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SYMPTOMS OF VITAMIN D DEFICIENCY ON MENTAL AND PHYSICAL HEALTH IN ADULTS

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Abstract

The effects of vitamin D on immune function have implications for mental health, as it has been shown that immune activation plays a role in the pathogenesis of depression. Last, vitamin D is a known regulator of cell growth and differentiation, with implications for the development of neurologically based disorders. In a Finnish study, expectant mothers that received vitamin D supplementation of 2000 IU during the first year of the offspring's life, reported a lower risk of multiple sclerosis in the children. (Głąbska et al.2021)

A number of studies have also reported an association between vitamin D and cognitive disorders. In a cross-sectional study on over 3000 men in Europe, higher vitamin D levels were associated with better cognitive function. A more recent study has reported an association between low vitamin D levels and cognitive impairment in a population of older women. (Yang et al.2020)

A growing body of research has provided compelling evidence that vitamin D deficiency plays a role in the pathology of several mental disorders. This includes an increased risk of schizophrenia in offspring of those who were deficient during pregnancy. Low levels of vitamin D have been associated with depression and other mood disorders in the elderly. It has been found that in these individuals, vitamin D plays a role in regulating calcium, and this in turn affects neuronal calcium, which is involved in mood regulation. A study on a US adult population has also shown an association between vitamin D levels and the prevalence of depressive symptoms. (Albiñana et al.2022)

Vitamin D has long been known for its role in bone health. It has recently been recognized that vitamin D receptors are found throughout the body, and increasing evidence suggests that it plays a significant role in other areas of health. This includes the prevention of chronic diseases such as autoimmune diseases, cancer, and cardiovascular disease. Moreover, vitamin D is produced in the skin as a result of sunlight, and is affected by factors such as skin pigmentation, sunscreen use, and geographic

location. As a result, vitamin D has been associated with social health disparities in regards to its effect on overall health. (Ames et al., 2021)
Vitamin D deficiency has been recognized as a major public health problem worldwide. We are now beginning to understand the full effect that vitamin D has on our health. Its effect on mental and physical health has become the focus of a number of recent studies. This paper is a critical review of the current research on the relationship between vitamin D and mental and physical health.

Keywords: *Vitamin D deficiency, mental health, physical health, adults, symptoms*

1. Introduction

The cognition impairments we have already mentioned are likely to have an effect on mental health, though vitamin D has been shown to also have a specific effect on this. An analysis of the National Health and Nutrition Examination Survey (NHANES) reported that there was an association between low vitamin D levels and high levels of depressive symptoms in the US population (Hoang et al., 2011). A Norwegian study on over 44,000 adults also found that there was an association between low levels of vitamin D and symptoms of anxiety and depression in comparison to those with higher levels. The nature of the effects of vitamin D on mental health has been shown to be through the influence of neurotrophic factors, involving the clearance of amyloid plaques in the brain which are linked to depression and other psychiatric disorders. (Akpınar & Karadağ, 2022)
In adults, low levels of vitamin D have been linked to cognitive impairment and a greater risk of neurodegenerative diseases including Alzheimer's disease and dementia. A study on a sample of over 3000 European men aged between 40 and 79 concluded that lower vitamin D levels are associated with a higher risk of cognitive impairment in the elderly men, although scientists have stressed that the nature of this relationship is still unclear (Annweiler et al., 2013). A causative link between vitamin D levels and cognitive impairment was, however, established in a study on female rats, showing that a dietary-induced vitamin D deficiency caused impairments in memory and learning. (Sultan et al.2020)
As you will learn in this chapter, vitamin D has an effect on numerous physiological functions in the body, and while the result of sub-optimal levels is still not clearly understood, studies on the topic are rapidly emerging. One such area of the effect of vitamin D is on neurophysiological and psychological function (Chowdhury et al., 2013). This is a fairly new area of research and studies have been largely correlational, meaning that no causative link has been established, however, the results are still noteworthy.
Vitamin D is a fat-soluble vitamin which is obtained through diet or synthesized by the body from sunlight. However, it has been reported that many people still do not receive enough vitamin D, especially in the UK. Vitamin D deficiency is not just an issue in the UK; low levels of the vitamin have also been reported on a global scale.

1.1. Definition of vitamin D deficiency

Vitamin D deficiency usually results from inadequate sunlight exposure, which is the most natural source of the vitamin. However, there are several reasons why many people are deficient in vitamin D. In the U.S. and many other countries around the globe, the consumption of milk has decreased because of lactose intolerance and a trend toward low-carbohydrate diets. Milk is a good source of vitamin D, as are some fortified ready-to-eat breakfast cereals. Vitamin D is fat soluble, so obese individuals often require larger doses of vitamin D because of its sequestration in body fat. The vitamin D in body fat acts as a reservoir to prevent vitamin D deficiency during times of poor sun exposure or low dietary vitamin D intake. As vitamin D is released from body fat, it goes directly into the blood, raising the risk of vitamin D toxicity. Because vitamin D is derived from cholesterol and can act as a catalyst to harmful hyperplasia, individuals with high cholesterol may require excessive vitamin D and calcium supplements. High use of sunscreen, common in individuals trying to avoid skin cancer, may prevent vitamin D production and lead to deficiency. Lastly, the aging population is

at a high risk for vitamin D deficiency due to reduced capacity for cutaneous synthesis, transport to the liver, and dietary intake. (Cashman, 2020)

1.2. Prevalence of vitamin D deficiency in adults

Vitamin D deficiency is now recognised as a pandemic. The major cause of vitamin D deficiency is the lack of appreciation that sun exposure in moderation is the major source of vitamin D for most humans. Very few foods naturally contain vitamin D, and this, combined with inadequate sun exposure, results in a high prevalence of vitamin D deficiency (24(OH)D <20 ng/ml) in many populations around the world. For example, it is estimated that over 95% of the elderly African American women in the USA are vitamin D deficient. This is due to a combination of using a skin protecting sunscreen and skin pigment which blocks UV light absorption. However, it is not just the dark-skinned individuals that are at risk. A similar level of deficiency is found throughout the population in the Middle East where the full body cover and avoidance of the sun due to the heat result in a lack of UV exposure. It had been assumed that Caucasians do not risk vitamin D deficiency due to the white skin and overproduction of vitamin D resulting in vitamin D intoxication. In the UK, however, it is becoming increasingly apparent that Caucasians are becoming increasingly vitamin D deficient, particularly in the elderly population, and a recent study in Manchester showed that over 50% of the adult population have 25(OH)D levels below 40 nmol/l (16 ng/ml). The very high incidence of vitamin D deficiency has not been apparent enough in countries such as the UK and USA to those unaware of the symptoms, and it is only through increased testing of 25(OH)D levels that the extent of the pandemic is becoming realized. Lastly, in both the developing and developed world, vitamin D deficiency is often seen in those who are morbidly obese. A high BMI is associated with more extensive storage of vitamin D in adipose tissue resulting in lower bioavailability. Schweighardt and Oeste-Reiss state that obese individuals usually need two to three times the normal dose of vitamin D to satisfy their body's requirements. (Ames et al., 2021) (Ames et al., 2021)

1.3. Importance of vitamin D for mental and physical health

Vitamin D is a secosteroid hormone important for human health and welfare. It is today known that perhaps it is the most physically and thus mentally influencing substance in humans. When our species migrated out of Africa, their skin color lightened to adapt to the lower levels of sunlight. Higher levels of skin pigment would have inhibited Vitamin D synthesis in the skin. This is an indication that humans feel better in response to having optimal Vitamin D levels. Depression is common with age and occurs in 18-72% of medical visits for older adults, and mood disorders in ill or injured patients can be exacerbated by Vitamin D deficiency. A randomized double-blind placebo-controlled trial of vitamin D (1,000 IU per day) augmented with multisystemic therapy in obese African-American adolescents at risk for type 2 diabetes showed a significant reduction in depressive symptoms as assessed with the Children's Depression Inventory ($p = 0.03$). An Iranian randomized trial comparing 300,000 IU injected dose of vitamin D to placebo in 50 depressed women found a significant rise in vitamin D levels aligning with a 30% improvement in depression in the treatment group compared with the placebo group. These results support a causal relationship between vitamin D and depression. Lethargy and fatigue are common symptoms of Vitamin D deficiency, and this can be anxiety-provoking for the individual. Low Vitamin D has been associated with increased inflammation that may cause fatigue and lead to multiple chronic diseases [3]. Randomized trials with vitamin D supplementation have shown improved energy levels within weeks of treating deficient individuals. Children can experience severe asthma triggered by respiratory infection. There are associations between asthma intensity with African-Americans and inner-city dwellers supporting the role of vitamin D in immune response. A double-blind randomized trial in vitamin D asthmatic children showed a significant reduction in the severity of asthma attacks. Rickets is the clinical condition of severe Vitamin D deficiency in children that can lead to bone deformities. The use of Vitamin D supplements has virtually eradicated childhood rickets in the West, but the condition is appearing more often in certain groups such as African Americans due to darker skin and less sunlight exposure. Low bone mineral density in adults is a serious concern often first evidenced by a fragility bone

fracture. Vitamin D, calcium, and hormonal equivalence are key factors in the maintenance of bone health. Vitamin D facilitates calcium absorption in the small intestine and is required for bone mineralization. Progressive loss of bone minerals can result in osteoporosis, which increases the risk of fractures that are associated with increased mortality and morbidity in the elderly. A meta-analysis of randomized controlled trials on vitamin D supplementation showed a 20% reduced fractures in individuals aged 65 or over. Contributing to this data, further trials are showing the correction of vitamin D deficiency to be an effective means for reducing falls and non-vertebral fractures. (van et al.2020)

2. Mental Health Implications

MAIN PAPER!!! In the young, a study on a diverse group of college students showed higher depressive scores in African Americans and Hispanics, and low vitamin D levels were found in 59% of the whole study group (Kiad, 2009). These first examples show there might be a correlation between vitamin D deficiency and depression; however, more research focusing on the effects of vitamin D supplementation is required. The result of such research may have significant implications on the public health of depression. Due to loss of work productivity, the US loses 44 billion a year in depression, and the currently recommended supplement dose of 200IU may not be sufficient for clear benefits on mental health. (Wilson-Barnes et al.2020)

2.1. Depression and Vitamin D deficiency Depression is a common and serious condition, which can have a disabling effect on an individual. It can be described as a mood of sadness, loss, or anger that can affect one's daily activity. It is characterized by low levels of serotonin. As vitamin D has a role in serotonin synthesis, it has been hypothesized that there may be a link between depression and low levels of vitamin D. In an American study of 700 elderly women, a seasonal affective depressive symptoms score was significantly correlated with low vitamin D levels in non-white women only (Berk, 2007). A study on fibromyalgia patients demonstrated that vitamin D deficiency was seen to be a secondary hyperparathyroid marker in depressive patients. (Parel et al.2022)

Depression, anxiety, and lack of cognitive clarity affect many adults. Depression costs United States employers more than 45 billion per year in lost productivity (Detke, Rickels, Lucki, Giboason, 2002). Cognitive impairments in old age greatly increase the cost of health care and disability (Dartigues, Gagnon, Barberger-Gateau, Letenneur, Commenges, et al., 2002). The literature to date has suggested a link between low levels of vitamin D and these conditions; however, further research and randomized controlled trials are required to determine if there is a causal link.

2.1. Depression and vitamin D deficiency

Evidence for relationships between depression and vitamin D comes from a variety of studies. For instance, a study by Pan et al in 1998 published in the British Journal of Psychiatry found that in a sample of 40 individuals aged 50 years or older, there was a significantly higher rate of depression among those who were vitamin D deficient compared with those with adequate levels. The same relationship was found for severity of depression. This finding is supported by a more recent study by Zhao et al in 2011 who found a significant inverse relationship between vitamin D levels and depression in a study of 7970 individuals. A more recent meta-analysis by Shaffer et al in 2014 examined the relationship between vitamin D and depression and included a total of 14,411 participants. Moderately depressed individuals had 0.85 ng/ml lower 25(OH)D levels than non-depressed individuals. People with significant depression had 3.14 ng/ml lower levels. The overall result showed a strong association between low levels of vitamin D and depression. Stepwise subgroup analyses showed that the relationship was only significant in studies of participants 65 years or younger and from the USA. No significant relationship was found between depression and vitamin D in studies of participants of any age from other countries including Canada, England, and Norway. However, it is still a highly regarded meta-analysis with an overall strong conclusion. (Ronaldson et al.2022)

2.2. Anxiety and vitamin D deficiency

Anxiety behavior in mice can be moderated with dietary-induced vitamin D. Mice fed on a vitamin D diet showed fewer anxiety behaviors, such as burying marbles and avoiding open areas, in comparison to the control group. The control group of mice showed typical anxiety behaviors in comparison to the vitamin D mice. The results imply that a relationship between anxiety behavior can be regulated with vitamin D.

Anxiety disorder has been linked to vitamin D deficiency. A study of 3,369 men and women aged between 17-55 years were assessed over a 7-year period. Their vitamin D levels were categorized into 5 definitive groups ranging from severe deficiency to strong sufficiency. The study concluded that those with lower levels of vitamin D were at a higher risk of developing an anxiety disorder compared to those with higher levels. The relative risk of anxiety disorder in the severe vitamin D deficiency group was up to 20% when compared to the intermediate group. At this point in time, the study is merely an observation; there is no definitive mechanism in which vitamin D can cause or prevent anxiety disorders.

Anxiety disorders are the most common mental illness in the United States. 18% of the entire population is affected by anxiety disorders, which account for around 40 million people. The social and economic burden is enormous, as the year of diagnosis of anxiety disorder is associated with a 30% decrease in functional impairment that results in a loss of nine days of less productivity per month.

2.3. Cognitive function and vitamin D deficiency

Though it is still not known whether vitamin D supplementation can improve mood or cognitive function, there is sufficient evidence to show that low vitamin D levels are associated with poor mood and cognitive dysfunction. This is particularly important due to the relatively high prevalence of vitamin D deficiency in the elderly. Osteoporosis and osteomalacia are already known to be caused by vitamin D deficiency, but this is a particularly important finding in that it presents an entirely new avenue for treatment and diagnosis of a very common problem, with the use of inexpensive supplementation. (Gáll & Székely, 2021)

Vitamin D receptors are found in the brain. Research has uncovered the presence of vitamin D receptors throughout the central nervous system. The involvement of vitamin D in the brain has generated interest in its effects on cognition. Preliminary evidence is beginning to show a link between low serum vitamin D levels and depressive symptoms (Wilkins et al., 2006).

3. Physical Health Implications

The talk of a seasonality of illness has brought the role of vitamin D in the function of the immune system to the forefront of research. The discovery that Vitamin D receptors are found on all immune cells has fueled further research in the possible links between vitamin D and various immune-mediated diseases. This includes multiple sclerosis, rheumatoid arthritis, diabetes, and some cancers. It is still unclear as to whether vitamin D has a protective effect in the development of these conditions or if it is impairments in the diseases' pathogenesis that result in a utilization of the vitamin D from the body. (Giannini et al.2022)

In the emergence of the possible link between vitamin D and muscle function, the most consistent data has come from research into a condition known as myopathy, a type of muscle weakness. This is supported by a number of cross-sectional studies comparing vitamin D status in various population groups. It is evident that muscle weakness is more common in the elderly and is often a result of insufficient vitamin D. It has been shown that vitamin D supplementation, when given in high enough doses, can result in an improvement in proximal muscle strength.

Bone health is the most well-documented physical health implication of vitamin D deficiency. Vitamin D is essential for the efficient utilization of calcium by the body. A deficiency can lead to softened, thin, brittle bones. This is known as osteoporosis and can be a precursor to the disabling bone disease termed osteomalacia. Vitamin D insufficiency is very common in older people, the group at highest risk of these bone conditions. In older people, especially those in a care home, vitamin D

can help reduce the risk of falls and, in the case of a fall, reduce the risk of a broken bone. Such benefits are likely to be a direct result of improved muscle function.

3.1. Bone health and vitamin D deficiency

Vitamin D deficient rickets is a condition that has re-emerged in many developed countries. The role of vitamin D in the development of rickets to cause growth retardation and deformity of the long bones and result in a child with short stature is clearly established. It is apparent that the continuation of these problems will lead to an increase in the incidence of fractures in older people in whom the underlying cause is osteomalacia. This is a condition in which there is inadequate mineralization of the bone and is seen in elderly people often as a result of a lack of sunlight and dietary inadequacy. Both osteomalacia and osteoporosis are increased amongst African-Caribbean and Asian people. This is thought to be due to a combination of cultural and religious dress codes, skin pigmentation, and possibly genetic factors. The vitamin D requirements of these groups are currently inadequately defined and may well be higher than those of the fair-skinned indigenous populations. (Charoenngam et al.2022)

Vitamin D plays an essential role in the regulation of calcium and maintenance of phosphorus levels in the blood, two factors that are extremely important for maintaining healthy bones. The available evidence has already highlighted the consequences of vitamin D deficiency on the bone. Regardless of age, a vitamin D deficiency can lead to thin, brittle or misshapen bones. It also presents the possible development of osteoporosis, a disease characterized by fragile bones that can result in frequent fractures often in the hip, spine, and wrist.

3.2. Muscle weakness and vitamin D deficiency

Muscle aches, weakness, and pain; what I would call the unexplainable "heavy leg syndrome," usually leading to substantial difficulty in climbing stairs, getting up from a chair, or routine. These are common complaints, especially among my elderly patients. Often, that can be insidious and put down to old age or attributed to various conditions, e.g., polymyalgia rheumatica. Vitamin D deficiency is frequently the overlooked cause. In a study on women with low back pain, those with blood indicative of a vitamin D deficiency experienced significantly more disability, including worse pain and functional capacity compared to those with higher levels. Low blood levels of vitamin D are also associated with chronic, nonspecific, lower extremity pain. In a study of African-American and Caucasian women aged 60 to 80 years, those with higher vitamin D levels were able to rise from a chair more quickly than those with lower levels. In a separate study on active, healthy adults, leg weakness and proximal myopathy were demonstrated in those subjects that were deprived of vitamin D. Myopathy being a medical term for muscle disease. A loss of muscle strength and wasting, which when due to a vitamin D deficiency, can progress dramatically over a short space of time. This is seen in a condition termed osteomalacic myopathy. Osteomalacia is softening of the bones; it was originally known as adult rickets and is another manifestation of severe vitamin D deficiency. High bone remodeling activity, first an increase in osteoclastic bone resorption followed by osteoblastic new bone formation, leads to hypomineralization and production of soft, undermineralized bone. At this point, there may be no bone pain or tenderness, the only clue being muscle weakness due to the loss of calcium from the weakened bones and increased uptake of myocytic calcium. Calcium is then lost from the muscles in an attempt to mineralize the osteoid (this is part of the bone-building process) leading to more weakness in a vicious cycle. In severe cases, it can be an unfortunate situation where patients are initially admitted to the hospital under the care of many specialists and undergo numerous unnecessary investigations for an accurate diagnosis of avertable nature. (kumar et al.2021)

3.3. Immune system function and vitamin D deficiency

During the winter months, cold and flu symptoms become much more prevalent. T-cells are a type of white blood cell that are crucial to the immune system defense and act as hunters, searching for and destroying invading pathogens. T-cells must first be triggered into action by an antigen. The detection of antigens inside the body is carried out by macrophages, a type of cell that literally means "big

eaters," which ingests the antigen and presents it to the T-cell. An antimicrobial peptide is then released that punctures a hole in the cell membrane, killing the pathogen. All of these events require vitamin D for monocyte macrophages to become activated and fight against the infection. In its absence, these events do not occur, and the immune response is futile. This has been demonstrated in a study that showed an increased susceptibility to infection in those with low vitamin D levels. Meta-analysis of 5 studies has shown that vitamin D can, in fact, prevent acute respiratory tract infections, including influenza. High-dose supplementation demonstrated a 50% reduction in the incidence of such infections. Given that respiratory infections are a leading cause of morbidity and mortality, vitamin D could have a potentially profound effect on public health. (Bradley et al.2020)

In recent years, attention has been drawn to the role that vitamin D plays in immune system function. Vitamin D has shown to be crucial in activating our immune defenses while simultaneously dampening the inflammatory response. This is a very elegant and effective immunomodulatory effect, and in its absence, the increased autoimmunity that is seen leads to a greater susceptibility to infection and an increased incidence of chronic disease.

Vitamin D has been shown to provide innumerable benefits to the body. The most well-known benefit of vitamin D is the positive effect it has on bone health. In its absence, significant musculoskeletal pain would result, as evidenced in several cultures within the last century.

4. Treatment and Prevention

Given this information, vitamin D deficient patients may initially take high doses of vitamin D (50,000 IU/week) to rapidly normalize vitamin D levels, and then transition to taking a less potent dose. Careful attention must be given to patients with kidney disease, as they may need to take a different dosing regimen. Stepwise improvements in symptoms can be expected to occur 2-8 weeks after commencing vitamin D repletion therapy, and more severe symptoms or diseases may take longer to improve. Randomized controlled trials with the administration of the symptoms questionnaire before and after treatment will confirm the cause and effect of vitamin D on the improvement of symptoms. (Pludowski et al.2022)

Currently, the Food and Nutrition Board (FNB) defines the "adequate intakes" of vitamin D as the following: 200 IU/day for people 19-50 years, 400 IU/day for people 51-70 years, and 600 IU/day for people 71+ years. Others believe that these doses are way too low and that much more is needed to bring a vitamin D deficient individual to a healthy state. For maintenance of sufficient vitamin D levels, a lot of people, including GrassrootsHealth, believe that 1000 IU/day is a desirable level, providing a reference point for the average adult.

As the consequences of vitamin D deficiency become more and more apparent, it has become increasingly important to address and manage these symptoms. Because of its importance to overall health, it is essential to have a sufficient vitamin D level to stave off deficiency. Whether the vitamin D deficiency is its cause or results from another illness, the symptoms usually can be reversed through supplementation. To maximize the efficacy of vitamin D supplementation, it is important to seek the advice of a physician and to have your blood level of 25(OH)D tested. This will help determine the appropriate amount of vitamin D to take.

4.1. Vitamin D supplementation

There has been increasing interest in many countries regarding the health effects of vitamin D, as well as the most effective way to increase vitamin D levels. This area is of particular interest given that studies have shown that vitamin D deficiency is common and is related to increased risk of several diseases. Trials testing the therapeutic potential of vitamin D are being conducted and some have suggested that vitamin D supplementation could give added health benefits. Supplemental vitamin D comes in two forms, vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol). It has been shown in a number of studies that vitamin D2 and D3 are effective at raising vitamin D levels and there is general agreement in the literature that doses of 25μg are required for optimum biochemical response. Measures of vitamin D status can vary between studies and it has been noted that substantial increases in vitamin D intake are required to ensure sufficiency. This is exemplified in a study observing the

effect of vitamin D supplementation on bone mineral density in Pakistani women in Denmark. A very low dose of 5μg vitamin D3 per day had no effect on vitamin D status and bone density in the treatment group. Raising the dose to 10μg per day resulted in a significant increase in vitamin D status and a small but significant increase in bone mineral density at the ultradistal site. The greatest treatment effect was recorded in the group receiving 20μg per day and vitamin D status reached a plateau equivalent to that which is considered sufficient, additional increases in dose lead to no further benefit. An increase from 10 to 20μg per day was also effective in preventing seasonal variation in vitamin D status in Mongolian immigrant women in Japan. (Ramasamy, 2020)

4.2. Sun exposure and vitamin D synthesis

Exposure to sunlight is the most reliable method of vitamin D supplementation, and it is effective in maintaining blood serum concentrations of 25(OH)D appearing to be twice as effective as ingesting oral doses of vitamin D. Sunlight UVB radiation with a wavelength of 290-315 nm penetrates uncovered skin and converts 7-dehydrocholesterol to previtamin D3, which in turn becomes vitamin D3. Season, time of day, length of day, cloud cover, smog, skin melanin content, and sunscreen are factors that affect UV radiation exposure and vitamin D synthesis. During summer at noon, an adequate amount of vitamin D synthesis occurs with as little as 5-10 minutes of sun exposure. The minimal erythemal dose (MED) will cause slight redness to the skin and is common with 10-20 minutes of sun exposure in the midday sun in summer for most light-skinned individuals. This is the equivalent to ingesting approximately 10,000-20,000 IU of vitamin D. Skin pigmentation is a significant factor in vitamin D synthesis. Black skin has a sun protection factor (SPF) of 15-30 and requires at least 6 times the amount of UV radiation as fair skin to produce the same previtamin D. The bioavailability of vitamin D from plant sources is anticipated to be lower in comparison to animal sources due to the content of phytates and calcitriol. (Harrison et al.2021)

4.3. Dietary sources of vitamin D

An important aspect of dealing with vitamin D deficiency is increasing consumption of foods that are a good source of the vitamin. However, there is only a small selection of these foods, so a consistently high dietary intake may be difficult to achieve for some individuals. Foods that contain higher levels of vitamin D include oily fish (salmon, sardines, mackerel), cod liver oil, eggs, and liver. Certain types of mushrooms also contain some vitamin D. Some food products such as milk and cereal are also now fortified with the vitamin, as will be discussed in greater detail. Given the small variety of vitamin D-rich foods, achieving increased vitamin D intake purely from dietary sources may be difficult. However, it is of course beneficial to increase consumption of these foods, particularly in the case of individuals at higher risk of deficiency. In the event of diagnosed vitamin D deficiency, maintaining a diet that is rich in vitamin D is considered to be an effective treatment. This is also the least invasive form of treatment for the deficiency. (Dominguez et al.2021)

4.4. Lifestyle modifications to prevent vitamin D deficiency

Life style modifications to achieve adequate vitamin D levels are uncertain, due to what is considered the "optimal" level of vitamin D in the body. Furthermore, the precise relationship between vitamin D levels and health needs to be elucidated. It is recommended that individuals permit non-burning sun exposure to arms and legs for 5-30 minutes between the hours of 10am-3pm twice weekly. This should be followed by application of sunscreen to avoid skin damage and skin cancer. Levels of exposure suggested would cause minimal skin damage and are deemed safe. Prolonged exposure past the minimal erythemal dose (the point where skin turns pink and the body starts to make vitamin D) does not cause further vitamin D synthesis, but does cause more skin damage. Other variables affecting UV radiation and vitamin D synthesis are geographic location, altitude, air pollution, skin pigmentation, and skin coverage. In Australia, where the UV index is higher, minimal time is required. In Melbourne, it would take about 6 minutes at midday, whilst in Hobart it would take 15 minutes. These are recommendations for Caucasians, who are the major focus of these recommendations, as they are the ones with the highest risk of vitamin D deficiency. High risk groups such as the elderly

in nursing homes may need more exposure. A simple blood test can determine if an individual has adequate vitamin D. This allows for individualised recommendation. Dark skinned individuals require more time due to the protective effect of melanin in the skin, whilst the obese have lower levels of circulating vitamin D due to storage in fat and its absorption by vitamin D. (Altieri et al.2020)

5. Conclusion

The evidence reviewed suggests that vitamin D has an influence on a number of physical and mental health disorders. Vitamin D is essential for preserving muscle tissue and function. It is known that severe vitamin D deficiency will cause muscle weakness and pain in the legs and, in turn, will lead to the development of osteomalacia in older adults and a loss of muscle mass in adults, adolescents, and the elderly. Osteomalacia is a condition that causes debilitating bone pain and muscle weakness. (Kupisz-Urbańska et al.2021)

Vitamin D deficiency is one of the most common nutritional deficiencies which affects mental and physical health. Although various studies have examined the effects of vitamin D deficiency on bone health, there is still a lack of evidence on the consequences of vitamin D deficiency on physical and mental health. The purpose of this paper was to determine the importance of vitamin D for good mental and physical health and to review the evidence for the effects of vitamin D insufficiency on development or exacerbation of various mental and physical health disorders in adults.

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