REVIEW

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Vitamin D status and sun exposure in Southeast Asia

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Vitamin D deficiency is more common in South Asia and Southeast Asia than in appreciated. Most studies defined 25-hydroxyvitamin D levels [25(OH)D] levels of less than 50 nmol/L (20 ng/mL) as vitamin D deficiency. With this cut-off level, the prevalence of vitamin D deficiency was about 70% or higher in South Asia and varied from 6–70% in Southeast Asia. The determinants for the variation of vitamin D status are skin pigmentation, aging, the sun protection behaviors such as application of a sunscreen, religious, lifestyle and nutritional differences. Advanced age is a known risk factor for vitamin D deficiency. Interestingly, elderly in countries such as Korea and Thailand, had higher 25(OH)D levels when compared with young people. This widespread vitamin D deficiency problem especially in the young generation is an urgent health issue that needs to be remedied.

Prevalence of Vitamin D Deficiency in Asia

Vitamin D plays an important role in bone metabolism and maintaining bone health and muscle function.[1] Vitamin D inadequacy is a worldwide problem and affects developed as well as developing countries, subtropical and temperate regions, and populations of all ages.[2] Vitamin D deficiency may be overlooked in Asian countries, perhaps on the assumption that vitamin D deficiency is unlikely to occur in regions with plentiful sunshine. This topic aims to review the current evidence about the prevalence of vitamin D deficiency and the sun exposure behavior in Asian populations.

Regardless of the definition of vitamin D deficiency, insufficiency and sufficiency {defined as 25-hydroxyvitamin D [25(OH)D] < 50, 51–74 and > 75 nmol/L, respectively},[3,4] studies carried across different countries in South Asia and Southeast Asia revealed widespread prevalence of vitamin D deficiency and insufficiency. In India, located between 8°N-38°N, there is plenty of sunshine all year round and thus people in India should not have and inadequate vitamin D status. On the contrary, epidemiologic studies from different parts in India reported higher than 70% prevalence of vitamin D deficiency [25(OH)D < 50 nmol/L] in all age groups, including toddlers, school children, pregnant women and their neonates and adult males.[5] For example, a study in school girls (n = 404, 48% lower socioeconomic strata) in Delhi, located at 28.38°N, reported 91% were vitamin D deficient.[6] The prevalence of vitamin D deficiency was similar in both lower and upper socioeconomic strata with the mean 25(OH)D levels of 29 ± 13 and 34 ± 17 nmol/L, respectively (p = ns).[6] Seventy percent of healthy volunteers (n = 1,137) in Mumbai, the western part of India located at 18.56° N, had vitamin D deficiency [mean 25(OH)D levels = 44 ± 23 nmol/L] with a slightly higher prevalent (79%) in females.[7]

Vitamin D status in Southeast Asian countries has recently received more attention. There were some health examination surveys (n~2,500–7,000) of countries in this region as summarized in **Table 1**.[8-10] Most studies defined vitamin D deficiency as 25(OH)D levels of < 50 nmol/L. In the Singapore Chinese Health Study (SCHS), 504 middle age and elderly participants (aged 45–74 y, 56% female) were evaluated for the distribution of serum 25(OH)D concentration.[11] As Singapore is 1°N, this study population provided a unique opportunity to evaluate the factors associated with vitamin D status in the absence of seasonal variation in UV exposure. The mean 25(OH)D concentration was 69 nmol/L overall, lower in females (64 nmol/L) compared with males (74 nmol/L), p < 0.001. A greater percentage of vitamin D deficiency was also found in females (18% vs. 9%).[11] Among these Southeast Asia countries, Thailand had the least prevalence of vitamin D deficiency, possibly related to its geographical location close to the equator.[10] Singapore had slightly higher prevalence of vitamin D deficiency than in Thailand, partly due to being a more industrialized country even though Singapore is located closer to the equator. Overall, the common predictors of having low vitamin D status in this Southeast Asia were younger age, being female, living in an urban area and being less physically active.[8-11]

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Sunlight as a Source of Vitamin D: Some Limitation in Asia

For most people, the main source of vitamin D is skin exposure to sunlight. After exposing to UVB (UVB: 290–315 nm), UVB

Table 1. Summary of prevalence of vitamin D deficiency and its determinants from National population based studies in Southeast Asia

	China[8] Nutrition and Health of Aging Population in China (NHAPC) project	South Korea[9] Korean Fourth Korea National Health and Nutrition Examination Surveys (KNHANESIV)*	Thailand[10] Thai 4th National Health Examination Survey (2008–9) cohort (NHESIV)**
Date of subjects enrollment	April to June 2005	2008	2008–2009
Latitude of residency	Beijing (40° N) and Shanghai (31° N)	33° N and 38° N	5°30' N and 20°30' N
No. of subjects	3,262	6,925	2,641
Mean age (year)	50–70	M: 42 ± 20 (10–91) F: 45 ± 19 (10–93)	Total: 40 ± 0 M: 40 ± 1 F: 41 ± 0
M/F	1,443/1819 (44/56%)	3,047/3,878 (44/56%)	1,321/1,320 (50/50%)
BMI (kg/m^2)	- Reported BMI according to 25(OH)D quintile -The mean of BMI = 24–25	Classified BMI in to 3 groups: < 23: 45% in M 53% in F 23–25: 24% in M 20% in F ≥ 25: 31% in M 27% in F	Total: 24 ± 0 M: 23 ± 0 F: 24 ± 0
Method of 25(OH)D measurement	RIA (Diasorin, Stillwater, MN)	RIA (Diasorin, Stillwater, MN)	LC-MS/MS
Mean 25(OH)D (nmol/L)	40.4	M: 53 ± 19 F: 46 ± 18	Total: 79 ± 1 M: 86 ± 1 F: 73 ± 1
Percent of subjects with 25(OH)D < 50 nmol/L	Total: 69%	M: 47% F: 65%	Total: 6% M: 2% F: 9%
Percent of subjects with 25(OH)D < 75 nmol/L	94%	M: 87% F: 94%	Total: 45% M: 33% F: 57%
Latitude at risk	Northern (Beijing)	N/A	Southern part (excluding Bangkok: a capital city of Thailand)
Season with the lowest 25(OH)D levels	N/A	spring, winter	N/A
Predictors for vitamin D deficiency	- living in northern (Beijing) and urban area - having a physical examination in April - having higher educational levels - having a family history of CVD and diabetes - having less physically active - being female	Analyzed in adult 20–80 y (both gender): - younger age (20–49 y) - living in urban - occupations (indoors worker) - no regular exercise	- being female - younger age - living in urban area - living in Bangkok

Data from National population based study in Asia. *Data was expressed as mean ± standard deviation (mean ± SD). **Data was expressed as mean ± standard error of mean (mean ± SEM). M, male; F, female; BMI, body mass index; RIA, radioimmunoassay; LC-MS/MS, liquid chromatography/tandem mass spectrometry; CVD, cardiovascular disease.

photons causes the photolysis of 7-dehydrocholesterol (7-DHC, provitamin D_3; the immediate precursor in the cholesterol biosynthetic pathway in the skin) to previtamin D_3, which thermally isomerized (37°C) to vitamin D_3 by a membrane enhanced mechanism. Vitamin D_3 is further 25-hydroxylated at the liver to become $25(OH)D_3$ and then 1-α-hydroxylated at the kidneys to become active form; 1,25-dihydroxyvitamin $D_3[1,25(OH)_2D_3]$.[1] Many factors reduce the skin's production of vitamin D_3, including increased skin pigmentation, aging, and the sun protection behaviors such as application of a sunscreen or cover most part of their bodies with clothes.[12-14] An alteration in the zenith angle of the sun caused by a change in latitude, season of the year, or time of day dramatically influences the skin's production of vitamin D_3.[12,14]

Age and gender. In general, the cutaneous production of vitamin D declines with age.[15,16] Aging is associated with decreases the 7-DHC concentration in the skin, resulting reduction by more than 4-fold vitamin D_3 production in a 70-y-old compared with a 20-y-old adult.[15,16] In addition, elderly usually stay indoors for prolong periods of time and have limited physical activity due to multiple co-morbidities, which further contribute to less sun exposure. Interestingly, elderly in Southeast Asia such as Thailand[10] and Korea[9] have a better vitamin D status when compare with younger people. The possible explanation is these elderly have more free time and spend time doing outdoor activities.[10] The rapid economic development over the past decade in many countries of Southeast Asia has resulted in young adults having indoor jobs, while elderly adults tend to have outdoor jobs.[9] The high prevalence of vitamin D deficiency in young adults, especially in adolescents, raises about a bone health concern in this critical period when they are achieving peak bone mass. Studies finding appropriate strategies to improve vitamin D status in this group of population are urgently wanted.

As in western countries, there is evidence that females in Asian countries have lower 25(OH)D levels than in males.[8-11,17,18] Gender differences occur mainly due to clothing and sun protection behavior in females because of the cosmetic concerns. Fair skin is associated with beauty in these populations. For example, a telephone interview survey of 547 middle-aged and elderly Chinese women living in Hong Kong (an industrialized city situated on the southern coast of China at latitude of 22.5 degrees north) revealed that 62% of respondents did not like going in the sun.[18] As high as 67% and 58% of respondents spent an average of 6–10 h indoors and between 6:30 a.m. and 7:00 p.m. during weekdays and Sundays, respectively. Almost half of the respondents used a parasol to shade themselves from the sun.[18] Muslims, especially in females, traditionally have most part of their body covered when compare with males.[17]

Skin color and culture behavior. Human skin has a huge capacity to produce vitamin D_3. From the experimental data that exposure of the body in a bathing suit (almost 100% of body surface area) to sunlight that causes a minimal erythemal dose (MED) is equivalent to taking between 10,000 and 25,000 IU of vitamin D orally.[12] Therefore, exposure of 6% of the body to 1 MED is equivalent to taking about 600 and 1,000 IU of vitamin D. However, the simplest strategy is "Holick's rule" which is exposing face, arms and legs for a period equal to 25% of the time that it would take to cause 1 MED for two to three times a week can satisfy the body's vitamin D requirement while minimizing sun damage.[12] To apply this strategy we need to know MED for each skin type at the specific latitude and time. Generally, exposure of arms and legs for 5 to 30 min (depending on time of day, season, latitude, and skin pigmentation) between the hours of 10 a.m. and 3 p.m. twice a week is often adequate.[1] Comparing to Caucasians (mostly skin type2 or 3), Asians have skin type 4 or 5. Therefore, with the same amount of MED, dark-skin individuals require greater duration of exposure than their light-skinned counterparts to synthesis comparable amount of vitamin D_3.[19] Setiati S et al.,[20] conducted a study of sun exposure in elderly women in Jakarta, Indonesia (latitude of 6°S). They did repeated measurement of sun exposure intensity from 7 a.m. to 4 p.m. by using UV meter to get the MED/hour. They found that in Jakarta, the highest intensity of UVB occurred at 11 a.m. to 1 p.m. (~2 MED/hour). But for more convenience, they decided to ask subjects (n = 74 elderly women with type-4 skin) to expose to sunlight at 9 a.m. which contained about 0.6 MED/hour by average. According to Holick's rule, exposing to sunlight at the face and both arms for 25 min, 3 times a week at 9 p.m. should maintain adequate vitamin D status. After exposing to sunlight at this specific time and duration for 6 weeks, mean 25(OH)D levels of participants increased from 59 nmol/L at the baseline to 84 nmol/L.[20] One of limitation in this study is that their UV meter detected both UVA and UVB. And in general, MED is not always a marker of vitamin D_3 synthesis in the skin. For example, at the higher-wavelengths UVA radiation can produce skin erythema without any vitamin D synthesis.[19] The sunlight in the early morning and late afternoon contain mostly UVA, not UVB.[12] Nonetheless, this study proved the concept that people with dark skin have ability to achieve sufficient vitamin D status by going to the sun at the proper time with adequate duration of sun exposure.

The variation of vitamin D status in people who live in the same city or country is partly link to religious, lifestyle and nutritional difference. Such as the Thai 4th National Health Examination Survey reported that non-Muslims (~97% of total subjects) had 10 nmol/L higher levels of 25(OH)D when compared with Muslims (80 ± 1 vs. 69 ± 4 nmol/L, respectively).[10] There was a report that only 1/3 of participants were vitamin D sufficient [25(OH)D ≥ 50 nmol/L] in Malaysia which is a tropical country located at the equator and is sunny all year round. Most of the populations are Muslim. It's not surprise that the lower 25(OH)D levels were found in females, explained by the tradition costume (wearing long sleeves, long skirts and veil).[17] In addition, lower 25(OH)D levels in the urban population were consistently found in almost geographical region of Asia.[8-10,21] Limiting outdoor activity due to urbanization underlie lower vitamin D status. Air pollutants efficiently absorb UVB radiation and thus reduce the amount that reaches the earth's surface. This phenomenon may partially explain why residents of big cities such as Bangkok (Thailand),[10] Delhi (India)[22] had the lowest 25(OH)D concentration when compared with other cities/area in those countries. Consuming fatty fishes and sundried mushrooms which are major sources of vitamin D in food might help maintain proper vitamin D status in scanty UVB environments such as in winter. For example, a study of 157 elderly Japanese women in Toyosaka City, Niigata (latitude 38°N) reported that the mean 25(OH)D concentration of woman who consumed ≥ 4 times/week fish was higher by 10 nmol/L than those who consumed fish only of the 1–3 times/week group in winter.[23] However, there was no such finding in their summer study in which demonstrated that sunlight exposure was sufficient.[23]

Latitude and season. Countries near to the equator receive more sunlight all year round compare with those far from the equator. However, sun-seeking behavior is uncommon in these populations because climate is frequently too hot.[2] Thus, sun protective behaviors; including wearing a hat, applying sunscreen, using an umbrella, wearing long sleeves or staying in the shade, influence on vitamin D status in this sunshine area. It is well established that sunscreens markedly reduce transmission of UVB radiation in to the skin.[24] But often inadequately applied may have little impact on vitamin D status. One study in Australia reported that staying in the shade is the most important determinant than other behaviors, including wear a hat, apply sunscreen, use an umbrella and wear long sleeves, of poor vitamin status in these areas.[25] However often people do not apply the proper amount of sunscreen which could help explain their observation. When a sunscreen with an SPF of 8 was properly applied to the skin, vitamin D_3 production was reduced by more than 90%.[13]

Health benefit of sun exposure in Southeast Asia. The health benefit of UVB exposure in population of Southeast Asia is demonstrated as in Caucasian. For example, mortality rates for all cancers and cancers of esophagus, stomach, colon and rectum, liver, lung breast, and bladder were negatively associated with average daily ambient UVB irradiance in 263 countries in China during 1990–1992, a report by Chen W, et al.[26] Juzeniene A, et al. reported the correlation between seasonal variations in vitamin D photosynthesis and non-pandemic influenzas in Singapore and Japan.[27] A small seasonal variation in influenza has been observed in Singapore, a country which is close to the equator and thus less seasonal variation in vitamin D photosynthesis throughout the year. On the other hand, in subtropical region such as Okinawa, Japan (26 degree north), which the rate of vitamin D photosynthesis in winter is only ¼ of those in the summer, there is a regular, major outbreak of influenza in the winter and a minor outbreak in the summer. This pattern is similar to influenza circulation in other subtropical areas.[27]

In conclusion, vitamin D deficiency is common in South Asia and Southeast Asia, affecting all age groups. Latitude of the countries as well as attitudes and behavior toward sunlight exposure are the major determinants of vitamin D status in a population where sunshine is abundant. Health benefit of sun exposure in population of Southeast Asia, such as the cancer mortality rate and non-pandemic influenzas incidence, was reported as those observed in population in other part of the world.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

References

1. Holick MF. Vitamin D deficiency. N Engl J Med 2007; 357:266-81; PMID:17634462; http://dx.doi.org/10.1056/NEJMra070553
2. Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, et al.; IOF Committee of Scientific Advisors (CSA) Nutrition Working Group. Global vitamin D status and determinants of hypovitaminosis D. Osteoporos Int 2009; 20:1807-20; PMID:19543765; http://dx.doi.org/10.1007/s00198-009-0954-6
3. Institute of Medicine. Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC: National Academy of Sciences 2011
4. Holick MF, Binkley NC, Bischoff-Ferrari HA, Gordon CM, Hanley DA, Heaney RP, et al.; Endocrine Society. Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab 2011; 96:1911-30; PMID:21646368; http://dx.doi.org/10.1210/jc.2011-0385
5. Babu US, Calvo MS. Modern India and the vitamin D dilemma: evidence for the need of a national food fortification program. Mol Nutr Food Res 2010; 54:1134-47; PMID:20440690
6. Puri S, Marwaha RK, Agarwal N, Tandon N, Agarwal R, Grewal K, et al. Vitamin D status of apparently healthy schoolgirls from two different socioeconomic strata in Delhi: relation to nutrition and lifestyle. Br J Nutr 2008; 99:876-82; PMID:17903343; http://dx.doi.org/10.1017/S0007114507831758
7. Shivane VK, Sarathi V, Bandgar T, Menon P, Shah NS. High prevalence of hypovitaminosis D in young healthy adults from the western part of India. Postgrad Med J 2011; 87:514-8; PMID:21508424; http://dx.doi.org/10.1136/pgmj.2010.113092
8. Lu L, Yu Z, Pan A, Hu FB, Franco OH, Li H, et al. Plasma 25-hydroxyvitamin D concentration and metabolic syndrome among middle-aged and elderly Chinese individuals. Diabetes Care 2009; 32:1278-83; PMID:19366976; http://dx.doi.org/10.2337/dc09-0209
9. Choi HS, Oh HJ, Choi H, Choi WH, Kim JG, Kim KM, et al. Vitamin D insufficiency in Korea--a greater threat to younger generation: the Korea National Health and Nutrition Examination Survey (KNHANES) 2008. J Clin Endocrinol Metab 2011; 96:643-51; PMID:21190984; http://dx.doi.org/10.1210/jc.2010-2133
10. Chailurkit LO, Aekplakorn W, Ongphiphadhanakul B. Regional variation and determinants of vitamin D status in sunshine-abundant Thailand. BMC Public Health 2011; 11:853; PMID:22074319; http://dx.doi.org/10.1186/1471-2458-11-853
11. Robien K, Butler LM, Wang R, Beckman KB, Walek D, Koh WP, et al. Genetic and environmental predictors of serum 25-hydroxyvitamin D concentrations among middle-aged and elderly Chinese in Singapore. Br J Nutr 2012; In press; PMID:22583563
12. Holick MF. Vitamin D: importance in the prevention of cancers, type 1 diabetes, heart disease, and osteoporosis. Am J Clin Nutr 2004; 79:362-71; PMID:14985208
13. Matsuoka LY, Ide L, Wortsman J, MacLaughlin JA, Holick MF. Sunscreens suppress cutaneous vitamin D3 synthesis. J Clin Endocrinol Metab 1987; 64:1165-8; PMID:3033008; http://dx.doi.org/10.1210/jcem-64-6-1165
14. Hyppönen E, Power C. Hypovitaminosis D in British adults at age 45 y: nationwide cohort study of dietary and lifestyle predictors. Am J Clin Nutr 2007; 85:860-8; PMID:17344510
15. MacLaughlin J, Holick MF. Aging decreases the capacity of human skin to produce vitamin D3. J Clin Invest 1985; 76:1536-8; PMID:2997282; http://dx.doi.org/10.1172/JCI112134
16. Holick MF, Matsuoka LY, Wortsman J. Age, vitamin D, and solar ultraviolet. Lancet 1989; 2:1104-5; PMID:2572832; http://dx.doi.org/10.1016/S0140-6736(89)91124-0
17. Moy FM. Vitamin D status and its associated factors of free living Malay adults in a tropical country, Malaysia. J Photochem Photobiol B 2011; 104:444-8; PMID:21636288; http://dx.doi.org/10.1016/j.jphotobiol.2011.05.002
18. Kung AW, Lee KK. Knowledge of vitamin D and perceptions and attitudes toward sunlight among Chinese middle-aged and elderly women: a population survey in Hong Kong. BMC Public Health 2006; 6:226; PMID:16956420; http://dx.doi.org/10.1186/1471-2458-6-226
19. Webb AR, Engelsen O. Calculated ultraviolet exposure levels for a healthy vitamin D status. Photochem Photobiol 2006; 82:1697-703; PMID:16958558
20. Setiati S. Vitamin D status among Indonesian elderly women living in institutionalized care units. Acta Med Indones 2008; 40:78-83; PMID:19054885
21. Harinarayan CV, Ramalakshmi T, Prasad UV, Sudhakar D, Srinivasarao PV, Sarma KV, et al. High prevalence of low dietary calcium, high phytate consumption, and vitamin D deficiency in healthy south Indians. Am J Clin Nutr 2007; 85:1062-7; PMID:17413106
22. Agarwal KS, Mughal MZ, Upadhyay P, Berry JL, Mawer EB, Puliyel JM. The impact of atmospheric pollution on vitamin D status of infants and toddlers in Delhi, India. Arch Dis Child 2002; 87:111-3; PMID:12138058; http://dx.doi.org/10.1136/adc.87.2.111
23. Nakamura K. Vitamin D insufficiency in Japanese populations: from the viewpoint of the prevention of osteoporosis. J Bone Miner Metab 2006; 24:1-6; PMID:16369890; http://dx.doi.org/10.1007/s00774-005-0637-0
24. Holick MF. McCollum Award Lecture, 1994: vitamin D--new horizons for the 21st century. Am J Clin Nutr 1994; 60:619-30; PMID:8092101
25. Jayaratne N, Russell A, van der Pols JC. Sun protection and vitamin D status in an Australian subtropical community. Prev Med 2012; 55:146-50; PMID:22634425; http://dx.doi.org/10.1016/j.ypmed.2012.05.011
26. Chen W, Clements M, Rahman B, Zhang S, Qiao Y, Armstrong BK. Relationship between cancer mortality/incidence and ambient ultraviolet B irradiance in China. Cancer Causes Control 2010; 21:1701-9; PMID:20552265; http://dx.doi.org/10.1007/s10552-010-9599-1
27. Juzeniene A, Ma LW, Kwitniewski M, Polev GA, Lagunova Z, Dahlback A, et al. The seasonality of pandemic and non-pandemic influenzas: the roles of solar radiation and vitamin D. Int J Infect Dis 2010; 14:e1099-105; PMID:21036090; http://dx.doi.org/10.1016/j.ijid.2010.09.002