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Vitamin D and its influence on human immune system

This review presents modern domestic and foreign studies of vitamin D levels effect on the human immune system. Numerous data are presented on the participation of vitamin D in the regulation of immune responses. In recent years, more and more attention has been paid to the problem of vitamin D deficiency in the body of patients with autoimmune diseases. The significance of vitamin D in immune regulation is confirmed by the results of many experimental studies, clinical and epidemiological observations that demonstrate the relationship between low levels of the vitamin D and increased susceptibility to various infections, as well as the activity of the infectious process of viral, bacterial, and fungal etiology. Vitamin D acts both directly and indirectly on immune cells such as B and T lymphocytes, dendritic cells and macrophages. The review focuses on the molecular mechanisms of activation of the immune response under the influence of vitamin D. Vitamin D exerts its effect through binding to the vitamin D receptor (VDR), which, in turn, together with other proteins, activates the transcription of protein genes involved in the body's immune response. In this regard, it is necessary to draw the attention of researchers to the problem of the daily intake of vitamin D, especially in a pandemic situation.

Keywords: vitamin D, calcitriol, vitamin D receptor (VDR), innate immunity, adaptive immunity, autoimmune diseases.

In recent years, there has been a global trend of deterioration in the health of the population, which is associated with environmental disasters, deterioration of food quality, an increase in viral infections, and social instability in society. Currently, a special place in the development of various human pathologies is given to VD, which is considered a multifunctional hormone that regulates numerous processes in the human body at the gene level [1–3].

The VD status in the human body is assessed by measuring blood levels of 25(OH)D, since its serum concentrations are more stable and are less influenced by hormonal mechanisms and by changes in calcium and phosphorus levels, as compared to $1,25(OH)_2D_3$ [4]. Most researchers agree that 25(OH) D levels below 10–12 ng/mL (25–30 nmol/L) represent clinical deficiency, which is considered a global health problem [5–7].

VD deficiency provokes the development of diabetes mellitus (DM), cardiovascular diseases, multiple sclerosis, and other autoimmune diseases, chronicity of infectious diseases such as tuberculosis and periodontal disease [1, 8]; it is associated with an increased risk of colorectal and bladder cancers, while for breast, ovarian, and prostate cancers, this association appears to be more controversial [9].

This review focuses on the current data on the effect of VD on various parts of the immune system in normal conditions, as well as in autoimmune diseases. The purpose of the review is to study the VD effects on the mechanisms of both innate and acquired immunity.

VD is a secosterol produced endogenously in the skin due to sunlight or obtained from the outside (food, drugs) [1–3]. In the human body, VD is hydroxylated. The first stage of hydroxylation occurs in the liver and converts VD to 25-hydroxyVD (25(OH) D), also known as calcidiol. The second stage of hydroxylation occurs mainly in the kidneys (with the participation of the enzyme CYP27B1 — α-hydroxylase), and its result is the synthesis of the physiologically active D-hormone, 1,25 dihydroxyVD ($1,25(OH)_2D$) [8]. The level of calcitriol in the blood is determined mainly by the activity of CYP27B1 in the kidneys and the action of parathyroid hormone, it is tightly regulated by negative feedback, which is closed by the inhibition of CYP27B1 by a high concentration of calcitriol itself and fibroblast growth factor 23. Stimulation of the CYP24A1 enzyme also acts as a limitation in the formation of the active form of the vitamin (24-hydroxylase), which converts calcitriol into an inactive, water-soluble form of calcitric acid, which is subsequently excreted from the body with bile [10]. Immune cells also express CYP27B1 and are able to convert a circulating in the 25(OH)D into $1,25(OH)_2D$ in an autocrine and paracrine manner. It is noteworthy that it is in immune cells such as macrophages and dendritic cells (DC), unlike kidney cells, that

there are no negative feedback mechanisms, which makes it possible to produce very high, but local concentrations of calcitriol for the needs of immunomodulation [11].

$1,25(OH)_2D_3$ exerts most of its biological effects through the activation of the nuclear VD receptor (VDR) transcription factor, which can lead to the activation of more than 1000 genes [12, 13]. In recent years, scientists have scanned parts of the human genes that mediate the action of VD. These regions, called VDRE (VD response elements), are adjacent to genes activated by the VDR protein complex [14].

Strong evidence from epidemiological data and laboratory and animal studies suggests that VD plays an important physiological role in the normal functioning of the immune system. The evidence to date shows that VD inhibits adaptive immunity but contributes to innate immunity. VD inhibits cell proliferation while stimulating cell differentiation. However, the mechanisms of VD action on the immune system and its therapeutic potential in pathology require further study. Prevention of VD deficiency helps not only to optimize mineral metabolism, but also to reduce the risk of the formation of many chronic diseases [15].

The key to the wide-ranging effects of VD is intracellular 1-α-hydroxylase, which is found in cells throughout the body. The exact role that VD plays in every cell is not yet clear, but researchers are working on possible mechanisms. There are two main effects of VD on immunity: increased immunity against antigens and modulation of the autoimmune response. These actions of VD are achieved through a variety of mechanisms. Below is a basic explanation of the mechanisms as we understand them today [16].

Liu et al. explained the mechanism of increased immunity against antigens [17]. They implemented a series of experiments on human macrophages and showed that 25(OH)D is converted intra-cellularly to $1,25(OH)_2D$ in response to the interaction of a Toll-like receptor with a bacterial antigen. This interaction activates the expression of 1-α-hydroxylase and cathelicidin genes. This results in increased production of cathelicidin, a bactericidal peptide, but only in the presence of 25(OH)D or $1,25(OH)_2D$. Cathelicidin is effective against bacteria and viruses [18] such as herpes simplex [19] and influenza [20]. They also showed a dose-dependent effect of 25(OH)D in human serum. Serum containing higher levels of 25(OH)D (mean: 78 nmol/L) doubled cathelicidin gene expression compared to serum with lower levels of 25(OH)D (mean: 22 nmol/L). This explains the use of circulating 25(OH)D for intracellular production of $1,25(OH)_2D$, so the person is not at risk of hypercalcemia due to high systemic levels of $1,25(OH)_2D$. When this intracellular mechanism is activated, the enzyme responsible for $1,25(OH)_2D$ catabolism is also activated, keeping the production and catabolism of $1,25(OH)_2D$ completely self-sufficient. This mechanism explains the role that VD may play in other types of cells. Other cells are likely activated by a stimulus and, in the presence of adequate 25(OH)D, express genes specific to that cell's function (e.g., T cells and cytokines).

VD prevents inflammation too much by blocking the interaction of immune cells through cytokines. VD immune suppression has opened up new possibilities for the therapeutic use of this substance and its analogs for the control of autoimmune diseases, presumably associated with cytokine overproduction. VD deficiency increases the risk of developing autoimmune diseases. Among such diseases are type 1 diabetes mellitus, multiple sclerosis, systemic lupus erythematosus, rheumatoid arthritis, chronic inflammatory diseases of the gastrointestinal tract. The anti-proliferative and differentiation-stimulating activity of VD suggested a role for this hormone in suppressing neoplastic processes (colon, breast, lung, pancreas, ovarian, prostate cancer) [21]. Considering the aforementioned intracellular 1-α-hydroxylase, the effect of VD on autoimmune disease occurs through several mechanisms, each of which is specific to the cell it targets. VD acts both directly and indirectly on several immune cells, including B and T lymphocytes, dendritic cells, and macrophages. T lymphocytes (T cells) play a central role in autoimmune diseases. When stimulated with such antigens as tumor cells or viruses they produce inflammatory cytokines IFN-γ, IL-2 and TNF-α. There are two types of T-helpers: Th1 and Th2. $1,25(OH)_2D$ directly suppresses proliferation of Th1 cells and decreases the production of their cytokines [22]. In mouse models, if VD is deficient or VDR is absent, Th1 effects are more pronounced [23, 24]. In vitro treatment with $1,25(OH)_2D$ suppresses Th1 cell production and promotes Th2 cell development [25]. The overall effect of T cells is to increase self-tolerance [26]. B lymphocytes (B cells) are also affected by VD. Cell cultures show some inhibitory effects of $1,25(OH)_2D$ and 25(OH)D on B cell responses, including proliferation, cell differentiation, and immunoglobulin secretion, especially IgG and IgM [27].

The effect of VD on innate immunity

The research was distributed roughly 25 years showing that $1,25(OH)_2D$ unequivocally stifles the multiplication of the irresistible microorganism *Mycobacterium tuberculosis* (M. tuberculosis) in human monocytes [28]. At that point, the physiological meaning of this was muddled. It was realized that patients with tuberculosis (TB) regularly had an overproduction of $1,25(OH)_2D$ [29]. Be that as it may, this was not at

first connected with the capacity of CYP27B1 monocyte movement to help intracrine killing of *M. tuberculosis*. Rather, helpful organization of $1,25(OH)_2D$ or engineered non-calcemic analogs $1,25(OH)_2D$ was relied upon to give the best channel to translational VD usage in patients with tuberculosis. Information from Liu et al. displayed interestingly that the localized synthesis of $1,25(OH)_2D$ by monocytes is a necessary piece of the normal innate immune function of these cells. Current works uncover in more detail the instruments by which calcitriol improves the antimicrobial impact of macrophages and monocytes, which are significant effector cells in the battle against microbes like *M. tuberculosis*.

Calcitriol builds the chemotaxis and phagocytic capacity of immune cells [11]. It should be noticed that VD likewise actuates qualities encoding endogenous antimicrobial peptides — catalicidin and defensin-2, which have antimicrobial action against numerous microscopic organisms, viruses and fungi [21]. Monocytes presented *to M. tuberculosis* show a solid acceptance of 1α-hydroxylase, or CYP27B1, and the VD receptor after acknowledgment of microbes by cost-like receptors, which prompts an adjustment of quality articulation for cathelicidin creation [17]. Notwithstanding cost-like receptor flagging, it was found that different cytokines like interferon-γ or IL-4 additionally influence the statement of CYP27B1 [30]. Human cathelicidin (hCAP18), which is divided from IL-37 (the 37-buildup dynamic cationic peptide) and is expanded in people in light of irresistible specialists. Its fundamental activity is the destabilization of microbial films, regarding which it has a lytic impact on microorganisms, viruses, and parasites [31].

In extreme diseases, the level of enrollment of granulocyte cells, for example, neutrophils is exceptionally high. Early discoveries recommended that neutrophils are the primary wellspring of cathelicidin, yet current proof debates this guarantee because, although neutrophilic granulocytes communicate VDR, they do not seem to have CYP27B1, which keeps them from changing 25(OH)D into a bioactive structure vital over to start articulation of the cathelicidin quality [32].

Research results show that VD status directs antimicrobial protein levels, which might assume a basic part in battling contamination. For instance, in cross-sectional research, the degree of 25(OH)D in ill patients with sepsis was fundamentally lower, and this is related to abatement in the grouping of the antimicrobial protein cathelicidin [33].

It is currently realized that LL-37 is not the main antibacterial objective for VD in monocytes. The other antibacterial protein, β-defensin 2 (DEFB4), contains VDRE in an advertiser locale correspondingly to LL-37 [34]. Late information has shown $1,25(OH)_2D$ -VDR acceptance of DEFB4 in mix with enactment of another record factor, NF-kB. Acceptance of NF-kB after treatment of monocytes with cytokines, for example, IL-1b [35] or as a result of motioning through the acknowledgment receptor of an intracellular microbe, non-large diabetic 2 (NOD2) [36], has been displayed to improve $1,25(OH)_2D$-intervened enlistment DEFB4. In addition, VD establishes a climate wherein monocytes kill microorganisms. Monocytes treated with $1,25(OH)_2D$ show an expanded degree of autophagy [37]. Autophagy and the development of related autophagosomes are significant as a system for the intracellular disconnection of microorganisms and their resulting destruction by antibacterial proteins [38]. VD-intervened enlistment of autophagosomes in monocytes is related to an expanded limit with respect to intracellular obliteration of *M. tuberculosis*, yet is intervened through an expansion in LL37 record [39]. Ensuing investigations have shown that steady with introductory investigations of LL-37 enlistment by intracrine *M. tuberculosis*, TLR2/1-intervened autophagy enlistment seems to include acceptance of 25(OH)D digestion by means of CYP27B1 [40], recommending that this system would likewise be strong relies upon changes in VD status.

In a new randomized controlled preliminary, VD3 supplementation of 100,000 IU month to month in 322 solid grown-ups did not diminish the rate of upper respiratory plot diseases [41], which might be because of the impediments of the exploration work, specifically the incorporation in the investigation of the individuals who had adequate blood VD level at pattern (mean 25(OH)D level 29 ng/ml). As opposed to this review, a randomized controlled preliminary involving invigorated milk in 247 Mongolian kids with extreme VD lack (standard mean 25(OH)D 7 ng/ml) recorded a huge decrease in the frequency of intense respiratory contaminations more than a 3-month follow-up period [42].

Notwithstanding the immediate battle against organisms, monocytes and other antigen-introducing cells (APCs) of natural resistance, specifically dendritic cells (DC), are significant focuses of the immunomodulatory activity of VD. APCs are answerable for starting a versatile insusceptible reaction by introducing antigens to T-and B-lymphocytes. They are additionally ready to adjust the resistant reaction by sending either an immunogenic or a tolerogenic signal utilizing cytokines and the statement of costimulatory atoms [43]. The consequences of different investigations have shown that calcitriol and its analogs can change the capacity and morphology of DCs to instigate their more tolerogenic, youthful state [44]. Youthful

DCs are portrayed by a lessening in the level of class II significant histocompatibility mind boggling and the outflow of k-animating atoms (CD40, CD80, CD86), which prompts a decline in antigen show, a reduction in IL-12 emission and an increment in the development of tolerogenic IL-10. Calcitriol represses T-cell cytokines, for example, IL-2 and IL-17, as well as cost can imagine receptors on monocytes [11]. The utilization of high dosages of calcitriol in sound individuals — 1 μg two times per day for seven days, prompts a huge diminishing in the degree of proinflammatory cytokines IL-6, orchestrated by fringe mononuclear cells. All things considered, the blend of this large number of impacts causes the acceptance of potential administrative T cells, which are significant for the control of the resistant reaction and the improvement of auto-reactivity [45].

Dynamic and local VD, calcitriol, and cholecalciferol are equipped for instigating tolerogenic properties in DCs since these cells likewise express the CYP27B1 catalyst. Articulation of this compound permits them to accomplish a high neighborhood convergence of dynamic types of VD, which are important for immunomodulatory activity. The aftereffects of in vitro examinations are additionally upheld by the consequences of studies on strains of mice taken out by the VDR and CYP27B1 qualities, showing a huge expansion in the quantity of mature DCs and impeded chemotaxis in them [11]. A new clinical review where 95 patients got high dosages of VD or fake treatment notwithstanding standard TB treatment showed a sped-up goal of fiery responses [46].

The effect of VD on adaptive immunity

VD has an improving impact on the working of vague protection instruments and versatile resistance. It is realized that, no matter what its inborn resistant action, VD can likewise go about as a strong controller of the versatile invulnerable framework [47]. One of the principal perceptions connecting VD to the versatile safe framework was that T cells and B lymphocytes (B cells) express VDR [48], with these levels expanding as T or B cells multiply. As a result, introductory investigations of the impacts of VD on T cells zeroed in on the capacity of 1,25(OH) $_2$D to stifle T cell multiplication [49]. Nonetheless, resulting studies have demonstrated that VD may likewise influence the aggregate of T cells, specifically by repressing Th1 cells, a subset of CD4+ effector T cells firmly connected with cell invulnerable reactions [50]. Alongside this, 1,25(OH) $_2$D has likewise been displayed to potentiate Th2 cell-related cytokines, a subset of CD4+ T cells related to humoral insusceptibility [51].

Also, ongoing works have affirmed the immediate impact of calcitriol on B-cell hematopoiesis, including hindrance of their separation into memory cells and plasma cells, as well as advancing apoptosis of immunoglobulin-delivering B-cells [11, 27]. Such control of B-cell initiation and expansion might be clinically significant in immune system illnesses since B cells that produce auto-reactive antibodies assume a significant part in the pathophysiology of autoimmunity.

Versatile insusceptible T cells are additionally perceived as a significant objective for the immune-modulatory activity of different types of VD. A new audit [52] proposed four expected instruments by which VD might influence T cell work: foundationally coursing calcitriol;

• direct, intracrine transformation of 25(OH)D to calcitriol in T cells;

• direct, paracrine impact of calcitriol on T-cells because of the change of 25(OH)D to calcitriol in monocytes or DCs;

• roundabout impact on antigen show to T-cells through nearby APCs animated by calcitriol.

Openness to VD prompts a change from a favorable to fiery to a more open-minded insusceptible status. Calcitriol represses multiplication and separation of Th and regulates their creation of cytokines [53]. Specifically, treatment of T cells with calcitriol or its analogs represses the discharge of pro-inflammatory cytokines Th1 (IL-2, IFn-γ, cancer rot factor α), Th9 (IL-9) and Th22 (IL-22) [11] and along with consequently advances the emission of mitigating Th2 cytokines (IL-3, IL-4, IL-5, IL-10) [51]. IL-17, which produces Th17 cells, is likewise impacted by VD. Hindrance of Th17 movement assumes a significant part in the treatment of immune system sicknesses, as has been displayed in a strain of mice with diabetes, however not stoutness (nOD, non-obese diabetic mice) [54]. As of late, it was found that calcitriol straightforwardly hinders the development of IL-17 at the degree of record of this cytokine; enacted human T cells presented to calcitriol emit essentially lower levels of IL-17, IFnγ and IL-21 [55].

VD and autoimmune diseases

World literature information demonstrates that the issue of VD lack is acquiring pandemic extents and matches with an expansion in the pervasiveness of immune system illnesses. Regardless of whether this reality demonstrates a causal connection between occasions involves broad discussion. A few immune system infections (various sclerosis, type 1 diabetes mellitus, fiery gut sickness, rheumatoid joint

inflammation) are occasionally and geologically reliant. Their commonness is higher in northern scopes and is contrarily relative to UV light, which may by implication show the investment of VD in the indication of these sicknesses [56, 57]. Consistently, a number of distributions given to the arrangement of VD in patients with immune system sicknesses, the impact of prophylactic admission of VD on the danger of pathology and remedial dosages of nutrients — on its course is developing. Right now, the relationship of VD lack with the advancement of immune system sicknesses, for example, type 1 diabetes mellitus, various sclerosis, rheumatoid joint pain, fundamental lupus erythematosus, foundational scleroderma, and incendiary gut illnesses are being examined [58].

Various examinations done in creature models have shown a conspicuous reduction in safe movement when VD or its metabolites are managed in mice with immune system illnesses [59]. Studies on patients with immune system issues have not found correspondingly precise sustained results. Specifically, in the survey articles by Kriegel et al. and Antico et al. committed to the examination of the degree of serum VD and its metabolites in various illnesses of immune system beginning, they got results are exceptionally heterogeneous, and on their premise, it is difficult to reach unambiguous inferences about the relationship of the centralization of VD in the blood serum with the event of immune system pathology [60, 61].

Hence, the clearest connection was viewed between VD lack and the advancement of type I diabetes mellitus and different sclerosis. In the main case, the degree of VD was lower in patients with an ineffectively controlled course of the sickness, ketoacidosis, arising nephropathy, and tubulointerstitial harm. In various scleroses, diminished levels of the VD metabolite have been related to moderate infection, expanded danger of repeat and inability. The connection between a reduction in VD levels and the improvement of sicknesses, for example, foundational lupus erythematosus, scleroderma, and Crohn's illness have been shown less convincingly. In rheumatoid joint pain, in the greater part of the investigations remembered for the evaluated audits, serum VD levels were not measurably altogether unique between the debilitated and sound gatherings. Simultaneously, a few creators show a constructive outcome of the presentation of a functioning metabolite of VD (alfa calcidiol) in the course of rheumatoid joint pain [62]. Patel et al. observed a solid reverse connection between gauge serum 25(OH)D levels in patients with recently analyzed rheumatoid joint pain (45% had a sickness history of under a year) and pattern illness movement (on the DAS28 infection action scale and wellbeing status poll) [24]. The expansion in 25(OH)D level for each 10 ng/ml was portrayed by an abatement in DAS28 by 0.3 and in the degree of C-responsive peptide by around 25%. Nonetheless, the plasma convergence of 25(OH)D did not associate with the presence of auto antibodies in rheumatoid joint pain.

The works committed to the investigation of the danger of creating immune system infections with prophylactic VD admission in adolescence are intriguing. Accordingly, Antico et al. leading a meta-examination, showed that the danger of type 1 diabetes mellitus is essentially lower in kids who involved VD in adolescence contrasted and youngsters who did not get it (all-out chances proportion 0.71, 95% certainty stretch 0.60–0.84 [61]. Likewise, the review showed the impact of the circumstance of VD supplementation on the occurrence of type 1 diabetes mellitus. Thus, the age time frame from 7 to a year is thought of as particularly good for the counteraction of the illness, since it is then that the development of obtained insusceptibility responses happens. It may be expected that other immune system infections are portrayed by a comparable reliance. This end could track down incredible reasonable application, particularly in pediatric practice. The found portion reliance on the impact of VD is additionally significant. Current proposals recommend an OK limit worth of 25(OH)D_3 in blood serum of something like 20 ng/ml. Simultaneously, an abatement in the level of the VD metabolite under 30 ng/ml animates the creation of parathyroid chemical by the parathyroid organs, which shows the inadequacy of the laid out "typical" level of VD [63, 64]. Furthermore, a new report showed that the support of the limit worth of serum 25(OH) D_3 degree of somewhere around 30 ng/ml is expected for the execution of the immune-regulatory work, which is accomplished while utilizing an everyday portion of VD of around 2000 IU [65]. The introduced information brings up the issue of the need to reconsider the Russian standards with respect to the suggested every day admission of VD. The importance of this issue is connected with the worldwide commonness of VD inadequacy, remembering for our country. As indicated by A. Hossein-Nezhad and M. Holick from 43 to 63 % of the populace in Russia has a serum 25(OH)D degree of under 20 ng/ml, which shows a lack of huge VD among Russians [58]. Additionally, a new multicenter study "Rodnichok" directed in Russia showed that VD levels ≥30 ng/ml happen in just 60% of kids matured 6 a year, under 30% of kids matured 2 years of life and just in 13% of offspring of the third year of life [66, 67]. Low serum 25(OH)D levels were additionally connected with more unfortunate visualization in patients with hematological malignancies, including

leukemia and lymphoma [68, 69]. Studies given in Central Kazakhstan show that plasma 25(OH)D degrees of yet untreated grown-up patients with various sorts of leukemia had a lack of VD (10.8±7.0 ng/mL) contrasted with a fringe adequate VD status (21.6±7.8 ng/mL) in paired solid volunteers ($p < 0.0001$) [70].

Subsequently, the elements of VD are different and diverse, and that implies that its inadequacy will influence the condition of numerous organs and frameworks of the body, including the insusceptible framework. In such manner, it is important to draw the consideration of scientists to the issue of standards concerning the suggested every day admission of VD for different geographic locales, particularly in the gathering of kids with a high danger of creating immune system sicknesses. Prophylactic admission of VD in portions satisfactory for the immune-regulatory capacity might add to a diminishing in the predominance of immune system infections or be an essential for a less articulated seriousness of the neurotic cycle.

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D дәрумені және оның адамның иммундық жүйесіне әсері

Мақалада адамның иммундық жүйесіне D дәрумені деңгейінің әсері туралы заманауи отандық және шетелдік зерттеулер ұсынылған. Иммундық жауаптарды реттеуге D витаминінің қатысуы туралы көптеген деректер келтірілген. Соңғы жылдары аутоиммунды аурулары бар науқастардың денесінде D дәруменінің жетіспеушілігі мәселесіне көбірек көңіл бөлінуде. Иммундық реттеудегі D дәруменінің маңыздылығын растау витаминнің төмен деңгейі мен әртүрлі инфекцияларға сезімталдықтың жоғарылауы, сондай-ақ вирустық, бактериялық және саңырауқұлақ этиологиясының инфекциялық процесінің белсенділігі арасындағы байланысты көрсететін көптеген эксперименттік зерттеулердің, клиникалық және эпидемиологиялық бақылаулардың нәтижелері болып табылады. D дәрумені В және Т лимфоциттері, дендритті жасушалар және макрофагтар сияқты иммундық жасушаларға тікелей және жанама әсер етеді. Сонымен қатар D дәруменінің әсерінен иммундық жауапты белсендірудің молекулалық механизмдеріне ерекше назар аударылған. D дәрумені өз әсерін D дәруменінің рецепторымен (VDR) байланыстыру арқылы көрсетеді, ол өз кезегінде басқа ақуыздармен бірге организмнің иммундық реакциясына қатысатын ақуыздардың гендерінің транскрипциясын белсендіреді. Осыған байланысты, әсіресе пандемия жағдайында D дәруменін күнделікті тұтыну нормалары мәселесіне зерттеушілердің назарын аудару қажет.

Кілт сөздер: D витамині, кальцитриол, D витаминінің рецепторы (VDR), туа біткен иммунитет, адаптивті иммунитет, аутоиммунды аурулар.

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Витамин D и его влияние на иммунную систему человека

В настоящем литературном обзоре представлены современные отечественные и зарубежные исследования, посвященные влиянию уровня витамина D на иммунную систему человека. Приведены многочисленные данные об участии витамина D в регуляции иммунных реакций. В последние годы все больше внимания уделяется проблеме дефицита витамина D в организме пациентов с аутоиммунными заболеваниями. Подтверждением значимости витамина D в иммунной регуляции являются результаты многочисленных экспериментальных исследований, клинических и эпидемиологических наблюдений, которые демонстрируют связь между низкими уровнями витамина и повышенной восприимчивостью к различным инфекциям, а также активностью инфекционного процесса вирусной, бактериальной и грибковой этиологии. Витамин D действует как прямо, так и косвенно на иммунные клеток, такие как В- и Т-лимфоциты, дендритные клетки и макрофаги. В обзоре особое внимание уделено молекулярным механизмам активации иммунного ответа под влиянием витамина D. Витамин D оказывает свой эффект посредством соединения с рецептором витамина D (VDR), который, в свою очередь, совместно с другими белками активирует транскрипцию генов белков, участвующих в иммунном ответе организма. В связи с этим необходимо привлечь внимание исследователей к проблеме норм суточного потребления витамина D, особенно в условиях пандемии.

Ключевые слова: витамин D, кальцитриол, рецептор витамина D (VDR), врожденный иммунитет, адаптивный иммунитет, аутоиммунные заболевания.

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