005		< 0.005 vs. < 0.005	
	ß [CI]-model 1	0.84 [-0.60; 2.28]	0.253	0.34 [-1.18; 1.86]	0.660
	ß [CI]-model 2	0.72 [-0.71; 2.16]	0.323	0.17 [-1.36; 1.7]	0.827
	ß [CI]-model 3	0.20 [-1.55; 1.96]	0.820	-0.44 [-3.16; 2.29]	0.754
Sum lycopene	Median	0.29 vs. < 0.09		< 0.09 vs. < 0.09	
	ß [CI]-model 1	2.04 [-0.44; 4.52]	0.107	1.07 [-1.55; 3.69]	0.423
	ß [CI]-model 2	1.83 [-0.63; 4.30]	0.145	0.74 [-1.89; 3.36]	0.582
	ß [CI]-model 3	0.33 [-2.69; 3.35]	0.831	1.99 [-2.77; 6.74]	0.413
astaxanthin	Median	0.42 vs. 0.36		0.48 vs. 0.31	
	ß [CI]-model 1	0.11 [-0.051; 0.26]	0.187	0.20 [0.034; 0.36]	0.018
	ß [CI]-model 2	0.099 [-0.059; 0.26]	0.218	0.19 [0.023; 0.35]	0.025
	ß [CI]-model 3	0.11 [-0.075; 0.30]	0.242	0.12 [-0.16; 0.41]	0.395
lutein	Median	< 0.88 vs. < 0.02		< 0.88 vs. < 0.88	
	ß [CI]-model 1	0.96 [0.46; 1.46]	< 0.001	0.33 [-0.16; 0.81]	0.190
	ß [CI]-model 2	0.85 [0.37; 1.33]	< 0.001	0.20 [-0.28; 0.68]	0.413
	ß [CI]-model 3	0.83 [0.25; 1.40]	0.005	-0.19 [-1.05; 0.68]	0.675
canthaxanthin	Median	0.18 vs. 0.17		0.15 vs. 0.18	
	ß [CI]-model 1	0.041 [-0.047; 0.13]	0.363	-0.042 [-0.13; 0.048]	0.362
	ß [CI]-model 2	0.038 [-0.051; 0.13]	0.404	-0.046 [-0.14; 0.045]	0.321
	ß [CI]-model 3	0.12 [0.012; 0.23]	0.029	-0.12 [-0.28; 0.047]	0.162
β-cryptoxanthin	Median	0.78 vs. 0.24		0.69 vs. 0.24	
	ß [CI]-model 1	0.74 [0.51; 0.97]	< 0.00001	0.41 [0.17; 0.64]	< 0.001
	ß [CI]-model 2	0.74 [0.51; 0.97]	< 0.00001	0.4 [0.16; 0.64]	0.001
	ß [CI]-model 3	0.66 [0.38; 0.95]	< 0.00001	0.47 [0.038; 0.91]	0.033

ß, difference between groups; CI, confidence interval.

Model 1— adjusted for age and sex. Model 2—adjusted for age, sex and physical activity. Model 3—adjusted for the variables used in model 2 plus energy intake, the modified Mediterranean diet adherence score (subtracting the questions regarding F&V, fat and wine) and alcohol consumption (g/day). *P*-values < 0.05 were considered significant.