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**Assessing vitamin D deficiency among adolescents in
sun-abundant regions of India**

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Abstract

Vitamins, essential organic compounds necessary for human health, are categorized into water-soluble (B and C) and fat-soluble types, with vitamin D being particularly crucial for bone health due to its role in calcium and phosphorus absorption. Known as the "sunshine vitamin," vitamin D is synthesized in the skin through sunlight exposure but can also be obtained from dietary sources like fatty fish, fortified foods, and supplements. Deficiency in vitamin D is a widespread issue, even in sun-rich regions, leading to conditions like rickets in children and osteomalacia in adults. Factors such as limited sun exposure, lifestyle changes, and inadequate dietary intake contribute to this deficiency, with a significant prevalence observed globally, including in countries like India where a study reported a 91% deficiency rate among adolescents. Effective management of vitamin D levels involves adequate sunlight exposure, consumption of vitamin D-rich foods, and supplementation when necessary to maintain optimal health.

Keywords: Sunshine vitamin, adolescents, water-soluble, sun-rich regions

1. Introductions

Vitamins are essential organic compounds crucial for human growth, maintenance, and bodily functions, forming a vital part of a well-rounded diet. They are divided into water-soluble (like vitamins B and C) and fat-soluble types based on their solubility (Holick, 1989)^[1]. Among these, vitamin D holds significant importance in the body. Being lipid-soluble, it aids in the absorption and maintenance of calcium and phosphorus, crucial for bone health, earning it the nickname "SUNSHINE VITAMIN". While abundant sunlight provides natural vitamin D synthesis, supplementation becomes necessary during periods of limited sunlight to ensure optimal health. Vitamin D encompasses six different molecules, but only D2 (ergocalciferol) and D3 (cholecalciferol), along with their metabolites, actively circulate in the bloodstream.

Vitamin D role is eminent for its involvement in bone mineralization and preserving bone health. Sunshine Vitamin deficiency brings about problems such as bone loss and osteomalacia (malacia = softening) in adults and rickets (softening or increase fragility of bones) in youngster over a course of time. Vitamin D plays several roles in body maintenance. In adolescent vitamin D deficiency is becoming a reason to worry for PHC, as juvenility is time and beginning of the reproductive phase and its inadequate amount leads to downturn in growth. According to research reports whose evidence indicates that younger girls (age between 16-25) are more susceptible to deficit to a greater extent than boys. Even areas with plenty of sunshine, high frequency has been found across all age categories. The following prevalence is reported by developed countries based on representative data: Europe has 42%, the United States has 33%, Iran has 42%, Mexico has 9%, Saudi Arabia has 81% and Korea has 68%.

According to a report which was published during 2014 stated, in adolescents of India from individual study deduced common occurrence of insufficiency is 91% around, which is high. Adults are facing Vitamin D deficiency in India too because of decreased outdoor activity, change in lifestyles, food habit and decreased physical activities which scale up possibilities of vitamin D deficit threat.

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Vitamin-D

Vitamin D is a lipid-dissolvable seco-sterol (broken ring) Harmon which indulge in endocrine and in addition to this it indulge in autocrine character also. Vitamin D's primary endocrine role is to keep up and support phosphorus and calcium and stability by modulating calcium absorption in the intestine and kidneys. Because of the VDR appearance over the core that is nucleus among several cells and group of cells in the human body, along with cells of the mixed gland, mammary gland, PTH gland, epidermis, immune system, endo-thelium, Hypophysis, female gonads, prostate gland, liver, vascular involuntary muscle and voluntary

muscle, vitamin D in addition also enact non-skeletal purpose.

The autocrine role of sunshine vitamin is interpret as changes in order of a gene of the nucleotide (basic block of nucleic acids [RNA and DNA]) which is distinctive and not common to cell type which demonstrate receptors of vitamin. Vitamin D's autocrine (molecule act on the same cells that produce them) impact comprise, amidst more things, as its aspects and role in immunity and also its aspects in CVD, cancer. In addition to it Vitamin D assist and hinder cell reproduction, apoptosis (schedule death of cells), and inflammatory route or tract.

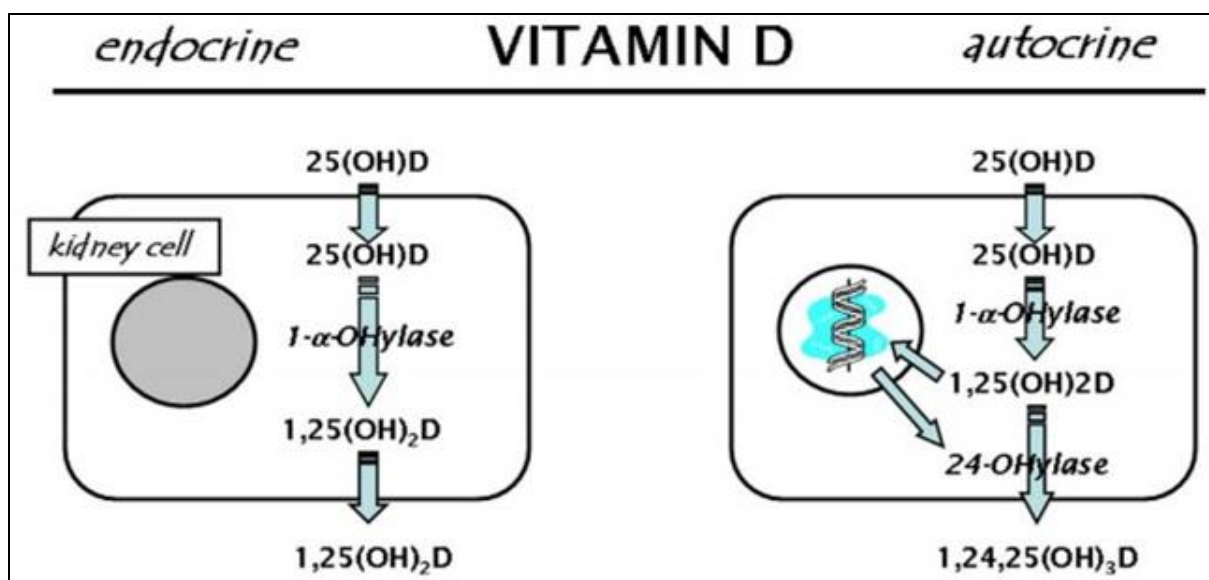


Fig 1: Vitamin D (Endocrine and Autocrine)

Figure 2. (In the figure endocrine side, the improvement to articulation and activity of the 1- α -hydroxylase is regularly FGF23 and Parathyroid hormone, and essential result is (1,25(OH)₂D) Calcitriol. In the figure On the autocrine side, the improvement for 1- α -hydroxylase articulation will contrast from one tissue to another, and the essential result of the interaction (however not let out of the phone) will be the proteins flagging, like cell separation and apoptosis. Since flowing calcitriol levels are seldom high adequate to get the full autocrine reaction, serum 25(OH)D will be the essential info variable for the autocrine character. All things being equal, each tissue controls its own Autocrine arousing freely of the others, yet is dependent on an adequate flowing degree of 25(OH)D.

1.1 Why is vitamin D named as Sunshine Vitamin?

There's grounds fow why vitamin D is known as "SUNSHINE VITAMIN ". When our skin is bare and unveil to sunlight, our skin generates vitamin D from cholesterin. UVB beams from the sun associate with cholesterol in epidermis cells, providing energy for vitamin D union. When exposed to UV radiation, the skin produces vitamin D. The length of effective UV exposure is determined by the sun's angle and atmospheric pollution, and the sun must be above 35° to be effective. The Ultraviolet B rays band about wavelengths ranging from 290 nm–315 nm is needed for the photo-transformation of 7-hydroxycholesterol to pre-nutrient D3, which is then different in to nutrient D3. The quantity of vitamin D3 produced is dependent on number of agents, which involve

bare skin surface, season, latitude, skin pigmentation (Ross, 2011) [23].

1.2 Conformations of Vitamin D

There are two conformation or structure if vitamin D which is vitamin D2 and vitamin D3 whereas scientifically known as Ergocalciferol (vitamin D2) and Cholecalciferol (vitamin D3). Vitamin D2 vary from vitamin D3 in that it has an extra twofold connection between the 22-23 carbon and 24 extra methyl bunch. Vitamin D isn't completely open in the food supply. The plant sterol ergosterol and UV illumination of yeast outcomes in the production of vitamin D2. Vitamin D3 is delivered normally in the skin and is tracked down in greasy fish and cod liver oil (obtained primarily from the liver of the Atlantic cod, *Gadus morhua* and aloes other species). Evidence recommends that supplementing with vitamin D3 is more fruitful than supplementing with nutrient D2 in speeding up degree of serum 25-hydroxyvitamin D [25(OH)D] engagement in people (Trang *et al.*, 1998; Tripkovic *et al.*, 2008) [29, 30].

UV illumination of 7-dehydrocholesterol, a forerunner of cholesterol, produces nutrient D3 normally in the skin. Bright B beams photons of frequencies between the scope of 290 to 315 nm puncture the skin and are enrapture by the epidermal and dermal stores of 7-dehydrocholesterol (pro vitamin D3) (Vieth, 1994) [34]. Because of which it results in the splitting of the 9-10 carbon bond of 7-dehydrocholesterol, which results in the formation of pre vitamin D3, which is biologically inert and must undergo isomerisation via the skin's temperature to result in the

arrangement of nutrient D3 in the skin. At the point when nutrient D3 is shaped, it enters the dermal hairlike bed and ties to the vitamin D restricting protein (DBP) prior to entering the course (Vieth, 1994) ^[34].

The essential fluctuation between nutrient D2 and D3 is the organization of the sterol skeleton's side chain, which include an extra methyl bunch on carbon 24 and a twofold connection between carbon molecules 22 and 23. In spite of the fact that the two structures have been seem to have comparative sub-atomic activities, nutrient D3 has been demonstrated to be more persuasive than nutrient D2 in requirement of bioavailability and vitamin D status maintenance in the human body. Notwithstanding, there is proof that nutrient D2 is essentially as effective as nutrient D3 in keeping up with serum 25(OH)D3 fixation.

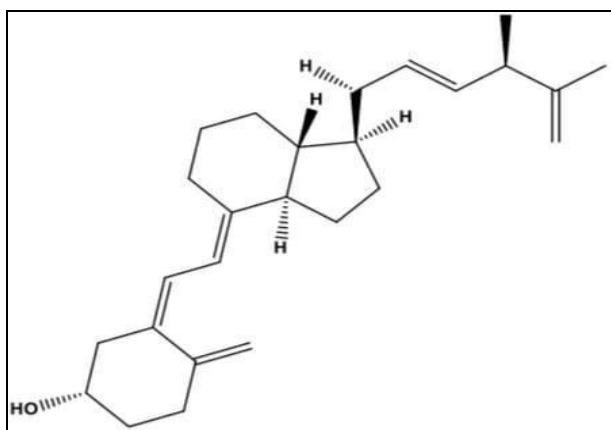


Fig 3: Sub-atomic construction of ergocalciferol (D 2) (Agbalalah, 2017) ^[1]

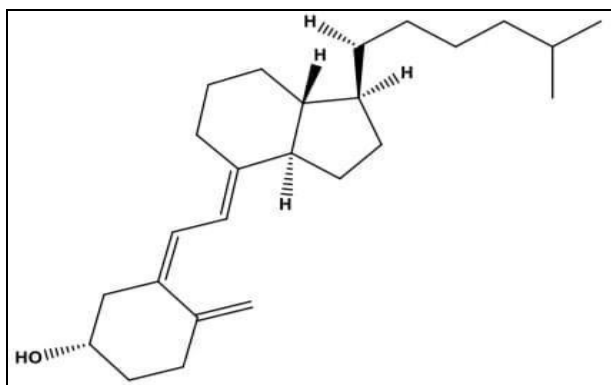


Fig 4: Sub-atomic construction of cholecalciferol (D3) (Agbalalah, 2017) ^[1]

As concluded when the basal and supra-basal layers of the skin's epidermis are uncover to Ultra violet B beams light between the frequency of 290-315nm, photolytic transformation of 10-15% happen. 7-DHC, also recognized as pro vitamin D3, is originated in the skin's epidermis and dermis (Lehmann and Meurer, 2010) ^[19]. Photolysis leads isomerisation, which awakens twofold connections between C-9 and C-10, which brings about the kickoff of the B rings. The B rings reunify to shape 9, 10 secosterol, a thermodynamically unpredictable isomer of a sterol with a messed up ring likewise ordinarily called as pre nutrient D3. Non-enzymatic warm isomerisation of previtamin D3, which is a temperature-delicate realignment of three twofold bonds, which prompts the development of organically dormant nutrient D3 (Cholecalciferol). In the course of time

of three days, this process take place in the plasma membranes of the dermis as well as epidermis epidermis (Holick, 2010) ^[13].

It has been distributed that half of pre nutrient D3 is productive of isomerising to vitamin D3 in the skin with in the time span of 2.5 hours, which clarify the rapid enhancement or increase in the serum vitamin D3 levels following UVB exposure (Holick *et al.*, 1981) ^[14]. It is very crucial to mark that increased UVB exposure does not mean it will result in the synthesis of more pre vitamin D3, but rather it will lead to the transformation of vitamin D3 to organically dormant metabolites like Lumisterol, pyrocalciferol, and tachysterol to end poisonous degrees of nutrient D3. Dermal nutrient D3 is photograph changed over and isomerised reversibly into suprasterol I and II and 5, 6-trans-nutrient D3, which get available when pre nutrient D3 levels fall (Hossein-nezhad and Holick, 2013) ^[15].

2. Vitamin – D Deficiency

Lack of nutrient D can happen when regular utilization is lower than recommended sums over the long haul, daylight openness is limited because of mostly indoor work and the kidneys are inadequate to transform or convert 25(OH)D to its dynamic structure, or assimilation of vitamin D from the gastrointestinal system is not enough. ^[28] The term 'deficiency' refer to the severe rapid decrease in 25(OH)D levels (commonly the level is between 25nmol to 30nmol/L, contingent upon the review).

Insufficiency is summarized to be widespread around the world, as there is deficiency of sunshine vitamin in both sun-deprived and sun-rich countries. In spite of that, it is the world's most under diagnosed and undertreated nutritional deficiency (Van Schoor and Lips, 2011; Mithal *et al.*, 2009) ^[33, 7]. Various reports and studies, has concluded that people of all ages, genders, and locations had low nutrient D levels. Because there is no universally accepted standard for characterizing nutrient D status, these investigations involved different end values for inadequacy. The significant piece of these investigations expressed lack of nutrient D as a serum 25(OH) D of level 20 ng/ml. Studies that used several cutoffs were noted in the footnotes (Aparna *et al.*, 2018) ^[4]. Expect for one review, which detailed a far reaching presence of 34.5 percent because of the low end, local area put together Indian investigations with respect to evidently solid powers over the course of the past ten years revealed a pervasiveness going from 50% to 94 percent. These investigations, which included individuals of different ages, exhibit the extent of the issue. Throughout the country, there was a high prevalence. Kadam *et al.*, directed a school put together review with respect to premenarchal young ladies (n = 214) in Pune in 2011. According to the study Vitamin D prevalence is of 34.2 percent. A review was directed which was school based which was led in 2017 on 1222 younger students matured between 6-18 years in the locale Kangra and Kullu of HP (Himachal Pradesh) which had pervasiveness paces of 81% and 80 percent in like manner. According to the US Endocrine Society cutoff, the two investigations distributed the pervasiveness of lack of vitamin D (Kapil *et al.*, 2017; Holick, 2011) ^[9].

The causes of the widespread rapid scale up in vitamin D insufficiency are still not known, but scale down in levels of 25(OH)D have been connected a link to less consumption of vitamin D-fortified milk, increased and extra usage of

sunscreen in recent times, and an increase in body mass index more than 30 which contribute to increase in deficiency and health problem. It has been recommended that worldwide expansion in corpulence is one of the fundamental supporter of the developing pestilence of lack of vitamin D (Nebhinani *et al.*, 2017)^[21].

2.3 Vitamin D status worldwide

According to a study research Vitamin D deficiency has affected approximately 30-50 percent of people globally. As concluded More than one billion people worldwide may be deficient or insufficient in vitamin D serum level. According to National Health and Nutrition Examination Survey (NHANES) 25% to 57 percent of American grown-ups dwelling in lower scope regions during winter and 21 percent to 58 percent dwelling in higher scope regions during summer had lack of vitamin D which was deciphered as under 62.5 nmol/L (Looker *et al.*, 2002)^[20]. The study also concluded that African Americans had a more severe deficiency, which was 17.5nmol/L, than other races.

Most of people residing in Central and Western Europe were estimated to have vitamin D levels lower according to minimalistic range of 30-50 ng/mL, as it was agreed in unison at the Warsaw conference. This value scale for optimal vitamin D status, on the other hand was higher than that of different rules. Rockell *et al.* (2006) directed a study on 2,946 members matured 15 and more seasoned in New Zealand and in result he concluded that 48 percent who participated in the survey had serumvalue lower than 50 nmol/L and 84 percent who participated in survey had levelslower than 80 nmol/L. People dwelling in area of Pacific and Mori, had lower vitamin d levels specifically as per overview report. Their particular mean 25(OH)D fixations were 37 nmol/L and 42 n mol/L. Overviews directed in a few nation including Brazil, Korea, Australia, Japan, Iran, Canada and India uncover the same results and

results, with a high pervasiveness of serum 25 (OH) D lack in various gatherings and identities.

Considering various survey and research reports Vitamin D insufficiency become frequent in people of in all nationality and age groups throughout the world, even in those countries which are get appropriate amount of sunlight (sun-rich countries) such as, sunny places like Singapore (Hawkins, 2009)^[7]. It ought to be noticed that the discoveries of the previous investigations indicate the presence of lack of vitamin d somewhat nonetheless, the discoveries were not practically identical as there are several definition according to different reports and survey of sufficiency and inadequacy of nutrient d.

Vitamin deficiency is emerging one of biggest untreated deficiency throughout the globe which has become a great topic of concern for all countries. Adolescent age group has come out one of greatly affected by vitamin D insufficiency even in the sun-rich countries where there is abundance of sunlight (Stokvis *et al.*, 2005; Hewavitharana *et al.*, 2014)^[28, 8].

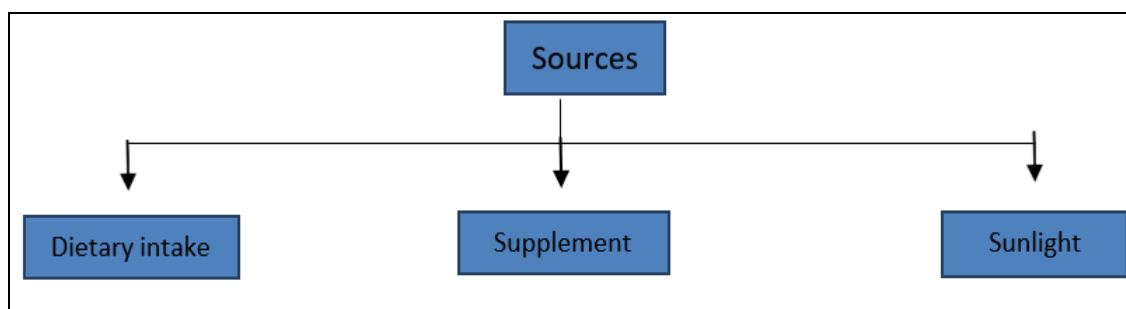
Various supplementation and additive for vitamin D has been introduced which help us scale up vitamin D serum assimilation in our body which add up to better calcium absorption and better body working reducing the risk of developing several disease and help our body fight (Shah *et al.*, 2012)^[26].

3. Sources

There are three important sources of vitamin D:

- Sunshine (UVB Radiation)
- Food sources
- Supplements

Oral vitamin D counting normal sources and strengthened food sources and refreshments supplements^[65].



Dietary Intake

There are numerous foods that are good normal sources of vitamin d. As seen Fatty fish (rich in vitamin D), eggs, organ flesh, and Ultraviolet-irradiated mushrooms, are all good source as they have righteous amount of vitamin D. In addition to this, enriched or fortified meals in Saudi Arabia are limited to some places like few milk byproducts items and cereals.

According to survey report which stated that some countries like Canada, customarily fortify particular food stuffs with natural vitamin D dietary sources and their shortage in human regular diets. Vitamin D3 is added to both fluid milk products and margarine in Canada. All fluid milks (skim, 1%, 2% and homogenised) carry around 100 IU per 250 mL, while margarine consist of 530 IU per 100g (El-Khoury *et al.*, 2011)^[6].

Greasy/slick fish model herring, salmon, mackerel, fish, sardines, and cold and meat liver, cheddar, and egg yolks are some of the more natural dietary sources of vitamin D (Aronov, 2008)^[5].

Metabolites of nutrient D3 25(OH) D3 commonly found in these foods. Cod liver oil is one more source which consist of vitamin d even though they consist good amount of vitamin D but vitamin A focuses in most present day cod liver oil supplements for surpass vitamin D concentrations, several researches instructed against usage as it has great risk of vitamin A toxicity. Vitamin D2 from irradiated mushrooms maybe efficient as vitamin D2 or D3 from tablets in improving vitamin D status, as it is concluded in new research. Vitamin D is found in handful foods naturally, but oily fish in addition can be considered one of the exceptional sources. Vitamin D have also good quantity

in fortified foods namely milk, margarine, cereals and orange juice. But the amount of vitamin D in fortified food varies according to the companies or manufacturers (Qi *et al.*, 2015; Volmer, 2015) [22].

Salmon, a natural fatty fish, has a considerable a good amount of vitamin D3. It's a good source of vitamin D3 and may help to stop and prevent vitamin D insufficiency and disease associated with it (El-Khoury *et al.*, 2011) [6].

Vitamin D2 comes from a few numbers of sources, most of which are plants. D2 created in plants by irradiating ergosterol with ultraviolet light, and it can also be found in foods including shiitake mushrooms, wild mushrooms and egg yolks. Vitamin D2 (ergosterol), which is obtained from plant sources, is utilised for fortification in several countries.

3.2 Supplements

D2 (ergosterol) and D3 (cholecalciferol) are two category of vitamin D supplements that diverge chemically in their side-

chain structure. Both forms scale up or level up 25(OH)D levels in the bloodstream. Nutrient D2 is short of what 33% as compelling as nutrient D3 and has a sorted time span action, according to a study which contrast impacts of very high portions (50,000 IU) of nutrient D2 against D3 supplementation in solid male grown-ups. Although the two supplements produced alike initial level up in serum 25(OH)D throughout the stretch of time of three days of treatment, serum 25(OH)D levels continue with raise in the nutrient D3 bunch, reaching the high point at 14 days, though serum 25(OH)D levels in the nutrient D2 bunch swiftly level down and did not vary from baseline at 14 days.

Use of supplement for vitamin D has scale down insufficiency according to a survey report which is positive indicator as vitamin D deficiency issue is becoming one of major health issue which is linked up with various disease which is harmful to human health and can affect human population badly (Singh *et al.*, 2015) [27].

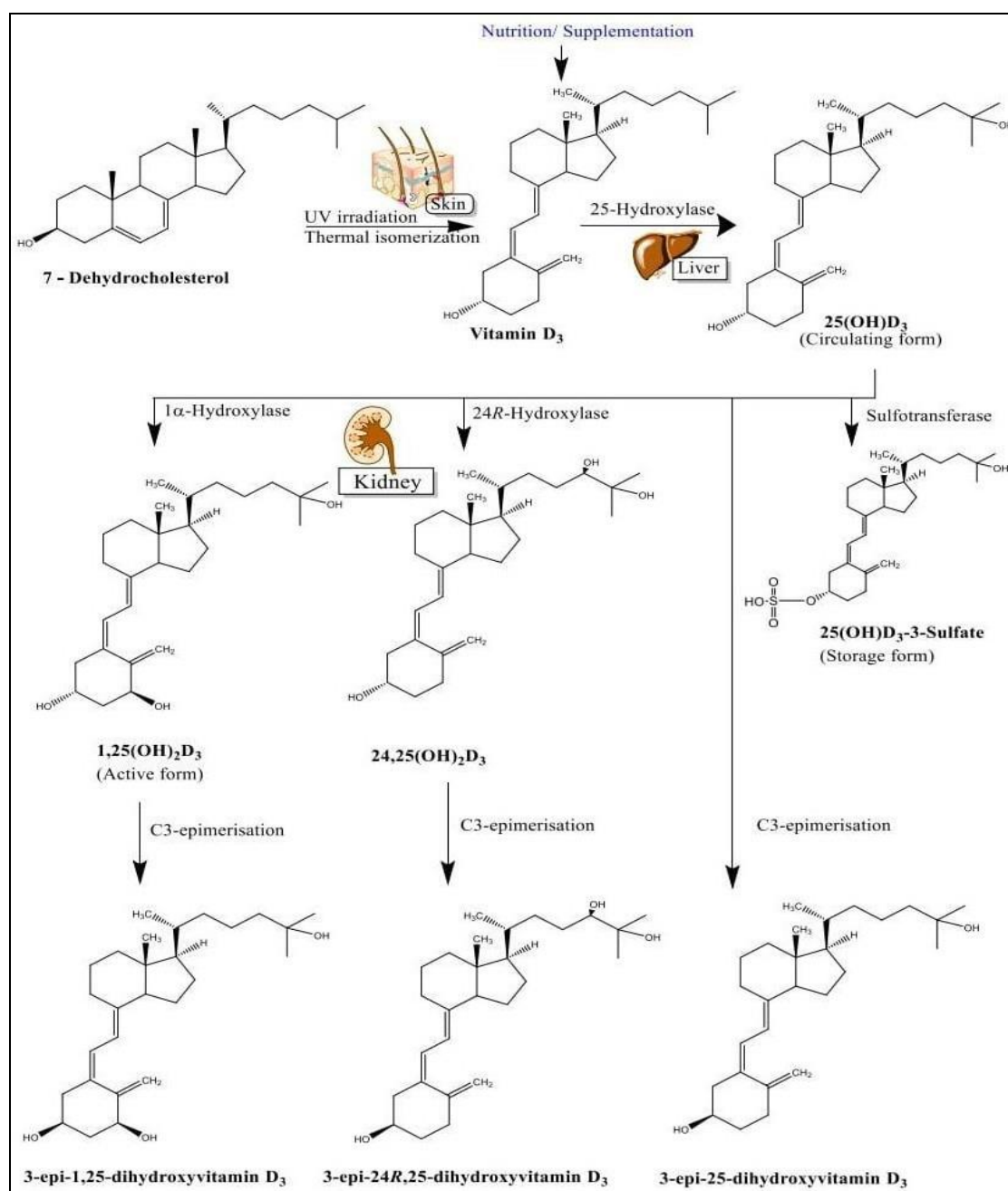


Fig 7: sunshine vitamin synthesis in body (Nebhinani *et al.*, 2017) [21].

Sunlight

Vitamin D is distinctive in that it can only be produced by exposure to the sunlight. Ultra-violet B radiation penetrates skin at a wavelength which is in the range of 290-300 nanometres and transforms⁷ dehydrocholesterol to pre-nutrient D₃, which is then adjusted to nutrient D₃ in the human. Season or time duration and length of day or cloudiness, haze, skin melanin and over use of sunscreen can change the amount of UVB light exposure and vitamin D production in epidermis. In spite the fact that variances through various geographical reasons (i.e., latitude) it have been recorded and concluded, scope doesn't in every case expect normal serum vitamin D fixations at the populace level (Umhau *et al.*, 2013) ^[31].

According to studies, total cloudiness can scale down Ultra-violet radiation by half, while shade can diminish it by 60%. Moreover, in light of the fact that UVB radiations doesn't enter glass, sunlight though a window does not bring about cutaneous vitamin D production. Sunscreen which comprise SPF of 8 or higher seems to forestall UVB beams in terms of sun protection. Even when sunscreen is worn, the skin is likely to synthesis some vitamin D since a great many people don't utilize enough, don't cover all sun-uncovered skin similarly, or don't reapply frequently (Lappe *et al.*, 2007) ^[17].

Anyway a new randomized clinical exploration found that serum vitamin D fixations rise dramatically with diminishing sunscreen thickness, suggesting that sunscreen use might restrain cutaneous vitamin D creation. An entire day in the sun in a bathing suit can create 10,000-20,000 IU vitamin D whereas vitamin D-fortified milk normally contains 100 IU per 8 fluid ounces. Sun exposure remains the most potent, dependable and cost-effective source of vitamin D when Sunshine is available. Sun exposure remains the most potent, dependable and cost-effective source of vitamin D when sunshine is available (Anderson *et al.*, 2010; Ahn *et al.*, 2008) ^[2, 3].

People who are exposed to sunshine on a daily basis have never had to worry about vitamin D toxicity because pre-vitamin D₃ and vitamin D₃ can absorb UVB and UVA radiation after they are formed in the skin. This causes them to be converted into a range of photoproducts that have practically zero effect on Ca digestion (Wang *et al.*, 2008) ^[37].

Database and literature search approach

Using the MESH (medical subject heading) phrases such as "Vitamin – D Deficiency", a methodical and wide-ranging internet search for published literature was conducted in PubMed, ResearchGate, NCBI, and Google Scholar. In order to do a full-text search, terms such as "vitamin D in adults and vitamin D status" were used interchangeably. We have expanded our search scale in order to broaden our scope of search. Published article searching time was restricted between November 2019 and April 2022 without any region restrictions. In the end, studies were identified manually along with manual screening, selection, and data extraction.

Study selection

A survey-based study was conducted using online tools such as Google forms and manual questionnaires. Questions of the survey included personal details of the patients such as name, age, gender, residing city (state), etc., their

knowledge about Vitamin - D, their medical history, their lifestyle, food habits and symptoms such as fever, fatigue, bone pain, muscle weakness, mood change, change in sleep patterns. The selection of these symptoms is entirely based on the searched literature.

Data selection (included and excluded)

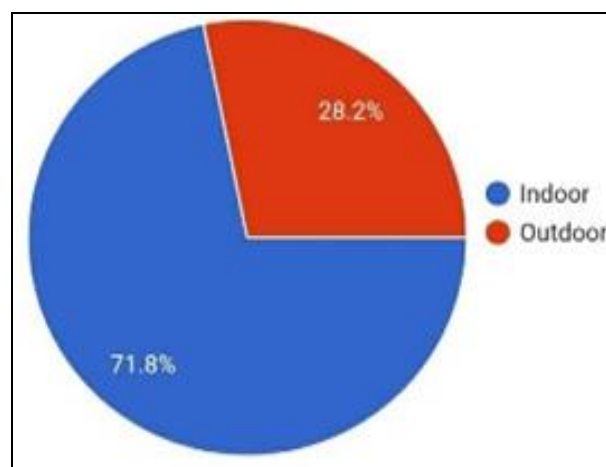
Included data considered are the status of vitamin d in Adolescent age groups, and both genders. Food habits (outside oily food and lees intake of vitamin d regularly) and lifestyle such as working indoor or outdoor have been selected as major tools for the study among them. Whereas Data such as knowledge about Vitamin – D and some of the patients' personal details were excluded data

Results

This study delved into the factors contributing to the escalating prevalence of vitamin D deficiency in adults. A comprehensive analysis was conducted on 320 participant forms, yielding significant insights as follows:

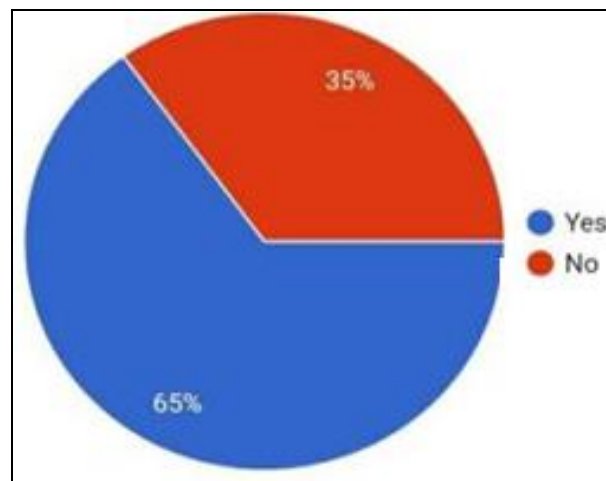
Dietary Intake

Where do you work mainly?



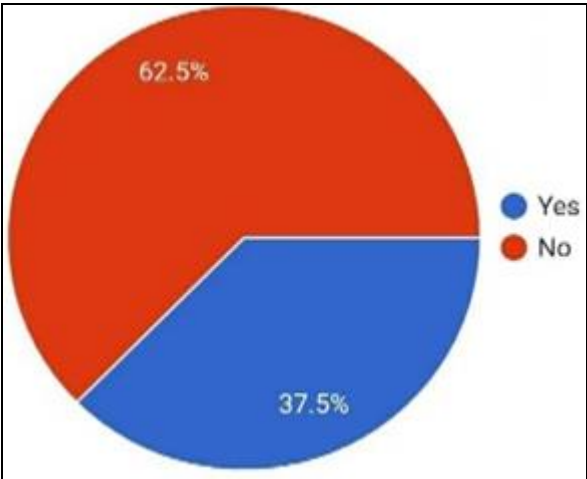
Dietary consumption in Adults

Do you consume fish, egg or mild products every week?



Pie chart: Working of adults outdoor VS indoor and Dietary consumption in adults

Do you take vitamin D supplement in routine?



Pie Chart: Vitamin D supplements

Examining dietary habits revealed a concerning trend: 35% of the surveyed individuals (40 in total) reported irregular consumption of fish, eggs, or milk. This erratic dietary

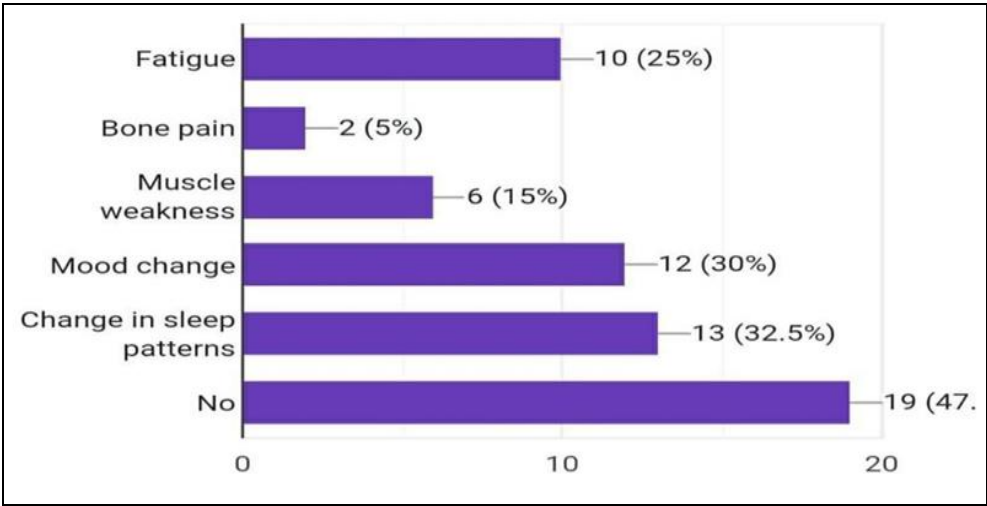
pattern suggests a lack of consistent intake of vitamin D-rich foods among adults, potentially serving as a pivotal factor in the onset of vitamin D deficiency within this demographic.

Sun exposure

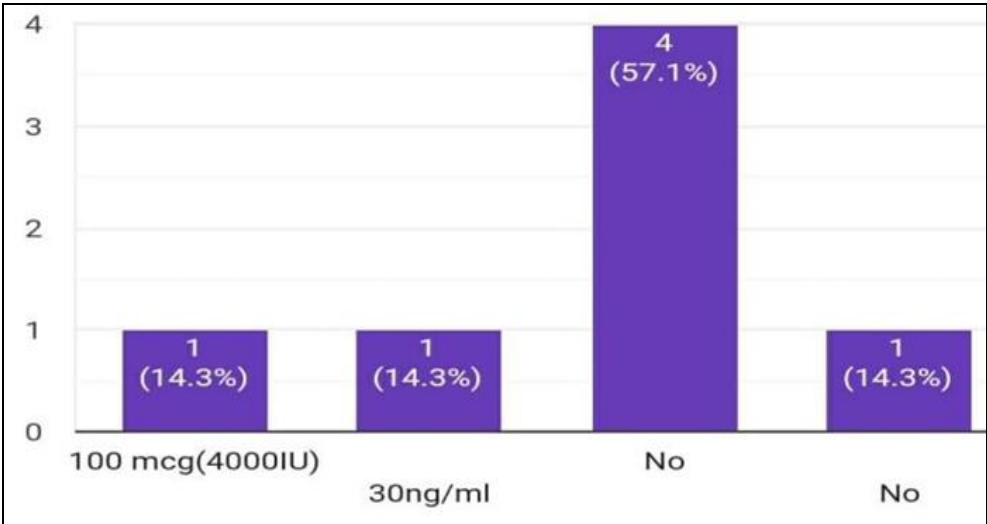
A substantial majority of adults, comprising 71.8%, reported working predominantly indoors, with only 28.2% engaged in outdoor work. This discrepancy in occupational settings directly correlates with diminished exposure to sunlight, a primary source of vitamin D synthesis. The prevalent indoor-centric lifestyle observed among adults emerges as a significant contributor to the escalating deficiency of vitamin D, owing to limited sun exposure.

Survey data revealed that a notable portion of adults, approximately 37.5% of the total respondents, regularly resort to vitamin D supplementation. These individuals opt for supplements to mitigate deficiency-related symptoms such as bone pain, muscle weakness, and fatigue, underscoring the necessity of supplementary interventions to address vitamin D insufficiency in the adult populace.

Do you experience any of these symptoms?



Graph 1: representing symptoms experienced by adults



Graph 2: Vitamin D Status

While symptoms experienced by adults due to vitamin D deficiency were graphically represented, the specific vitamin D status of the participants was not detailed in this report, warranting further investigation into the correlation between symptomatology and deficiency severity.

Conclusion

Vitamin D deficiency has become increasingly prevalent among adults aged 18-25 years. Through our research, we have identified several contributing factors, including irregular dietary habits such as excessive junk food consumption, unhealthy diets, alcohol intake, low physical activity levels, and insufficient sun exposure. These lifestyle factors, along with indoor work environments, have been found to impact vitamin D levels significantly.

Our study indicates that individuals with healthier lifestyles and regular routines, coupled with adequate sun exposure, are less likely to experience vitamin D deficiency. This underscores the importance of prioritizing interventions to address this widespread medical issue at both clinical and community levels.

Educational initiatives, increased awareness, and lifestyle modifications can play a crucial role in identifying and mitigating vitamin D deficiency among adults. By making changes to daily routines and dietary habits, individuals can better understand and address the underlying causes of deficiency.

The findings of this study have important implications for future research. It highlights the urgent need for larger population-based studies to explore the epidemiology, underlying causes, risk factors, and impact on quality of life among adults suffering from vitamin D deficiency. Additionally, it underscores the importance of providing adequate medical assistance and support to individuals affected by this condition.

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