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Review Article

A review on relationship between serum Vitamin D levels and depression severity in young adults

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Abstract:

Depression is one of the most often occurring mental health problems that affect young people and can be detrimental to their lives, studies, and social. The main causes behind the occurrence are often a mix of biological, psychological, and environmental factors. Recently, scientists have started to investigate whether vitamin D, which mainly comes from sunlight and a few food sources, could be related to depression. Vitamin D plays a role in numerous brain functions, including brain maturation, nerve activities, and mood stabilization via neurotransmitters like serotonin.The aim of the study is to determine if young adults with varying degrees of depression also have varying blood levels of vitamin D. The study intends to gather and scrutinize data from earlier studies so as to determine whether low vitamin D causes being depressed worse or more like a case. A lot of studies found that people with less vitamin D tend to have bad depression. This might be because vitamin D helps calm down swelling and keeps your brain healthy.So, most signs point to low vitamin D being tied to worse depression. This study tries to show why keeping vitamin D levels up is good for mental health and pushes for more research to prove how vitamin D affects mood depression in young adults.

Keywords: Depression, Vitamin D, Young Adults, Mental Health , Serotonin, Serum Level, Neurobiology, inflammation.

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Introduction

Depression or major depressive disorder (MDD), is a widely experienced and severe mental disorder that involves constant feelings of sadness, loss of interest or pleasure, and inability to think clearly which incapacitate the person [1] It is one of the most common causes for being unable to work or study and thus is a major contributor to the global disease burden [2,3]. The Global Burden of Disease Study 2017 revealed that over 264 million people suffer from depression worldwide and still it is one of the primary causes of years lived with disability [4].

The period of transition from adolescence to adulthood, usually from 18 to 35 years, is very crucial as it is characterized by major changes in the areas of education, job and social life [5]. During this period, the likelihood of individuals getting mental health problems increases, with depression being the most common one [6]. The young adult population is often under great stress because of the high expectations in school, financial difficulties, problems in personal relationships as well as the uncertainty about career paths, and all these factors can bring about the symptoms of depression [7].

Moreover, even when patients have access to effective medical and psychological therapies, it is still the case that about a third of them do not go through with the full treatment and thus face the hardships related to chronic depression, difficulties in daily activities, and a higher risk of dying from suicide [8,9]. The World Health Organization (WHO) points out that one of the most effective ways to reduce depression's impact on individuals and the society, is through early identification and preventive measures among young adults [3]. Therefore, it is very important to know the biological and psychosocial risk factors that

can be changed during this sensitive period so as to improve treatment outcomes and support mental health.

The role of Vitamin D as a neurosteroid hormone

Vitamin D, which has been known for its important part in keeping calcium levels and bones strong, has also been classified as a neurosteroid hormone having considerable impact on the development and functioning of the brain [10]. Calcitriol (1,25-dihydroxyvitamin D_3) is the most active vitamin D and it has ability to penetrate the blood–brain barrier (BBB) and interact with the vitamin D receptors (VDRs) that are found throughout the brain including the hippocampus, prefrontal cortex, and hypothalamus [11]. This generalized distribution underlines the possibility of vitamin D affecting many neural activities such as neuroprotection, neurotransmission, and neuroimmunomodulation [12].

From a mechanistic view, vitamin D increases the activity of those genes that produce neurotrophic factors, e.g. nerve growth factor (NGF) and brain-derived neurotrophic factor (BDNF), both of which are equally important for the life of neurons and their connection through synaptic plasticity [13,14]. Besides, vitamin D action is reducing brain oxidative stress and inflammation by downregulating pro-inflammatory cytokines and upregulating the antioxidant defense systems in the brain [15]. All these mechanisms contribute to the maintenance of brain health and cognitive function.

A lot of research has demonstrated that low levels of vitamin D in the blood are linked to different mental disorders, the most important of them being depression, schizophrenia, and multiple sclerosis [16,17]. The neurosteroid effects of vitamin D are thus believed to be the means by which mood is regulated through the control of serotonin production, the activity of the dopamine system, and the hypothalamic–pituitary–adrenal (HPA) axis [18,19]. These findings suggest that lack of vitamin D could disrupt the neurochemical balance and consequently lead to increased susceptibility to mood disorders such as depression.

Proposed biological mechanisms in depression

Various biological mechanisms have been put forward to clarify the relationship between vitamin D and mood regulation as well as its role in the development of depression. Vitamin D has several neurobiological functions that affect both structural and chemical [10] brain processes.

Firstly, vitamin D had a say in the synthesis of neurotransmitters, mainly that of serotonin, by controlling the activation of tryptophan hydroxylase 2 (TPH2), which is the rate-limiting enzyme in the production of serotonin in the brain [18]. This control might have a direct influence on serotonergic transmission, mood stabilization, and cognitive performance. Vitamin D, on the other hand, does not only increase the production of serotonin through the brain-derived neurotrophic factor (BDNF) and the nerve growth factor (NGF) but also supports the development of the synapse [13,17].

Besides, vitamin D has anti-inflammatory properties and also modifies the immune response. It does this by blocking the secretion of such pro-inflammatory cytokines as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) and, on the other hand, it encourages the secretion of the anti-inflammatory cytokine IL-10. Thus, the release of neuroinflammation that is often connected to depression is reduced [15,20]. This anti-inflammatory effect might be one of the reasons the brain is able to withstand chronic activation of immune processes that are correlated with the symptoms of depression.

Vitamin D is a contributing factor to the regulation of the hypothalamic–pituitary–adrenal (HPA) axis, which is the main pathway in the human body for reacting to stress. The HPA axis dysregulation is one of the main characteristics of the major depressive disorder, and vitamin D might assist in correcting this imbalance through glucocorticoid receptor modulation [21]. Moreover, it has been established that vitamin D has a protective effect against neuronal death due to its ability to enhance glutathione production and diminish the level of reactive oxygen species that are increased in depression [12].

All these processes point in the direction that the lack of vitamin D might cause the disturbance of the neurotransmitter systems, neuroinflammation, oxidative stress, and the decline of the brain's ability to change and adapt all these being the essential elements of the biological theory of depression [22,19].

Review strategy

The review took a narrative synthesis route to evaluate the connection between the serum vitamin D levels and the degree of depression in young adults. A thorough search for literature published was done in the period January-February 2025 across the top scientific databases, namely PubMed, Scopus, Web of Science, ScienceDirect, SpringerLink, and Google Scholar. In order to achieve full coverage, manual searching of reference lists and patents was also carried out. The keywords used were combinations of: "vitamin D," "25-hydroxyvitamin D," "vitamin D deficiency," "depression," "depressive symptoms," "mental health," "young adults," "university students," "college students," "emerging adults," and "adolescents." Boolean operators ("AND," "OR") were employed to sharpen the search strategy.

The studies that were conducted included the criteria: (1) participants' ages were around 18-39 years; adolescents, young adults, or university students were the subjects;

(2) 25-hydroxyvitamin D [25(OH)D] levels were reported; (3) depression, depressive symptoms, or mental health outcomes were measured by validated scales (e.g., PHQ-9, CES-D, BDI, HADS, DASS-21); and (4) quantitative study designs like cross-sectional studies, randomized controlled trials (RCTs), cohort studies, genetic/Mendelian randomization analyses, or systematic reviews and meta-analyses for young populations were used. Animal studies, qualitative papers, case reports, conference abstracts lacking complete data, studies where vitamin D was not directly measured were among the exclusion criteria, as well as papers focusing on unrelated psychiatric outcomes.

Out of the screening process that included checking for relevance and duplication, a total of 35 studies were found to be relevant and eligible. The literature that was eventually included consisted of observational cross-sectional studies mostly, trials that were controlled and randomized that assessed the effects of vitamin D supplementation, huge datasets in epidemiology (like NHANES), studies that were using Mendelian randomization to evaluate genetic causality, and global multi-country student surveys. The main characteristics were extracted for each trial, which were study design, location, sample size, serum vitamin D measurement, depression evaluation tools, main statistical techniques, and main results. The data taken out were shown in tables and combined to show patterns that were typical for different methods.

Findings and Discussions

Statistical Methodologies in Cross-Sectional Studies

To ensure a precise interpretation of the data, Polak et al. (2014) utilized specific statistical methods to examine the correlation between serum vitamin D levels and depressive symptoms among 615 young adults in Dunedin, New Zealand. Multiple linear regression was employed to analyze continuous scores from the Center for Epidemiologic Studies Depression Scale (CES-D), while the likelihood of clinically significant depressive symptoms (defined as a CES-D score of 16 or above) was assessed using logistic regression. These two techniques allowed for the measurement of both the clinical presence and the symptomatic severity of depression. While logistic regression identified individuals crossing the clinical threshold, linear regression was instrumental in determining the rate of change in depressive symptoms relative to varying vitamin D levels [23].

These regression models were adjusted for several significant factors, including age, sex, body mass index (BMI), ethnicity, and time spent outdoors, to minimize bias and enhance the validity of the observed relationships. Such adjustments were necessary because these variables can

independently influence both vitamin D levels and mood. For instance, Jorde and Grimnes (2018) noted that sunlight exposure significantly affects serum vitamin D production, while demographic determinants like ethnicity and BMI are established factors influencing mental health outcomes [24].

The results of the analyses by Anglin et al. (2013) demonstrated an inverse relationship between vitamin D levels and symptoms of depression, showing that participants in the lower quartiles of vitamin D were more likely to have higher CES-D scores. The use of effect sizes and 95% confidence intervals allowed for a rigorous test of the strength and precision of these connections. Reporting such measures is considered a best practice in regression analysis, as it ensures transparency and clarifies the clinical significance of the statistical findings [25].

Black et al. (2014) focused on the association between vitamin D and mental health outcomes through a cross-sectional analysis of 735 young adults from the Raine cohort. In this study, negative binomial regression was employed—a method specifically suited for count-based and over-dispersed data, such as DASS-21 scores for stress, anxiety, and depression. Unlike Poisson regression, which assumes equal mean and variance, the negative binomial model adjusted for unobserved heterogeneity, providing more accurate rate ratio estimates. The inclusion of sex-stratified subgroup analyses and adjustments for BMI, age, and race further improved the explanatory power of the model and isolated the independent effect of vitamin D [32].

Almuqbil et al. (2023) examined the relationship between vitamin D deficiency and depression among 480 Saudi university students using a cross-sectional design. The researchers employed binary logistic regression, calculating Odds Ratios (ORs) to quantify the likelihood of clinical depression associated with low vitamin D levels after controlling for confounders identified in univariate studies. This approach is highly effective in health sciences for interpreting clinical risk in a practical setting [33].

Kouider et al. (2019) conducted a cross-sectional study involving 699 college students from 39 countries to investigate the prevalence and association between vitamin D levels and depression. To test group differences and identify how specific vitamin D categories manifest depressive symptoms, the study primarily utilized Chi-square tests. While this non-parametric approach is effective for measuring associations between categorical variables in epidemiological research, the authors noted that Chi-square analysis does not determine the strength or directionality of these connections. They suggested that the results could have been reinforced with effect size measures such as Cramer's V or the phi coefficient, and that future studies should utilize multilevel or hierarchical modeling to better account for inter-country and cultural variability [34].

Chen et al. (2020) estimated the correlation between serum vitamin D and depressive symptoms among 2,708 young adults using a cross-sectional design. The study employed multiple linear regression, an approach suitable for continuous dependent variables, allowing researchers to assess the relationship between vitamin D and depression while eliminating confounders such as age, gender, BMI, and socioeconomic status. Interaction terms were also evaluated to identify effect modification among subgroups. While the inclusion of standardized coefficient and confidence limits provided clear signs of the strength and reproducibility of these relations, the authors suggested that longitudinal path analysis or structural equation modeling (SEM) would be more efficient in capturing complex mediation and time-based interplay [35].

Alqahtani et al. (2023) applied a cross-sectional correlational method to determine vitamin D deficiency prevalence among 360 medical students. The major statistical analyses included Chi-square testing for categorical associations and logistic regression for adjusted risk estimation. By adjusting for factors such as age, gender, and lifestyle choices, the researchers calculated the relative risk of depression for students with low vitamin D levels. While the succession of categorical and regression analyses is statistically valid, the researchers noted that logistic regression assumes linearity in the logit; thus, future work might consider generalized additive models (GAMs) to explore potential nonlinear structures [36].

Yılmaz and Demir (2020) utilized descriptive cross-sectional methods to examine the undergraduate population, employing ANOVA and independent samples t-tests to compare mean depression rates across groups with different vitamin D levels. These parametric tests are appropriate for continuous data when assuming equal variance and normal distribution. Although group comparisons are advantageous for initial exploration, the authors highlighted that adding multiple regression or ANCOVA to the model would provide a better interpretation by controlling

for age, sex, and sun exposure as potential confounding factors [37].

Tuna et al. (2019) scrutinized the link between depressive symptoms and serum vitamin D levels among Turkish university students using Pearson correlation and independent t-tests. Given the assumptions of linearity and normality, Pearson's correlation was used to evaluate the direction and strength of associations. Additionally, binary logistic regression was performed to ascertain predictors of clinically significant depression while accounting for physical activity and academic stress. The study recommended that hierarchical regression be applied in subsequent studies to uncover the added influence of vitamin D over various psychosocial variables [38].

Asdaq (2018) utilized a cross-sectional design with 328 university students to investigate the link between vitamin D deficiency and depression. The study compared prevalence and vitamin D status through Chi-square tests, while independent samples t-tests were applied to demonstrate symptom intensity differences between deficient and sufficient groups. Furthermore, a binary logistic regression analysis yielded interpretable depression odds ratios while controlling for age, gender, and lifestyle factors. By integrating descriptive, bivariate, and multivariate methods, the study provided a comprehensive evaluation of vitamin D as a predictor of depression in this population [45]. Khan et al. (2022) conducted a cross-sectional study investigating the connection between vitamin D and depression in a sample of 200. The researchers summarized vitamin D levels and BDI scores using descriptive statistics, including mean, standard deviation, and coefficient of variation. To test group differences, independent samples t-tests were applied, which suggested significant associations between the variables [46].

Anuroj (2022) utilized a cross-sectional approach to determine the relationship between vitamin D concentrations and depression among 99 Thai medical students. Subgroup comparisons, such as Year 4 versus Year 5 students, were conducted using independent samples t-tests, while Pearson correlation assessed the linear relationship between vitamin D and PHQ-A depression scores. These approaches are suitable for continuous data, providing initial evidence of possible associations [47]. Furthermore, through linear regression analysis and after controlling for confounders such as perceived stress and lifestyle factors, the independent impact of vitamin D on depression ratings was tested. The researcher noted that due to the nesting structure of students within academic years, future work should employ hierarchical or multilevel regression to ensure more accurate and generalizable findings.

Suhag et al. (2021) applied a statistical methodology that allowed for a systematic examination of vitamin D differences across demographic groups using traditional methods of inference. Descriptive statistics formed the groundwork for understanding serum 25(OH)D distribution among young medical students. The authors explored the prevalence of deficiency in relation to gender and lifestyle through Chi-square and Fisher's exact tests, the latter of which was used to prevent the violation of assumptions in cases of small cell counts. Additionally, independent t-tests and a one-way ANOVA were performed to compare mean vitamin D levels, assuming a normal distribution and equal variances. By setting the significance level at $p < 0.05$, the relationships were detected according to established academic norms [48].

Callegari et al. (2015) determined that vitamin D significantly impacts the psychological well-being of young women. Their cross-sectional research in the Safe-D cohort showed that serum 25-hydroxyvitamin D concentrations varied significantly and corresponded with fluctuations in self-reported anxiety and depression. Despite residing in a sunny region, this group frequently exhibited deficiency. Correlation studies linked higher depressive scores to decreased vitamin D levels, and regression models, adjusted for sun exposure, physical activity, and BMI—strengthened the validity of this link. The results suggested that vitamin D is involved in emotional functioning separately from other behavioral or physiological factors [59].

Hassan (2019) investigated vitamin D insufficiency patterns among university students in the UAE using both descriptive and inferential methods. Comparisons of deficiency rate distributions across academic year, gender, and study programs were carried out using Chi-square testing. This analytical approach presented a profile of students most at risk and was suitable for categorical associations. Although the cross-sectional design limited causal conclusions, the consistent application of the $p < 0.05$ threshold ensured clarity in declaring that vitamin D deficiency is associated with specific socio-demographic and academic factors [51].

Kwasky and Groh (2012) performed a thorough analysis of the correlation between vitamin D and depression intensity in young women using t-tests and Pearson correlations. By measuring linear

relationships between serum 25(OH)D and BDI scores, the authors presented effect estimates that surpassed simple categorical comparisons. Independent t-tests provided further subgroup insights by differentiating mean differences across racial categories (e.g., comparing Black and White student populations) and between depressed and non-depressed individuals. The calculation of Cohen's d provided interpretative value by characterizing the practical significance of these group differences, substantiating the correlation between vitamin D and mental health in young females [52].

Despite these methodological strengths, Schober et al. (2018) emphasized that the cross-sectional nature of such studies limits the ability to establish causality. While regression models identify correlations, they cannot determine if depression leads to decreased vitamin D due to behavioral changes—such as reduced sun exposure or dietary shifts—or if low vitamin D levels actively drive the development of depressive symptoms [26].

Longitudinal and Repeated-Measures Study Designs

To address these temporal limitations, West et al. (2014) utilized a repeated-measures longitudinal approach to investigate the relationship between depressive symptoms and serum vitamin D among 185 healthy undergraduate women. By measuring CES-D scores on a weekly basis, the researchers gathered a high density of observations per participant. To account for this data structure, mixed-effects and repeated-measures designs were adopted, as these are uniquely suited to handle correlated data points across time within individuals [27]. This design allowed for the differentiation between within-subject changes and between-subject differences in average vitamin D levels.

To assess the dynamic nature of mood, Singer and Willett (2003) utilized linear mixed-effects models to evaluate weekly CES-D scores, adjusting for critical confounding variables such as BMI, season, and other relevant covariates. Their methodology integrated both random and fixed effects, where random effects accounted for individual differences in baseline depression and progress over time, while fixed effects characterized the overall relationship between vitamin D and depressive symptoms. By accounting for intra-individual correlations and effectively managing missing data challenges common in longitudinal psychological research this modeling approach provided results that were more accurate and generalizable than those derived from traditional OLS regression [28].

Kerr et al. (2015) combined logistic and linear regression with mixed-model analysis to examine the occurrence of clinically significant depression (CES-D > 16). These models estimated the likelihood of depressive symptomatology across various vitamin D levels after adjusting for significant confounders. This dual statistical approach allowed for a comparison between mixed-effects models, which identified temporal variations within individuals, and regression models, which determined overall population relationships, thereby enhancing the internal validity of the findings [29].

The application of mixed-effects analysis, repeated measures, and regression provided a robust analytical framework for evaluating longitudinal mental health data. As noted by Jorde and Grimnes (2018), these methods are regarded as best practices in clinical studies because they partition intra- and inter-individual variability and account for seasonal and biological fluctuations, leading to less biased estimations of relationships that change over time [30].

Prospective Observational and Athlete-Focused Studies

In a prospective observational design, Tomlinson et al. (2021) investigated the link between vitamin D and depressive symptoms in 51 collegiate athletes using pre- and post-season measurements. The researchers applied paired-sample t-tests to compare dependent data from the same subjects across distinct time points, identifying significant mean differences in mental health status. Additionally, Pearson correlations were used to determine the strength of the linear association, while simple linear regression evaluated the predictive capacity of vitamin D levels. While these techniques provided an in-depth depiction of cross-variable relationships, the authors noted that internal validity might have been limited by insufficient controls for sunlight exposure

and physical activity [31].

Randomized Controlled Trials and Intervention Studies

Choukri et al. (2018) evaluated the impact of vitamin D3 supplementation on healthy adult women through a double-blind, placebo-controlled, randomized clinical trial. Depression and mood outcomes were analyzed using ANCOVA, which accounted for intervention and placebo groups by adjusting for pre-treatment scores and confounders like BMI and ethnicity. In experimental designs where reducing error variance is critical, ANCOVA offers high statistical power for detection. The researchers further explored the 6-month intervention outcomes using mixed-model linear regression with time-by-treatment interactions. Mixed-effects models are the preferred choice when outcome data is measured repeatedly, as they account for both fixed effects (treatment) and random effects (individual variability) while handling missing data more robustly than a typical repeated-measures ANOVA. This combined analytical approach ensured that baseline differences and repeated measures were effectively controlled, providing a comprehensive view of vitamin D's effect on mental health [39]. The combination of ANCOVA and mixed models ensures that all confounders, baseline differences as well as repeated measures are controlled for. Future studies could boost precision even more by the use of hierarchical modeling for any clustering effects, such as the recruitment of individuals from different study locations.

Dean et al. (2011) tested the effects of vitamin D on healthy young adults through a randomized, placebo-controlled, double-blind study. The researchers utilized mixed-effects modeling, which is particularly suited for repeated-measures designs as it accounts for both random effects (individual differences) and fixed effects (treatment groups). This methodology robustly managed missing or imbalanced data, a common issue in longitudinal trials. Furthermore, an Intent-to-Treat (ITT) analysis was applied to minimize dropout bias and maintain the benefits of randomization. Secondary analyses further emphasized the importance of assessing continuous predictors alongside categorical variables to understand the relationship between serum vitamin D variations and depression scores [43].

In a triple-blind, randomized, placebo-controlled trial, Tirani et al. (2024) assessed the influence of vitamin D supplementation on migraine-related depression. Baseline comparisons were established through independent samples t-tests and Pearson's chi-square tests, matching the continuous and categorical nature of the data. A repeated measures approach, utilizing paired-sample t-tests, was used to evaluate within-group changes over time. Additionally, the researchers adjusted for baseline scores and concomitant medication using ANCOVA, which reduced error variance and gained statistical power. The ITT analysis preserved the validity of the originally randomized samples, allowing the investigators to effectively analyze both longitudinal changes and between-group differences [44]. Kusmiyati et al. (2020) applied linear regression in a randomized controlled study to evaluate the relationship between vitamin D levels and academic stress. This approach provided a measure of how much psychological stress change is predicted by vitamin D supplementation after adjusting for covariates such as baseline stress and demographics. The use of regression modeling allowed for the assessment of both group differences and effect magnitude, aligning with the modern psychological research paradigm that shifts focus from simple mean comparisons to effect measurement. The results suggested that vitamin D status plays a role in a student's capacity to withstand stress during high academic loads [50].

Advanced Statistical Approaches and Interaction Analyses

Yamashita et al. (2025) performed a more complex statistical analysis to capture the biological and psychological diversity of mental health outcomes. The researchers selected between t-tests and Mann-Whitney U tests based on data normality as supported by Shapiro-Wilk analyses, ensuring that group comparisons were statistically valid regardless of distributional assumptions. The predominant analytical approach was the Classification and Regression Tree (CART), which revealed multilevel interactions among predictors like serum vitamin D, loneliness, sleeplessness, and social jetlag. This hierarchical method allowed the study to reveal combinations of risk factors that conventional regression might overlook, proving that vitamin D insufficiency—when

interacting with psychosocial factors, that is a superior predictor of mental suffering compared to single-variable approaches [49].

Ma et al. (2023) expanded on these findings by applying weighted logistic regression to determine odds ratios, which illustrated the prevalence of depression across different vitamin D categories. This methodological choice enabled the estimation of the independent effect of vitamin D deficiency while simultaneously controlling for lifestyle and demographic factors. The researchers highlighted that continuous and categorical regression analyses provide complementary insights into the probability and severity of depressive outcomes. They noted that future studies utilizing multilevel modeling could further improve precision by addressing clustering effects across geographic or demographic strata [41].

Zhu et al. (2019) utilized a multistep statistical method incorporating regression, correlation, and mediation analysis. Pearson correlations initially established the relationships between vitamin D, total intracranial volume (TIV), and depression ratings. Linear regression was then applied to clarify if vitamin D exerted an effect on depression independent of TIV. Crucially, mediation analysis with bootstrapping provided strong support for the hypothesis that brain volume acts as a mediator in the relationship between vitamin D and depression. Bootstrapping increased the reliability of these findings by providing confidence intervals for indirect effects without relying on strict normality assumptions, supporting a neurobiological interpretation of the data [57].

Categorical Analyses and Demographic Stratification

Vinod et al. (2025) employed Chi-square and Fisher's exact tests to track vitamin D deficiency trends among depressed populations by demographic categories. These tests determined whether categorical distributions for depression severity levels were significantly different. The application of Fisher's exact test ensured trustworthy inferential findings despite potential cell-size limitations. The finding that deficiency is specifically related to the severity of ICD-10 depression, independent of sociodemographic factors, suggests a biological link that reinforces the therapeutic importance of vitamin D monitoring [53].

Ozkayar (2014) provided a significant analysis of the connection between depression and vitamin D insufficiency in kidney transplant patients, a group vulnerable to metabolic instability and chronic inflammation. Participants were divided based on their HADS-D scores, revealing clearly lower vitamin D levels in the group at risk for depression. Pearson correlation showed a moderately significant negative correlation ($r = -0.365$) between vitamin D and symptom severity. Given that renal transplant recipients often have impaired vitamin D metabolism, these results suggest that regular evaluation of vitamin D could be vital for early risk identification in medically complex patients [60]. Morales-Suárez-Varela et al. (2025) utilized survey-weighted logistic regression to represent national prevalence trends accurately in a large cross-sectional study. This method is critical for large cohort studies as it accounts for sample design and applies weights to obtain population-level estimates. The study initially used Chi-square testing to compare the prevalence of depression across different categories of fish intake and nutritional variables. By reducing confounding through logistic regression models—which included adjustments for BMI, physical activity, stress, and demographics Morales-Suárez-Varela et al. (2025) enhanced the strength of their causal inference. This thorough modeling method allowed the scientists to ascertain whether eating patterns predicted depressive symptoms independently of lifestyle factors, aligning their statistical approach with the established criteria of nutritional epidemiology [56].

Anaswaradev et al. (2025) provided powerful evidence from a community population in India aged 18 to 49. Testing via Chi-square showed that depression was significantly more prevalent in individuals with low vitamin D3 levels. This connection remained strong after sociodemographic variables were controlled for through logistic regression, which indicated that the probability of depression more than doubled with vitamin D3 insufficiency. These findings are particularly significant in regions like India, where cultural dressing restrictions or diet may lead to widespread deficiency despite high levels of sunlight [63].

Genetic and Causal Inference Studies

To address the limitations of observational data, Lyu et al. (2025) utilized genetic instrumental

variables, specifically single nucleotide polymorphisms (SNPs), in a two-sample Mendelian Randomization (MR) investigation. Unlike traditional studies prone to confounding and reverse causation, MR capitalizes on the random allocation of alleles to provide a stronger basis for causal inference. The study employed Inverse Variance Weighting (IVW) to merge causal estimates from multiple genetic instruments, alongside sensitivity analyses such as weighted median and MR-Egger regression to detect and adjust for pleiotropy. These various MR techniques effectively tackled potential biases, yielding support for a causal link between vitamin D exposure and depression risk [42].

Evidence Synthesis, Meta-Analyses, and Systematic Reviews

Menon et al. (2019) summarized effect size outcomes, including ORs, RRs, and correlation coefficients, by combining several primary research works in a narrative review. This methodological analysis highlighted how the interpretation of findings can be influenced by the presence or absence of confounder adjustments. For instance, the review noted that logistic regression models often reveal stronger associations post-adjustment for BMI, lifestyle, and seasonal variations. This approach emphasizes that evidence synthesis must be based on an understanding of statistical validity and the risk of bias across different literatures [54].

Wang et al. (2025) utilized Weighted Mean Difference (WMD), Standardized Mean Difference (SMD), and meta-regression methods for an extensive meta-analysis. By synthesizing various trials, the authors evaluated the impact of vitamin D on depressive symptoms, utilizing chi square tests to ensure reliable model selection between fixed and random effects. Subgroup analyses and meta-regression solidified the results by identifying factors like intervention duration and comorbidities. The robustness of the methodology was further supported by Egger's test and trim-and-fill methods to detect publication bias, concluding that vitamin D treatment significantly reduces the severity of depressive symptoms [55].

Nguyen et al. (2025) performed two meta-analyses: one for dichotomized deficiency results and another for continuous vitamin D levels. This distinction facilitated a deeper understanding of both the risk of developing depression and the severity of symptoms. Standardized effect sizes were computed using RevMan, and heterogeneity was assessed via I^2 statistics. The researchers demonstrated a commitment to evidence certainty by employing the GRADE approach and the Newcastle-Ottawa Scale to assess study quality. Their methodologically sound approach supported strong conclusions regarding the link between vitamin D and depression in adolescent and young adult populations [58].

Roșian et al. (2025) provided a thorough synthesis of evidence across various study designs, narrowing approximately 14,000 records down to 70 pertinent studies. Their qualitative synthesis showed that while cross-sectional research consistently revealed inverse relationships, cohort and interventional trials yielded more inconsistent results. Due to this high diversity in data, the authors chose a narrative synthesis over a meta-analysis. A major finding was that vitamin D supplementation appeared to benefit depressive symptoms specifically in individuals who were deficient at baseline [61].

Callegari et al. (2017) further investigated the Safe-D cohort with a sample of 468 participants. Bivariate correlations showed that anxiety and depression scores negatively correlated with vitamin D levels. By conducting multivariable regression modeling, the authors adjusted for an extensive range of variables including BMI and seasonal variation. The persistent significance of vitamin D after these adjustments points toward a biological influence on mood regulation [62].

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Table 1 summarizes the key statistical methods used in the literature, highlighting a shift from simple bivariate correlations to more complex adjusted regression models and Mendelian Randomization.

Table 1: Summary of Study Designs and Statistical Methodologies in Research on Vitamin D and Depressive Symptoms.

Study (year)	Design & sample	Key statistical methods used	Reference
Polak et al. (2014)	Cross-sectional, community sample of n = 615 young adults, age 17–25.	The statistical methods of multiple regression and logistic regression which are adjusted models were employed. The linear models to predict CES-D which is a continuous variable taking into account different factors like age, sex, BMI, ethnicity, and time outdoors; logistic regression for CES-D ≥16 were adjusted by vitamin-D quartiles, the effect sizes and their corresponding 95% CIs were also reported.	[23]
Kerr et al. (2015)	Repeated-measures in sample of 185 healthy young women which are undergraduates; baseline and weekly CES-D across term.	The first method used was Multiple Regression, which was specifically a temporal prediction model. Then, Chi-square tests were applied to see if there were any differences in the incidence of clinically significant depressive symptoms CES-D-16 between the groups of Vitamin D sufficient and insufficient. An analysis of variance (ANOVA) was used to test for seasonal differences in symptoms. The models took into account confounding factors such as season, BMI, race/ethnicity, diet, exercise, and time spent outdoors.	[29]
Tomlinson et al. (2021)	Prospective observational in sample of 51 collegiate athletes preseason and postseason measurements.	Paired comparisons and correlation, the application of paired t-tests which pre versus post, calculation of Pearson correlations between vitamin-D and CES-D, and performing a simple linear regression to investigate the relationships; the authors also provide descriptive statistics and significance tests for the pre or post changes reported.	[31]
Black et al. (2014)	Cross-sectional analysis from the Raine cohort which involve the sample of 735 young adults	Negative-binomial regression has been utilized in the modeling of DASS-21 scores which are count-type and over-dispersed, and the following variables were taken into account: age, race, BMI, and physical activity; subgroup which is sex-stratified analyses provided rate ratios (RR) with corresponding 95% confidence intervals (CIs).	[32]
Almuqbil et al. (2023)	The researchers performed a cross sectional comparative study from March to May 2021 in a Riyadh university in Saudi Arabia.They included 480 students, with 287 (59.79%) diagnosed with vitamin D deficiency.	The statistical analyses covered univariate descriptive statistics that were used to create a profile of the participants and their characteristics, binomial regression analyses that were performed to get odds ratios for the links between vitamin D deficiency and depression, anxiety, and stress with ORs and 95% CIs reported and a significance level ($p < 0.05$) that was used to find out if there were significant differences in the prevalence of psychological burden between the two groups which is deficient and non-deficient that considered statistically significant or not.	[33]
Kouider et al. (2019)	Multinational cross-sectional study in sample of 699 university students from 39 countries.	Chi-square test for group comparison and prevalence difference analysis with p-value testing.	[34]
Chen et al. (2020)	Cross-sectional study in sample of 327 Black & White young adults	The study applied multiple linear regression to assess continuous associations and stratified regression analyses to test for moderation by race and sex, adjusting for confounders such as BMI and physical activity.	[35]

Alqahtani M (2023)	Cross-sectional study among medical university students in Jazan, Saudi Arabia.	The authors used bivariate correlation to assess the relationship between vitamin D and DASS-21 scores and multivariate logistic regression to identify independent predictors of depression after adjusting for lifestyle variables.	[36]
Yılmaz et al (2020)	Cross-sectional study among 100 Turkish university students.	The study used descriptive statistics for vitamin D distribution, chi-square tests for categorical comparisons, and simple linear regression to examine the relationship between vitamin D levels and mental health indicators.	[37]
Tuna et al. (2019)	Cross-sectional study of 126 female university students in Turkey.	The researchers implemented Pearson correlation analysis to determine associations between vitamin D and BDI scores and independent sample t-tests to compare mean depression scores across vitamin D status groups.	[38]
Choukri et al . (2018)	Double-blind, placebo-controlled, randomised clinical trial.152 Healthy adult women aged 18–40 years were randomised into a vitamin D_3 supplementation group (n = 76) or placebo (n = 76) for 6 months.	ANCOVA was used to compare the effects depression, anxiety, flourishing, positive or negative mood across different groups at the study's end while controlling for initial measurements and covariates are age, ethnicity, BMI, recruitment wave, and mixed-model linear regression which includes time versus treatment interaction was implemented to analyze the changes over time.	[39]
Ganji et al. (2010)	Cross-sectional study taking data from the Third National Health and Nutrition Examination Survey (NHANES III) (1988–1994). The specific sample included a subpopulation approximately 7970 of young adults aged 20-39 years.	The main method used was weighted logistic regression, which is commonly used to deal with the complex survey design of NHANES and to provide population estimates. This method was applied to the serum 25-hydroxyvitamin D concentrations analyzed either by quartiles or deficiency categories in relation to depression status as per the CIDI-DSM-III-R criteria to estimate the Odds Ratios (ORs). Numerous confounders were included in the models such as age, sex, race/ethnicity, BMI, smoking status, poverty-to-income ratio, and physical activity.	[40]
Ma et al. (2023)	Cross-sectional study using NHANES data (2007–2018) in a large, nationally representative sample of young adults in the US population.	The assessment of the constant inverse relationship between the serum 25-hydroxyvitamin D level and the severity of depression scores was done using the weighted multiple linear regression technique. A weighted logistic regression model was applied subsequently to calculate Odds Ratios (ORs) for depressed patients, a binary outcome will come out based on the categories of Vitamin D status while taking into account the complex design of the survey and controlling for a range of demographic and lifestyle confounding factors.	[41]
Lyu et al. (2025)	Two-Sample Mendelian Randomization (MR) Study. In this method, genetic variations which are Single Nucleotide Polymorphisms (SNPs) linked to serum vitamin D levels are employed as instrumental variables. The source of sample data for analysis are from extensive genome-wide association studies (GWAS) that have public results available. The genetic dataset utilized to estimate vitamin D levels generally consists of over 400,000 subjects, thus offering considerable statistical power and representation at the population level.	Mendelian Randomization (MR) is the main method used and It utilizes the instrumental variables (SNPs) associated with Vitamin D to identify a cause-and-effect relationship. Inverse Variance Weighting (IVW) is the most important MR technique applied for merging causal predictions from every genetic variant. MR-Egger and Weighted Median are utilized as sensitivity checks to uncover and adjust for breaches of MR assumptions such as pleiotropy, in which a gene affects both Vitamin D and depression via distinct paths.	[42]

	Major Depressive Disorder (MDD): More than 480,000 people from the Psychiatric Genomics Consortium. The focus of the analysis is the genetic connection, which is generally separated from age or sex distribution; the data source contains a wide adult population but still includes the 15 -19 age range.		
Dean AJ et al . (2011)	Double-blinded, placebo-controlled randomised trial. Sample of 128 healthy young adults recruited, randomized to either vitamin D (n=63) or placebo (n=65).	Mixed-effects modeling. The treatment outcomes were assessed through this analytical approach as the primary analysis such as emotional functioning score changes by taking time and treatment group as fixed effects. Intention-to-Treat (ITT) Analysis: It was the primary method that was used, including all randomized participants irrespective of their completion. Secondary Analyses: The impact of the change in 25-hydroxyvitamin D level on outcomes was assessed and a subgroup analysis was also carried out on the participants whose baseline was below the median.	[43]
Tirani et al. (2024)	Randomized, Triple-Blind, Placebo-Controlled Trial. Sample of 72 adult patients diagnosed with Migraine Headache. The mean age of the participants was 37.46± 8.32 years.	Independent Samples t-test and Pearson's Chi-square test which compares baseline characteristics. Paired Sample t-test which analyzes within-group changes. ANCOVA (Analysis of Covariance) evaluated differences between groups intervened by and placebo, controlling baseline values and medication covariates such as tricyclic antidepressants. An intention-to-treat (ITT) analysis also was done.	[44]
Asdaq et al. (2018)	Cross-sectional study. Sample: n = 328 Al-Maarefa University students includes males and females in Riyadh, Saudi Arabia. University students are a core young adult population.	Chi-square Test is applied to assess the distribution of students suffering from depression (BDI-II ≥ 14) in various categories of Vitamin D status. Independent Samples t-test is employed to evaluate the difference in average BDI-II scores between the groups (e.g., deficient vs. sufficient). Binary Logistic Regression is employed to deduce the Odds Ratio (OR), evaluating the independent risk of having depression in a case of being Vitamin D deficient, while controlling for demographic factors.	[45]
Khan et al. (2022)	A descriptive cross-sectional design was employed to examine the relationship between vitamin D levels and depression in 200 participants which involve 100 depressed outpatients and 100 healthy controls. Participants were further stratified into three age groups: ≤20 years, 21–60 years, and ≥61 years.	The Beck Depression Inventory (BDI) was used for the evaluation of depression, while the serum concentration of 25-hydroxyvitamin D was determined. The application of statistics was mainly through descriptive methods, which included the calculation of the means, standard deviations, standard error of the mean, and coefficients of variation for vitamin D levels, age, and BDI scores across various groups. The evaluation of significance between the groups was done through p-values, with a threshold of $p < 0.05$ that showing statistically significant results. The authors of the study did not employ multivariable regression or any other modeling approaches, so the links between vitamin D and depression mentioned were not corrected for potential confounders such as gender, body weight, or lifestyle.	[46]
Anuroj (2022)	Cross-sectional study. A sample of 99 Thai medical students which is Year 4 and Year 5 from Srinakharinwirot University Hospital. Participants had no diseases associated with Vitamin D deficiency and had not taken Vitamin D supplements in the past year. The study was conducted during the COVID-19 pandemic. 63 female and 36 male medical	Independent Samples t-test was utilized for comparison of mean Vitamin D levels between different groups, for example students in Year 4 versus those in Year 5. Pearson Correlation Analysis was undertaken to investigate the direct linear relationship that exists between Vitamin D level and PHQ-A score. Linear Regression Analysis was used. By means of this analysis, the independent association of Vitamin D level with PHQ-A score was evaluated after controlling for confounders, with the focus specifically on total perceived difficulties score.	[47]

	students participated.		
Suhag et al. (2021)	Cross-sectional study conducted among 100 healthy MBBS medical students aged 18–25 years at Liaquat University of Medical & Health Sciences, Jamshoro, Pakistan.	Statistical analysis was carried out using SPSS version 20.0. Data were summarized using descriptive statistics. The chi-square test and Fisher's exact test were employed for categorical variables, and independent t-test was used for the comparison of mean serum 25-hydroxyvitamin D levels between male and female students. One-way ANOVA was applied for comparison among more than two groups. The level of significance for statistical tests was set at $p < 0.05$.	[48]
Yamashita et al. (2025)	Cross-sectional research was conducted with 224 Japanese female university students who are nursing undergrads from two universities located in Nagasaki Prefecture and the final sample was composed exclusively of 224 participants.	The connection between vitamin D deficiency and mental issues was examined by means of different statistical methods by the researchers among Japanese female university students. Initially, descriptive statistics were used for the purpose of summarizing the characteristics of the participants, and then the Shapiro–Wilk test followed up to check the normality of the data. Depending on the distribution, either independent t-tests or Mann–Whitney U tests were performed to compare the continuous variables, while Fisher's exact test was utilized for the categorical data. The Classification and Regression Tree (CART) analysis was the most significant method of the analysis that successfully identified the factors like vitamin D levels, insomnia symptoms, loneliness, and social jetlag that together indicated a mental health problem ($K6 \geq 5$). By this approach, it was possible to show the interactions between the biological and psychosocial variables, thus giving a deeper understanding into the factors that influence the students' mental health. A significance level of $p < 0.05$ and a 95% confidence interval were set to eliminate any uncertainty and to define the statistical relevance and accuracy.	[49]
Kusmiyati, Y. et al. (2020)	Randomized Controlled Trial (RCT). The study population consisted of midwifery students residing in the Health Polytechnic dormitory, Ministry of Health, Yogyakarta (2017). Sample size: n = 77 students without chronic diseases and or pre-existing academic stress.	Researchers used linear regression analysis to evaluate the data to study the relationship between vitamin D levels and changes in academic stress and to control for possible confounding variables at the same time. In this way, the authors could discover how strong the relationship was and at the same time and researchers also ruled out the influence of any other factors that might affect stress levels, thus providing a clearer view of the impact of vitamin D supplementation on academic stress.	[50]
Hassan (2019)	A cross-sectional study conducted among 417 urban university students in the UAE.	SPSS-IBM was the software that facilitated the statistical analysis, and descriptive statistics were used to summarize the participants' characteristics and vitamin D levels, while Chi-square was employed to test the differences between the groups' proportions. The researchers considered a p-value of less than 0.05 to indicate statistical significance which permitted them to propose vitamin D deficiency as a factor associated with the severity of depression, in addition to gender, level of study and type of study programme.	[51]
Kwasky AN & Carla J. Groh (2012)	A descriptive correlational study was performed by the authors in 2012, and the study was based on a convenience sample of 139 young adult females aged 18 to 24 years, all of whom were either African American or Caucasian and were drawn	The research employed various statistical techniques among which was included descriptive statistics that provided a summary of the sample characteristics, independent t-tests that were utilized to make comparisons of depression scores and vitamin D levels between different races as well as between participants who had depression and those who did not, and Pearson's correlation coefficients that were used to assess the presence of a statistically significant relationship between serum vitamin D concentrations and Beck Depression Inventory scores.Furthermore, effect sizes	[52]

	from an urban university population.	(Cohen's d) were computed to provide an understanding of the extent of the differences between the groups.	
Vinod, Kunjumon & Finoz (2025)	A cross-sectional study conducted among 71 adult patients diagnosed with depression at a psychiatric outpatient clinic in India.	The statistical evaluation was done with the help of SPSS software version 20, and categorical variables including vitamin D status, sociodemographic factors, and depression severity to be determined by HAM-D and ICD-10 were subjected to Chi-square tests or Fisher's Exact tests according to the distribution of the samples. The researchers selected a significance level of $p < 0.05$ for the detection of interesting differences, which allowed them to establish that the correlation between vitamin D deficiency and depression severity according to the ICD-10 classification was in fact significant, while at the same time they observed that no such correlations existed with sociodemographic factors.	[53]
Menon, V. (2020)	A narrative/critical review of the literature on vitamin D status and depression, covering multiple observational and interventional studies rather than a single empirical sample.	The writer merged and mixed data from different studies, giving a summary of results by using descriptive comparisons of effect sizes such as odds ratios, relative risks, and it considered the methodological quality such as bias, confounding, and statistical power by explaining how individual studies employed logistic regression, correlation analyses and meta-analytic techniques; a significance threshold ($p < 0.05$) was reported in a number of the included studies, and the review elaborates on how diversity in statistical methods like management of confounders, stratification, regression adjustments that affects the reading of the links between low vitamin D levels and depression.	[54]
Wang. L,et al. (2025)	Meta-analysis of 20 randomized controlled trials (RCTs) conducted between 2000 and 2024. Adults ≥18 years were diagnosed with major depression or depressive tendencies; varied populations including with/without medical comorbidities also pregnant women included.	The analysis of the data was carried out with the help of RevMan 5.3 software. The weighted mean difference (WMD) was computed for continuous outcomes that were measured on the same scale. Standardized mean difference (SMD) was the metric used for the outcomes measured on different scales. The extent of variability among the studies was evaluated by means of a Chi-square test and the I^2 statistic. In case of a considerable amount of variability, a random-effects model was applied, and this was defined as I^2 being greater than 50% or p-value being less than 0.05. Furthermore, subgroup analyzes were performed with respect to intervention dose, duration, physical activity, sex, medical conditions, and sample size. Publication bias was assessed through the use of funnel plots, Egger's regression, and trim-and-fill methods. Additionally, a meta-regression analysis was performed to determine the influence of initial depression severity. The executed meta-analysis eventually remarked that the vitamin D supplementing had a significant effect on the reduction of depressive symptoms, with an SMD value of -0.36 and a confidence interval of 95% that ranged from -0.52 to -0.20 ($p < 0.00001$). Moreover, the effect was particularly strong in the case of long-term interventions that lasted for more than one year. The patients who were suffering from other diseases and depression at the same time, were reported to have received the maximum benefit from the vitamin supplements. However, the variability was quite large and this was shown by the studies and the methods for measuring the outcome.	[55]
Morales-Suá rez-Varela et al. (2023)	A cross-sectional study that included a total of 11,485 Spanish university students consisting of first-year students of 11 universities making up a nationally representative sample.	Descriptive statistics were used in this study to summarize the participant characteristics and mental-health measures. The categorical variables were compared for depression prevalence in different fish-intake groups by Chi-square tests. Binary logistic regression is the most important analysis which provided the odds ratios (ORs) and 95% confidence intervals (CIs) for the association between fish-intake compliance and depressive symptoms. This analysis was done by adjusting for	[56]

		possible confounding factors like age, sex, BMI, physical activity, and academic stress. A logistic regression model was applied to the national university cohort to ensure a representation of the population-level that was accurate, while taking into account the complex sampling design. A p-value of less than 0.05 was set as the threshold for showing statistical significance.	
Zhu, Zhao, Zhang, et al. (2019)	The authors performed a cross-sectional observational study in 2019 that included fifty consecutive right-handed patients with Major Depressive Disorder from outpatient and inpatient departments of a hospital in Hefei, China. However, vitamin D serum levels were not available for two of the recruited fifty patients, thus the main analyses were carried out on the 45 participants who provided the necessary data.	The statistical strategies applied in the study included Pearson correlation examining the total intracranial volume (TIV), serum 25-hydroxyvitamin D concentration and Hamilton Rating Scale for Depression (HAMD) score,linear regression analyses for assessing the predictive power of the TIV and serum vitamin D levels on HAMD and mediation analyses (via the PROCESS macro in SPSS) using 5,000 bootstrap samples to determine whether TIV mediated the connection between serum vitamin D and HAMD score.	[57]
Nguyen, N. et al., 2025	In 2025, the authors performed a systematic review and meta-analysis that consisted of seventeen observational studies namely,cross-sectional studies, cohort studies, and a pilot study by targeting the adolescent population of 10–17 years and young adults of 18–39 years, with together mean sample sizes of 32,844 individuals and individual study samples from 51 to 483,683 people, respectively.	The analytical method consisted of conducting two different meta-analyses in RevMan 5.4.1: the first one was for continuous outcomes, which considered the pooled mean differences of vitamin D levels between the depressed group and the non-depressed group; the second one was for dichotomous outcomes, where the associations between depression and vitamin D deficiency or insufficiency were studied through odds ratios and 95% confidence intervals; heterogeneity was measured with χ^2 tests and I^2 statistics, and the quality of the methodologies was assessed using the Newcastle-Ottawa Scale, while GRADE was used to determine the level of certainty of the evidence.	[58]
Callegari, E. T., Reavley, N., Garland, S. M., Gorelik, A., & Wark, J. D. (2015)	The authors conducted a cross-sectional observational study Part A of the Safe-D Study throughout 2015 in Victoria, Australia, enlisting young women from 16 to 25 years old who reacted to Facebook ads, aiming at a sample size of about 468 individuals.	The methods used for statistical analysis encompassed descriptive statistics which were used to provide an overview of the participants in terms of their vitamin D status, bone mineral density, and mood symptoms, besides that correlation and regression analyses were done to check the relationships among the serum 25-hydroxyvitamin D concentration, bone mineral density obtained by DXA/pQCT, and self-reported depressive or anxiety symptoms, and also for adjusting lifestyle and clinical covariates.	[59]

[60]	Ozkayar, N., et al. (2014)	The authors performed a cross-sectional descriptive study involving a total of 117 renal transplant patients were 44 females, 73 males; average age ~39.0 ± 11.7 years, who underwent kidney transplantation and divided the participants into groups according to a depression subscale cut-off score (Hospital Anxiety and Depression Scale-Depression [HADS-D] ≥ 7) to analyze the ones at risk of depression versus the ones not at risk.	The statistical method employed consisted of descriptive statistics used for depicting sample characteristics in terms of demographics and serum 25-hydroxyvitamin D (25-OH-D) levels, independent group comparisons for instance, comparing average 25-OH-D levels between the depression-risk group and non-risk group carried out through t-tests or equivalent, and Pearson correlation analysis applied to investigate the connection between HADS-D scores and serum 25-OH-D levels ($r = –0.365$, $p < 0.0001$) within the participant group.	[60]
[61]	Roșian et al. (2025)	In a systematic review conducted by the authors in 2025, the first step was to identify 13,976 records that were published between 2008 and 2024, and then they chose 70 articles including cross-sectional, cohort and interventional studies that analyzed the links between serum 25-hydroxyvitamin D levels or vitamin D supplementation and major depressive disorder (MDD) or depressive symptoms.	Critical appraisal of the evidence base was done by assessing the methodological quality of the included studies such as risk of bias, study design heterogeneity. The statistical methodology was descriptive synthesis of study characteristics, qualitative assessment of associations like inverse relationships between vitamin D levels and depression risk or symptom severity, reporting pooled findings in narrative form rather than performing a quantitative meta-analysis, and assessing the methodological quality of included studies like risk of bias, study design heterogeneity.	[61]
[62]	Callegari et al. (2017)	The team performed an observational cross-sectional analysis on the data collected from the "Safe-D" cohort which comprised young Australian ladies aged around 17 to 25 years.The total number of participants was n = 468 who had their serum 25-hydroxyvitamin Dlevels assessed and also filled in the mental health questionnaire completely.	The statistical technique applied was made up of calculating theserum 25-hydroxyvitamin D concentration and mental healthevaluation scores in terms of their descriptive statistics, performing bivariate correlation analyses to explore the relationship between vitamin D status and scores of depressive or anxiety-type symptoms, and finally applying multivariable regression modeling to draw the attention of the confounding factors like age, BMI, lifestyle factors, and seasonality when assessing the case of vitamin D level being a mental health determinant independently.	[62]
[63]	Anaswarade v, A., et al. (2025)	The writers performed a cross-sectional observational study, gathering a total of 126 adult patients, aged between 18 and 49 years who were going to private clinics in Ernakulam, Kerala, India, and were not suffering from any major chronic diseases or had previous psychiatric diagnoses.	The study involved conducting the descriptive statistics to characterize serum 25-hydroxyvitamin D (vitamin D3) levels and the individuals' depression status; carrying out chi-square tests to see if there was a difference between the depression rates in the vitamin D3 deficient group and the sufficient one; and making use of logistic regression modeling to determine the adjusted odds ratios for the relationship between vitamin D3 deficiency and depression taking into account the socio-demographic factors.	[63]

Conclusion

The comprehensive evidence from different types of studies such as cross-sectional university-based samples, large national cohorts, athletic populations, randomized controlled trials, as well as major meta-analyses has led to a conclusion that lower vitamin D serum levels correlate with a worse case of depressive symptoms in young adults. The majority of cross-sectional studies indicate that deficiency of vitamin D is associated with a notable increase in the scores of depression like CES-D, BDI, DASS-21, PHQ-A, or HADS-D and that sometimes this correlation remains significant even after taking into consideration the lifestyle factors like BMI, physical activity, and seasonal sunlight exposure. The application of multiple regression and logistic regression analyses to these investigations shows that the quality of being vitamin D deficient is a factor that not only indicates but also gives the possibility of being 2-4 times more likely to have clinically relevant depression in student and young adult populations. Furthermore, longitudinal and experimental evidence provide additional backing: future studies on athletes demonstrate that lower vitamin D predicts the development of more severe depressive symptoms over time while RCTs show that vitamin D supplementation results in better mood outcomes or less severe depressive symptoms especially in subjects with low baseline levels. Large-scale genetic causal analyses and meta-analyses offer a great deal of support to a probable causal pathway by discovering that raising 25(OH)D concentrations through supplementation or genetically determined higher vitamin D status is associated with a lower risk of major depression.

Conflict of interest

The authors declare no conflict of interest.

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