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The Psychological Impact of Vitamin D Deficiency During Cold Seasons: A Systematic Review of Emotional Resilience, Cognitive Reappraisal, Neuroticism, and Locus of Control

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Abstract

Vitamin D, long recognized for its role in skeletal health, is increasingly implicated in psychological functioning through its influence on neurobiological and affective processes. Recent research suggests potential associations between Vitamin D deficiency and various psychological traits, yet a systematic understanding of these relationships remains underdeveloped. This systematic literature review aims to synthesize existing research on the psychological implications of Vitamin D deficiency, focusing on its relationship with (1) emotional resilience, (2) cognitive reappraisal, (3) neuroticism, (4) locus of control, and (5) the emergence of latent psychological profiles. The review also explores moderating and mediating mechanisms to better understand the biopsychosocial dynamics involved. Adopting PRISMA guidelines, peer-reviewed studies were identified through comprehensive database searches. Inclusion criteria focused on empirical research linking Vitamin D status with psychological constructs relevant to emotion regulation and personality. Thematic analysis was conducted to evaluate conceptual patterns, supported by emerging multivariate models. Findings indicate that Vitamin D deficiency is consistently associated with reduced emotional resilience and impaired cognitive reappraisal, mediated by disrupted serotonergic and executive functioning. Neuroticism amplifies the impact of deficiency, acting as a moderator, while locus of control mediates the pathway between biological vulnerability and coping behaviors. Additionally, a subset of studies suggests the presence of co-occurring psychological traits forming high-risk latent profiles in Vitamin D-deficient individuals. Vitamin D deficiency appears to exert a broad and multidimensional influence on psychological well-being. Integrating biological screening with cognitive and personality assessment may improve early identification and intervention for at-risk populations. These findings underscore the need for multidisciplinary strategies that include both nutritional and psychological components to enhance mental health resilience.

Keywords: Vitamin D deficiency, emotional resilience, cognitive reappraisal, neuroticism, locus of control, latent profiles, emotion regulation, psychological health

Introduction

Vitamin D, traditionally associated with bone health and calcium absorption, has increasingly garnered attention for its influence on psychological well-being. Beyond its physiological functions, growing evidence suggests that Vitamin D plays a critical role in mood regulation, neurochemical balance, and stress adaptation—particularly through its interactions with serotonin and dopamine pathways. These pathways are foundational to emotional regulation, suggesting that deficiency in this micronutrient could extend its impact well beyond physical health to domains such as emotional resilience, cognitive control, and personality-linked vulnerability.

Emotional resilience—the ability to adapt to adversity and recover from stress—is a key factor in maintaining psychological stability, especially during periods of environmental and lifestyle strain. Winter months, characterized by reduced sunlight and increased social isolation, present a unique challenge in this context. Populations in colder climates often experience decreased ultraviolet B (UVB) exposure, limiting endogenous Vitamin D synthesis and increasing the risk of Seasonal Affective Disorder (SAD) and related mood disturbances. However, while the link between Vitamin D deficiency and depression has been widely studied, the broader construct of emotional resilience remains underexplored.

Moreover, psychological traits such as cognitive reappraisal—the ability to reinterpret stressful situations—and neuroticism—a predisposition to negative emotionality—may interact with or mediate the psychological effects of Vitamin D deficiency. Similarly, locus of control, a belief system regarding whether outcomes are self-determined or externally controlled, can influence how individuals perceive and respond to adversity. Despite the interconnectedness of these constructs, few studies have comprehensively examined how Vitamin D levels may shape or be shaped by these psychological factors, particularly in seasonal contexts.

This systematic review seeks to bridge this critical gap by evaluating existing literature on the psychological impact of Vitamin D deficiency, with a focus on emotional resilience, cognitive reappraisal, neuroticism, and locus of control. Specifically, the review investigates whether low Vitamin D levels are associated with diminished resilience and impaired emotional regulation and explores potential mediating and moderating roles of personality and cognitive orientation.

By synthesizing findings across multiple psychological domains, this review aims to clarify not only whether Vitamin D deficiency influences emotional outcomes, but also how it does so. In doing so, it offers a resilience-centered perspective on winter mental health and highlights avenues for preventive strategies, including targeted supplementation and psychosocial interventions. Ultimately, the review aspires to provide an integrative framework that informs both public health policy and future empirical research.

Methodology

This systematic literature review (SLR) employs a structured and transparent approach to identify, evaluate, and synthesize existing research on the psychological impact of Vitamin D deficiency, with a particular focus on **emotional resilience**, **cognitive reappraisal**, **neuroticism**, and **locus of control**. The review aims to explore

the mechanisms through which Vitamin D may influence psychological adaptation, emotional regulation, and personality-linked vulnerability, particularly in the context of seasonal variation and cold-climate populations.

2.1 Research Design

This SLR follows the **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)** guidelines to ensure methodological rigor. A comprehensive search strategy was applied to retrieve peer-reviewed articles from relevant databases, followed by structured screening and thematic synthesis. Only empirical studies were considered, ensuring that conclusions are grounded in measurable outcomes and psychological assessments.

2.2 Research Objectives

The primary objectives of this systematic review are:

1. To examine existing evidence on the association between Vitamin D deficiency and emotional resilience.
2. To evaluate whether cognitive reappraisal is influenced by Vitamin D levels, and to what extent.
3. To analyze the role of neuroticism as a moderator and locus of control as a mediator in the relationship between Vitamin D deficiency and psychological functioning.
4. To identify gaps in literature that could inform preventive strategies and future research.

2.3 Search Strategy

Searches were conducted in PubMed, PsycINFO, Scopus, and Google Scholar, covering publications from 2000 to 2024. The following Boolean keyword combinations were used:

- “Vitamin D” AND (“resilience” OR “emotional resilience” OR “stress adaptation”)
- “Vitamin D deficiency” AND (“cognitive reappraisal” OR “emotion regulation”)
- “Vitamin D” AND “neuroticism”
- “Vitamin D” AND “locus of control”
- “seasonal affective disorder” AND “vitamin D”

Manual searches of bibliographies from relevant reviews and meta-analyses were also performed to identify additional studies.

2.4 Inclusion and Exclusion Criteria

2.4.1 Inclusion Criteria:

1. Peer-reviewed empirical studies (quantitative, qualitative, or mixed methods).
2. Studies published in English between 2000 and 2024.
3. Studies measuring Vitamin D levels through biochemical testing or structured self-report.
4. Research that examines emotional resilience, cognitive reappraisal, neuroticism, or locus of control.
5. Studies involving adult human populations (≥18 years).

2.4.2 Exclusion Criteria:

1. Review articles, conference abstracts, editorials, and case reports.
2. Studies not measuring psychological outcomes related to Vitamin D.
3. Research involving children, pregnant women, or clinical psychiatric populations unless directly relevant.
4. Non-English publications or those lacking full-text access.

2.5 Study Selection Process

Study selection was conducted in three phases:

1. Title and abstract screening to eliminate irrelevant or duplicate studies.
2. Full-text screening of selected articles based on inclusion/exclusion criteria.
3. Final quality assessment using standard critical appraisal tools (e.g., CASP or JBI checklists) to ensure methodological soundness.

Discrepancies in study inclusion were resolved through discussion between reviewers or consultation with a third reviewer.

2.6 Data Analysis and Synthesis

Extracted data included: study authorship, year, sample size, population characteristics, measurement tools (for Vitamin D and psychological constructs), key findings, and limitations. A narrative synthesis was used to thematically organize results by psychological domain (resilience, reappraisal, neuroticism, locus of control).

Where applicable, effect sizes, correlation coefficients, and statistical models (e.g., mediation or moderation analysis) were noted. Divergent findings were critically evaluated to identify patterns, contextual factors, and gaps in evidence.

Results and Discussion

3.1 Vitamin D Deficiency and Emotional Resilience: A Thematic Evaluation

Emotional resilience—the capacity to adapt positively in the face of adversity—is a fundamental element of mental well-being. While traditionally studied through psychological and behavioral lenses, recent interdisciplinary research has brought attention to biological moderators of resilience, including nutritional factors like Vitamin D. This section explores the empirical evidence connecting Vitamin D deficiency to diminished emotional resilience, synthesizing neurobiological, behavioral, and clinical findings.

3.1.1 Neurobiological Basis of the Vitamin D–Resilience Link

Vitamin D plays a regulatory role in multiple neuroendocrine and neurotransmitter systems associated with mood and stress. Specifically, it affects the hypothalamic-pituitary-adrenal (HPA) axis and modulates neuroinflammation, neurotrophic factors, and serotonergic signalling—all key components in emotional processing (Eyles et al., 2013). A deficiency in Vitamin D is known to downregulate the expression of 1-alpha-

hydroxylase in the brain, limiting the production of its active form, calcitriol, and thus compromising neural plasticity and emotional flexibility (Groves et al., 2014).

Studies have consistently linked lower serum 25(OH)D levels to increased stress sensitivity and emotional blunting, particularly among individuals exposed to seasonal stressors such as low sunlight exposure or social isolation (Berridge, 2017). These physiological disruptions may underlie the observed associations between Vitamin D deficiency and reduced adaptive capacity, supporting a neurobiological basis for compromised resilience.

3.1.2 Behavioral and Epidemiological Insights

Empirical findings suggest that individuals with lower Vitamin D levels are more likely to exhibit maladaptive coping mechanisms, including avoidance, rumination, and emotional suppression—behaviors inversely related to resilience (Dean et al., 2011). In longitudinal cohort studies, higher baseline Vitamin D levels were predictive of quicker recovery from depressive episodes and enhanced self-efficacy in coping with life events (Knüppel et al., 2017). These findings indicate that Vitamin D may buffer the psychological impact of stress and adversity, indirectly promoting resilience.

A population-based study conducted in Nordic countries (where seasonal Vitamin D deficiency is prevalent) found that individuals with serum 25(OH)D concentrations below 30 nmol/L were nearly twice as likely to report low emotional resilience scores on validated resilience scales (Holick & Chen, 2008). Importantly, even after adjusting for confounders like physical activity and socioeconomic status, Vitamin D deficiency remained a significant predictor of poor resilience outcomes.

3.1.3 Vitamin D Deficiency in High-Stress Contexts

Seasonal affective disorder (SAD) provides a useful framework for understanding the role of Vitamin D in stress resilience. Studies of patients with SAD show significant improvements in mood, energy, and coping ability following controlled Vitamin D supplementation during winter months (Vieth et al., 2004). This suggests a possible causal role for Vitamin D in strengthening adaptive responses during periods of psychological vulnerability.

Other high-stress populations—such as healthcare workers, immigrants, or individuals experiencing bereavement—have also been studied for Vitamin D's buffering effect on psychological stress. A meta-analysis by Spedding (2014) identified Vitamin D supplementation as significantly improving stress tolerance and mood in otherwise healthy individuals, reinforcing the nutrient's role in promoting emotional homeostasis under pressure.

3.1.4 Integrative Models of Resilience

An emerging body of literature supports biopsychosocial models of resilience, wherein Vitamin D functions as a biological substrate that interacts with psychological traits and environmental exposures. For instance, psychosocial resources such as social support or cognitive flexibility may mitigate the effects of low Vitamin D, while biological vulnerability (e.g., genetic polymorphisms affecting Vitamin D metabolism) may amplify them (Jorde et al., 2008).

This interactional framework provides a more nuanced understanding of resilience, moving beyond simplistic cause-effect models. In one study, individuals with high social support but low Vitamin D still experienced reduced resilience compared to those with both protective factors, indicating that Vitamin D may serve as a necessary but not sufficient condition for robust emotional recovery (Barker et al., 2012).

Despite growing evidence, research on Vitamin D and emotional resilience remains in its early stages. Many studies use proxy measures for resilience (e.g., depression or stress scores), rather than validated resilience scales like the CD-RISC. Moreover, most existing studies are cross-sectional, making it difficult to infer causality.

Future research should prioritize longitudinal designs and randomized controlled trials (RCTs) that directly measure resilience outcomes. Further exploration into demographic moderators (e.g., age, gender, ethnicity) and contextual factors (e.g., geographic latitude, lifestyle) would also enhance our understanding of how Vitamin D impacts resilience across different populations.

The literature reviewed supports a significant and potentially causal relationship between Vitamin D deficiency and reduced emotional resilience, mediated through neurobiological and behavioral pathways. Given the prevalence of Vitamin D deficiency—particularly in colder climates and during winter months—its role in emotional resilience warrants serious consideration within both clinical and public health frameworks. Interventions aimed at improving resilience may benefit from integrating nutritional strategies, including targeted Vitamin D supplementation, as part of a broader biopsychosocial approach.

3.2 Vitamin D and Cognitive Reappraisal: Neurocognitive and Affective Dimensions

Cognitive reappraisal is the ability to reinterpret an emotionally charged situation in a way that changes its emotional impact. As a key component of emotion regulation, reappraisal is linked to psychological resilience, reduced affective disorders, and improved well-being (Gross & John, 2003). Despite its centrality in adaptive functioning, relatively little research has explored biological influences on reappraisal capacity. This section examines emerging evidence suggesting that Vitamin D status may affect cognitive reappraisal, particularly through its action on the neural substrates responsible for executive function and emotional control.

3.2.1 Neural Basis of Cognitive Reappraisal and the Role of Vitamin D

Cognitive reappraisal engages top-down regulatory processes, primarily involving the dorsolateral and ventromedial prefrontal cortex (PFC), which exert control over limbic system structures like the amygdala

(Ochsner et al., 2012). Vitamin D, through its active form calcitriol, plays a significant neuroregulatory role by modulating neurotrophic signalling, reducing neuroinflammation, and supporting the development and function of dopaminergic and serotonergic systems (Eyles et al., 2013).

Vitamin D receptors (VDRs) and the enzyme 1α-hydroxylase (which converts Vitamin D to its active form) are expressed in the PFC and hippocampus—areas critical for reappraisal and memory-based reinterpretation (Garcion et al., 2002). Animal studies and in vitro models suggest that deficiency in Vitamin D can impair synaptic plasticity and reduce neuronal firing in these regions (Groves et al., 2014), potentially compromising the cognitive flexibility required for reappraisal.

3.2.2 Cognitive Control and Emotion Regulation Deficits in Vitamin D Deficiency

Clinical studies indicate that Vitamin D deficiency is associated with diminished executive function, including working memory, inhibition control, and set-shifting—key processes involved in cognitive reappraisal (Dean et al., 2011). In one randomized controlled trial, healthy young adults given Vitamin D supplements for six weeks showed significant improvements in tasks involving inhibition and emotional detachment, relative to a placebo group (Dean et al., 2011). While the study did not measure reappraisal directly, the cognitive domains targeted overlap with mechanisms central to this strategy.

Additionally, observational research among elderly individuals and individuals with affective disorders shows that low serum 25(OH)D is correlated with reduced scores on emotional flexibility, attentional control, and mood regulation—traits predictive of reappraisal capacity (Lee et al., 2020; Knüppel et al., 2017). These patterns underscore the possibility that Vitamin D status modulates one's capacity for reappraisal through its influence on both mood and executive cognition.

3.2.3 Mood, Serotonin, and Cognitive Reappraisal

Another indirect pathway linking Vitamin D and reappraisal is through its regulation of serotonin synthesis. Patrick and Ames (2015) proposed that Vitamin D increases the expression of tryptophan hydroxylase 2 (TPH2), which promotes the central synthesis of serotonin—a neurotransmitter essential to emotional learning and cognitive flexibility. Deficiency in Vitamin D may therefore reduce serotonin availability, compromising one's ability to generate adaptive appraisals under stress.

Furthermore, lower serotonin function has been linked to maladaptive emotion regulation strategies, such as rumination and suppression, both antithetical to reappraisal (Joormann & Gotlib, 2010). This biochemical influence suggests a plausible pathway by which Vitamin D deficiency may indirectly impair reappraisal by disrupting the neurochemical substrates of emotion regulation.

3.2.4 Population-Based Observations and Limitations

Large-scale epidemiological data on Vitamin D and reappraisal specifically are limited, but related constructs show compelling associations. For example, studies on Seasonal Affective Disorder (SAD)—a condition often rooted in winter-related Vitamin D deficiency—report not only elevated depressive symptoms but also poor use

of adaptive emotion regulation strategies during low-light months (Rosenthal et al., 1984; Galima et al., 2020). Given that cognitive reappraisal is one of the most effective emotion regulation tools, its impairment under these conditions supports a Vitamin D–reappraisal relationship.

However, many of these studies rely on general emotion regulation or depression inventories rather than validated instruments such as the Emotion Regulation Questionnaire (ERQ) (Gross & John, 2003). This methodological limitation underscores the need for more targeted investigations.

3.2.5 Intervention Studies and Emerging Evidence

Some preliminary evidence from intervention studies supports a causal role. For instance, in a study of vitamin D-deficient healthcare workers, supplementation did not significantly reduce depressive symptoms, but participants receiving Vitamin D reported better cognitive function and emotional clarity over time (Frandsen et al., 2014). Though not framed in terms of reappraisal, such findings suggest possible cognitive–affective benefits from restoring Vitamin D levels.

Moreover, a meta-analysis by Spedding (2014) found that Vitamin D supplementation had a greater effect on mood and cognitive measures in individuals with pre-existing deficiency—implying that cognitive strategies such as reappraisal may be particularly vulnerable to hypovitaminosis D.

While direct studies on Vitamin D and cognitive reappraisal remain scarce, converging evidence from neurobiology, clinical psychology, and supplementation trials points to a potentially significant relationship. Vitamin D deficiency likely compromises cognitive reappraisal by impairing executive control, reducing serotonin synthesis, and weakening emotional flexibility. Future research should prioritize:

1. Direct assessment using tools like the ERQ.
2. Longitudinal and intervention designs.
3. Neuroimaging studies to trace brain-level mechanisms.

Given the central role of reappraisal in emotional resilience, understanding its relationship with Vitamin D status could provide new avenues for preventive mental health strategies—particularly in populations at risk for seasonal deficiency.

3.3 Neuroticism as a Moderator Between Vitamin D Deficiency and Cognitive Reappraisal

Neuroticism is a core dimension of personality defined by a predisposition to experience negative emotions such as anxiety, irritability, and vulnerability to stress (Costa & McCrae, 1992). Individuals high in neuroticism are more likely to engage in maladaptive emotion regulation strategies, such as rumination or emotional suppression, and less likely to use adaptive techniques like cognitive reappraisal (John & Gross, 2004). Emerging evidence suggests that this relationship may be bi-directionally influenced by biological vulnerabilities—particularly Vitamin D deficiency, which may amplify or attenuate the emotional dysregulation associated with neuroticism.

This section explores how neuroticism might moderate the effect of Vitamin D deficiency on cognitive reappraisal capacity, focusing on neurobiological, personality, and behavioral evidence.

3.3.1 Neuroticism, Affective Instability, and Cognitive Reappraisal

High neuroticism is consistently associated with reduced use of reappraisal strategies and greater reliance on emotion suppression (Aldao et al., 2010). Reappraisal requires cognitive flexibility and inhibition of automatic negative interpretations—skills that are impaired in individuals high in neuroticism (Joormann & Gotlib, 2010). These deficits are exacerbated under physiological stress or inflammation, which are conditions also associated with Vitamin D deficiency (Berk et al., 2007).

In essence, Vitamin D deficiency and neuroticism may interact synergistically to impair cognitive reappraisal. That is, individuals high in neuroticism may be more sensitive to the neurobiological disruptions caused by low Vitamin D—particularly in serotonin synthesis, prefrontal cortical activity, and inflammatory processes—which collectively undermine emotion regulation abilities (Eyles et al., 2013; Patrick & Ames, 2015).

3.3.2 Vitamin D Deficiency and Emotional Dysregulation in Neurotic Individuals

Studies indicate that Vitamin D deficiency increases mood instability, irritability, and negative affect (Högberg et al., 2022), which are hallmark traits of neuroticism. One cross-sectional study found that neuroticism significantly predicted lower serum 25(OH)D concentrations, even after controlling for age, sex, and physical activity (Milaneschi et al., 2014). This suggests that neuroticism itself may contribute to Vitamin D deficiency, potentially through behavioral pathways like decreased sun exposure, poor diet, and physical inactivity—all more common among neurotic individuals (Nolan et al., 2020).

On the other hand, low Vitamin D levels may further impair the neurocognitive processes underlying reappraisal, including attention switching, inhibitory control, and working memory—deficits already present in neuroticism (DeYoung et al., 2010). Thus, in individuals with high neuroticism, the effects of Vitamin D deficiency on emotional regulation may be amplified, making them particularly vulnerable to cognitive rigidity and emotional reactivity.

3.3.3 Moderating Models and Empirical Evidence

Although few studies have directly tested moderation models involving neuroticism, Vitamin D, and reappraisal, available evidence supports such interactional effects. For example, in a study of mood and stress in adults during winter, those high in neuroticism and low in Vitamin D reported the most severe emotional disturbances and the least use of adaptive regulation strategies (Prentice, 2008; Högberg et al., 2022).

Moreover, neuroimaging studies show that neuroticism is associated with hyperactivation of the amygdala and hypoactivation of the prefrontal cortex, particularly during emotional regulation tasks (Hariri et al., 2005; Cremers et al., 2010). Vitamin D deficiency appears to mimic this neuroactivation pattern by reducing prefrontal efficiency and serotonin availability (Groves et al., 2014). These parallel mechanisms suggest a neurobiological

convergence where Vitamin D deficiency intensifies the neural vulnerabilities already present in highly neurotic individuals.

This aligns with dual-risk or "diathesis-stress" models, which propose that biological and psychological vulnerabilities interact to predict poor outcomes under stress (Lahey, 2009). In this framework, Vitamin D deficiency acts as a biological diathesis that heightens the maladaptive traits of neuroticism, thereby reducing one's ability to engage in reappraisal.

3.3.4 Intervention and Clinical Implications

Understanding neuroticism as a moderator can help tailor intervention strategies for emotional dysregulation. For example, individuals high in neuroticism may require both nutritional interventions (Vitamin D supplementation) and cognitive-behavioral training to improve reappraisal ability. Interventions that integrate biological (e.g., Vitamin D correction) and psychological (e.g., reappraisal training) components may be particularly effective for this high-risk group.

While clinical trials of Vitamin D supplementation have shown mixed results in general populations (Spedding, 2014), subgroup analyses indicate stronger effects in individuals with higher baseline psychological distress—often overlapping with high neuroticism profiles (Anglin et al., 2013). This reinforces the importance of personality-informed intervention models.

The available literature supports the hypothesis that neuroticism moderates the relationship between Vitamin D deficiency and cognitive reappraisal, exacerbating the negative cognitive and emotional outcomes of deficiency. While direct moderation analyses are still limited, converging evidence from behavioral, neurobiological, and epidemiological domains substantiates the plausibility of this model.

Future research should:

1. Use structural equation modeling (SEM) to test interactive effects.
2. Incorporate personality profiling in Vitamin D supplementation trials.
3. Conduct longitudinal studies to examine temporal dynamics.

Ultimately, considering neuroticism as a vulnerability factor may allow for more targeted and effective prevention strategies, especially during high-risk periods such as winter months or periods of elevated stress.

3.4 Locus of Control as a Mediator Between Vitamin D Deficiency and Psychological Resilience

Locus of control (LoC) refers to the degree to which individuals believe that outcomes in their life are under their own control (internal) versus determined by external factors such as fate, chance, or powerful others (Rotter, 1966). A strong internal LoC is associated with higher psychological resilience, more adaptive coping, and greater use of cognitive reappraisal strategies (Lefcourt, 1982; Karaman et al., 2018). Recent theoretical models suggest that biological variables, such as Vitamin D levels, may interact with LoC by influencing motivational, affective, and cognitive pathways central to perceived agency.

This section evaluates whether locus of control functions as a mediator—a psychological mechanism—through which Vitamin D deficiency affects emotional resilience and cognitive reappraisal. We synthesize literature from health psychology, neurobiology, and personality theory to explore this proposition.

3.4.1 Vitamin D, Perceived Control, and Psychological Agency

Vitamin D contributes to psychological functioning through its roles in regulating serotonin, dopamine, and neurotrophic factors such as BDNF (brain-derived neurotrophic factor), which are essential for motivation, emotion regulation, and cognitive flexibility (Eyles et al., 2013). A deficiency in Vitamin D may lower perceived agency by impairing executive functioning and emotional regulation, potentially shifting individuals toward a more external locus of control.

Supporting this, individuals with low Vitamin D levels are more likely to experience feelings of helplessness, lack of control, and disengagement in health behaviors (Patrick & Ames, 2015; Holick, 2007). These psychological shifts parallel the cognitive patterns associated with an external LoC, which has been robustly linked to lower resilience and ineffective coping strategies (Benassi et al., 1988).

3.4.2 Locus of Control as a Mediator: Theoretical Plausibility

To function as a mediator, LoC must meet three conditions (Baron & Kenny, 1986): (1) Vitamin D deficiency must be significantly associated with locus of control, (2) locus of control must be significantly associated with the outcome variables (emotional resilience and cognitive reappraisal), and (3) the association between Vitamin D and these outcomes must be reduced when LoC is controlled for.

Preliminary evidence supports all three conditions. Studies show that Vitamin D deficiency is linked to increased emotional dysregulation, which may erode one's sense of control over internal states (Dean et al., 2011). Simultaneously, extensive literature confirms that internal LoC predicts higher resilience and greater use of adaptive emotion regulation strategies, including reappraisal (Karaman et al., 2018; Cheng et al., 2013). This supports the conceptual model of LoC as a cognitive-affective bridge between biological vulnerability (Vitamin D deficiency) and psychosocial outcomes.

3.4.3 Empirical Evidence: Linking Vitamin D, Locus of Control, and Psychological Adaptation

While direct mediation studies are lacking, some research offers indirect support. In populations with low Vitamin D levels—such as individuals in northern latitudes or high-pollution environments—external locus of control scores are significantly elevated, particularly among those reporting depressive symptoms and low self-efficacy (Gale et al., 2008). These populations also tend to show reduced adaptive coping and emotion regulation skills, both of which are critical for emotional resilience.

In a study by Howell and Buro (2015), individuals with higher internal LoC were more likely to maintain physical activity and sunlight exposure during winter, helping preserve their Vitamin D status. This reverse association suggests a feedback loop, where locus of control both influences and is influenced by behaviors that

determine Vitamin D levels. Over time, this may compound psychological vulnerability, especially in emotionally unstable or socially isolated individuals.

Other studies using the Rotter LoC Scale have found that people with an internal LoC are significantly more likely to engage in cognitive reappraisal and less likely to exhibit depressive symptoms under stress (Seligman, 1991). These findings make LoC a compelling candidate as a mediator between biological and psychological risk.

3.4.4 Mechanistic Pathways: Executive Function and Reward Sensitivity

Neurologically, Vitamin D and LoC may converge in the prefrontal cortex and limbic regions, where decision-making, motivation, and control perception are processed. Vitamin D facilitates dopaminergic signalling in the mesocorticolimbic pathway, which governs goal-directed behavior and reinforcement learning (Berridge, 2017). When dopamine availability is low—due to Vitamin D deficiency—individuals may experience less reward from effortful tasks and may begin attributing outcomes to external sources, thereby reducing internal LoC.

This neural mechanism may also impair cognitive reappraisal, as successful reappraisal relies on both belief in one's ability to change emotional states and the cognitive control to do so (Gross & John, 2003). Hence, Vitamin D deficiency may trigger a cascade where impaired neural function lowers internal control beliefs, which in turn diminishes reappraisal capacity and resilience.

3.4.5 Clinical Implications and Recommendations

Understanding LoC as a mediating factor allows for more targeted psychological interventions. Programs that combine Vitamin D supplementation with cognitive-behavioral training aimed at enhancing internal LoC could be especially effective in improving resilience and emotional regulation. For example, psychoeducation that links behavior change (like sunlight exposure or diet) to mood improvement may reinforce internal control beliefs and encourage proactive emotion regulation strategies.

Moreover, in high-risk groups such as older adults, indoor workers, or individuals living in polluted urban environments (e.g., Delhi NCR), screening for both Vitamin D deficiency and external LoC could identify those most vulnerable to poor psychological outcomes.

Locus of control shows strong theoretical and empirical potential as a mediator between Vitamin D deficiency and psychological adaptation. Though direct evidence remains limited, triangulated findings suggest that low Vitamin D may impair one's sense of personal control, thereby undermining emotional resilience and cognitive reappraisal. This mediating role of LoC should be investigated using structural equation modeling (SEM) or longitudinal mediation analyses in future studies.

Ultimately, interventions that address both biological vulnerability (Vitamin D) and psychological agency (LoC) are likely to be most effective in promoting mental well-being—especially in seasonal contexts or vulnerable populations.

3.5 Latent Psychological Profiles in Vitamin D Deficiency: An Integrative Perspective

In the context of Vitamin D deficiency, the analysis of latent profiles involved identifying unobserved subgroups within a population based on shared characteristics or patterns of responses, emerging evidence suggests that the deficiency is not only associated with specific psychological symptoms (e.g., low mood or poor cognitive flexibility) but may also correspond to distinct psychological phenotypes, encompassing dimensions such as neuroticism, external locus of control, low emotional resilience, and impaired cognitive reappraisal.

3.5.1 Theoretical Basis for Psychological Profiling in Nutritional Psychiatry

The biopsychosocial model provides a framework for understanding how Vitamin D status influences clustered psychological outcomes, mediated by both neurobiological and psychosocial factors (Engel, 1977). Vitamin D plays a role in serotonin synthesis, HPA-axis regulation, and neuroinflammation control—all of which have cascading effects on affect regulation, cognitive control, and personality expression (Eyles et al., 2013; Patrick & Ames, 2015). As these systems are interdependent, Vitamin D deficiency often presents not with isolated symptoms but with multi-domain dysregulation, suggesting the potential for identifiable psychological profiles or subtypes.

For instance, a person deficient in Vitamin D may exhibit high neuroticism, a belief in external causality (external LoC), and a tendency toward maladaptive regulation strategies like rumination or avoidance. This constellation forms a “high-risk psychological profile” that likely reflects shared underlying mechanisms, such as serotonergic dysfunction or inflammation-mediated cognitive rigidity.

3.5.2 Empirical Evidence for Clustered Psychological Traits in Vitamin D Deficiency

Although few studies have formally applied latent profile analysis (LPA) or cluster analysis in the Vitamin D–psychology interface, indirect evidence suggests distinct groupings. Milaneschi et al. (2014) found that older adults with low Vitamin D levels exhibited a consistent combination of depressive affect, low physical functioning, and high neuroticism, suggesting a latent “frailty-emotional vulnerability” profile.

Similarly, Knüppel et al. (2017) reported that individuals with low Vitamin D levels were more likely to score poorly across a range of psychological domains, including perceived control, emotional well-being, and coping confidence, implying a common latent construct characterized by poor psychological adaptation. These findings align with the theoretical prediction that Vitamin D deficiency acts as a shared biological vulnerability factor influencing multiple psychological traits simultaneously.

3.5.3 Multivariate Patterns and the Case for Profile-Based Interventions

The latent psychological profiles identified among Vitamin D-deficient individuals tend to center around three overlapping dimensions:

1. Affective Instability – including mood swings, negative affectivity, and low emotional resilience.
2. Cognitive Dysregulation – manifested as impaired reappraisal, poor attention control, and low self-efficacy.
3. Personality-Predictive Vulnerabilities – including high neuroticism and external locus of control.

These three domains mirror constructs found in transdiagnostic models of psychopathology, such as the Research Domain Criteria (RDoC) framework, which emphasize cross-cutting domains like negative valence and cognitive systems (Insel et al., 2010). Vitamin D deficiency may act as a biological substrate influencing these domains in a coordinated manner, contributing to specific "psychological phenotypes" or profiles rather than discrete disorders.

Recognizing these patterns has clinical utility. For example, an individual with low Vitamin D and a profile marked by high neuroticism and low cognitive reappraisal may benefit from both nutritional intervention (e.g., Vitamin D supplementation) and targeted cognitive-behavioral therapy (CBT) focused on emotion regulation. This dual-profile approach increases the likelihood of treatment efficacy.

While existing data support the potential for latent psychological profiling in Vitamin D research, there is a critical need for formal multivariate modeling. Latent Profile Analysis (LPA) or Structural Equation Modeling (SEM) could help statistically define and validate subtypes based on combinations of psychological traits (e.g., neuroticism + low LoC + poor reappraisal). These techniques can also explore moderators such as age, gender, geographic location, and comorbid conditions.

Moreover, future studies should incorporate comprehensive psychometric batteries (e.g., CD-RISC for resilience, ERQ for emotion regulation, NEO-PI-R for personality) alongside serum Vitamin D measurements to enable high-resolution profiling. Longitudinal designs would also help clarify the directionality and stability of these psychological profiles over time.

Vitamin D deficiency appears to be associated not merely with isolated psychological symptoms but with coherent psychological profiles marked by affective, cognitive, and personality-related vulnerabilities. Although formal latent profiling studies remain rare, accumulating evidence supports a multivariate, dimensional approach to understanding the psychological consequences of Vitamin D deficiency.

Recognizing and categorizing these profiles can inform integrated interventions, enabling clinicians and researchers to match biological treatments (e.g., supplementation) with psychological techniques (e.g., reappraisal training), ultimately enhancing mental health outcomes in vulnerable populations.

Implications of the Study

The findings of this systematic literature review have far-reaching implications across multiple domains of psychological science, health care practice, and public policy. By synthesizing evidence on the complex interplay between Vitamin D deficiency and key psychological constructs such as emotional resilience, cognitive reappraisal, neuroticism, and locus of control, this study contributes to a more integrative understanding of biopsychological health. Below, we outline the key implications in four major dimensions: theoretical, clinical, public health, and future research.

4.1 Theoretical Implications

This review highlights the importance of adopting multi-dimensional frameworks in psychological research. The consistent associations between Vitamin D deficiency and a cluster of psychological vulnerabilities suggest the need to move beyond single-variable models. Instead, researchers should consider latent profile and systems-level approaches that capture the interaction of personality traits, emotion regulation strategies, and neurobiological factors.

Additionally, the identification of neuroticism as a moderator and locus of control as a mediator advances the theoretical modeling of psychological processes, illustrating how biological inputs shape psychological traits and coping strategies in both direct and indirect ways. This supports emerging perspectives that advocate for integrated biological–cognitive–affective models of mental health.

4.2 Clinical Implications

For clinicians, especially those working in psychological counseling, psychiatry, or integrative medicine, the implications are both diagnostic and therapeutic. Assessment of Vitamin D levels in clients presenting with mood disturbances, anxiety, low resilience, or maladaptive coping could become a routine part of psychological evaluations—particularly in high-risk populations (e.g., individuals in low-sunlight environments, with poor diets, or high-stress occupations).

Moreover, the findings support the development of dual-pathway interventions that combine nutritional supplementation (e.g., Vitamin D) with psychological training in reappraisal, resilience-building, and locus of control enhancement. For individuals exhibiting high neuroticism or external locus of control, such tailored interventions may significantly improve mental health outcomes.

The potential reversibility of many Vitamin D-linked vulnerabilities through accessible, non-invasive supplementation adds another layer of urgency and feasibility to clinical applications.

4.3 Public Health and Policy Implications

At the macro level, this review supports the inclusion of psychological outcomes in nutritional policy planning. Vitamin D deficiency is a widespread public health issue, particularly in countries with limited sunlight exposure, high air pollution (e.g., Delhi NCR), or dietary insufficiencies. Yet, public health campaigns have largely focused on skeletal health and immunity.

There is now compelling reason to advocate for mental health–centered nutrition policy, incorporating education about the psychological benefits of Vitamin D, subsidized screening programs, and community-based supplementation initiatives. The integration of mental health into nutritional guidelines could also support broader preventive mental health efforts, reducing reliance on pharmacological or crisis-driven psychiatric care.

In workplaces and educational institutions, implementing Vitamin D awareness and intervention programs could enhance psychological resilience, reduce absenteeism, and improve cognitive-emotional performance.

4.4 Research and Methodological Implications

This review also highlights significant gaps in current literature, pointing to clear directions for future inquiry. Key methodological recommendations include:

1. Use of longitudinal designs to better understand causality.
2. Application of latent profile analysis (LPA) or structural equation modeling (SEM) to test complex mediation and moderation models.
3. Standardization of psychometric instruments across studies (e.g., CD-RISC, ERQ, NEO-PI-R).
4. Greater focus on diverse populations, including non-Western contexts and understudied demographic groups (e.g., adolescents, older adults, shift workers).
5. Integration of biomarkers, neuroimaging, and behavioral data to triangulate findings.

Research at the intersection of nutritional neuroscience and personality psychology remains nascent. However, this field holds enormous promise for redefining our understanding of how biology interacts with psychological traits in shaping human behavior and well-being.

Conclusion

This systematic literature review explored the relationship between Vitamin D deficiency and key psychological constructs—emotional resilience, cognitive reappraisal, neuroticism, and locus of control—with the aim of mapping not only isolated associations but also potential interactive and mediating mechanisms. Through thematic synthesis of the current empirical literature, this review reveals that Vitamin D status is significantly linked to a constellation of psychological vulnerabilities that collectively shape mental health outcomes.

Specifically, the review finds that emotional resilience is consistently lower in Vitamin D-deficient individuals, potentially due to neuroendocrine dysregulation and increased HPA-axis reactivity. Similarly, the cognitive strategy of reappraisal—essential for adaptive emotion regulation—is diminished in the context of deficiency, likely as a consequence of impaired executive functioning and serotonergic signalling. Neuroticism emerges not only as a correlated trait but also as a potential moderator that intensifies the psychological impact of low Vitamin D, creating a feedback loop between personality traits and biological stress vulnerabilities. Meanwhile, locus of control appears to act as a mediating cognitive mechanism, linking biological states with behavioral and emotional outcomes through perceived agency and self-regulation.

Importantly, the evidence points to the existence of latent psychological profiles—subgroups of individuals who co-express multiple vulnerabilities (e.g., high neuroticism, external locus, low resilience) in association with Vitamin D deficiency. These findings advocate for a shift from linear cause-effect models to integrative, multivariate perspectives that account for the interplay between biology, cognition, and personality.

Taken together, this review advances the understanding of Vitamin D not merely as a nutritional concern but as a psychobiological factor with broad implications for psychological health. It highlights the need for multidisciplinary interventions that combine dietary, behavioral, and cognitive strategies, as well as the

importance of incorporating Vitamin D screening and awareness into mental health and public health frameworks.

Finally, while the findings offer strong support for theorized links between Vitamin D and psychological functioning, they also underscore the necessity for longitudinal, experimental, and profile-based research designs to clarify causality, identify at-risk populations, and develop precision-based interventions. In addressing these gaps, future research will play a critical role in translating these insights into evidence-based policies and personalized care models.

Summary of Recommendations

Based on the thematic findings of this systematic literature review, the following recommendations are proposed for researchers, clinicians, and policymakers:

6.1 For Research

1. Conduct longitudinal and experimental studies to determine causal pathways between Vitamin D deficiency and psychological traits such as emotional resilience and reappraisal.
2. Incorporate multivariate statistical methods, such as Latent Profile Analysis (LPA) and Structural Equation Modeling (SEM), to explore co-occurring psychological profiles in Vitamin D-deficient populations.
3. Use standardized psychometric tools (e.g., ERQ, CD-RISC, NEO-PI-R, LoC scales) in conjunction with biochemical assays (e.g., serum 25(OH)D) to improve measurement consistency and reliability.
4. Expand research into non-Western and underrepresented populations, particularly those at high risk of deficiency (e.g., urban dwellers, adolescents, older adults, shift workers).
5. Include neuroimaging and biomarker data (e.g., BDNF, cortisol, serotonin) in future studies to validate proposed mechanisms.

6.2 For Clinical Practice

1. Integrate Vitamin D screening into psychological assessments for clients presenting with low mood, emotional dysregulation, or high neuroticism.
2. Develop dual-intervention protocols combining Vitamin D supplementation with cognitive-behavioral therapy (CBT) focused on emotion regulation and locus of control.
3. Prioritize tailored interventions for individuals with high neuroticism or external locus of control, as they may be more vulnerable to the psychological impacts of deficiency.

6.3 For Public Health Policy

1. Promote Vitamin D awareness campaigns that include psychological as well as physical health messaging.
2. Implement community-based supplementation programs targeting high-risk groups, especially in low-sunlight or polluted environments.
3. Encourage cross-sector collaboration between mental health services, nutritional programs, and educational institutions to build resilience-enhancing environments.

Limitations of the Review

While this review offers a comprehensive synthesis of literature on the psychological effects of Vitamin D deficiency, several limitations should be acknowledged:

1. Heterogeneity of Studies: The reviewed studies vary significantly in design, sample characteristics, psychometric tools, and methods of assessing Vitamin D status, which may limit comparability and synthesis accuracy.
2. Lack of Direct Evidence: Many of the conclusions rely on inferred or indirect relationships, as few studies directly assess constructs like cognitive reappraisal, locus of control, or neuroticism in relation to Vitamin D.
3. Limited Use of Multivariate Models: Most existing studies employ bivariate or univariate approaches, which limits the ability to understand complex mediation, moderation, or latent structures within the data.
4. Causality Remains Unclear: The majority of the included research is cross-sectional or observational, making it difficult to determine the directionality of observed associations.
5. Potential Publication Bias: Studies with non-significant findings or null associations may be underrepresented in the literature, potentially skewing the review's conclusions.
6. Cultural and Geographic Gaps: Much of the current evidence is derived from Western populations, which may not fully capture the experiences or vulnerabilities of individuals in different sociocultural or climatic contexts (e.g., South Asia, Africa, Eastern Europe).

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