*Original Article*

# Vitamin D Status and Its Associated Factors in Rural Subjects in Nakhon Si Thammarat Province, Southern Thailand

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***Objective:*** Vitamin D deficiency is a global health problem. The present study aimed to investigate the vitamin D status and its associated factors in rural subjects in Nakhon Si Thammarat province, Southern Thailand.

***Materials and Methods:*** A cross-sectional study of 839 healthy volunteers, aged 18 to 94 years in Southern Thailand was performed. Demographic variables including age, body mass index [BMI], gender, area of residence, religion, the use of multivitamin supplements, sunscreen used, and behavioral lifestyles were recorded. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured by electrochemiluminescent immunoassay.

***Results:*** The prevalence of vitamin D deficiency and insufficiency were 6.91% and 43.74%, respectively. Women showed a significantly higher in vitamin D deficiency than men (8.05% versus 2.38%, $p<0.001$). Logistic regression analysis demonstrated that vitamin D deficiency and/or hypovitaminosis D were associated with being Muslim, women, living inland, alcohol consumption, obesity, the use of sunscreen, and advancing age.

***Conclusion:*** The prevalence of vitamin D insufficiency is high in rural subjects in Nakhon Si Thammarat. The lifestyle modification such as increasing sun exposure, increasing outdoor activity, increasing vitamin D intake, avoiding alcohol intake, and reducing weight, should be implemented to prevent vitamin D deficiency and hypovitaminosis D.

***Keywords:*** Vitamin D deficiency, Vitamin D insufficiency, Risk factors, Prevalence

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Vitamin D is lipid-soluble hormone synthesized from skin when exposed to ultraviolet B [UVB] irradiation (280 to 320 nm) from sunlight(1). Vitamin D plays an important role in bone metabolism through regulation of calcium and phosphate homeostasis. Vitamin D deficiency causes impaired calcium absorption, which can lead to rickets, osteomalacia, osteoporosis, and an increased risk of fractures(2). Recently, it has been reported that vitamin D deficiency is associated with several chronic and infectious diseases including cancer, cardiovascular diseases [CVD], diabetes mellitus [DM], microbial infection, multiple sclerosis, and autoimmune disease(2). Vitamin D deficiency is a global health problem. It has been found in all age groups, even in those residing in countries with low latitude and countries with sun exposure all year round(3). Previous study has reported that about 1 billion people have a low vitamin D level, and this is found in all ethnicities and age groups(4). The prevalence of vitamin D deficiency among several populations in USA, Europe, and Asia varies, ranging from 15% to 80%(3). The low prevalence of vitamin D deficiency was observed in Thailand (6%), and Vietnam (1% to 3%)(3). The variation on the prevalence of vitamin D deficiency may be influenced by several factors such as dietary intake of vitamin D, the use of vitamin D supplements, sun exposure, outdoor activities, clothing style, and degree of urbanization(5). Although, several studies of vitamin D status in Thai population have been reported(6-14), the data on the predictors of vitamin D status in rural areas in Southern Thai subjects are rare. Thus, the aim of the present study was to determine vitamin D status and its associated factors in Southern Thai subjects.

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## Materials and Methods

### *Study subjects*

The present study was conducted in Kiriwong

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(inland area) and Bansakha (coastal area) districts of the Nakhon Si Thammarat, in Southern Thailand, in summer between April and August, 2015. The participants were healthy volunteers, aged 18 to 94 years. Subjects were excluded if they had chronic diseases such as liver disease, renal disease, cancer, or disorders known to affect bone mineral metabolism including hyperthyroidism, hyperparathyroidism, osteomalacia, or Paget's disease. Subjects using medications affecting either vitamin D or bone such as testosterone replacement or deprivation therapy, antiosteoporotic drugs, anticonvulsants, glucocorticoids, diuretics, thyroid supplements, lithium and thiazides, as well as subjects who had suffered from fracture and subjects with mobility problems were excluded. The present study was approved by the Ethics Committee of Walailak University (protocol No. 14/101). Written informed consents were obtained from all subjects.

### *Data collection*

The participants completed a questionnaire that included questions pertaining to age, gender, residential area, religion, chronic diseases, medications, family history of medical diseases, intake of multivitamin or fish oil, milk consumption, the use of sunscreen, alcohol consumption, smoking status, and physical activity. Subjects who smoked at least one cigarette per day were considered current smokers. Subjects who never smoked or stopped smoking at least one year before the study were considered non-smokers. Subjects who consumed any type of alcohol beverage at least once per week were defined as drinker. Subjects who had never drunk alcohol beverage or drank less than once a week were defined as non-drinker. Weight and height were directly measured, from which body mass index [BMI] (kg/m$^2$) was calculated. Blood was collected from a peripheral vein, quickly placed on ice, and transported to the laboratory where it was centrifuged at 3,000 rpm for five minutes, then serum and plasma were stored at -70°C until analysis.

### *Biochemical parameters*

The 25-hydroxyvitamin D [25(OH)D] levels were measured with an electrochemiluminescent immunoassay (the VITROS® 25-OH Vitamin D Total Assay) on an automated machine (Vitros ECi, Johnson and Johnson, Rochester, NY, USA). The inter-assay and intra-assay coefficients of variation of total serum 25(OH)D level were 6.5% to 12.8% and 5.3% to 10.1%, respectively. Based on published definitions of vitamin D status[2], 25(OH)D 75 nmol/L or greater (30 ng/mL or greater) was defined as sufficient, 25(OH)D 50 to 74.9 nmol/L (20 to 29.9 ng/mL) was defined as insufficiency, and 25(OH)D of less than 50 nmol/L (less than 20 ng/mL) was defined as vitamin D deficiency. Hypovitaminosis D was defined as 25(OH)D of less than 75 nmol/L (less than 30 ng/mL).

### *Statistical analyses*

Demographic characteristics were expressed using descriptive statistics. Results were expressed as mean and standard deviation [SD]. Significant differences between genders were assessed, using the student-t-test and Chi-square ($\chi^2$) test. The associations of predictors and vitamin D deficiency and hypovitaminosis D were modeled using multivariate logistic regression analyses. Covariates including gender, age, BMI, residential area, religion, intake of multivitamin or fish oil, milk consumption, the using of sunscreen, alcohol consumption, cigarette smoking, and physical activity were included in the multivariate model. A $p$-value smaller than 0.05 was considered statistically significant. All data were analyzed using SPSS (SPSS Inc., Chicago, IL; Version 16).

## Results

### *General characteristics*

The demographic characteristics and mean 25(OH)D levels of the study population are summarized in Table 1. Eight hundred thirty-nine subjects in Southern Thailand participated in the present study. The mean age was 53.43±13.52 years old. There was no significant difference in mean age between genders. Of the participants, 39.21% and 60.79% were from inland, and coastal areas, respectively. Women had significantly higher daily milk consumption, and the use of sunscreen, but had significantly lower alcohol consumption, and smoking than men. The mean serum 25(OH)D concentrations of all participants were 77.48±22.44 nmol/L. Serum 25(OH)D levels were significantly lower in women than in men (73.06±18.15 nmol/L versus 95.07±28.63 nmol/L, respectively, $p<0.001$).

### *Prevalence of vitamin D deficiency and insufficiency in the study subjects*

Vitamin D status and age, gender, BMI, residential area, religion, intake of multivitamin or fish oil, milk consumption, the use of sunscreen, alcohol consumption, smoking, and physical activity are shown in Table 2. Overall, 6.91% had vitamin D deficiency, 43.74% had vitamin D insufficiency, and 49.34% had sufficient levels of vitamin D. Vitamin D deficiency was significantly more common among women than men (8.05%, versus 2.38%, $p<0.001$, respectively). Similarly, vitamin D insufficiency was also significantly more common among women than men (48.58% versus 24.40%, $p<0.001$, respectively). The prevalence of vitamin D deficiency and/or insufficiency was significantly increased according to BMI, living in inland area, Muslim, and the use of sunscreen. Whereas, subjects who had alcohol consumption and smoking had significantly lower in prevalence of vitamin D deficiency and insufficiency compared with non-alcohol drinkers and non-smokers. This may be due to the small sample size of alcohol drinkers and smokers in the present population. Most alcohol drinkers and smokers were men, which are in a low proportion in this population.

### *Logistic regression analysis*

Logistic regression analysis of possible risk factors for vitamin D deficiency and insufficiency is shown in Table 3. Multivariate analysis demonstrates that women, age, inland living, and Muslim are significantly associated with an increased odds ratio [OR] of both vitamin D deficiency and hypovitaminosis D ($p<0.05$). Whereas, alcohol consumption was found to associated with increased OR of only vitamin D deficiency ($p<0.05$). In addition, obese subjects, and the use of sunscreen were significantly associated with increased OR of hypovitaminosis D ($p<0.05$).

## Discussion

In the present study, although vitamin D deficiency (6.91% in total, 2.38% in men, and 8.05% in women) was uncommon in Southern Thai population, a high prevalence of vitamin D insufficiency (43.74% in total, 24.40% in men, and 48.58% in women) was observed. The results in the present study are consistent with the previous study in Southern Thai subjects that the prevalence of vitamin D deficiency was low (6.30% in total, 1.50% in men, and 12.90% in women), but the prevalence of hypovitaminosis D was high (43.80% in total, 29.40% in men, and 65.80% in women)[10]. It is difficult to compare the prevalence of vitamin D deficiency, vitamin D insufficiency, and hypovitaminosis D with other reports in Thailand because the studies used different cut-off values to define vitamin D deficiency, vitamin D insufficiency, and hypovitaminosis D (Table 4).

**Table 1.** Demographic characteristics and mean 25(OH)D levels of the study population

| Characteristics | Total (n = 839) mean ± SD or n (%) | Women (n = 671) mean ± SD or n (%) | Men (n = 168) mean ± SD or n (%) | *p*-value |
|---|---|---|---|---|
| Age (year)** | 53.43±13.52 | 53.51±13.56 | 53.13±13.41 | 0.788 |
| BMI (kg/m$^2$)** | 24.51±4.16 | 24.84±4.27 | 23.18±3.42 | <0.001* |
| 25(OH)D (nmol/L)** | 77.48±22.44 | 73.06±18.15 | 95.07±28.63 | <0.001* |
| Area† | | | | 0.032* |
| Coastal | 510 (60.79) | 420 (62.59) | 90 (53.57) | |
| Inland | 329 (39.21) | 251 (37.41) | 78 (46.43) | |
| Religion† | | | | 0.250 |
| Muslim | 39 (4.65) | 34 (5.07) | 5 (2.98) | |
| Buddhist | 800 (95.35) | 637 (94.93) | 163 (97.02) | |
| Multivitamin use† | 116 (13.83) | 93 (13.86) | 23 (13.69) | 0.955 |
| Fish oil intake† | 34 (4.05) | 28 (4.17) | 6 (3.57) | 0.724 |
| Milk consumption† | | | | 0.014* |
| Daily | 123 (14.66) | 110 (16.39) | 13 (7.74) | |
| ≥1 to 6 days/week | 497 (59.24) | 393 (58.57) | 104 (61.90) | |
| No | 219 (26.10) | 168 (25.04) | 51 (30.36) | |
| The use of sunscreen† | 289 (34.44) | 278 (41.43) | 11 (6.55) | <0.001* |
| Alcohol consumption† | 130 (15.49) | 36 (5.37) | 94 (55.95) | <0.001* |
| Smoking† | 75 (8.94) | 7 (1.04) | 68 (40.48) | <0.001* |
| Physical activity† | 509 (60.67) | 416 (61.99) | 93 (55.36) | 0.115 |

BMI = body mass index; 25(OH)D = 25-hydroxyvitamin D; SD = standard deviation

* Significant level at *p*-value <0.05

** *p*-value obtained in the student t-test for the comparison between groups

† *p*-value obtained in the Chi-square test ($\chi^2$) for the comparison between groups

**Table 2.** Vitamin D status and age, gender, BMI, residential area, religion, intake of multivitamin or fish oil, milk consumption, the using of sunscreen, alcohol consumption, smoking, and physical activity

| Characteristics | 25(OH)D status, n (%) | | | *p*-value** |
|---|---|---|---|---|
| | Deficient(<50 nmol/L) | Insufficient(50 to 74.9 nmol/L) | Sufficient(≥75 nmol/L) | |
| Gender | | | | <0.001* |
| Men (n = 168) | 4 (2.38) | 41 (24.40) | 123 (73.21) | |
| Women (n = 671) | 54 (8.05) | 326 (48.58) | 291 (43.37) | |
| Total (n = 839) | 58 (6.91) | 367 (43.74) | 414 (49.34) | |
| Age (year) | | | | 0.028* |
| <50 (n = 338) | 14 (4.14) | 148 (43.79) | 176 (52.07) | |
| ≥50 (n = 501) | 44 (8.78) | 219 (43.71) | 238 (47.50) | |
| BMI (kg/m$^2$) | | | | 0.027* |
| Normal (<23) (n = 329) | 20 (6.08) | 123 (37.39) | 186 (56.53) | |
| Overweight (23 to 24.9) (n = 173) | 14 (8.09) | 78 (45.09) | 81 (46.82) | |
| Obese I (25-29.9) (n = 258) | 16 (6.20) | 125 (48.45) | 117 (45.35) | |
| Obese II (≥30) (n = 79) | 8 (10.13) | 41 (51.90) | 30 (37.97) | |
| Area | | | | <0.001* |
| Coastal (n = 510) | 21 (4.12) | 199 (39.02) | 290 (56.86) | |
| Inland (n = 329) | 37 (11.25) | 168 (51.06) | 124 (37.69) | |
| Religion | | | | 0.040* |
| Muslim (n = 39) | 5 (12.82) | 22 (56.41) | 12 (30.77) | |
| Buddhist (n = 800) | 53 (6.63) | 345 (43.13) | 402 (50.25) | |
| Multivitamin use | | | | 0.230 |
| Yes (n = 116) | 8 (6.90) | 59 (50.86) | 49 (42.24) | |
| No (n = 723) | 50 (6.92) | 308 (42.60) | 365 (50.48) | |
| Fish oil intake | | | | 0.429 |
| Yes (n = 34) | 1 (2.94) | 18 (52.94) | 15 (44.12) | |
| No (n = 805) | 57 (7.08) | 349 (43.35) | 399 (49.57) | |
| Milk consumption | | | | 0.691 |
| Daily (n = 123) | 7 (5.69) | 51 (41.46) | 65 (52.85) | |
| ≥1 to 6 days/week (n = 497) | 36 (7.24) | 226 (45.47) | 235 (47.28) | |
| No (n = 219) | 15 (6.85) | 90 (41.10) | 114 (52.05) | |
| The use of sunscreen | | | | <0.001* |
| Yes (n = 289) | 19) (6.57) | 154 (53.29) | 116 (40.14) | |
| No (n = 550) | 39 (7.09) | 213 (38.72) | 298 (54.18) | |
| Alcohol consumption | | | | 0.001* |
| Yes (n = 130) | 7 (5.38) | 39 (30.00) | 84 (64.62) | |
| No (n = 709) | 51 (7.19) | 328 (46.26) | 330 (46.54) | |
| Smoking | | | | <0.001* |
| Yes (n = 75) | 0 (0.00) | 20 (26.67) | 55 (73.33) | |
| No (n = 764) | 58 (7.59) | 347 (45.42) | 359 (46.99) | |
| Physical activity | | | | 0.055 |
| Yes (n = 509) | 31 (6.09) | 239 (46.95) | 239 (46.95) | |
| No (n = 330) | 27 (8.18) | 128 (38.79) | 175 (53.03) | |

BMI = body mass index

* Significant level at *p*-value <0.05

** *p*-value obtained in the Chi-square test ($\chi^2$) for the comparison between groups

The low prevalence of vitamin D deficiency in the present study is because Thailand is a sunny country, located near the equator. Thai people have the intense sun exposure all year round. Consequently, it is not surprising that the prevalence of vitamin D deficiency in Thai people is very low. Moreover, these results were in agreement with the studies in Malaysia (0.5%) and Vietnam (1% to 3%) that the prevalence of vitamin D deficiency was markedly low[3,15]. In contrast, these findings were inconsistent with the study in Bangladesh (80%), Iran (51%), Pakistan (58%), India (66%), and Sri Lanka (34% to 59%), which have shown the high prevalence of vitamin D deficiency even though they have high amounts of sun exposure[3]. This is the result

**Table 3.** Logistic regression for presumed risk factors for vitamin D deficiency (25-OH-D <50 nmol/L) and hypovitaminosis D (25-OH-D <75 nmol/L)

| Independent variables | Vitamin D deficiency, adjusted OR** (95% CI) | *p*-value | Vitamin D deficiency + vitamin D insufficiency (hypovitaminosis D), adjusted OR** (95% CI) | *p*-value |
|---|---|---|---|---|
| Gender | | | | |
| Women | 4.391 (1.336 to 14.432) | 0.015* | 3.613 (2.149 to 6.074) | <0.001* |
| Men | 1 | | 1 | |
| Age (year) | 1.029 (1.006 to 1.053) | 0.015* | 1.012 (1.000 to 1.024) | 0.049* |
| BMI (kg/m$^2$) | | | | |
| Normal (<23) | 1 | | 1 | |
| Overweight (23 to 24.9) | 1.253 (0.596 to 2.635) | 0.551 | 1.364 (0.914 to 2.037) | 0.128 |
| Obese I (25 to 29.9) | 0.897 (0.442 to 1.822) | 0.764 | 1.418 (0.992 to 2.025) | 0.055 |
| Obese II (≥30) | 1.519 (0.611 to 3.774) | 0.368 | 2.136 (1.233 to 3.698) | 0.007* |
| Area | | | | |
| Coastal | 1 | | 1 | |
| Inland | 3.790 (2.042 to 7.038) | <0.001* | 2.856 (2.089 to 3.905) | <0.001* |
| Religion | | | | |
| Muslim | 5.204 (1.701 to 15.920) | 0.004* | 3.698 (1.746 to 7.832) | 0.001* |
| Buddhist | 1 | | 1 | |
| Multivitamin use | | | | |
| Yes | 1.039 (0.441 to 2.445) | 0.930 | 1.426 (0.903 to 2.252) | 0.128 |
| No | 1 | | 1 | |
| Fish oil intake | | | | |
| Yes | 0.338 (0.041 to 2.766) | 0.312 | 1.033 (0.475 to 2.244) | 0.935 |
| No | 1 | | 1 | |
| Milk consumption | | | | |
| Daily | 0.804 (0.304 to 2.126) | 0.661 | 0.792 (0.489 to 1.281) | 0.341 |
| ≥1 to 6 days/week | 1.009 (0.522 to 1.951) | 0.979 | 1.162 (0.818 to 1.649) | 0.402 |
| No | 1 | | 1 | |
| The use of sunscreen | | | | |
| Yes | 0.936 (0.492 to 1.781) | 0.839 | 1.567 (1.114 to 2.204) | 0.010* |
| No | 1 | | 1 | |
| Alcohol consumption | | | | |
| Yes | 3.181 (1.183 to 8.548) | 0.022* | 1.209 (0.701 to 2.083) | 0.495 |
| No | 1 | | 1 | |
| Smoking | | | | |
| Yes | 0.000 | 0.997 | 0.899 (0.449 to 1.803) | 0.765 |
| No | 1 | | 1 | |
| Physical activity† | | | | |
| Yes | 0.642 (0.364 to 1.130) | 0.124 | 1.224 (0.904 to 1.659) | 0.192 |
| No | 1 | | 1 | |

OR = odds ratio; CI = confidence interval

* Significant level at *p*-value <0.05

** Models adjusted for gender, age, BMI, residential area, religion, intake of multivitamin, intake of fish oil, milk consumption, the using of sunscreen, alcohol consumption, smoking, and physical activity

† Physical activity is defined as exercising strenuously for at least 30 minutes for 3 or more days per week

that most of the people in these countries are Muslim. They are covered by religious and cultural reasons allowing less sunlight exposure to the skin[16]. Similarly, the authors also found that Muslim had increased odds ratio of vitamin D deficiency and hypovitaminosis D compared with Buddhist in the present study.

In addition, the mean vitamin D concentration (77.48±22.44 nmol/L) in these results was likely similar to adults from central (79.5±1.1 nmol/L)[10] and south (78.3±1.3 nmol/L)(10) regions of Thailand but higher than Thai premenopausal women (72.61±1.05 nmol/L)[8], healthy women (67.6±15.7 nmol/L)[9], and adults from Bangkok (64.8±0.7 nmol/L)[10], as well as elderly Thai women (64.3±14.9 nmol/L)[13]. Moreover, the mean vitamin D levels in the present study were lower than urban elderly women (83.17±17.82 nmol/L)[6],

**Table 4.** Mean serum 25(OH)D and prevalence of vitamin D deficiency, vitamin D insufficiency, and hypovitaminosis D in a population in Thailand

| Year | Population | Region | n | Age (year) | 25(OH)D detection method | Mean 25(OH)D (nmol/L), mean ± SD | Prevalence of vitamin D deficiency/ vitamin D insufficiency/ hypovitaminosis D |
|---|---|---|---|---|---|---|---|
| 2001 | Urban elderly women[6] | Khon Kaen Province, Northeast Thailand | 106 | Mean age: 69.42±6.77 | Radioimmunoassay (DiaSorin, USA) | 83.17±17.82 | Hypovitaminosis D (25(OH)D <75 to 87 nmol/L): 34.9% to 65.1% |
| 2009 | Rural elderly women[7] | Khon Kaen Province, Northeast Thailand | 129 | Mean age: 71.55±5.26 | Radioimmunoassay (DiaSorin, USA) | 112.07±27.51 | Hypovitaminosis D (25(OH)D <87 nmol/L): 17.4% |
| 2009 | Thai premenopausal women[8] | Multicenters study from 5 provinces of Thailand which cover all region of Thailand except southern area | 357 | 20 to 50 years Mean age: 35.20±0.47 | Radioimmunoassay (DiaSorin, USA) | 72.61±1.05 | Vitamin D insufficiency (25(OH)D <87 nmol/L): 77.81% |
| 2011 | Healthy women[9] | Bangkok, Thailand | 446 | 60 to 97 years Mean age: 67.5±6.0 | Radioimmunoassay (DiaSorin, USA) | 67.6±15.7 | Vitamin D insufficiency (25(OH)D ≤60 nmol/L): 32% |
| 2011 | Adults[10] | Thai 4th National Health Examination Survey (2008 to 2009) cohort | 2,641 | 15 to 98 years Mean age: 40.3±0.3 | LC-MS/MS | Bangkok: 64.8±0.7 Central: 79.5±1.1 Northern: 81.7±1.2 Northeastern: 82.2±0.8 Southern: 78.3±1.3 | Vitamin D deficiency (25(OH)D <50 nmol/L): 6.5% (Central) 4.3% (North) 2.8% (Northeast) 6.3% (South) Vitamin D insufficiency (25(OH)D ≤75 nmol/L): 43.1% (Central) 39.1% (North) 34.2% (Northeast) 43.8% (South) |
| 2011 | Urban elderly males[11] | Khon Kaen Province, Northeast Thailand | 100 | Mean age: 70.73±0.62 | Electrochemiluminescence (ECLIA) | 104.93±3.05 | Vitamin D insufficiency (25(OH)D <100 nmol/L): 48% |
| 2012 | Nurses[12] | The Royal Irrigation Hospital | 217 | Mean age: 42.16±11.8 | LC-MS/MS | N/A | Vitamin D deficiency (25(OH)D <50 nmol/L): 49.8% Vitamin D insufficiency (25(OH)D 50 to 74.9 nmol/L): 45.6% Hypovitaminosis D (25(OH)D <74.9 nmol/L): 95.4% |
| 2012 | Elderly Thai women[13] | Long-term nursing homes for the aged | 93 | 61 to 97 years Mean age: 75.2±6.0 | Radioimmunoassay (DiaSorin, USA) | 64.3±14.9 | Vitamin D insufficiency (25(OH)D <70 nmol/L): 38.7% |
| 2015 | Rural elderly males[14] | Khon Kaen Province, Northeast Thailand | 66 | Mean age: 68.09±0.81 | Electrochemiluminescence (ECLIA) | 135.63±3.42 | Vitamin D insufficiency (25(OH)D <100 nmol/L): 13.64% |
| 2017 | Healthy rural subjects (present study) | Nakhon Si Thammarat, South Thailand | 829 | 18 to 94 years Mean age: 53.43±13.52 | Electrochemiluminescence (ECLIA) | 77.48±22.44 | Vitamin D deficiency (25(OH)D <50 nmol/L): 6.91% Vitamin D insufficiency (25(OH)D <50 to 74.9 nmol/L): 43.74% |

25(OH)D = 25-hydroxyvitamin D; SD = standard deviation; N/A = not applicable; LC-MS/MS = liquid chromatography tandem-mass spectrometry

rural elderly women (112.07±27.51 nmol/L)[7], rural elderly males (135.63±3.42 nmol/L)[14], and urban elderly males (104.93±3.05 nmol/L)[11] from Khon Kaen province, adults from northern (81.7±1.2 nmol/L)[10], and northeastern (82.2±0.8 nmol/L)[10] regions of Thailand (Table 4). The variation in vitamin D levels among populations may be due to the differential distribution in risk factors e.g., age, sex, BMI, dietary vitamin D intake, smoking habits, alcohol consumption, physical activity, skin type, latitude, genetic predisposition, the sample size, as well as, the methodology used to assess serum 25(OH)D levels.

In the present study, the authors also found the mean 25(OH)D levels in men were significantly higher than women. Furthermore, the prevalence of vitamin D deficiency and insufficiency were more pronounce in women than men. These findings were consistent with a previous report in Thai population[10], suggesting that men may have more outdoor activity and more sunlight exposure than women. In addition, the authors observed that women used more sunscreen than men and the use of sunscreen showed the increased odds ratio of hypovitaminosis D. This is similar to a study in nurses at the Royal Irrigation Hospital, Thailand that showed a high prevalence of vitamin D deficiency (49.80%) and hypovitaminosis D (95.40%)[12]. Sunscreen usage was found associated with vitamin D deficiency[12]. A previous study has supported that the use of sunscreen with sun protection factor [SPF] of 15 decreases vitamin D synthesis in the skin by 99%(2).

Furthermore, the advancing age, obesity, living in inland, and alcohol consumption have been found as associated risk factors for vitamin D deficiency and/or hypovitaminosis D in the present study. The serum 25(OH)D levels were inversely associated with age. These findings were consistent with several studies(15,16). This suggested that the aging process may be related in the decreased vitamin D synthesis because of the reduction of 7-dehydrocholesterol in the skin(1). However, some studies have shown that low serum 25(OH)D levels were associated with younger age(10). This may be due to the more sedentary lifestyle, and less exercise in adolescents. In the present study, obese subjects had increased risk of hypovitaminosis D. These results were in accordance with a previous study(16). Obesity associated hypovitaminosis D is likely due to the decreased bioavailability of vitamin D because of its deposition in adipose tissue(18). In addition, vitamin D levels were significantly higher in coastal area than inland area. These results were agreed with the studies in UK(19) and Finland(20), suggesting that coastal area may have a climate favorable for vitamin D synthesis due to higher solar irradiance and temperature compared to inland area. Finally, alcohol drinker increased odds ratio of vitamin D deficiency in the present study. It has been found that chronic alcoholism resulted in disturbed vitamin D metabolism and chronic alcoholics usually have low serum 25(OH)D levels(21). Previous study had suggested that a low vitamin D levels in chronic alcoholics resulted from malabsorption, poor dietary intake, lack of sun exposure, or a direct effect of alcohol on vitamin D metabolism(22).

In conclusion, the prevalence of vitamin D insufficiency is high and it is needed to be aware in this population. Several risk factors including Muslim, women, living in inland, alcohol consumption, obesity, the use of sunscreen, and advancing age were associated with vitamin D deficiency and/or hypovitaminosis D in the present study. The lifestyle modification such as increasing sun exposure, increasing outdoor activity, increasing vitamin D intake, avoiding alcohol intake, and reducing weight should be implemented particularly in high-risk persons such as Muslim and people living in inland to prevent vitamin D deficiency and hypovitaminosis D.

## What is already known on this topic?

Several studies have demonstrated the vitamin D status among Thai adults, elderly, as well as, in children in rural or urban areas in Bangkok, Khon Kaen, Northern, and Southern Thailand. Although, the vitamin D status in Southern Thailand has been reported, the associated factors involving vitamin D status were not well clarified. Moreover, the data on the vitamin D status and its associated factors in rural areas, between inland, and coastal areas in Southern Thailand have not been examined. To our knowledge, this is the first study that aimed to evaluate the vitamin D status and its associated factors among rural subjects, between inland and coastal areas in Nakhon Si Thammarat province, Southern Thailand.

## What this study adds?

Our results showed that the prevalence of vitamin D deficiency and insufficiency were 6.91% and 43.74%, respectively. Women showed a significantly higher in vitamin D deficiency than men (8.05% versus 2.38%, $p = 0.000$). Logistic regression analysis demonstrated that vitamin D deficiency and/or hypovitaminosis D were associated with being women, advancing age, obesity, living in inland, Muslim, the use of sunscreen, and alcohol consumption.

In summary, the prevalence of vitamin D insufficiency is high in rural subjects in Nakhon Si Thammarat. The lifestyle modification such as reducing weight, avoiding alcohol intake, increasing outdoor activity, increasing sun exposure, and increasing vitamin D intake should be implemented to prevent vitamin D deficiency and hypovitaminosis D.

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## Potential conflicts of interest

The authors declare no conflict of interest.

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