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ORIGINAL CONTRIBUTION

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Vitamin E status and its dietary determinants in Taiwanese

Results of the Nutrition and Health Survey in Taiwan 1993–1996

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Summary *Background* A large proportion of Taiwanese are considered to have inadequate vitamin E intake according to Taiwanese RDA. *Aim of the study* To evaluate the vitamin E status in Taiwan using biochemical indicators, and to examine the influences of dietary factors. *Methods* The Nutrition and Health Survey in Taiwan 1993–1996 was conducted using a multi-stage sampling scheme. Data of 3614 subjects (1728 males, and 1886 females) aged 4 years and above were included in the current analysis. *Results* Females had higher levels of serum α-tocopherol than males. Serum level of α-tocopherol significantly increased with age and blood lipids ($p < 0.001$). The prevalence rate of deficiency, assessed by the ratio of serum α-tocopherol to cholesterol + triglyceride(TG) < 1.59 μmol/mmol, was 1.4 % for Taiwanese aged 4 and above. The prevalence was 1.02 % for adults. This biochemical profile was superior in women compared to men. The age-serum vitamin E status was U-shaped, being poorest in teenagers. Geographical variation in vitamin E/cholesterol + TG ratio was not apparent across regions. An association was observed between serum vitamin E status and frequency of vitamin E supplements, fresh fruits, and 100 % fruit juices. An association was also seen with dietary intakes of vitamin C and vitamin E assessed by 24-hour recall. *Conclusions* The prevalence rate of vitamin E deficiency in Taiwan was low. An association was observed between serum vitamin E status and dietary vitamins E and C intakes either from foods or supplements.

Key words vitamin E – deficiency – Taiwan – α-tocopherol – supplement

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Introduction

Vitamin E is an essential nutrient and is well known for its functions as an antioxidant, and in reducing risks of heart disease as well as cancer [1]. The RDA of vitamin E in Taiwan is 10 and 12 mg α-tocopherol equivalent for males and females aged 13 years or above [2]; it was much higher than that of US (10 and 8 mg α-tocopherol equivalent for males and females aged 11 years or above) [3]. This relatively higher recommendation was due to the consideration that high polyunsaturated fatty acids (PUFA) intake (Taiwanese PUFA intake is 21.6 ± 22.5 g and 17.9 ±20.1 g for males and females aged 19–64 years) [4] in Taiwanese may increase the vitamin E requirement. Consequently, a large proportion of subjects are considered to have low vitamin E intake [4]. Therefore, we initiated the present study to evaluate the vitamin E status of Taiwanese using biochemical markers. The vitamin E nutriture can be evaluated by the measurements of α-tocopherol or total vitamin E in serum, erythrocyte, or adipose tissue, among which the measurement of the serum level of tocopherol is the most common method. The major problem is that the results are often confounded by blood lipid concentration [5]. Many researchers suggest the use of a tocopherol to total lipid ratio to assess vitamin E status [6, 7], but the total lipid value is not measured routinely in clinical laboratories. Thurnham et al. [8] found that the ratio of tocopherol to the sum of serum levels of cholesterol and triglyceride (TG) is almost as powerful as the tocopherol-total lipid ratio in identifying vitamin E deficiency. Thus, in our

EJN 444

current study, the ratio of tocopherol to the sum of serum levels of cholesterol and TG was used to assess the nutritional status of vitamin E of the people in Taiwan. Data from food frequency questionnaire (FFQ) and 24-hour recall was used in the analyses of the relationship between food sources and serum vitamin E to understand how the serum vitamin E status was affected by diet in Taiwan.

Materials and methods

Design

Data were collected through the Nutrition and Health Survey in Taiwan (NAHSIT) 1993–1996, an island-wide survey focused on the nutrition and health status of the general population in Taiwan. A complex sampling scheme was used in this survey [9]. The 359 townships in Taiwan were stratified into 7 strata (see Table 2) according to the characteristics of dietary patterns of the residents, geographical location, and degree of urbanization. Samples collected in each year are a representative sample of Taiwan. In this study, the samples of 3614 subjects (1728 males and 1886 females), collected in the first and the second survey years, were used. The fasting blood samples were collected and centrifuged immediately after drawing. The serum samples were then frozen on the same day at –70 °C until assayed.

Measurement of vitamin E

The method developed by Miller et al. was modified and used for determining the plasma α-tocopherol [9]. The α-tocopherol was extracted from serum samples with ethanol and petroleum ether. The ethanol layer was removed and dried under N_2 gas, and the pellet was dissolved in 100 µl ethanol. A 15 µl of the solution was then injected into a high performance liquid chromatography, the column of which was eluted isocratically with methanol:acetonitrile:chloroform [47:55:10] at a flow rate of 1 ml/min. The analytical column Inertsil 5 ODS-2 (4.0 mm I.Dx10 mm, 5 µm particle size) was used. Standards for α-tocopherol and α-tocopherol acetate were obtained from Sigma. LC grade of methanol, acetonitrile, and chloroform, and 100 % absolute ethanol and petroleum ether (Merck) were used.

For the laboratory data, split samples for blood collection (split samples) were collected from 5 % of the participants systematically. There were 160 pairs of split samples collected within two years. Samples from a laboratory control pool (control samples) were measured repeatedly in different batches. The coefficient of variation (CV) for the first and the second years of split samples was 7.4 % and 2.6 %, respectively. The reproducibility of control samples was 2.8 % and 0.5 % for the first and the second years, respectively. The serum α-tocopherol status was classified according to the cut-points by Thurnham et al. [8]. The ratio of serum α-tocopherol (µmol/L) to the sum of serum cholesterol and TG (mmol/L) less than 1.59 (µmol/mmol) is considered deficient.

Dietary assessment

A simple food frequency questionnaire (FFQ) with no portion size information was administered to obtain information on usual dietary intake and consumption of vitamin supplements. Included were 42 food items of the six food groups, fermented foods, coffee, and tea. Daily dietary intakes of vitamins C and E and other related nutrients, not including intakes from supplements, were assessed by the 24-hour dietary recall method [4].

Statistical analysis

SAS for Windows, version 8.1, was used for all statistical analyses on the relations between diet and serum vitamin E status. Pearson correlation was performed to evaluate the relationship between dietary frequency and serum level of α-tocopherol. Items in FFQ that were significantly correlated to serum α-tocopherol level were retained for further regression analysis. Multiple linear regression was used to examine the relationship between serum α-tocopherol and frequency of dietary items in men and women separately, adjusting for age and blood lipids. The descriptive analyses on vitamin E status were weighted to represent the population in Taiwan, using SUDAAN, SAS-callable version 8.0. The age-sex specific population size in each stratum, obtained from the national registration system, was divided by its corresponding sample size to determine the sampling weights. T-test was applied to compare the means of serum α-tocopherol and α-tocopherol/[cholesterol + TG] ratio across age groups, genders, and strata. Chi-square test was used to examine if the prevalence rate of vitamin E deficiency varied with gender and age groups.

Results

Mean serum levels of α-tocopherol by sex and age groups are shown in Table 1. Females had significantly higher levels of serum α-tocopherol than males in most age groups. Children and adolescents had lower levels of α-tocopherol than adults (≥ 19 years). The lowest mean serum levels of α-tocopherol were observed in males (13.4 µmol/L) and females (14.4 µmol/L) within the

13–18 year-old age range. The mean serum α-tocopherol levels for adult males and females as a whole were 18.9 ± 0.3 μmol/L and 21.0 ± 0.9 μmol/L, respectively. Older adults had higher mean serum α-tocopherol levels than young adults.

Table 1 Mean serum levels of α-tocopherol levels, α-tocopherol/(cholesterol + triglycerides) ratios, and prevalence rates of vitamin E deficiency by sex and age in Taiwan

Age group (years)	Mean α-tocopherol (μmol/L)		Mean α-tocopherol/(cholesterol + TG[a]) (μmol/mmol)		Prevalence of vitamin E deficiency[b] (%)
	N	Mean (SE)	N	Mean (SE)	
Males					
4–6	144	15.1 (0.6)	118	2.99 (0.05)	0.11
7–12	406	14.1 (0.4)	370	2.80 (0.08)	3.67
13–18	312	13.4 (0.5)[c]	285	2.83 (0.15)	1.93
19–44	297	18.0 (0.5)[c]	275	2.93 (0.05)	0.93
45–64	383	20.7 (1.3)[c]	351	3.13 (0.16)	1.05
65–	186	20.0 (0.6)[c]	167	3.35 (0.12)[c]	0.13
4–18	862	14.0 (0.4)	773	2.84 (0.83)	2.37
≥19	866	18.9 (0.3)	793	3.03 (0.88)	0.87
Females					
4–6	142	16.5 (1.0)	125	3.08 (0.18)	6.83
7–12	406	14.8 (0.4)*	373	2.89 (0.04)	1.07
13–18	363	14.4 (0.5)*	332	2.83 (0.12)	2.68
19–44	394	18.8 (0.6)[d]	363	3.38 (0.09)*, [d]	1.17
45–64	405	25.3 (1.4)**, [d]	379	3.48 (0.09)*, [d]	1.31
65–	176	26.4 (2.3)*, [d]	164	3.66 (0.29)[d]	0.84
4–18	911	14.8 (0.3)*	830	2.89 (0.90)	2.60
≥19	975	21.0 (0.9)*	906	3.43 (1.16)*	1.17
Overall					
4–	3614	18.6 (0.4)	3302	3.14 (0.03)	1.39
19–	1841	20.0 (0.5)	1699	3.23 (1.04)	1.02

[a] *TG* triglyceride
[b] Based on the serum α-tocopherol/(cholesterol + TG) < 1.59. No statistical difference was detected between age groups.
Significantly different from males in the same age group, * $p < 0.05$; ** $p < 0.0001$
[c] Significantly different from males aged 7–12 years group (reference group)
[d] Significantly different from females aged 13–18 years group (reference group)

Table 1 also provides information on the status of the serum α-tocopherol/(cholesterol + TG) ratio in different age groups for males and females. The overall prevalence rate of deficiency (ratio < 1.59) was 1.4 %. The prevalence rates in various age groups of both genders ranged from 0.11 % to 6.83 %. The proportion of deficiency was relatively high in the age groups of 7–12 years (3.67 %) in males, and in the age group of 4–6 years (6.83 %) in females. The prevalence of deficiency gradually decreased with age in both males and females since their teens. In adults, the prevalence rates were lowest in those aged 65 years or above. However, there was no statistical difference in prevalence rates between age groups.

Table 2 shows the means and standard errors of the serum α-tocopherol, cholesterol + TG, and their ratio for the adults in Taiwan by sex and strata. Men living in the east coast area had a significantly higher mean serum α-tocopherol level than men living in other strata but not those living in the Hakka area and metropolitan cities. The mean serum α-tocopherol levels of females living in Peng-Hu Islands and Class II townships were lower than those of females in the metropolitan cities. For both genders, those in the mountainous area and Peng-Hu Islands had the lowest mean serum α-tocopherol/ [cholesterol + TG] ratio, but no statistical differences were observed across strata.

Multivariate analysis on the influences of food frequency on the serum α-tocopherol level is presented in Table 3. Serum α-tocopherol increased significantly with age in both genders. There was also a positive association between the serum levels of lipids and α-tocopherol ($p < 0.0001$). In males aged 13–64 years, adjusting for the

Table 2 The means and standard errors of the serum α-tocopherol, cholesterol + triglycerides, and their ratio for the adults (≥19 years) by sex and strata in Taiwan

Strata	Males				Females			
	N	Vit E (SE)[a] (μmol/L)	Serum lipid (SE)[b] (mmol/L)	Ratio (SE)[c] (μmol/mmol)	N	Vit E (SE)[a] (μmol/L)	Serum lipid (SE)[b] (mmol/L)	Ratio (SE)[c] (μmol/mmol)
Hakka area	130	20.65 (2.58)	6.31 (0.22)	3.31 (0.33)	136	22.93 (2.53)	6.15 (0.10)	3.72 (0.37)
Mountainous area	113	17.93 (0.72)[d]	6.80 (0.51)	2.72 (0.10)	133	20.78 (2.05)	6.76 (0.43)	3.17 (0.30)
East coast area	124	21.14 (0.98)	7.19 (0.53)	3.04 (0.18)	137	20.44 (1.11)	6.14 (0.22)	3.41 (0.18)
Peng-Hu islands	120	17.43 (0.84)[d]	6.08 (0.17)	2.91 (0.12)	141	19.59 (0.84)[d]	6.42 (0.11)	3.08 (0.14)
Metropolitan cities	112	19.83 (0.48)	6.52 (0.12)	3.06 (0.04)	130	23.07 (0.99)	6.39 (0.09)	3.52 (0.16)[e]
Provincial cities								
Class I townships	101	18.45 (0.48)[d]	6.10 (0.15)	3.04 (0.03)	116	21.11 (1.17)	6.07 (0.22)	3.47 (0.14)[e]
Class II townships	93	18.89 (0.28)[d]	6.39 (0.04)	2.98 (0.05)	113	18.88 (1.19)[d]	5.88 (0.27)	3.27 (0.07)

[a] *Vit E* serum α-tocopherol
[b] *Serum lipid* serum cholesterol + serum triglyceride
[c] *Ratio* serum α-tocopherol/(cholesterol + triglyceride)
[d] Mean serum α-tocopherol level significantly different from the reference group (East coast areas for males and Metropolitan cities for females), $p < 0.05$
[e] Mean serum α-tocopherol/(cholesterol + triglyceride) ratio different from the reference group (Peng-Hu Islands), $0.05 < p < 0.1$

Table 3 Multivariate linear regression of vitamin supplement and food frequency on serum α-tocopherol (μmol/L) by age groups (13–64 years)

Variable	Males			Females		
	N	β	SE	N	β	SE
Age (per 10 years)	992	1.04*	0.14	1162	1.02*	0.14
Serum lipid[a] (mmol/L)	991	0.00*	0.00	1157	0.46*	0.00
Multivitamin supplement (times/day)	45	2.58*	1.28	39	1.21	1.30
Vitamin E supplement (times/day)	22	8.70*	1.93	49	19.53*	1.42
Vitamin C supplement (times/day)	28	4.15*	1.81	52	0.07	0.95
Pickled vegetables (times/wk)	596	0.09	0.09	699	0.09*	0.05
Soy products (times/wk)	745	0.07	0.14	870	0.07	0.12
Fresh vegetables (times/day)	977	–0.09	0.16	1130	0.26*	0.14
Fresh fruits and 100 % juices (times/day)	935	1.07*	0.30	1099	0.86*	0.23
Eggs and products (times/wk)	919	–0.05	0.07	1019	0.21*	0.07
Low-fat milk (times/wk)	111	0.16	0.19	189	0.02	0.09

* $p < 0.05$
[a] *Serum lipid* serum cholesterol + serum TG

effect of age and lipid, the serum α-tocopherol level increased 2.58 μmol/L, 8.70 μmol/L, 4.15 μmol/L, and 1.07 μmol/L, respectively, per unit change of daily consumption frequency for multivitamin supplement, vitamin E supplement, vitamin C supplement, and fresh fruits/100 % juices. In females, as per unit of daily consumption frequency of vitamin E supplement, pickled vegetables, fresh vegetables, fresh fruits/100 % juices, and eggs/egg products changed, the serum level of α-tocopherol increased 19.53 μmol/L, 0.63 (0.09x7) μmol/L, 0.26 μmol/L, 0.86 μmol/L, and 1.47 (0.21x7) μmol/L, respectively. Similar results were obtained in both male and female subjects aged 19–64 years, except that the serum level of α-tocopherol was not significantly influenced by multivitamin supplementation in males, nor by pickled vegetable consumption in females (data not shown).

Table 4 shows that dietary intakes of vitamins C and E, calculated from 24-hour recall, corresponded to the serum α-tocopherol/(cholesterol + TG) ratio profile in both males and females. Dietary PUFA intake, also calculated from 24-hour recall, was not significantly different among tertiles of serum levels of α-tocopherol/(cholesterol + TG) in both genders (data not shown).

Table 5 compares the vitamin E nutritional status between Taiwan and other countries. The mean serum α-tocopherol concentrations in our adult subjects were 18–20.7 μmol/L and 18.8–26.4 μmol/L for males and females in various age groups, respectively. Compared to our male and female adults, the serum α-tocopherol levels in European adult males and females were 4.6–11.6 μmol/L and 7.0–16.2 μmol/L higher, respectively. The serum α-tocopherol concentrations in Japanese adult males and females are also 4.42–7.43 μmol/L and 0.1–4.3 μmol/L higher than our adults, respectively. On the other hand, the Malaysian elderly aged 60 years and above have a lower mean serum α-tocopherol level than that of our elderly subjects (65 years and above).

Table 6 shows the comparative status of serum α-tocopherol between Taiwanese and French children. The medians of serum α-tocopherol and α-tocopherol/cholesterol ratio were 12.71–15.47 μmol/L and 3.57–3.83 mg/g in Taiwanese children, and were

Table 4 Comparison of dietary vitamin C and vitamin E intake by serum vitamin E status tertiles (13–64 years)

Serum α-tocopherol/(cholesterol + TG) ratio tertile[a]	Males		Females	
	Vit E/Kcal[b] mean	Vit C/Kcal[c] mean	Vit E/Kcal[b] mean	Vit C/Kcal[c] mean
Lowest	0.0034[d, e]	0.0694[d, e]	0.0042[d]	0.0827[d, e]
Middle	0.0038	0.0943	0.0045	0.1135
Highest	0.0041	0.0986	0.0048	0.1155

[a] *Lowest* ratio ≤2.53 for males, ≤2.67 for females,
Middle 2.53 < ratio ≤3.08 for males, 2.67 < ratio ≤3.33 for females,
Highest ratio > 3.08 for males, ratio > 3.33 for females
[b] Vitamin E/total calories based on 24-hour diet recall data
[c] Vitamin C/total calories based on 24-hour diet recall data
[d] Significantly different from the mean of the highest group, $p < 0.05$
[e] Significantly different from the mean of the middle group, $p < 0.05$

European Journal of Nutrition (2004) Vol. 43, Number 2

Table 5 Comparison of the vitamin E nutritional status between Taiwan and other countries

Country	Age range	Males		Females		Prevalence of deficiency[a]
		N	Mean (μmol/L)	N	Mean (μmol/L)	
Taiwan (1993–1995)	19–44	297	18.0±6.2	394	18.8±6.7	7.2%
	45–64	383	20.7±8.7	405	25.3±11.8	
	65+	186	20.0±7.3	176	26.4±18.1	
Hungary [9] 1992–1994	18–34	388	28.3±8.4	343	28.6±6.5	
	35–59	732	34.5±12.0	938	32.0±11.5	
	60+	55	36.8±8.9	105	38.4±10.7	
Eastern France [10] 1983–1985	60–80	139	31.6±8.6	152	35.3±7.4	
Italy 1985–1988 (Central-Northern)[b] [11]	30–50	129	27.9±0.7	114	25.1±0.7	
	50–64	202	27.6±0.5	131	28.8±0.5	
	64–75	222	27.9±0.5	147	30.9±0.5	
Japan [12]	7–9	30	18.48	22	19.23	
	10–19	158	16.22	308	18.30	
	20–29	34	22.42	177	21.96	
	30–39	52	24.79	70	23.53	
	40–49	84	26.03	202	25.40	
	50–59	114	28.11	237	28.95	
	60–69	106	27.43	150	30.70	
	70+	40	27.75	30	30.38	
Taiwan [13] [(b)]	23–78	63	24.8±10.2	36	23.7±11.8	7% (< 11.6 μmol/L) 3% (< 6.97 μmol/L)
Malaysia 1995 [14]	60–118	140	16.8±9.1	150	17.6±6.9	26.9%

[a] Serum a-tocopherol < 11.6μmol/L
[b] Original data in μg/mL, converted into μmol/L by multiplying 2.32

Table 6 Comparison of serum α-tocopherol status between Taiwanese and French children

Country	Age (years)	Males		Females		PT/PC[a] Median (mg/g)
		N	Median (μmol/L)	N	Median (μmol/L)	
Taiwan (1993–1995)	4–6	144	14.45	144	15.47	3.83
	7–12	406	13.62	406	14.08	3.58
	13–18	312	12.71	363	13.71	3.57
France [22] [b] (1985–1986)	3–5	26	19.32	28	19.32	5.44
	6–8	85	21.34	76	21.92	5.21
	9–11	79	21.58	82	22.97	5.23
	12–13	41	19.32	36	20.76	5.32
	14–16	66	21.11	68	21.81	5.35

[a] *PT* plasma α-tocopherol; *PC* plasma cholesterol
[b] Original data in μg/mL, converted into μmol/L by multiplying 2.32

19.32–22.97 μmol/L and 5.21–5.44 mg/g in French children, respectively.

Discussion

Serum α-tocopherol status

Compared to the results from other countries, the serum α-tocopherol concentration in our subjects is lower than that of Hungarians [11], French [12], Italians [13], and Japanese [14] (Table 5), and is lower than that of an earlier study conducted in Taiwan in 1977 [15]. The mean serum level of α-tocopherol in our elderly subjects (65 years and older) was slightly higher than that of the rural elderly Malaysians aged 60 years and above [16] (Table 5). Given the cut-off point of serum α-tocopherol level at 11.6 μmol/l [17], the prevalence of deficiency in Taiwan is 7% (Table 5). However, it is not clear whether the prevalence defined by low α-tocopherol is comparable, since there is a great variation in blood lipids across nations. In our study of adults, the prevalence rate of de-

ficiency defined by the serum α-tocopherol/(cholesterol + TG) ratio < 1.59 was about 1 %, but the mean of ratio was around 3 μmol/mmol. It is also possible that the difference between ethnic groups is due to high PUFA intake in Taiwanese (P/S = 1.07 and 1.27 for males and females aged 19–64 years, respectively). The increased PUFA intake may have increased the requirement for vitamin E [18, 19]. Within Taiwan, the geographical variation on serum vitamin E status, adjusted for serum levels of cholesterol and TG, was not statistically significant, although our previous study showed that dietary patterns did vary across regions [4].

In the current analysis, we observed a U-shaped age-serum vitamin E relation with the poorest vitamin E status in the teenagers. The result that the serum α-tocopherol significantly increased with age in our adult subjects was consistent with the findings of other countries [11, 14, 15, 20–22]. This age-trend remained true when the serum α-tocopherol level was adjusted for the serum levels of cholesterol and TG. In addition, results from our analysis showed that adult females had a higher level of serum α-tocopherol than their male counterparts, which was also consistent with the results from several other studies [12, 13, 20, 22]. In contrast, Ito et al. [14] and Looker et al. [23] found no significant gender difference in the serum α-tocopherol level.

It has been reported that the circulating vitamin E level is lower in children than in adults [7, 21, 23]. In our analysis, the serum levels of α-tocopherol in children and adolescents were lower than that in adults (aged 19 years and older), yet the prevalence rates of deficiency were similar in both subgroups. Adolescents had a lower level of serum α-tocopherol, but the highest prevalence rate of deficiency (ratio < 1.59) was observed in children (Table 1). In addition, our results showed that the serum α-tocopherol level decreased with age during childhood and adolescence, and an increasing trend with advancing age was observed in the adults. Similar age-associated trends were also found in a study conducted in Japan, in which the mean serum α-tocopherol level of children and adolescents was higher than that of ours [14] (Tables 1 and 5). Moreover, compared to French children and adolescents, both the median of the serum α-tocopherol level, and the ratio of serum α-tocopherol to cholesterol were lower in our youngsters [24] (Table 6).

Relationship between serum α-tocopherol and dietary factors

Foods rich in vitamin E or vitamin E supplements have been shown to increase plasma α-tocopherol levels [11, 25–28]. Similar results were observed in our analysis that those persons taking more vitamin E supplements or fresh fruits and 100 % juices had higher serum levels of α-tocopherol in both genders. A positive correlation between dietary vitamin E and vitamin C, and the serum level of vitamin E has also been observed in our study. In Taiwan, the two major food sources of vitamin C are fruits and vegetables [29]. Although vegetables and fruits are not major sources of dietary vitamin E, the vitamin C content of these foods is very high, and it has been reported that dietary vitamin C supplementation increases the plasma level of vitamin E in guinea pigs [30]. Ascorbate has been shown to reduce the tocopheroxy radicals, and the synergistic effect makes vitamin C a good spare of vitamin E [30, 31].

In our study, no significant association between PUFA intake, assessed by 24-hour recall method, and serum levels of α-tocopherol was observed (data not shown). It is possible that the increased intake of dietary PUFA is accompanied by increased vitamin E intake, as diets high in PUFA generally also contain higher amounts of vitamin E. On the other hand, extra α-tocopherol may be required to protect PUFA from peroxidation, especially when the contents of longer-chain, more unsaturated fatty acids are increased [32], and increased intake of PUFA without a concomitant increase of vitamin E has been shown to result in a reduction in plasma levels of vitamin E [33].

In summary, results of our current analysis showed that the prevalence rates of vitamin E deficiency in Taiwan were about 1.4 % for those aged 4 and up and 1 % for adults based on the ratio of serum α-tocopherol/(cholesterol + TG). The level of serum vitamin E was generally higher in the females than in the males. A positive association between the higher level of serum α-tocopherol and age was observed in female adults. There appeared to be an association between serum vitamin E status and dietary intakes of vitamins C and E, either from foods or from supplements.

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