**Original Article**

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**Primary source of Vitamin D: sunlight or nutrition?**

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**ABSTRACT**

This study reviews the existing literature on whether sunlight or nutrition is the main source of vitamin D and explores the factors contributing to vitamin D deficiency in tropical regions. The key findings include urbanization, ethnicity, sun-avoidance, religion, and nutrition as causes for the high prevalence of vitamin D deficiency in tropical areas. While sunlight is considered the main source of vitamin D, factors such as air pollution, sun-avoidance behaviors, and the clothing style of certain religious denominations can affect sunlight absorption. Moreover, limited access to vitamin D-rich foods and low consumption of fortified foods contribute to the deficiency. The study suggests further research on the role of nutrition as a potential main contributor to vitamin D deficiency in tropical areas.

**Keywords:** Vitamin D deficiency, tropical country, main source.

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**INTRODUCTION**

Vitamin D is a prohormone that can be used by the human body mainly to facilitate absorption of calcium and phosphorus, among other biological functions, such as its role in cell proliferation and the immune system, although this has been less intensively studied.¹ Vitamin D can be obtained by transforming 7-dehydrocholesterol in the human skin with the aid of UVB light from the sun into provitamin D₃ which immediately transforms into vitamin D₃ through a heat induced reaction. Additionally, it can be acquired through consuming animal derived foods (such as liver, butter, fatty fish, eggs) for vitamin D₃ or mushrooms for vitamin D₂. This non-active form of vitamin D₂ and D₃, also called calciferols, is then hydroxylated by the liver with the aid of the enzyme 25-hydroxylase into 25-hydroxyvitamin D, which is usually measured to assess serum vitamin D concentration.²³ Consecutively, 25-hydroxyvitamin D is hydroxylated again in the kidneys with the aid of the enzyme 1-alpha-hydroxylase to obtain the biologically active 1,25-dihydroxyvitamin D. This active form of vitamin D can then bind to vitamin D receptors to manifest biological effects.¹⁻⁷

A deficiency in vitamin D, defined as a serum concentration of <15 ng/L as defined by the American Academy of Pediatrics, or <20 ng/L as defined by Endocrine society, can lead to various adverse events, such as osteoporosis, rickets, muscle weakness, hypertension, multiple sclerosis, diabetes, tuberculosis, and cancer, among others.⁴⁻⁸

Currently, vitamin D deficiency is still a very common phenomenon, with a prevalence of 24–40% in the western world and 6–73% in southeast Asia.⁹⁻¹¹ While medical issues such as malabsorption or chronic kidney disease account for some of these cases, a large part is also due to a lack of intake of vitamin D. Therefore, it is important to identify the most important source of vitamin D: sunlight or nutrition.

Many articles have stated that sunlight accounts for 80–90% of vitamin D levels in humans,¹²⁻²¹ but only a few research has been done into the exact contribution of nutrition to vitamin D concentrations. Most importantly, even though there is an abundance of sunlight in tropical countries all year long, rates of vitamin D deficiency are often still high in these regions, which seemingly directly contradicts the suggestion of sunlight as the primary vitamin D source.

Therefore, in this narrative review we would like to examine current literature about the causes of vitamin D deficiency in tropical countries, as

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well as determine whether the primary source of vitamin D is sunshine, or rather nutrition.

**METHODS**

Literature research was conducted in order to collect information about the cause of vitamin D deficiency in tropical countries and the primary source of vitamin D. The main database used in this study was PubMed, in which multiple search strings have been applied, including MeSH terms for vitamin D deficiency. Excluding search strings that yielded no relevant articles: (Vitamin D deficiency [Title/Abstract] OR Vitamin D deficiency [MeSH]) AND (tropical [Title/Abstract])

(Vitamin D deficiency [Title/Abstract] OR Vitamin D deficiency [MeSH]) AND (Southeast asia [Title/Abstract]). The Searching filters were within the last 12 years.

Additional articles from other databases were obtained through snowballing. Only articles published between 2010 and 2022 were included, data collection was carried out in July 2022.

Articles were firstly selected based on the title and then filtered based on the abstract. Reasons to exclude articles were limited usability for the topic of the study and unavailability of the full article. Outcomes and conclusions drawn in the articles were considered and combined to draw our own conclusions in this study. No statistical analysis of the outcomes was performed.

**RESULTS**

**Articles**

Using the search strings mentioned in the material & methods section, initially 106 articles were found, of which 8 were deemed relevant based on the title and abstract. Articles were deemed relevant if they had the source of vitamin D as their main topic and were conducted in a tropical area. One article was excluded because the full article was not available. Finally, 7 articles remained for further analysis. 10, 13, 22–26

**Narrative review**

Overall, when considering all articles included, there were multiple causes mentioned to explain why there can still be such a high prevalence of vitamin D deficiency in tropical countries. All mentioned causes of this phenomenon are connected to the underlying mechanism of Vitamin D metabolism. Even though in theory, problems could occur on the sunlight absorption level, the biological metabolism level, or the Vitamin D receptor level (Figure 1), most found articles only report potential causes regarding either sunlight absorption or nutrition intake. 10, 13, 22–26 However, these issues on the sunlight absorption level are diverse and thus further highlighted below in five key points.

**Urbanization**

Three out of seven articles mentioned urbanisation as one of the causes that there is still a high prevalence of vitamin D deficiency in tropical areas. 10, 22, 23 It was explained that the rate of vitamin D deficiency was much higher or the vitamin D level much lower in urban areas compared to rural areas, and that people living a herder-like lifestyle reportedly often have sufficient levels of vitamin D. 22

**Figure 1.** The metabolism of vitamin D (7). 7-DHC: 7-dehydrocholesterol. VDR: Vitamin D Receptor. 7

**Figure 2.** Summary of key findings of the narrative review.
One of the reasons explicitly mentioned why urbanisation was a cause of vitamin D deficiency, was that air pollution absorbs UVB rays, and therefore the actual effective sunshine reaching the population is decreased. An additional reason was that people in urban areas tend to stay indoors more often, especially schoolkids. Additionally, and relatedly, residents with a higher education level also had a higher prevalence of vitamin D deficiency, as they were more likely to study and work indoors and use sun protection.

**Ethnicity**
In tropical areas the population is generally of ethnicity with a darker skin tone compared to non-tropical areas, such as African or Malay. Since a darker skin is also less sufficient in absorbing sunlight for the production of vitamin D, individuals with darker skin may need three times as much sunlight exposure to obtain the same vitamin D levels compared to a person with lighter skin. This also decreases the effectiveness of the sunlight present in the country. It was also mentioned that this probably explains why in Malaysia low levels of vitamin D are mostly found in individuals of Malay or Indian ethnicity, compared to those of Chinese ethnicity which generally have a lighter skin type.

**Sun-avoidance**
Sun avoiding behaviour such as staying inside, covering up and using sunscreen, can limit the absorption of UVB as the skin will not be directly exposed to sunlight. Therefore, the vitamin D levels will also stay low. It was mentioned that the lack of sun-seeking behaviour may be due to the hot temperatures which would prevent people from going outside more, or the popular beauty standards in some of these areas (particularly southeast Asia) where fair skin is seen as preferable, especially for women. Relatedly, the use of sunscreen was seen more among the female population. In the end, however, the factor that contributed most to the lack of vitamin D, above sunscreen and wearing covering clothing, was staying in the shade.

**Religion**
Multiple articles mentioned that the high percentage of Muslim population in parts of southeast Asia (notably Malaysia) contributed to the lower levels of vitamin D. The reason mentioned was mainly that Muslim women usually wear a clothing style that covers most of the skin, which limits UVB absorption. It was mentioned that the larger Muslim population in South Thailand, for example, was probably one of the bigger contributors to the difference in vitamin D level between North and South Thailand. This covering clothing style was also mentioned as one of the reasons why being female was considered a risk factor for vitamin D deficiency. According to a national health survey conducted in Thailand, non-Muslims had a mean vitamin D level 10 nmol/L higher than Muslims, although it must be noted that this survey had an overrepresentation of non-Muslims (97%).

**Nutrition**
Another contributor mentioned, although not in much detail, was that in Thailand there are not many vitamin D-rich foods that are consumed daily, and additionally Thailand does not fortify their foods with supplementary vitamin D. Similar problems were mentioned for Brazil, as oily fish and mushrooms are not widely available and not often consumed by the general population, and additionally the use of vitamin D supplements is reportedly very low (6% of the adult population). It was also mentioned that in Malaysia, there is insufficient baseline data about what foods are fortified and to what extent they are consumed by the population, and they report this being crucial to developing a strategy to tackle the still insufficient vitamin D intake, implying the importance of nutrition to the vitamin D deficiency problem. Also, it was mentioned that the population of the tropical island Hainan experienced especially low rates of vitamin D deficiency, of which reportedly one of the main contributors was the high consumption of oily fish, stressing the importance of nutrition in avoiding low levels of vitamin D. Finally, all key points mentioned in the narrative review can be summarised in one figure, as can be seen in Figure 2.

**DISCUSSION**
In total, 7 articles were analysed for this narrative review, originating mostly from the PubMed database, in order to find causes for why people living in tropical areas with a year-long abundance of sunlight still suffer from high rates of vitamin D deficiency, and assess the importance of nutrition in this issue.

The key causes found in this review were urbanisation, ethnicity, sun-avoidance, religion, and nutrition, which were all mentioned in multiple articles across this narrative review. However, few articles researched the role of nutrition as a cause for the vitamin D deficiency in tropical areas, and rather regarded it as a possible solution and compensation.

There are various reasons mentioned why there is still a high prevalence of vitamin D deficiency in tropical countries, notably southeast Asia, even if sunlight is the main source of vitamin D for humans. The fact that people in these tropical areas avoid sunlight because of the heat and cannot absorb sunlight as effectively because of their darker skin tone might be factors that neutralise the advantage of having an abundance of sunlight all year long. After all, if the sunlight will not or cannot be effectively used, this advantage is meaningless. However, it must be noted that previous studies reported that even people with darker skin tones should be able to get enough vitamin D from sunlight exposure if they go outside at the right time of the day. Therefore, skin tone may be ruled out as one of the main contributors to the issue.

When it comes to urbanisation and religion, these are not factors present only in tropical areas, so this does not necessarily fully explain why these tropical areas have a high prevalence of vitamin D deficiency compared to most western countries.

The last factor, nutrition, is the one that was least researched and often not considered at all. It has rarely been investigated as a possible cause of the vitamin D deficiency prevalence and is mostly mentioned as a possible solution to battle vitamin D deficiency. For future research, it may be wise to consider nutrition and especially malnutrition as a potential main contributor to the
CONFLICT OF INTEREST

The authors declare no conflict of interest in this study.

ETHICS CONSIDERATION

This review does not require any form of ethical approval.

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AUTHORS’ CONTRIBUTION

BF responsible for concept of the study, design of the study, definition of intellectual content, manuscript preparation, and guarantor of the study. AJ responsible for definition of intellectual content and manuscript review. SE responsible for literature search and manuscript preparation. AMP, ZH, ADBF, SHP, NRR, EA, AE, NM, Y, DI, and HK responsible for manuscript review.

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