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Epidemiological survey of vitamin deficiencies in older Thai adults: implications for national policy planning

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Abstract

Objective: To examine the prevalence and risk factors of vitamin deficiencies among older Thai adults.
Methods: The cross-sectional study was conducted in four rural communities, one from each of the four main regions of Thailand. In total, 2336 subjects aged 60 years and over were recruited. Anthropometric variables, demographic data, blood glucose and lipid profile, albumin, globulin and blood levels of vitamin A, β-carotene, folic acid, vitamin B_{12}, vitamin C, vitamin E and vitamin B_1 were all measured.
Results: The prevalence of vitamin deficiencies was 0.6% for vitamin B_{12}, 6.1% for vitamin A, 9.9% for vitamin C, 30.1% for vitamin B_1, 38.8% for erythrocyte folate, 55.5% for vitamin E and 83.0% for β-carotene. Male gender was a common risk factor for at least three vitamin deficiencies, i.e. β-carotene, folate and vitamin E. Being a manual worker was a common risk factor of β-carotene and vitamin B_1 deficiency. Poor income was found as a risk factor only in erythrocyte folate deficiency while increasing age was a significant factor only in vitamin C deficiency.
Conclusion: The prevalence of vitamin deficiencies among older Thai people was quite different from that found in Western countries, reflecting different socio-economic backgrounds. Vitamin deficiency was not only from poor food intake but also from the dietary habit of monotonous food consumption in older people. Some common associated factors of atherosclerosis were also significantly related to folate and vitamin E deficiencies.

Keywords
Vitamin
Deficiency
Elderly people
Thailand

The proportion of older Thai people is growing rapidly as a result of increased life expectancy. Since older people tend to suffer from various vascular and neurodegenerative disorders as well as cancers, preventive measures are needed to keep them fit as they are living longer. Nutrition and physical activity are two main lifestyle factors for which there is strong evidence of a positive effect in the prevention and management of such disabling conditions[1,2]. Although many nutritional surveys have previously been done in developed countries, surveys recruiting large numbers of older subjects in developing countries have been scarce and would be expected to yield different results due to socio-economic and cultural differences. However, the vitamin status of older people varies even within developed countries. For example, only 5% of blood vitamin concentrations analysed in the German VERA study (Verbundstudie Ernährungserhebung und Risikofaktorenanalytik) were found to be below the physiological range, while the prevalence of vitamin B_{12} deficiency was found to be 3–44% in the USA[3,4]. Furthermore, according to the Euronut SENECA study (Survey in Europe on Nutrition and the Elderly; a Concerted Action) involving 12 European countries, biochemical vitamin E deficiency was found in seven centres with prevalence ranging from 0.5 to 25%[5]. Therefore, the specific purpose of this mega-project funded by the Thai government was to gain the necessary health data for national policy planning.

Materials and methods

The present cross-sectional study was part of a comprehensive survey of older people in Thailand approved by the Research Committee of Mahidol University. The whole project finished in the year 2000. One district in each of the four regions of the country was randomly selected. For the nutritional survey, around 500 older people aged 60 years and over in each region were randomly recruited, leading to a total number of 2336 subjects. After background characteristics were assessed, the subjects underwent anthropometric measurements as well as blood tests to measure biochemical data and various vitamin levels, i.e. vitamin A (retinol), β-carotene, vitamin B_1 (thiamin),

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vitamin B_{12} (cyanocobalamin), folic acid, vitamin C (ascorbic acid) and vitamin E (α-tocopherol).

Whole blood and serum were kept at $-20°C$ before biochemical assays to guarantee the accuracy of measurement. Retinol, β-carotene and α-tocopherol were measured by high-performance liquid chromatography (HPLC). Since normal levels of retinol[6], β-carotene[7] and α-tocopherol[8] are respectively 20–50, 25–125 and 600–1200 $\mu g\,dl^{-1}$, the cut-off points for vitamin A, β-carotene and vitamin E deficiency were set at <20, <25 and <600 $\mu g\,dl^{-1}$, respectively. Erythrocyte transketolase activity and the thiamin pyrophosphate (TPP) effect were used to identify thiamin deficiency. Those who had a TPP effect of $>15\%$ were classified as vitamin B_1-deficient. A microbiological assay using *Lactobacillus casei* ATCC 7469 was used to measure the folic acid level. A laboratory technique employing radioisotope dilution and coated charcoal was used in the measurement of cyanocobalamin. Since normal levels of cyanocobalamin, serum folate and erythrocyte folate among the Thai population are 200–800 $pg\,dl^{-1}$, 5–21 $ng\,dl^{-1}$ and 221–1113 $ng\,dl^{-1}$, the cut-off points indicating biochemical deficiency of vitamin B_{12}, serum folate and erythrocyte folate were 200 $pg\,dl^{-1}$, 5 $ng\,dl^{-1}$ and 221 $ng\,dl^{-1}$, respectively[9–12]. Serum ascorbic acid was measured by HPLC. As normal ascorbic acid level is in the range 0.4–1.5 $mg\,dl^{-1}$, levels $<0.4\,mg\,dl^{-1}$ indicate vitamin C deficiency[13].

The software package SPSS version 10.0 (SPSS Inc., Chicago, IL, USA) was for statistical analyses with the level of significance set at $P<0.05$. Descriptive statistics (mean ± standard deviation, SD) were calculated for each parameter of demographic characteristics, underlying medical conditions, lifestyle patterns and biochemical data and analysed by univariate analysis (chi-square and Student *t*-tests) to determine the factors associated with the examined vitamin deficiencies. The statistically significant factors were sequentially entered in a multiple logistic regression analysis to find the independent risk factors for each biochemical vitamin deficiency.

Results

The percentage of participants from the central, north-eastern, northern and southern regions was 26.2, 25.3, 25.4 and 23.0%, respectively. The proportion of males to females was 889:1447 (1:1.63). The mean (± SD) age of subjects was 68.94 ± 6.76 years (range 60–97 years). The mean (± SD) body mass index was 22.62 ± 4.34 $kg\,m^{-2}$ (range 10.74–47.94 $kg\,m^{-2}$). Regarding the educational background of the subjects, 24.6% had never been to formal school and 65.8% had achieved only a primary education. About 57% still lived with their spouse while 6.3% lived alone. Although 14.4% had satisfactory financial status, 18.7% admitted that they had inadequate income for daily life. Regarding health-risk behaviours, 31.8% were either current smokers or had quit smoking for 10 years or less and 25.0% were either current alcohol drinkers or had quit drinking for 10 years or less.

The prevalence of vitamin deficiencies was 6.1% for vitamin A, 83.0% for β-carotene, 30.1% for vitamin B_1, 38.8% for erythrocyte folate, 9.9% for vitamin C and 55.5% for vitamin E. The prevalence of vitamin B_{12} deficiency was only 0.6%. Since the prevalence of vitamin B_{12} deficiency was very low among older Thai adults, we decided not to study the factors associated with this deficiency in detail.

Table 1 shows the prevalence of vitamin deficiencies according to selected demographic characteristics and underlying medical conditions, while Table 2 compares the factors associated with the various vitamin deficiencies in univariate analyses. The independent factors determining each vitamin deficiency derived from multiple logistic regression analyses are shown in Table 3.

Discussion

With the exception of vitamin B_{12} deficiency, the lowest prevalence was found for vitamin A deficiency (6.1%) which is consistent with surveys in other parts of the world[14]. This universal finding may be due to large hepatic retinol stores and reduced renal clearance of retinyl esters in the elderly. It takes up to 9 months for severely retinol-depleted subjects to show a biochemical deficiency[15]. However, although our survey was done nearly 20 years after the NHANES I study (National Health and Nutrition Examination Survey), the prevalence among older Thai people was much higher than in that study (0.3%)[16]. The subjects who were at risk of vitamin A deficiency were

Table 1 Prevalence (%) of each qualitative factor found in various vitamin deficiencies

	Vitamin A deficiency	β-Carotene deficiency	Vitamin E deficiency	Vitamin B_1 deficiency	Folate deficiency	Vitamin C deficiency
Male	6.4	85.4*	61.2*	31.7	47.3*	8.9
No formal education	6.1	80.8	52.0	36.5*	32.4*	10.9
Manual worker	5.6	84.3*	50.9*	34.3*	37.0*	9.7
Poor financial status	8.7*	80.3	56.1	29.9	43.6*	9.7
Diabetes mellitus	7.7	87.2	65.5*	11.7*	32.2	11.2
Hypertension	6.3	78.0*	46.7*	24.3*	41.5	7.7
Heart disease	6.4	75.0*	65.9*	23.2	51.1*	10.3

* Significant difference compared with those who did not have the vitamin deficiency (univariate analysis): $P<0.05$.

Table 2 Comparisons of quantitative factors associated with various vitamin deficiencies by univariate analysis

	Vitamin A		β-Carotene		Vitamin E		Vitamin B_1		Folate		Vitamin C	
	Normal	Deficiency	Normal	Deficiency	Normal	Deficiency	Normal	Deficiency	Normal	Deficiency	Normal	Deficiency
Age (years)	69.0 ± 6.7	68.4 ± 7.2	68.3 ± 6.5	69.1 ± 6.8	69.8 ± 6.9	69.0 ± 6.6	68.9 ± 6.7	69.0 ± 6.8	69.3 ± 6.8	68.5 ± 6.5*	68.8 ± 6.7	70.4 ± 7.4*
BMI (kg m^{-2})	22.6 ± 4.4	22.7 ± 4.0	22.8 ± 4.5	22.5 ± 4.3	22.4 ± 4.3	22.7 ± 4.4	22.9 ± 4.4	22.1 ± 4.1*	22.5 ± 4.3	22.8 ± 4.5	22.7 ± 4.3	22.8 ± 4.2
TPP effect (%)	11.9 ± 8.1	11.2 ± 6.9	10.3 ± 6.6	12.2 ± 8.3*	12.4 ± 8.5	11.3 ± 7.7*	NA	NA	12.5 ± 8.5	10.9 ± 7.4*	11.9 ± 8.1	11.8 ± 8.2
Serum folic acid (ng dl^{-1})	5.4 ± 5.0	4.5 ± 3.9	4.7 ± 5.4	5.5 ± 4.9*	6.0 ± 5.5	4.9 ± 4.5*	5.2 ± 4.8	5.9 ± 5.3*	NA	NA	5.5 ± 5.2	4.9 ± 3.4*
Erythrocyte folate (ng dl^{-1})	278.5 ± 130.5	258.0 ± 106.1	238.8 ± 107.1	284.4 ± 131.8*	274.2 ± 128.2	279.3 ± 130.8	269.4 ± 124.9	298.8 ± 138.2*	NA	NA	275.1 ± 128.9	305.0 ± 134.2*
Vitamin C (mg dl^{-1})	1.1 ± 0.5	0.9 ± 0.5*	1.3 ± 0.5	1.1 ± 0.5*	1.2 ± 0.5	1.0 ± 0.6*	1.1 ± 0.5	1.1 ± 0.5	1.0 ± 0.6	1.1 ± 0.5*	NA	NA
Vitamin A (μg dl^{-1})	NA	NA	65.7 ± 32.8	66.1 ± 32.5	74.9 ± 33.4	59.2 ± 30.0*	65.6 ± 33.1	67.1 ± 31.9	66.8 ± 32.1	63.7 ± 34.1	66.2 ± 32.7	60.8 ± 30.9 *
B-Carotene (μg dl^{-1})	12.4 ± 15.8	6.8 ± 11.0*	NA	NA	15.2 ± 17.4	9.7 ± 13.7*	13.3 ± 16.3	9.6 ± 13.6*	9.4 ± 13.5	15.0 ± 17.0*	12.9 ± 16.1	5.2 ± 8.4*
Vitamin E (μg dl^{-1})	595.0 ± 357.1	281.3 ± 332.0*	729.6 ± 375.5	545.2 ± 352.5*	NA	NA	562.3 ± 369.8	615.2 ± 345.1*	540.5 ± 362.6	574.6 ± 358.6	592.1 ± 361.9	413.3 ± 319.4*

BMI – body mass index; TPP – thiamine pyrophosphate; NA – not applicable.
Values are expressed as mean ± standard deviation.
* Significant difference compared with those who did not have the vitamin deficiency: $P < 0.05$.

Table 3 Independent factors determining each vitamin deficiency by multiple logistic regression analysis

	Adjusted OR	95% CI		Adjusted OR	95% CI
Fat-soluble vitamin deficiencies			*Water-soluble vitamin deficiencies*		
Vitamin A deficiency			Vitamin B_1 deficiency		
Poor memory	1.940	1.086–3.463	No formal education	1.359	1.038–1.779
DBP (mmHg)	1.024	1.009–1.039	Manual worker	1.619	1.124–2.332
Vitamin E ($\mu g\,dl^{-1}$)	0.997	0.996–0.998	No diabetes mellitus	3.096	1.498–6.399
β-Carotene deficiency			BMI ($kg\,m^{-2}$)	0.959	0.938–0.981
Male	1.970	1.379–2.813	Erythrocyte folate ($ng\,dl^{-1}$)	1.001	1.001–1.002
Manual worker	2.004	1.364–2.943	β-Carotene ($\mu g\,dl^{-1}$)	0.986	0.977–0.995
Haematocrit (%)	0.935	0.905–0.966	Folate deficiency		
Albumin ($g\,dl^{-1}$)	1.898	1.327–2.714	Male	1.591	1.220–2.075
Globulin ($g\,dl^{-1}$)	1.553	1.193–2.023	Poor finance status	1.407	1.040–1.903
Triglycerides ($mg\,dl^{-1}$)	1.003	1.001–1.005	Heart disease	1.956	1.220–3.137
HDL ($mg\,dl^{-1}$)	1.025	1.009–1.040	Albumin ($g\,dl^{-1}$)	0.505	0.390–0.655
Erythrocyte folate ($ng\,dl^{-1}$)	1.470	1.046–2.066	Globulin ($g\,dl^{-1}$)	0.779	0.636–0.953
Vitamin C ($mg\,dl^{-1}$)	0.644	0.461–0.898	Haematocrit (%)	1.071	1.044–1.099
Vitamin E ($\mu g\,dl^{-1}$)	0.999	0.998–0.999	HDL ($mg\,dl^{-1}$)	0.986	0.977–0.996
Vitamin E deficiency			TPP effect (%)	0.973	0.958–0.988
Male	1.279	1.001–1.636	β-Carotene ($\mu g\,dl^{-1}$)	1.015	1.006–1.024
Ex-office worker	1.695	1.232–2.332	Vitamin C deficiency		
No hypertension	1.767	1.276–2.446	Age (years)	1.056	1.030–1.082
Heart disease	1.666	1.023–2.713	Albumin ($g\,dl^{-1}$)	3.124	2.057–4.744
DBP (mmHg)	1.014	1.005–1.022	Erythrocyte folate ($ng\,dl^{-1}$)	1.642	1.085–2.483
Triglycerides ($mg\,dl^{-1}$)	0.998	0.997–0.999	Vitamin E ($\mu g\,dl^{-1}$)	0.999	0.998–0.999
HDL ($mg\,dl^{-1}$)	1.019	1.008–1.030	β-Carotene ($\mu g\,dl^{-1}$)	0.968	0.949–0.988
Vitamin C deficiency	1.734	1.148–2.617			
Vitamin A ($\mu g\,dl^{-1}$)	0.985	0.981–0.989			
β-Carotene ($\mu g\,dl^{-1}$)	0.982	0.974–0.990			
Serum folate ($ng\,dl^{-1}$)	0.964	0.941–0.988			

OR – odds ratio; CI – confidence interval; DBP – diastolic blood pressure; HDL – high-density lipoprotein; BMI – body mass index; TPP – thiamine pyrophosphate.

those who had memory problems, high diastolic blood pressure and a low vitamin E level. This may be due to poor dietary habits among people with cognitive inability. The coexistence of vitamin A and E deficiency, both lipid-soluble vitamins, was previously described in patients with chronic leg ulcers and poor wound healing[17].

In the light of factors known to affect carotene levels such as gender and fat intake[18], our results accordingly showed that male gender, higher triglycerides and high-density lipoprotein significantly determined the cases of β-carotene deficiency. Not only because of its highest prevalence (83.0%) among our survey of vitamin levels, but also because it is one of the antioxidant nutrients, older male adults and especially those who once worked as manual workers must be targeted by health personnel to increase the intake of β-carotene-rich foods in their daily diet. Other independent nutritional factors which were found more among β-carotene-deficient subjects were higher albumin and globulin and a higher folate level. This may be due to the lack of nutritional knowledge among older people and recommendations to increase diet variety should be implemented.

Subjects with vitamin B_1 deficiency also had other poor general nutritional indices, e.g. body mass index. This association was much more striking than for other vitamin deficiencies. Since the main sources of vitamin B_1 among Thai people are rice, pork and legumes, which are the main ingredients in Thai dishes, cases with vitamin B_1 deficiency consequently suffer from protein–energy malnutrition. Our prevalence (30.1%) was quite high compared with previous studies, where a prevalence of 3–15% has been found[19]. It was not surprising that independent factors of vitamin B_1 deficiency were no formal education and being a manual worker. Poverty was found to be a significant factor for vitamin B_1 deficiency in the NHANES I study[16]. However, subjects with diabetes were protected from vitamin B_1 deficiency; this may be due to the common vitamin B complex prescribed by doctors for diabetic patients who usually complain of peripheral numbness due to diabetic neuropathy. It is a common medical myth that dry beriberi has a burning paresthesia, so vitamin B_1 might do well in diabetic neuropathy also.

Some conflicting results showed that those who had folate deficiency had significantly higher vitamin B_1 (lower TPP effect) and β-carotene levels. Because both folic acid and β-carotene are mostly found in green leafy vegetables and fruits, the explanation cannot be from poor intake; however, 50–95% of the natural folate content of foods is lost in the cooking and canning processes. Edentulous older people could only consume overcooked boiled rice as their main food, which is a good source of vitamin B_1. Edentulism is not associated with total energy or food intake, but rather with the food groups consumed[20]. Since folate deficiency is associated with the pathogenesis of atherosclerotic lesions, our results accordingly revealed that male gender, history of heart disease, lower high-density lipoprotein and haematocrit were independent risk factors of folate deficiency. Furthermore, our prevalence of erythrocyte folate deficiency was 38.8%, much higher than that found in developed countries; it was only 3.3% in New Zealand and hardly found in the Euronut SENECA study[5,21]. Folate supplements, which are relatively inexpensive and safe, should be routinely prescribed to those older people with atherosclerotic risk. Folate status appears to be of greater concern than vitamin B_{12} status for older people[22]. This opinion is consistent with our very low prevalence of vitamin B_{12} deficiency, i.e. only 0.6%. The main explanations for this finding are the nationwide consumption of fish sauce, which is not only inexpensive but also rich in vitamin B_{12}, and the low incidence of atrophic gastritis (11.6%) in Thailand[23].

As a result of geographic differences, our prevalence of vitamin C deficiency was much lower than the general figure, i.e. 9.9% versus 25%[24]. Various kinds of oranges can easily be found all year round and are affordable throughout Thailand due to its tropical climate. This may also be the main reason why smoking was not an independent factor for vitamin C deficiency in our study, as seen in a study from The Netherlands in which the vitamin C level was not affected by smoking but was strongly associated with the daily intake[25]. Interestingly, vitamin C deficiency was the only deficiency found in which increasing age independently determined cases. This highlights the poor access to food and the higher requirements of the older adult[26]. Those who had vitamin C deficiency had a higher erythrocyte folate level. Since both vitamin C and folic acid are found in large amounts in leafy green vegetables, poor intake could not explain such a dilemma. However, as vitamin C is essential in the biochemical effect of folate reductase, which changes folate to tetrahydrofolate resulting in the synthesis of nucleic acids and DNA, lack of vitamin C might lead to the accumulation of folic acid in tissue and not in serum. Serum folic acid reflects daily intake, which should be low in subjects with vitamin C deficiency because it is commonly found in the same food sources. This explanation is supported by our evidence that those who had vitamin C deficiency also had lower serum folic acid ($P = 0.024$) but a higher erythrocyte folate level than those who had a normal vitamin C level.

The prevalence of vitamin E deficiency was quite high compared with that found in developed countries, i.e. 55.5% versus 2.5%[27]. The same explanation as in folate deficiency may be applied in this case, since vitamin E could easily be degraded during the cooking process as well. The scenario that a majority of those with vitamin E deficiency were of male gender, ex-office workers and had higher diastolic blood pressure giving rise to more heart disease may be related to the antioxidant role of vitamin E in atherosclerosis. Those who had vitamin C deficiency and lower β-carotene, serum folate and vitamin A levels were also more likely to suffer from vitamin E deficiency. These relationships are simply explained by inadequate intake of vegetables and fruits.

For national policy planning in primary prevention of vitamin deficiencies among older Thai people, those who are at risk of each vitamin deficiency can be targeted in the community as follows.

- Those who consume their daily diet inappropriately, e.g. have a monotonous daily diet. This group involves older people who have one kind of vitamin deficiency but have other better nutritional parameters.
  - For edentulous older people, easy access to dentures should be promoted nationwide.
  - For those who live alone or are unaware of the importance of diet variety in maintaining health, repeated heath education should be implemented in the community.
- Those who are unable to access adequate nutrition. This group has multiple vitamin deficiencies which are derived from the common food sources.
  - For the poor (poor financial status, low education, manual workers) who are more likely to have vitamin B_1 deficiency, folate deficiency and protein–energy malnutrition, social input should be the first priority.
  - For the very elderly who are more likely to have vitamin C deficiency, repeated health education to caregivers should be highlighted.
- Those who are at high risk of atherosclerosis (male gender, high blood pressure, ex-office worker, history of heart disease, low high-density lipoprotein, haemocrit).
  - Folic acid and vitamin E status should be routinely considered by the physicians who look after older patients.
- The three most common vitamin deficiencies among older Thai people are vitamin E, folic acid and vitamin B_1. Vitamin B_{12} deficiency is not a primary health problem in the country.

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