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Vitamin D – public health significance

Abstract

Vitamin D, a quintessential micronutrient, is critically important for the development, growth, and maintenance of a healthy skeleton. Vitamin D deficiency (VDD) is an important public health problem that has emerged as a pandemic because low levels of vitamin D in the blood is a risk factor for some chronic disabling disorders and it is the most undermined, underdiagnosed and undertreated nutritional deficiency. Worldwide, about 1billion people have been estimated to have insufficient levels of vitamin D. Rapid and rising emergence of this pandemic warrants greater attention of the vast and varied populations which can be achieved through various public health interventions including education, public and professional awareness regarding risk factors, lifestyle interventions, food fortification, vitamin D supplementation, vaccination, routine assessments and early treatment measures.

Keywords: vitamin D, deficiency, public health, fortification, supplementation

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Abbreviations: UVB, ultraviolet B; MED, Minimal erythemal dose; RDA, recommended dietary allowance; VDD, vitamin D deficiency; SPF, sun protection factor; IU , international units; L, litre; ADHD, Attention deficit hyperactivity disorder; Mcg , microgram; Gm, gram; Ng, nanogram; Ml, millilitre; Nmol, nanomole.

Introduction

Vitamin D, a quintessential micronutrient, has evolved from the status of a simple vitamin to a key hormone with various pivotal effects on multiple body systems. It is gravely significant for the growth, evolution and the sustenance of a healthy skeletal system by maintaining a calcium homeostasis from birth until death.[1] It is a vitamin that is lipid soluble and hydrophobic, which exists as dual major structures which are ergocalciferol, the D_2 form (plant derived) and cholecalciferol, the D_3 form by a process of two-step hydroxylation. Apart from the skeletal effects, it has got many extra skeletal actions on various systems including immune system, skin, colon, brain, pancreas, breast, prostate, etc where vitamin D receptors have been found. Over the last decade vitamin D has gained wide importance for its disease fighting mechanisms.

Sources of Vitamin D include

i. **Sunlight:** It is a major source of Vitamin D contributing upto 80% of the daily requirement. The process involves an endogenous synthesis that occurs in the epidermal malphigian lamina of the skin when exposed to ultraviolet B radiation. During this, the structure 7-dehydrocholesterol is transformed to precursor-vitamin D_3 which expeditiously photoisomerizes to the form of cholecalciferol (D_3). $_{D3}$ is then converted into the active 1,25-dihydroxy cholecalciferol by hepatic and renal hydroxylations.[2]

ii. **Dietary sources:** including dairy, fishes like salmon, mackerel and sardines, eggs, meat products. Plant sources provide Ergocalciferol instead of cholecalciferol which is known as vitamin D_2. Ergocalciferol also undergoes similar hydroxylations as cholecalciferol to get converted into an active form.

Endogenous production

Sunlight is the best known source for UV-B spectrum of radiation, which is the requisite for the endogenous manufacture of vitamin D. Sun exposure from around 10 am to 3pm is highly suggested because the proportion of UV-B to UV-A is the maximum during this time span. When the body is exposed to one minimal erythemal dose(MED), 10,000 to 20,000 IU of vitamin D_3 can be produced, thus considering that, when 6-10% of body (face and hands) are bared to 0.5 MED, about 600 to 1000 IU of vitamin D_3 can be availed. The time required for 1 MED is nearly 4-10min in case of white skinned persons and about 60-90min for dark persons.[3]

Daily recommended allowance

The dietary allowance of vitamin D recommended is 200IU per day. But in the circumstances of inadequate exposure to sunlight, 400-600IU is necessitated to avert the deficiency.

Diagnosis of vitamin D deficiency: The serum levels of 25hydroxy-vitamin D are used to diagnose the deficiency. The levels can be interpreted as follows Table 1.

Table 1 Diagnosis of vitamin D deficiency

>30ng/ml =sufficiency
30 to 20ng/ml=insufficiency
< 20ng/ml=deficiency

Vitamin D deficiency

Vitamin D plays a crucial role in the prevention and treatment of some skeletal as well as non-skeletal conditions. Vitamin D deficiency (VDD) is an important public health problem that has emerged as a pandemic because subjacent levels of vitamin D in the body system is a risk factor for some chronic disabling disorders like rickets in children, osteoporosis, osteomalacia, cancer, heart disease, autoimmune disorders, fractures and falls etc. All the more it is the most undermined, underdiagnosed and undertreated nutritional deficiency in the world hence warrants more attention.

Global prevalence

In spite of several studies, there is significant data gap and inadequate picture of the global scenario owing to the paucity of large population based standardized studies. Worldwide, about 1 billion people are found to be having faulty levels of vitamin D and the VDD can be found in all kinds of ethnic groups, age groups or races. In

the case of developing countries, the insufficiency is heightened by certain systemic infections or parasitic infestations by reducing the absorption of nutrients and thereby their biological utilization.[4]

Vitamin D deficiency disorder has emerged as a comprehensive all over the globe public health distress over the recent years owing to rapid emergence. Among the important causes for higher prevalence of this nutritional deficiency is determined to be dearth of awareness regarding the significance of vitamin D, its advantages on health, lack of identification of deficiency, lack of adequate treatment and preventive measures.

However**,** the evidence suggesting the prevalence of the vitamin D deficiency, to be the highest in developing countries of Asia, Africa, Middle East along with their immigrants living in countries at higher latitudes, has been consistent. In a recent review done in USA, vitamin D deficiency is still widely prevalent with approximately 36 percent of people with levels <20ng/mL. A number of compact studies conducted in Asia have pointed out that a larger part of the infants have levels of 25-hydroxycalciferol below 30nmol/L: some of the examples include Turkey with 51%, Iran with 86%, India and Pakistan with 61% infants having levels below 30nmol. However, the Middle East accounts for the highest neonatal prevalence of vitamin D deficiency.[3,5] There is a resurgence of rickets even in the industrialized countries that had been largely eradicated through vitamin D fortification. It is found from studies done on expectant; breast feeding females in pan-Asian and Middle East countries also have high risks of deficiency as in India with 60%, Turkey with 50% and Pakistan with 45% females at risk. Females are more prone for deficiency due to occupational, dressing and cultural differences. In studies on children from Asia, Africa and the Middle East, the nutritional rickets has a prevalence range of 1% to 24%.[6,7] In India, community-based studies of the past decade done on apparently healthy controls reported a prevalence ranging from 50% to 94%.

Groups at risk of VDD:[8]

i. Inadequate sunlight exposure – long term hospitalized patients, people living northern latitudes, certain religious cults;

ii. Inadequate intake - strict vegetarians;

iii. Malabsorption;

iv. Non-white ethnic groups;

v. Elderly age groups;

vi. Obese.

Inadequate sunlight exposure contributes to the vast majority of the cases as it contributes to major source of vitamin D. In infants and toddlers, due to safety issues and certain cultural practices, the exposure to sunlight may be typically limited. Neonates whose mothers have an insufficient blood vitamin D levels during the initial years following birth, those infants whose lactating mothers did not take supplements or even in those infants who did not receive surplus supplementation, are also distinctly endangered to insufficiency. Individual life patterns or skin color are also significant influencing factors on the status of vitamin D. Dark colored persons need longer duration of UVB exposure to produce a specific quantity of vitamin D in comparison to light colored individuals. Irrespective of the skin color, low levels of 25hydroxy-calciferol can occur due to consistent use of sunscreen lotions or creams or by wearing clothes that prevent skin exposure to sun. Other groups who are at risk of deficiency include people who work or spend most time indoors, elderly individuals with partial or total immobility etc.

Some environmental factors such as high latitude, inferior quality of air, high raised buildings may also weaken exposure to sunlight. Those cities located above 35° latitudes get none or scarce UVB radiation particularly in winter seasons (the time span of the "vitamin D winter" expands as the latitude increases), thus making it impossible for vitamin D production from sunlight, even in clear skies. Factors like air pollution, thick clouds can also affect the vitamin D production in certain other areas despite abundant sunlight UVB exposure throughout the year. Vertical height from ground also called altitude too can have a marked effect on the volume of UVB reaching the surface of the earth. As the altitude increases, the length to which solar rays have to travel through becomes shorter and hence the skin exposure to precursor UVB is more and thus the vitamin D_3 produced will be higher. This phenomena was fairly depicted in a study at places at different altitudes such as Agra in India(169 M altitude), Katmandu in Nepal (1400M), and Mount Everest(5300M), India (27°North). A survey of in vitro synthesis of vitamin D_3 based on sun-exposure was also carried out at higher altitudes places at the similar latitudes around the identical months.

Results from the above study showed that in Agra in northern India during November, previtamin D_3 produced on exposure to sunlight was very minimal. But at the base camp of Mt Everest at an altitude of5300M, the previtamin D_3 produced was found to be 5times more than that in Agra. This showed that the synthesis of previtamin D_3 had a direct correlation with increased altitude. Skin when exposed to sunlight which passes across glass, plastic or plexiglass will not be able to produce Vitamin D3because of the fact that different forms of glass has the capability to absorb all the ultraviolet B radiation and do not allow radiation to pass through them.[9] Air pollution is a barrier for adequate UVB exposure as pollutants like nitrous oxide, ozone, sulphur dioxide, etc absorb UVB rays and contribute to the problem even if adequate exposure is there. Rapid urbanization, increased vehicular use, excess utilization of the fossil fuels in the developing world has led to worrisome levels of pollution in the recent times.

It was also seen that prenatal exposure to particulateair pollutants has got influence on maternal plasma vitamin D levels. Sunscreen skin products were basically manufactured in order to absorb the sun UVB radiation. Such a sun blocking product with a sun protection factor (SPF) of 30soaks up to nearly 95–98% of UVB rays. Thus, its application reduces the ability of the skin to synthesize vitamin D_3 by almost the equal amount i.e., 95–98%. This was further affirmed from the study report on the use of sunscreen products with an SPF of mere 8, which showed dramatic reduction in the production of vitamin D_3 on exposure to cultured source of sunlight as in a tanning bed. In a study on farmers from the Midwest with a history of skin cancers other than melanoma, those farmers who used a sunscreen agent most of the time before stepping outdoors for greater than one year exhibited that by the end of the summer season, serum levels of vitamin D3 were remarkably lower and also most were found to be deficient than the blood levels of their counterpart control group.[9,10] According to the data from a recent article, irrespective of the country`s latitudinal position, human development index, there is vast deficiency in the vitamin D nutritional status globally. In addition, deficiency is widespread even in those countries which have effective and adequate food fortification practices in place. Sadly, most of the data available on the rates of deficiency and status of the nutrient levels were not derived from the ideal broad population based studies with representative samples but

rather were chosen primarily from the comparatively infinitesimal studies with discerning samples or old time obsolete studies.

Additionally, there is a shortfall on the standardized methods of testing and evaluating the levels of 25-hydroxy-calciferol although it can be quantified by a number of variant assays which differ in their validity and accuracy. Hence the sample values are likely to be dissimilar from assay to assay and laboratory to laboratory. This pitfall also makes it more complex to derive appropriate population based data and further complicates comparative studies over a period of time. Regardless**,** the evidence suggesting the prevalence of the vitamin D deficiency, to be the highest in developing countries of Asia, Africa, Middle East along with their immigrants living in countries at higher latitudes, has been consistent. It was also established that in these places, the consumption of supplemental calcium was low, thus exacerbating the threat of developing bone diseases like rickets and others associated with the VDD.

Vitamin D deficiency sequelae

Rickets and Osteomalacia are the bone related manifestations of deficiency of vitamin D in children and adults respectively.

Children: rickets and skeletal health: Nutritional rickets has found a resurgence to be a disorder of public health significance in countries with low or high economic status. Blunted growth, fractures, bony aches, gross delay of developmental motor milestones, malformation of chest wall making them prone to pneumonia, disability secondary to deformed legs, and possible fatal complications like cardiomyopathy, myocardial infarction, hypocalcemic convulsions are the major clinical outcomes.[6] The predisposing factors causing nutritional rickets are typically similar to those related to VDD. For instance, most cases of rickets are seen in dark colored children because such individuals with darker skin color need longer time span of exposure to UVB in order to synthesize the equal quantity of vitamin D when compared to children with lighter colored skin. The other aspects that restrict the children from getting adequate amounts of exposure to UVB include use of sunscreens, remaining indoors; clothes that cover most of the body surface, poor air quality, thick clouds etc. and thus predispose them to deficiency. Neonatal or congenital rickets can occur as a result of severe insufficiency of vitamin D in the mothers, thus making the level of vitamin D in the expectant mothers an important decisive factor of the vitamin D levels in their neonates.

Concentration of vitamin D in breast milk is normally low at around 40IU or 1gram per liter or 1gram per provided the lactating mother is given supplements of vitamin D at a higher dose. Hence exclusive breastfeeding for extended period may cause rickets in healthy infants at lower threat of deficiency or those toddlers who receive suboptimal exposure to sunshine, unless and until the child gets additional supplements or compatible foodstuff with calcium and vitamin D.

Adults: Osteomalacia and skeletal health: Generally, severe insufficiency of vitamin D in the older adults manifests as Osteomalacia analogous to rickets in children. It occurs due to imperfect mineralization ascribed to sparse availability of calcium or phosphorus or imprudent resorption of calcium from the bones. Research work on the muscular and skeletal manifestations of vitamin D deficit in older individuals are largely suggestive of the principal results such as osteoporosis ensuing hazards of falls and fractures, which contribute greatly to the high morbidity and high financial burden on the health care system in countries with higher total gross income.[4,6] The likelihood of falls in adults may occur due to its influence on balance, muscular energy and functioning.

Pregnant cum lactating women: Women in whom serum levels of vitamin D are insufficient, may give birth to children who in turn may foster deficiency posing a threat to development and occurrence of congenital rickets or hypocalcemia. Innumerable research studies on mothers done in the last two decades studying the prospects of vitamin D levels on pregnancy associated complications like preterm birth, low birth weight, pre-eclampsia and growth retardation in the first year following birth.[6,7,11] Certain research findings typify the functions of vitamin D on the growth in children including fetal femur length and birth length, which throws light on the fact that if prenatal serum levels of vitamin D could be improved, overall morbidity on child growth or low birth weight rates can be diminished.[6]

Bronchial Asthma, Acute respiratory tract infections and tuberculosis: Recent breakthrough evidence has surfaced relating the deficiency of vitamin D to untoward effects on the respiratory system, modulated via the actions of vitamin D on the immune systems, specifically predisposing to exacerbations of asthma and resurgence of tuberculosis. From the newer research, it is found that supplementation with vitamin D is beneficial in reducing the recurrences of asthma and upper respiratory tract infections (URTI). Irrespective of the family financial status, ARIs remain to be most frequent infections in kids below the age of 5years of which URTI is the most frequent condition. Though these illnesses may not cause mortality, they have a significant impact on the efficiency and the financial circumstances.[4,6] Deficiency of vitamin D is linked with higher predisposition to autoimmune diseases, diabetes, cancers, infections, allergies. VDD in childhood and adolescence is furthermore implicated in mental disorders like ADHD, autism, depression, schizophrenia, seasonal affective disorders etc. Though there are no strong studies to prove the cause effect relation between vitamin D deficiency and various conditions, many observational studies have shown an association between its deficiency and major health effects.[4–8]

Preventive and therapeutic interventions

In order to potentiate the salutary outcomes of vitamin D on health, serum levels should be more than 75nmol/L, or 30ng/mL. Several interventions are currently being propagated and practiced to ward off and to deal with the pandemic of VDD.

Public education: Education of the people plays a very crucial role. General public and especially health care workers must be educated regarding the recommended dietary allowance of vitamin D based on specific age groups and in high risk groups. Based on the physiological condition and the age, the daily consumption of vitamin D supplements is recommended to be between 200 to 800IU. Awareness and educational campaigns must be actively conducted across societies, aimed at predisposed and general populace. Easily interpretable tables or charts can help the masses to know the requirements and various sources of vitamin D Table 2.

Awareness of public and medical personnel regarding causative factors and outcomes of deficiency, risk of toxicity due to long term exorbitant supplementation, occasionally due to fortification of food products in excess, which can result in renal dysfunction secondary to hypercalcemia and consequent hypercalciuria and excessive gastrointestinal calcium absorption.[14]

Table 2 Daily allowance according to various age groups and in special conditions[12,13]

Age	Male	Female	Pregnancy	Lactation
0–12months	400 IU (10mcg)	400 IU (10mcg)		
1–13years	600 IU (15mcg)	600 IU (15mcg)		
14–18years	600 IU (15mcg)	600 IU (15mcg)	600 IU (15mcg)	600 IU (15mcg)
19–50years	600 IU (15mcg)	600 IU (15mcg)	600 IU (15mcg)	600 IU (15mcg)
51–70years	600 IU (15mcg)	600 IU (15mcg)		
>70years	800 IU (20mcg)	800 IU (20mcg)		

Lifestyle interventions: Regular exposure to sunlight for at least 15min could play a key factor in improving the vitamin D status in populations. Studies have shown that direct exposure to sunrays for about half an hour would be sufficient to meet the daily requirements. Encouraging schools to include compulsory extracurricular outdoor activities and playground sports for students of all ages.[15]

In spite of the well-established fact that sunlight is a vital factor in the production of vitamin D, it is essential to restrict the amount of UV radiation that the skin may be exposed to. In the as per data from USA, yearly about 8000 cases of metastatic melanoma causing death and about 1.5million dermatological cancers occur, suggesting that the ultraviolet rays are a proven cancer causing factor. Conglomerate harm caused by UV exposure to skin in a lifetime is majorly accountable for a few age-related skin changes including dryness and other dermatological disorders. Hence it may be advisable to take measures to protect self from exposure to excessive sunlight by the use of sun blocking products, as and when required. To increase the daily intake of vitamin D loaded food sources, thereby improving circulating levels of vitamin D of the body system.

Selected food sources along with the dose of vitamin D per serving:

Table 3, in specific, the majority of the vegetarian populations have a very restricted choice of food sources affluent in vitamin D, since maximum of the inherently procurable sources of vitamin D seem to be meagre or they may be animal products. Moreover, milk which is a good source is an expensive affair for the financially weaker sections of people or the economically backward countries like India; and is also less fortified in several developing countries.

Table 3 Various sources of vitamin D[14]

Food	Quantity	IUs per serving	Percentage of daily value
Cod liver oil	1tablespoon	1360	340
Swordfish	3ounces	566	142
Cooked salmon	3ounces	447	112
Tuna fish (canned and drained)	3ounces	154	39
Orange juice fortified with vitamin D	1cup	137	34
Vitamin D fortified milk	1cup	115–124	29–31
Vitamin D fortified yogurt	6ounces	80	20
Margarine fortified	1tablespoon	60	15
Liver, beef, cooked	3ounces	42	11
Egg yolk	1large	41	10
Cereals fortified with vitamin D	0.75 – 1cup	40	10

Food fortification

Food Fortification of the core consumable products is one of the effective, simple and applicable, a more viable and also cost effective solution for the deficiency. It is a process in which various carriers like milk and other dairy, grain flour, soy or rice beverages, yogurt and cheese and esculent oils are enriched with vitamin D. Vitamin A may also be added to the above process. It is also included as a part of national food fortification program.[6,15] Universality of fortification and greater compliance are the certain advantages of fortification, but there are also drawbacks like dose is relative to the quantity of fortified food consumption, lower specificity, varying standards recommended across different countries, standards and constitutional issues relating to the production units individual levels of fortification.[8]

Voluntary and compulsory fortification: Fortification of food may be either mandatory in which by law the specific entire 100percent food products should be fortified or may be voluntary in which the manufacturer has the freedom to decide about fortification of the specific foods but in case they choose to do so, they must abide by the

specific requirements. A government regulated fortification process of the staple goods is the utmost fruitful means to make sure that a proposed nutrient intake is enhanced in any given population. Vitamin D fortification of foods is a voluntary process in the USA but it is sternly controlled based on different types of food products, their utilization quantity and quality thereby curbing the over-fortification.

In Canada at present, milk and infant formula need to undergo fortification mandatorily, while in USA different kinds of milk like non-fat dry, evaporated or formula milk must be fortified by mandate. Such regulations regarding fortification have been under the control of the government since more than nine decades in the USA and nearly for four decades in Canada. In case of Canadian regions, governmental regulation compels that milk should be fortified at level of 180IU of Vitamin D per 250ml whereas products like margarine or milk derivatives must be fortified at 530IU per 100gm. Fortification level in those assigned products should not go past 20IUper 100 Calories.[6,16,17] Such means of intervention have been efficient in deterrence of large proportion of rickets. Manufacturer compliance is a must for the fortification schedules to run promptly and such is secured effortlessly by effective enforcement of impetus and incentives. By using suitable vitamin D products, the visionary government can safeguard a safe range of fortification. The Indian diet is also amenable to fortification.

Fortification done voluntarily may have certain disadvantages:

i) It may cause less impact on the status of vitamin D, because it may vary between different food-manufacturers due to lack of uniformity. This can further elevate the threat as these industries may concentrate more on either expensive or hollow products more than the products for at risk individuals especially in those who have restricted consumption of vitamin D from food of other origin.

ii) Another disadvantage of optional fortification is that it would be less successful in extending to the masses in the developing countries like India; reason being the bulk food supplies is from the local produce and may not be from the government regulated manufacturers.

iii) Even in case of financially sound countries, it has been found to be less authentic, which may misguide the public to over- or under-consume sources of vitamin D, which in themselves may differ from product to product or even between alike stuff made by differing makers.[6]

Strategy for the choice of food staples for mandatory vitamin D fortification: In order to meet the requirement of the considerable segments of the populace, a cautious choice of the food that would be frequently consumed should be used as carriers for fortification. For this, it is quite essential to ascertain the typical food style and their key products used in a specific geographical region.

i) The selected typically used food ingredients for fortification must be economical, widely available and used across the entire population and must be obtainable in rural and urban setups.,

ii) It is preferable to have a low variance in the quantities eaten so that the chances of some people ingesting above the suggested limits of the vitamin D might be curtailed.

iii) The chosen food must be refined industrially and extensively dispersed to the target populations via fewer producers in order to promote industrial compliance by the way of appropriate training and routine checking.

But the major problem in several developing countries is that the bulk of the food is often cultivated by various small-scale producers or even in their own houses, and hence is less likely to be involved in the fortification schemes be it mandatory or voluntary.

iv) Stability of vitamin D on refining, processing, cooking and even storing need be considered. Due consideration must be given to the proper storage of the fortified foods at the outset.

Disadvantage: markets in the developing countries usually sell products stored in large sacks or tins for extended periods, as mini packets, thereby causing a risk of impaired quality and stability of the fortifying product.

v) Vehicle should also possess the ability to be co-fortified with other micronutrients like vitamin A, calcium etc.[16,17]

In the third world countries, implementation of fortification projects, failed to be progressive enough. Numerable hindrances were found. They are

(1) Data considering the position of micronutrient deficiency was insufficient.

(2) The knowledge about the essentiality of the those micronutrients and the healthcare costs borne was scarce

(3) Food styles of people in need are poorly understood

(4) Fear of the food manufacturers with respect to the cost factors, approval of the buyers and the competition between industries.

(5) Deficit of engaging administrative or legislative supervision for making plans, to commence, to control and to perpetuate the conduct of various fortification projects.

Scientific dimensions required for fortification: Scientific prowess to manufacture D_2 and D_3 products is handy. In fact, India has been producing and selling D3.[17]

1. D_2 or D_3 can be utilized together or in single as both are found to impact the 25hydroxy form of vitamin D similarly in blood.

2. Vitamin D can be fortified with both fat-full or fat-free food products such as whole milk, cheese or skimmed milk, yogurt, juices etc. respectively even though vitamin D is lipid solvable.

3. Tocopherols like anti-oxidants can be added to Vitamin D to stabilize them and keep them potent for greater duration.

4. The process of fortification will be fruitful only if a befitting vehicle or agent would be used. There are wide ranges of easily procurable agents that have been examined and are ideal to be used as vehicles for fortification.

They include milk and its analogues, flours like wheat or rice flour, other dairy products, rice, fruit juices, sugar, salt, soya milk etc.[15,17]

5.1 The vehicles used for fortification should be available throughout all seasons, and should be either an easily accessible, most commonly used staple food or a commercial refined product that is cost effective.

5.2 The process of adding a fortificant should be an affordable, simple and uniform throughout.

5.3 Concentration of vitamin D in the above mentioned fortified food products which are either oil or non-oil based forms are found to be approvable and good, but it is not having a strong scientific proof as to the which expedients and fillers go well with the basic ingredient.

6. Stability: Ultraviolet rays, oxygen, acidic substances, hydrolyzed proteins can alter the stability of vitamin D.

For vitamin D to remain in highly stable state, an ideal temperature of below zero or 4 to 8degree Celsius is optimum; however it can remain stable for a few weeks at 25degree Celsius. Generally vitamin D is known to be a heat stable vitamin which can undergo changes from 110 to 170degree Celsius of temperatures, but can withstand up to 200degree Celsius while cooking. However the level of conformation it undergoes when subjected to heat will be inversely related to the time duration of exposure to heat.

For example when a fat rich fish like salmon was fried in edible oil, vitamin D_3 recovered was but 50 percent in comparison to baked fish in which 100 percent of D_3 was recovered. Vitamin D_3 stability percentages were about 55 and 91percent for low fat cheese and cheddar cheese respectively when subjected to processing.

Most importantly, fortified food stuff is found to more than 90percent stable. Such foods examples are 2% milk processed for ultra-short time and high degree temperatures, 2% fat chocolate milk made at ultra-high temperature etc. These examples show that vitamin D can resist food processing procedures quite capably.

7. Measuring the levels of vitamin D also is important and techniques for which are available. This will be a key factor in optimizing the vitamin D levels and would prevent the over or under fortification.

Supplementation

Vitamin D supplementation is a more specific treatment approach and allows better dose adjustment. It is found to be an effective modality to tackle deficiency in high risk sections of population like women during pregnancy and lactation and breastfeeding children. Vitamin D is available in various formulations like Multivitamins with 400 IU of vitamin D or supplements containing 400 IU, 1000 IU, 2000 IU, 4000IU, 5000IU, 50000IU and even 60000IU of vitamin D_3.[3,6,15,17]

According to the recommendations by the American Academy of Pediatrics (AAP), partially or exclusively breast feeding kids should be given vitamin D sources of strength 400 IU every day, following birth and should be continued on these supplements till weaning. They should also be supplied with more than 1,000mL of fortified formula milk or whole milk per day. Non-breastfed children who take milk in any form less than 1000mL per day need an additional supplement with 400IU of vitamin D per day. School going children and also adolescents, found taking inadequate vitamin D enriched food, must be provided an additional supplement containing 400IU of vitamin D. Disadvantages of supplementation include higher incurred costs, meek compliance to supplementation, own-medication and hazard of toxicity.[3]

Vaccination programmes for children are a good opportunity to introduce vitamin D supplementation.

Early evaluation of symptoms and diagnosis and ensuring adequate treatment in at risk populations to avert long term health aftermaths by early corporation of corrective treatment steps

Including assessment for vitamin D deficiency in routine health evaluations and more so in the high risk populations starting from the primary health care setups to the most advanced care facilities.

To establish national and international agencies to bring about laws regarding regulation of food fortification, improving access to healthcare and to build upon population based strategies to improve outcomes.

Conclusion

Vitamin D, the vitamin cum hormone has recently gained enormous importance due to its multi-organ, multi-system effects. Vitamin D deficiency has been found to have a very high prevalence irrespective of region, race, and ethnicity and results in a vast variety of disorders, ranging from mild symptoms to gross chronic disabilities. High risk population should be subjected to determination of serum vitamin D levels routinely and need to be treated early and appropriately. Prompt implementation of various effective measures like public awareness and education, lifestyle interventions, food fortification and supplementation are the key solutions to curb the rampant pandemic of vitamin D deficiency.

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Conflict of interests

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References

1. Heaney RP. Long–latency deficiency disease: insights from calcium and vitamin D. *Am J Clin Nutr.* 2003;78(5):912–919.
2. Vitamin D. In: Bringhurst FR, Demay MB, Kronenberg HM, editors. Williams textbook of endocrinology. 13th edn. Philadelphia: Elsevier; 2016. p. 1269.
3. Holick M, Binkley N, Bischoff–Ferrari H, et al. Evaluation, treatment, and prevention of vitamin D deficiency: an endocrine society clinical practice guideline. *J Clin Endocrinol Metab*. 2011;96(7):1911–1930.
4. Michael F Holick, Tai C Chen. Vitamin D deficiency: a worldwide problem with health consequences. *The American Journal of Clinical Nutrition*. 2008;87(4):1080S–1086S.
5. Lips P. Worldwide status of vitamin D nutrition. *J Steroid Biochem Mol Biol*. 2010;121(1–2):297–300.
6. Roth DE, Abrams SA, Aloia J, et al. Global prevalence and disease burden of vitamin D deficiency: a roadmap for action in low and middle income countries. *Annals of the New York Academy of Sciences.* 2018;1430(1):44–79.
7. Palacios C, Gonzalez L. Is vitamin D deficiency a major global public health problem?. *J Steroid Biochem Mol Biol*. 2014;144:138–145.
8. Borji S, Rafieian–Kopaei M. Vitamin D and its importance on public health. *J Parathyr Dis*. 2016;4(1):20–24.

9. Holick MF. *Photobiology of vitamin D.* In: Feldman D, Pike JW, Glorieux FH, editors. *Vitamin D*. Second Edition, Volume I. Burlington, MA: Elsevier; 2005.

10. Wacker M, Holick MF. Sunlight and Vitamin D: A global perspective for health. *Dermato–endocrinology*. 2013;*5*(1):51–108.

11. Fiscaletti M, Stewart P, Munns C. The importance of vitamin D in maternal and child health: a global perspective. *Public Health Reviews. Springer Nature*. 2017;1;38(1):19.

12. Institute of Medicine, Food and Nutrition Board. Dietary Reference Intakes for Calcium and Vitamin D. Washington, DC: National Academy Press, 2010.

13. National Institute of Heath, Office of dietary supplements. 2019.

14. US. Department of Agriculture. *Agricultural Research Service Food Data Central*. 2019.

15. Aparna P, Muthathal S, Nongkynrih B, et al. Vitamin D deficiency in India. *Journal of family medicine and primary care*. 2018;7(2):324–330.

16. Lhamo Y, Chugh PK, Gautam SR, et al. Epidemic of Vitamin D Deficiency and Its Management: Awareness among Indian Medical Undergraduates. *Journal of environmental and public health*. 2017;2517207.

17. Gupta A. Vitamin D deficiency in India: prevalence, causalities and interventions. *Nutrients*. 2014;6(2):729–775.