

Original Article

Plasma retinol and α -tocopherol status of the Taiwanese elderly population

Wei-Yi Cheng MS,¹ Ming-Ling Fu MS,^{1,4} Li-Jou Wen BS,² Cheng Chen MS,³
Wen-Harn Pan PhD^{1,3} and Ching-jang Huang PhD^{1,2}

¹*Institute of Microbiology and Biochemistry, National Taiwan University, Taipei, Taiwan*

²*Department of Biochemical Science and Technology, National Taiwan University, Taipei, Taiwan*

³*Institute of Biomedical Sciences, Academia Sinica, Taipei, Taiwan*

⁴*Department of Food Nutrition, Chung Hwa College of Medical Technology, Tainan, Taiwan*

Biochemical assessment of vitamin A and vitamin E status of Taiwanese elderly persons was conducted by quantitative analysis of the concentration of retinol and α -tocopherol in plasma samples collected in the Elderly Nutrition and Health Survey in Taiwan (1999-2000). Plasma samples were analyzed by a reverse phase HPLC that can detect retinol and α -tocopherol simultaneously. The mean (SE) plasma retinol and α -tocopherol values in the 2373 valid samples were 2.73 (0.03) and 27.12 (0.47) μ M, respectively, after weighting to the whole population using the SUDDAN program. Among the elderly persons studied, 99.52% of the population demonstrated normal plasma vitamin A status (plasma retinol equal to or greater than 0.7 μ M or 0.2 μ g/mL). The prevalence of deficient (less than 11.63 μ M or 5 μ g/mL) and marginal (greater than or equal to 11.63, but less than 16.28 μ M or 7 μ g/mL) plasma α -tocopherol concentrations in the elderly population in Taiwan were 2.91% and 10.61%, respectively. However, the prevalence of low or inadequate vitamin E status decreased to 4.20% when the plasma α -tocopherol/cholesterol ratio was used as the indicator (less than 2.8 μ g/mg). Results of the multiple linear regression analysis revealed that serum lipids had a strong influence on plasma α -tocopherol concentration. The results also showed that elderly men, those living in two Central Taiwan regions, and subjects with plasma cholesterol levels higher than 200 or lower than 174 mg/dL all had higher risk of low or inadequate α -tocopherol status than their counterparts. In conclusion, the plasma vitamin A and vitamin E status in the Taiwanese elderly are comparable to those reported for adults of developed Western societies.

Key Words: plasma α -tocopherol, plasma retinol, elderly, nutrition survey, biochemical status, Elderly Nutrition and Health Survey in Taiwan (1999-2000)

Introduction

Vitamin A and E are fat-soluble vitamins that are essential for human health. Results from dietary surveys in Taiwan over past decades have shown that vitamin A intake is adequate, but biochemical assessment of vitamin A status of elderly persons in Taiwan is not commonly reported. Signs of severe vitamin E deficiency due to inadequate dietary intake of vitamin E such as neurological abnormalities are rarely found in humans.¹ However, being the most important fat-soluble biological antioxidant in the body, vitamin E is suggested to play a significant role in preventing pathological conditions in which free-radical mediated oxidative stress is implicated, including chronic diseases such as cardiovascular disease and cancer.^{2,3} It is well-known that these types of chronic disease are most prevalent in the aged population in developed countries. Vital statistics over the past decades have shown that chronic diseases are currently the main public health issue in Taiwan. The biochemical assessment of vitamin E status in elderly people in Taiwan is thus warranted from the public health point of view. A reverse phase HPLC for the simultaneous determination of α -tocopherol and retinol was employed in this study to assess vitamin A and vitamin E status by analyzing plasma samples from elderly

persons collected in the Elderly Nutrition and Health Survey in Taiwan (1999-2000).

Subjects and methods

Sampling and study design

The sampling scheme, anthropometric measurements, and blood collection and management procedures have been described elsewhere.⁴ Heparinized whole blood was used for on-site measurement of hemoglobin. Hemoglobin was measured colorimetrically by the cyanomethemoglobin method (Merckotest, Merck) using a portable filter photometer Flash calibrated with hemoglobin cyanide standard solution (Merck). Mean corpuscular hemoglobin concentration (MCHC) was calculated as a percentage of hemoglobin to hematocrit. Serum was analyzed within a month for

Correspondence address: Ching-jang Huang, Ph.D, Department of Biochemical Science and Technology, National Taiwan University, 1, Sec.4, Roosevelt Rd. Taipei 106, Taiwan
Tel/Fax: 886-2-2362-1301

E-mail: cjhuang@ntu.edu.tw

Accepted 30 June 2005

triglycerides, total cholesterol, and high-density lipoprotein cholesterol (HDL-C) using a Hitachi model 747 automatic analyzer. Low-density lipoprotein cholesterol (LDL-C) was calculated as follows: $LDL-C = \text{total cholesterol} - (\text{HDL-C}) - \text{triglycerides}/5$. These data, including serum cholesterol, were used in the present study for further data analysis. For the analysis of retinol and α -tocopherol, blood was drawn into heparinized tubes. After centrifugation, plasma samples were stored at -80°C until analysis.

Assay of plasma retinol and α -tocopherol

The method described by Miller *et al.*, was employed with some modification.⁵ After thawing, 0.1 mL of plasma sample was added to 0.1 mL of α -tocopheryl acetate (25 $\mu\text{g}/\text{mL}$) as an internal control and 0.1 mL of ice-cold ethanol containing 1% pyrogallol. This was then mixed by vortex for 1 min before adding 2 mL *n*-hexane and vortexing for an additional 5 mins. After centrifugation at 1000 rpm for 5 min, 1.8 mL of upper hexane phase was collected and the solvent was evaporated. The residue was dissolved in 0.1 mL of methanol-chloroform 2:1 (v/v) and analyzed by a reverse phase HPLC equipped with a LiChroCART[®] 125-4 RP-18 (5 μm) column (Merck Cat. No.1.50943) and a guard column, Jasco PU-980 Intelligent HPLC pump and Jasco AS-2055 plus intelligent autosampler. Isocratic separation was performed with a mixture of methanol, acetonitrile and chloroform 47:55:10 (v/v) and the flow rate was 1 mL/min. The effluent was monitored with two detectors in series: retinol was detected using a Jasco 870-UV Intelligent UV/VIS Detector at 325 nm; α -tocopherol and α -tocopherol acetate were detected using a Jasco 821-FP Intelligent Spectrofluorometer at Excitation 286nm/ Emission 330nm. The concentration of each peak was calculated by interpolation to standard curves established by analyzing various concentrations of standard compounds under identical HPLC conditions. The retention times of retinol, α -tocopherol acetate and α -tocopherol were 2, 5 and 6 min, respectively. Standard retinol (R-7632) and α -tocopherol acetate (T-3376) were obtained from Sigma, and α -tocopherol was obtained from CALBIOCHEM (Cat. No.613424). HPLC grade methanol, acetonitrile, chloroform, and *n*-hexane (Merck) were used for the preparation of the mobile phase.

The variation among different batches of analysis was monitored by including a quality control (QC) sample in each batch of analysis. This QC sample was prepared by aliquoting a thoroughly mixed batch of plasma. The coefficients of variation of this QC sample among the 52 analysis batches for retinol and α -tocopherol were 9.62 and 9.02 % respectively. For interlaboratory comparison, the procedure was also confirmed by similarly analyzing a standardized plasma sample (SRM[®] 968c, National Institute of Standards & Technology). Our results of this standardized sample were $0.519 \pm 0.04 \mu\text{g}/\text{mL}$ for retinol, which was similar to the reported value ($0.484 \pm 0.012 \mu\text{g}/\text{mL}$), and $16.02 \pm 0.87 \mu\text{g}/\text{mL}$ for α -tocopherol, which was within the range of the reported value ($16.79 \pm 0.76 \mu\text{g}/\text{mL}$).

Definitions for vitamin A and E status

Nutritional adequacy of vitamin A was represented by a plasma retinol concentration equal to or greater than 0.2 $\mu\text{g}/\text{mL}$.⁶ Values between 0.1 and 0.2 were considered as marginal, and values less than 0.1 were deficient. Nutritional adequacy of vitamin E was represented by a plasma α -tocopherol concentration equal to or greater than 7 $\mu\text{g}/\text{mL}$. Values less than 5 $\mu\text{g}/\text{mL}$ were considered as vitamin E deficient, values between 5 and 7 $\mu\text{g}/\text{mL}$ were regarded as marginal.⁶ Alternatively, a ratio of α -tocopherol/cholesterol equal to or greater than 2.8 $\mu\text{g}/\text{mg}$ was considered vitamin E adequate.⁷ Multiple logistic regression analysis of dichotomized plasma α -tocopherol or α -tocopherol/cholesterol ratio was performed to examine factors associated with a plasma α -tocopherol concentration of less than 7 $\mu\text{g}/\text{mL}$ or a α -tocopherol/cholesterol ratio of less than 2.8.

Statistical analysis

Anthropometric as well as blood and serum biochemical parameters obtained from the survey were first checked for their correlation with plasma α -tocopherol by Pearson's correlation using the SAS program. Factors showing significant and relatively high correlation coefficients were confirmed by linear regression and logistic regression analysis separately and then combined for multivariate analysis, each adjusted for age and gender using SUDDAN. In the logistic regression analysis with serum parameters, subjects were categorized by quartile based on their LDL-cholesterol, total cholesterol, triglycerides, hemoglobin and MCHC values. In addition to these statistical analyses, mean, SE and prevalence data were also weighted to the Taiwan population by SUDDAN SAS-callable version 8.0.

Results

Out of the plasma samples analyzed, 2373 samples had basic background data (age, gender and strata) and were included in the statistical analysis for weighting to the population according to the stratified study design. In addition, 2349 samples also had valid serum cholesterol data from which the α -tocopherol/cholesterol could be calculated as an alternative indicator of vitamin E status. As shown in Table 1, the mean value of plasma retinol concentration was 2.73 μM for elderly persons aged over 65 in Taiwan, well above the cut-off point for nutritional adequacy of vitamin A (0.7 μM). The prevalence of deficient and marginal plasma retinol levels were 0.36% and 0.12%, respectively. These results indicate that the biochemical status of vitamin A in the Taiwanese elderly population is quite satisfactory. Only 12 out of the 2373 samples analyzed showed a plasma retinol less than the cut-off point concentration, and only 3 fell into the frank deficiency category (less than 0.35 μM). These 12 cases did not seem to be clustered in specific age, sex or strata groups. Preliminary logistic regression analysis showed that elderly subjects with self-reported liver cirrhosis were more likely to have marginal and deficient plasma retinol concentrations. (Odds ratio 67.334, 95% confidence interval 5.29-857.0, $P=0.0012$).

Table 1. Plasma retinol concentrations in Taiwanese elderly persons by age, gender and strata from the Elderly Nutrition and Health Survey in Taiwan (1999-2000)

	Plasma Retinol			Prevalence		
	N	Concentration (μ M)		Normal ¹	Marginal ¹	Deficiency ¹
		Mean	SE	N (%)	N (%)	N (%)
All	2373	2.73	0.03	2361 (99.52)	9 (0.36)	3 (0.12)
Gender						
Male	1196	2.80	0.03	1190 (99.36)	5 (0.49)	1 (0.16)
Female	1177	2.66	0.03	1171 (99.70)	4 (0.22)	2 (0.8)
Ages						
65-69	919	2.69	0.07	915 (99.45)	3 (0.32)	1 (0.23)
70-74	777	2.80	0.03	771 (99.13)	5 (0.77)	1 (0.10)
75-79	438	2.62	0.07	437 (99.94)	1 (0.06)	0 (0)
\geq 80	239	2.80	0.10	238 (99.94)	0 (0)	1 (0.06)
Strata						
Hakka Areas	176	2.69	0.03	175 (99.38)	1 (0.62)	0 (0)
Mountain Areas	166	3.39	0.35	166 (100)	0 (0)	0 (0)
Eastern Areas	199	2.66	0.17	196 (98.66)	2 (0.92)	1 (0.41)
PengHu Islands	140	2.97	0.14	140 (100)	0 (0)	0 (0)
Northern Areas: 1st stratum	151	2.83	0.07	151 (100)	0 (0)	0 (0)
Northern Areas: 2nd stratum	193	3.04	0.10	193 (100)	0 (0)	0 (0)
Northern Areas: 3rd stratum	183	2.69	0.10	182 (100)	1 (0.56)	0 (0)
Central Areas: 1st stratum	159	2.69	0.21	159 (100)	0 (0)	0 (0)
Central Areas: 2nd stratum	209	2.69	0.07	208 (99.46)	1 (0.54)	0 (0)
Central Areas: 3rd stratum	225	2.48	0.03	224 (99.54)	1 (0.46)	0 (0)
Southern Areas: 1st stratum	165	2.87	0.07	162 (98.3)	2 (1.18)	1 (0.51)
Southern Areas: 2nd stratum	188	2.59	0.14	188 (100)	0 (0)	0 (0)
Southern Areas: 3rd stratum	219	2.55	0.17	217 (99.07)	1 (0.44)	1 (0.49)

¹Normal, $\geq 0.7\mu$ M (0.2 μ g/mL); 0.7 μ M \leq Marginal $<$ 0.35 μ M; Deficiency, $< = 0.35\mu$ M (0.1 μ g/mL)

The mean plasma α -tocopherol (27.12 μ M) was also higher than the cut-off point concentration (16.28 for marginal and 11.63 μ M for frank deficiency) for nutritional adequacy of vitamin E. However, 10.61% and 2.91% of the elderly population had plasma α -tocopherols that fell within the range of marginal and deficient respectively. The prevalence of marginal and deficient plasma α -tocopherol concentrations was higher in men than in women, and was higher in the eastern areas stratum, and the first and third strata in the central areas, as shown by results obtained from multiple logistic regression analysis by SUDDAN (Table 2). It is known that plasma α -tocopherol is highly associated with blood lipids and

we have also observed such an association in this study (Table 4). The plasma α -tocopherol/cholesterol ratio was therefore calculated as an alternative plasma vitamin E status indicator and data are shown in Table 3. The mean (SE) value of the plasma α -tocopherol/cholesterol ratio in the Taiwanese elderly population was 5.84 (0.11). The prevalence of inadequate vitamin E status using 2.8 μ mol/mmol as the cut-point was 4.2%. Elderly women had a lower risk of inadequate plasma α -tocopherol/cholesterol ratio than men (odds ratio 0.56, 95% confidence interval 0.38-0.81). Residents of the first stratum in the central areas, also had a higher risk of inadequate plasma α -tocopherol/cholesterol ratio (odds ratio 6.32, 95% confidence

Table 2. Plasma α -tocopherol concentrations and prevalence of deficiency in Taiwanese elderly persons by age, gender and strata from the Elderly Nutrition and Health Survey in Taiwan (1999-2000)

	Plasma α -tocopherol			Prevalence			OR(CI) ²
	concentrations (μ M)			Normal ¹	Marginal ¹	Deficiency ¹	
	N	Mean	SE	N (%)	N (%)	N (%)	
All	2373	27.12	0.47	2022 (86.48)	268 (10.61)	83(2.91)	
Gender							
Male	1196	25.07	0.35	975 (82.73)	172 (13.67)	49 (3.60)	1.00
Female	1177	29.33	0.67	1047 (90.50)	96 (7.33)	34 (2.17)	0.48 (0.36-0.65)*
Age							
65-69	919	26.70	0.51	791 (87.09)	103 (10.24)	25 (2.67)	1.00
70-74	777	28.07	0.74	666 (87.25)	83 (10.07)	28 (2.68)	1.00 (0.71-1.41)
75-79	438	26.60	0.65	373 (84.71)	52 (12.99)	13 (2.30)	1.20 (0.77-1.87)
\geq 80	239	26.86	0.95	192 (85.70)	30 (9.57)	17 (4.73)	1.19 (0.80-1.76)
Strata							
Hakka Areas	176	25.51	1.02	156 (88.46)	17 (9.79)	3 (1.75)	1.00
Mountain Areas	166	23.74	1.67	149 (89.06)	12 (8.24)	5 (2.71)	0.95 (0.30-3.04)
Eastern Areas	199	21.74	1.47	135 (67.31)	47 (24.36)	17 (8.33)	3.58 (1.64-7.82)*
PengHu Islands	140	26.91	1.23	129 (93.3)	11 (6.70)	0 (0)	0.54 (0.21-1.37)
Northern Areas: 1st stratum	151	32.74	1.84	142 (94.11)	9 (5.89)	0 (0)	0.45 (0.19-1.06)
Northern Areas: 2nd stratum	193	29.91	0.77	167 (87.15)	23 (11.29)	3 (1.56)	1.08 (0.42-2.75)
Northern Areas: 3rd stratum	183	27.26	0.93	162 (87.97)	16 (9.35)	5 (2.69)	1.01 (0.59-1.73)
Central Areas: 1st stratum	159	24.56	1.77	123 (76.47)	20 (14.16)	16 (9.37)	2.42 (1.20-4.87)*
Central Areas: 2nd stratum	209	25.56	1.58	176 (83.50)	28 (13.23)	5 (3.27)	1.49 (0.79-2.81)
Central Areas: 3rd stratum	225	21.40	0.81	170 (74.38)	39 (18.16)	16 (7.45)	2.79 (1.41-5.54)*
Southern Areas: 1st stratum	165	30.16	0.98	154 (93.83)	7 (3.98)	4 (2.19)	0.48 (0.19-1.25)
Southern Areas: 2nd stratum	188	28.35	1.60	168 (88.99)	16 (8.84)	4 (2.17)	0.92 (0.36-2.34)
Southern Areas: 3rd stratum	219	24.79	0.44	191 (86.46)	23 (10.91)	5 (2.63)	1.20 (0.62-2.30)

¹Normal, \geq 16.28 μ M (7 μ g/mL); 16.28 \leq Marginal <11.63; deficiency, \leq 11.63 μ M (5 μ g/mL); ²multiple logistic regression analysis of effects of gender, age and strata on marginal or deficient plasma α -tocopherol (\leq 11.63 μ M or 5 μ g/mL). OR: Odds Ratio, CI: Confidence Interval, analyzed by SUDDAN

interval 1.10-36.41). Results of multivariate linear regression analysis showed that sex, age, BMI (β =-0.0771, P =0.0071), MCHC (β =0.4186, P =0.0464), serum cholesterol (β =0.0560, P =0.0000) and triglycerides (β =0.0122, P =0.0000) were associated with plasma α -tocopherol. When the same analysis was conducted on the plasma α -tocopherol/cholesterol ratio, only BMI (β =-0.0004, P =0.0058), serum triglycerides (β =0.001, P =0.0000) and MCHC (β =0.0021, P =0.0380) showed an association. Table 4 shows the results of multivariate logistic regression

analysis on plasma α -tocopherol concentration and α -tocopherol/cholesterol ratio. Elderly persons whose serum cholesterol was at the lowest quartile (cholesterol 174 mg/dL) had significantly higher risk of having marginal or deficient plasma α -tocopherol (odds ratio = 4.4, 95% confidence interval 3.24 - 5.98, P =0.0000) when subjects with a cholesterol level in the third quartile (174-200mg/dL) were taken as the reference group. Elderly persons with a cholesterol level in the highest and second quartile had significantly lower risk (Table 4).

Table 3. Plasma α -tocopherol/cholesterol ratio and prevalence of deficiency in Taiwanese elderly persons by gender, age and strata from the Elderly Nutrition and Health Survey in Taiwan (1999-2000)

	α -Tocopherol /Cholesterol			Prevalence		OR (CI) ²
	(μg/mg)			Normal ¹	Deficiency ¹	
	N	Mean	SE	N (%)	N (%)	
All	2349	5.84	0.11	2245 (95.80)	104 (4.20)	
Gender						
Male	1188	5.53	0.08	1123 (94.68)	65 (5.32)	1.00
Female	1161	6.18	0.15	1122 (97.00)	39 (3.00)	0.56 (0.38-0.81)*
Ages						
65-69	912	5.68	0.13	872 (95.51)	40 (4.49)	1.00
70-74	767	5.90	0.14	737 (96.38)	30 (3.62)	0.79 (0.42-1.50)
75-79	433	5.86	0.15	414 (96.04)	19 (3.96)	0.84 (0.46-1.52)
≥80	237	6.08	0.26	222 (94.98)	15 (5.02)	1.11 (0.55-2.27)
Strata						
Hakka Areas	174	5.68	0.40	170 (97.79)	4 (2.21)	1.00
Mountain Areas	164	5.22	0.23	159 (97.10)	5 (2.90)	1.31 (0.17-9.92)
Eastern Areas	198	4.99	0.17	184 (93.30)	14 (6.70)	3.04 (0.59-15.68)
PengHu Islands	140	5.57	0.21	138 (98.79)	2 (1.21)	0.54 (0.07-3.89)
Northern Areas: 1st stratum	149	6.71	0.39	143 (95.90)	6 (4.10)	1.80 (0.32-10.19)
Northern Areas: 2nd stratum	190	6.50	0.19	181 (95.13)	9 (4.87)	2.21 (0.39-12.63)
Northern Areas: 3rd stratum	179	5.99	0.15	173 (96.36)	6 (3.64)	1.59 (0.28-9.09)
Central Areas: 1st stratum	157	5.58	0.41	137 (87.12)	20 (12.88)	6.32 (1.10-36.41)*
Central Areas: 2nd stratum	208	5.77	0.44	199 (95.16)	9 (4.84)	2.21 (0.45-10.71)
Central Areas: 3rd stratum	220	5.01	0.21	206 (94.27)	14 (5.73)	2.69 (0.53-13.68)
Southern Areas: 1st stratum	163	5.99	0.21	160 (98.31)	3 (1.69)	0.73 (0.12-4.46)
Southern Areas: 2nd stratum	188	5.85	0.35	180 (95.68)	8 (4.32)	1.94 (0.32-11.86)
Southern Areas: 3rd stratum	219	5.25	0.12	215 (98.11)	4 (1.89)	0.84 (0.10-6.72)

¹Normal: ≥ 2.8 $\mu\text{g}/\text{mg}$; Deficiency: < 2.8 $\mu\text{g}/\text{mg}$. ²Multiple logistic regression analysis for the effects of gender, age and strata on deficient plasma α -tocopherol/cholesterol ratio (≤ 2.8 $\mu\text{g}/\text{mg}$). OR: Odds Ratio, CI: Confidence Interval, analyzed by SUDDAN

Interestingly, when the same analysis was conducted on the plasma α -tocopherol/cholesterol ratio, elderly persons with a serum cholesterol level in the highest, second and lowest quartile all had significantly higher risk of having low or inadequate plasma α -tocopherol/cholesterol ratio. Elderly subjects with a BMI greater than 30 showed a significantly higher risk of marginal or deficient plasma α -tocopherol concentration (Table 4).

Discussion

The plasma retinol concentrations observed in this study indicate that the biochemical status of vitamin A in elderly persons in Taiwan is satisfactory. Not only is the mean value well above the cut-off point, but also the prevalence of marginal and deficient levels of vitamin A is as low as

0.48%. This result coincides with the fact that the mean vitamin A dietary intake of Taiwanese adult residents is ample.⁹ The mean vitamin A intake of Taiwanese adults was reported to be 162% (male) and 186% (female) of the RDA value in the Nutrition and Health Survey in Taiwan 1993-1996 (NAHSIT 1993-1996).⁸ In the survey from which plasma samples analyzed in this study were collected (the Elderly Nutrition and Health Survey in Taiwan (1999-2000); Elderly NAHSIT), the dietary vitamin A intake of Taiwanese elderly persons was reported to be 9194 IU/day, which is about 1.9 times the RDA value.⁹ The plasma level of vitamin E in elderly persons in Taiwan, however, is not as satisfactory as that of vitamin A. The prevalence of marginal and deficient levels were 10.61% and 2.91%, respectively. The strong dependence of plasma α -tocopherol on plasma lipids was

Table 4. Risks of marginal or deficient vitamin E status as affected by BMI and some blood and serum biochemical parameters

		α -tocopherol concentration			α -tocopherol/cholesterol ratio			
		Mean	<i>n</i> / <i>N</i> ¹	OR (95% CI) ¹	<i>P</i> value	<i>n</i> / <i>N</i> ¹	OR (95%CI) ¹	<i>P</i> value
Gender	Male		220 / 1193	1		45 / 1193	1	
	Female		132 / 1158	0.58 (0.37-0.90)	0.0167*	36 / 1158	0.62 (0.27-1.42)	0.2496
Age (year)	65-69	67.00	121 / 913	1		20 / 913		
	70-74	71.86	113 / 771	1.05 (0.74-1.50)	0.7820	29 / 771	1.56 (0.64-3.79)	0.3175
	75-80	76.61	66 / 430	1.06 (0.73-1.53)	0.7633	19 / 430	1.54 (0.60-3.97)	0.3543
	≥80	83.48	52 / 237	1.04 (0.62-1.75)	0.8861	13 / 237	1.93 (0.60-6.18)	0.2582
BMI (kg/m ²)	18.5-24	21.63	168 / 1101	1		39 / 1101	1	
	<18.5	17.22	57 / 211	1.51 (0.84-2.70)	0.1570	11 / 211	0.81 (0.38-1.71)	0.5618
	24-27	25.33	79 / 645	1.11 (0.68-1.81)	0.6687	20 / 645	1.25 (0.55-2.85)	0.5883
	27-30	28.27	27 / 275	1.10 (0.64-1.90)	0.7091	6 / 275	1.08 (0.30-3.87)	0.9034
	>30	31.76	21 / 119	2.47 (1.57-3.89)	0.0004*	5 / 119	1.57 (0.54-4.57)	0.3923
LDL-C ² (mg/dL)	122-145	132.52	51 / 573	1		17 / 573	1	
	<98	79.94	169 / 591	0.69 (0.40-1.17)	0.1613	29 / 591	0.82 (0.21-3.14)	0.7578
	98-122	108.95	104 / 589	0.87 (0.53-1.44)	0.5757	18 / 589	0.92 (0.38-2.24)	0.8481
	>145	168.81	28 / 598	1.34 (0.68-2.66)	0.3805	17 / 598	0.86 (0.44-1.68)	0.6374
	174-200	187.12	75 / 566	1		12 / 566	1	
Cholesterol ² (mg/dL)	<174	153.28	214 / 602	4.40 (3.24-5.98)	0.0000*	33 / 602	4.18 (1.55-11.29)	0.0065*
	200-227	212.54	47 / 569	0.65 (0.42-1.00)	0.0483*	18 / 569	3.11 (1.16-8.28)	0.0253*
	>227	256.36	16 / 614	0.21 (0.10-0.43)	0.0002*	18 / 614	3.31 (1.16-9.42)	0.0264*
	105-156	125.39	69 / 598	1		15 / 598	1	
TG ² (mg/dL)	<75	58.39	136 / 579	1.31 (0.74-2.32)	0.3344	29 / 579	1.58 (0.55-4.55)	0.3855
	75-105	89.07	106 / 580	1.28 (0.79-2.06)	0.2989	24 / 580	1.60 (0.68-3.80)	0.2701
	>156	235.14	41 / 594	0.64 (0.34-1.21)	0.1619	13 / 594	0.75 (0.28-2.01)	0.5563
	>14.6	15.45	80 / 602	1		24 / 602	1	
Hgb ² (g/dL)	13.6-14.6	14.01	80 / 593	1.12 (0.73-1.73)	0.5822	14 / 593	0.71 (0.33-1.52)	0.3682
	12.5-13.6	13.04	89 / 625	1.52 (0.97-2.39)	0.0667	17 / 625	0.99 (0.39-2.53)	0.9846
	<12.5	11.35	103 / 531	1.40 (0.86-2.29)	0.1653	26 / 531	1.60 (0.60-4.25)	0.3358
	>34.1	34.63	82 / 616	1		22 / 616	1	
MCHC ² (g/dL)	33.4-34.1	33.70	99 / 681	1.27 (0.73-2.19)	0.3812	21 / 681	0.84 (0.38-1.87)	0.6553
	32.7-33.4	33.00	87 / 555	1.55 (0.87-2.77)	0.1330	19 / 555	1.02 (0.52-2.02)	0.9413
	<32.7	31.84	84 / 499	1.30 (0.68-2.47)	0.4128	19 / 499	0.82 (0.33-2.08)	0.6710

Abbreviations: BMI, body mass index; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; Hgb, hemoglobin; MCHC, mean corpuscular hemoglobin concentration. ¹*n*/*N*: number of marginal or deficient/total number in this category. OR: odds ratio analyzed by multiple logistic regression analysis weighted by SUDDAN. Plasma α -tocopherol <16.28 μ M (7 μ g/mL); α -tocopherol/cholesterol ratio <2.8 μ g/mg. ²Quantile in each category

also observed in this study (Table 4). The prevalence of deficiency decreased to 4.2% when α -tocopherol/cholesterol ratio was used as the indicator. It is difficult to compare the present results on vitamin E status with those of other studies due to different indicators and cut-off points used. The prevalence rate of vitamin E deficiency in the Taiwanese population, based on a plasma α -tocopherol/cholesterol + triglycerides ratio less than 1.59 $\mu\text{mol}/\text{mmol}$, was reported to be as low as 1.02% for adults aged over 19 in the NAHSIT 1993-1996.¹⁰ In this same study, the vitamin E deficiency prevalence rate estimated from 186 elderly (age >65) men and 176 elderly women was 0.13% and 0.84%, respectively, and the estimated mean (SE) plasma α -tocopherol was 20.0 (0.6) and 26.4 (2.3) μM respectively.¹⁰ Age, sex and strata differences in plasma vitamin E status were observed in NAHSIT 1993-1996.¹⁰ We also observed significant effects of sex and strata, but not that of age in the present Elderly NAHSIT survey, possibly because of a smaller range of age distribution in this elderly specific study. In contrast, the age-adjusted mean (SE) of plasma α -tocopherol and prevalence of deficiency (less than 20 μM) in adults aged 18 years or over were 26.6 (0.2) and 27% respectively in the US NHANES III.¹¹

The known association of plasma α -tocopherol with serum lipids was also observed in this study. It is of note that elderly subjects with a serum cholesterol level higher than 200 or lower than 174 mg/dL all showed higher risk of a low or inadequate α -tocopherol/cholesterol ratio. However, elderly subjects with higher serum cholesterol seem to have a lower risk of marginal or deficient plasma α -tocopherol concentration, as observed from the results of multiple logistic regression analysis (Table 4). This result strengthens the importance of maintaining optimal serum cholesterol for achieving satisfactory vitamin E status. Since a role for vitamin E in the prevention of cardiovascular disease has been implicated, this observation may be of significance to public health.

In conclusion, the plasma vitamin A status of Taiwan's elderly population is satisfactory. The mean values of plasma α -tocopherol concentration and α -tocopherol/cholesterol ratio were all comparable to those of USA adults observed in the NHANES III. The risk of marginal or deficient plasma α -tocopherol concentration was higher in elderly men, in elderly persons with lower or elevated serum cholesterol, and in elderly persons living in certain strata particularly the eastern and central areas.

References

1. Food and Nutrition Board, Institute of Medicine: Vitamin E. In: Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. 2000 National Academy Press, Washington, D.C.
2. Diaz MN, Frei B, Vita JA, Keaney JF Jr.. Antioxidants and atherosclerotic heart disease. *N Engl J Med* 1997; 337: 408-16.
3. Byers T, Perry G. Dietary carotenes, vitamin C, and vitamin E as protective antioxidants in human cancers. *Ann Rev Nutr* 1992; 12: 139-59.
4. Pan WH, Hung YT, Shaw NS, Lin W, Lee SD, Chiu CF, Lin MC, Chen SY, Hong CM, Huang TY, Chang HY, Tu SH, Chang YH, Yeh WT, Su SC. Elderly Nutrition and Health Survey in Taiwan (1999-2000): research design, methodology and content. *Asia Pac J Clin Nutr* 2005; 14 (3): 203-210.
5. Miller KW, Lorr NA, Yang CS. Simultaneous determination of plasmaretinol, α -tocopherol, lycopene, α -carotene, and β -carotene by high-performance liquid chromatography. *Anal Biochem* 1984; 138: 340-345.
6. Sauberlich HE, Skala JH, Dowdy RP. Laboratory Tests for the Assessment of Nutritional Status. CRC Press. Cleveland, Ohio 1974; 7-80.
7. Horwitt MK, Harvey CC, Dahm CH, Searcy MT. Relationship between tocopherol and serum lipid levels for the determination of nutritional adequacy. *Ann. NY Acad. Sci* 1972; 203: 223-236.
8. Pan WH, Chang YH, Chen JY, Wu SJ, Tzeng MS, Kao MD. Nutrition and Health Survey in Taiwan (NAHSIT) 1993-1996: Dietary nutrient intakes assessed by 24-Hour Recall. *Nutr Sci J* 1999; 24: 11-39.
9. Wu SJ, Chang YH, Wei IL, Kao MD, Lin YC, Pan WH. Intake levels and major food sources of energy and nutrients in the Taiwanese elderly. *Asia Pac J Clin Nutr* 2005; 14 (3): 211-220.
10. Kang MJ, Lin YC, Yeh WH, Pan WH. Vitamin E status and its dietary determinants in Taiwanese: Results of the Nutrition and Health Survey in Taiwan 1993-1996. *Eur J Nutr* 2004; 43: 86-92.
11. Ford ES, Sowell A. Serum α -Tocopherol Status in the United States Population: Findings from the Third National Health and Nutrition Examination Survey. *Am J Epidemiol* 1999; 150: 290-300.