

ASSESSMENT OF VITAMIN D DEFICIENCY AND ITS ASSOCIATION WITH METABOLIC AND HEMATOLOGICAL PARAMETERS AMONG ADULT POPULATION: A REVIEW

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ABSTRACT

Vitamin D deficiency (VDD) has emerged as a significant global public health concern affecting individuals across all age groups, including adults living in tropical countries. Beyond its well-established role in calcium homeostasis and bone metabolism, vitamin D is increasingly recognized for its involvement in glucose metabolism, immune regulation, cardiovascular health, and hematopoiesis. Numerous epidemiological studies have demonstrated associations between low serum 25-hydroxyvitamin D [25(OH)D] concentrations and metabolic abnormalities such as obesity, insulin resistance, dyslipidemia, metabolic syndrome, and type 2 diabetes mellitus. In addition, vitamin D deficiency has been linked with hematological disturbances including anemia, reduced hemoglobin concentration, altered erythropoiesis, and impaired iron metabolism. This review summarizes current evidence regarding the prevalence of vitamin D deficiency among adults, its relationship with metabolic and hematological parameters, underlying biological mechanisms, clinical significance, and future research directions. The available evidence suggests that assessment of vitamin D status should be considered an important component of adult health evaluation, particularly among individuals at risk for metabolic disorders and anemia.

KEYWORDS: Vitamin D deficiency, 25-hydroxyvitamin D, metabolic syndrome, anemia, hematological parameters, insulin resistance, adults.

1. INTRODUCTION

Vitamin D is a fat-soluble secosteroid hormone essential for maintaining calcium and phosphorus homeostasis and preserving skeletal integrity. It is synthesized in the skin following exposure to ultraviolet-B radiation and is obtained in smaller amounts through dietary sources and supplementation. The circulating concentration of 25-hydroxyvitamin D [25(OH)D] is considered the most reliable indicator of vitamin D status.

Vitamin D deficiency has become increasingly common worldwide despite abundant sunlight in many regions. Factors such as limited outdoor activity, increased sunscreen use, skin pigmentation, aging, obesity, malabsorption syndromes, chronic kidney disease, and inadequate dietary intake contribute to low vitamin D levels. Current estimates indicate that vitamin D deficiency affects a substantial proportion of the global population, making it one of the most prevalent nutritional deficiencies.

Recent research has expanded the understanding of vitamin D beyond bone health. Vitamin D receptors are expressed in pancreatic β -cells, adipose tissue, skeletal muscle, immune cells, vascular endothelium, and hematopoietic cells, suggesting diverse physiological functions. Consequently, vitamin D deficiency has been associated with metabolic diseases, cardiovascular disorders, immune dysfunction, and hematological abnormalities.

2. Vitamin D Metabolism

Vitamin D exists primarily as vitamin D₂ (ergocalciferol) and vitamin D₃ (cholecalciferol). Vitamin D₃ is synthesized in the skin under ultraviolet-B exposure, whereas both forms can be obtained from dietary sources.

Following absorption or synthesis, vitamin D undergoes two hydroxylation reactions:

- Liver: formation of 25-hydroxyvitamin D [25(OH)D]
- Kidney: conversion to biologically active 1,25-dihydroxyvitamin D [1,25(OH)₂D]

The active hormone binds to vitamin D receptors (VDRs), regulating transcription of numerous genes involved in mineral metabolism, immune regulation, insulin secretion, and cellular proliferation.

3. Prevalence and Risk Factors of Vitamin D Deficiency

Vitamin D deficiency is observed in both developed and developing countries. Surprisingly, high prevalence has been reported in tropical regions, including India, despite abundant sunlight.

Factors contributing to deficiency include:

- Limited sunlight exposure
- Indoor lifestyle
- Obesity
- Aging
- Darker skin pigmentation
- Physical inactivity
- Poor dietary intake
- Chronic liver and kidney diseases
- Malabsorption disorders

Recent systematic reviews indicate particularly high rates of hypovitaminosis D among adults with type 2 diabetes in India.

4. Association with Metabolic Parameters

Growing evidence indicates that vitamin D deficiency contributes to several metabolic abnormalities.

4.1 Obesity

Obesity is consistently associated with lower serum vitamin D concentrations. Proposed mechanisms include sequestration of vitamin D within adipose tissue, reduced outdoor activity, and altered metabolism. Low vitamin D levels are frequently correlated with increased body mass index (BMI), waist circumference, and visceral adiposity.

4.2 Insulin Resistance and Diabetes Mellitus

Vitamin D enhances insulin secretion by pancreatic β -cells and improves insulin sensitivity through vitamin D receptor-mediated mechanisms.

Deficiency has been associated with:

- Increased fasting blood glucose
- Elevated HbA1c
- Reduced insulin sensitivity
- Higher incidence of type 2 diabetes mellitus

Although observational studies consistently report associations, intervention trials have shown mixed results regarding glycemic improvement after supplementation.

4.3 Dyslipidemia

Several studies demonstrate inverse relationships between serum vitamin D concentrations and adverse lipid profiles.

Vitamin D deficiency has been associated with:

- Increased triglycerides
- Elevated LDL cholesterol
- Reduced HDL cholesterol
- Increased cardiovascular risk

These alterations may result from chronic inflammation and impaired lipid metabolism.

4.4 Metabolic Syndrome

Metabolic syndrome consists of central obesity, hypertension, hyperglycemia, hypertriglyceridemia, and low HDL cholesterol.

Numerous observational studies suggest that lower serum 25(OH)D concentrations are associated with greater risk of metabolic syndrome, although causality remains uncertain.

5. Association with Hematological Parameters

Recent investigations suggest an important relationship between vitamin D deficiency and hematological health.

5.1 Hemoglobin

Adults with vitamin D deficiency frequently exhibit lower hemoglobin concentrations compared with vitamin D sufficient individuals. Vitamin D appears to influence erythropoiesis by reducing inflammatory cytokines and regulating erythropoietin activity. A recent systematic review found anemia to be consistently more common among adults with vitamin D deficiency.

5.2 Iron Metabolism

Vitamin D suppresses hepcidin synthesis, thereby facilitating intestinal iron absorption and mobilization of stored iron.

Vitamin D deficiency has been associated with:

- Reduced ferritin
- Lower transferrin saturation
- Functional iron deficiency
- Impaired erythropoiesis

These mechanisms may contribute to anemia, particularly in individuals with chronic inflammatory conditions.

5.3 Red Blood Cell Indices

Several studies have reported reduced:

- Hemoglobin
- Hematocrit
- Red blood cell count

among adults with vitamin D deficiency. Associations with mean corpuscular volume and other erythrocyte indices have been less consistent.

5.4 White Blood Cells and Platelets

Because vitamin D has immunomodulatory properties, deficiency has been associated with altered inflammatory responses. However, evidence regarding routine leukocyte and platelet indices remains inconsistent.

6. Biological Mechanisms

Multiple biological mechanisms may explain the observed associations.

Metabolic Effects

Vitamin D:

- Enhances insulin receptor expression
- Improves insulin sensitivity
- Regulates intracellular calcium
- Reduces oxidative stress
- Suppresses chronic inflammation

Hematological Effects

Vitamin D:

- Reduces inflammatory cytokines
- Suppresses hepcidin production
- Improves iron availability
- Supports erythropoiesis
- Protects bone marrow microenvironment

These mechanisms suggest that vitamin D deficiency contributes to both metabolic dysfunction and impaired hematopoiesis.

7. Clinical Implications

Assessment of serum 25(OH)D concentration may provide useful clinical information among adults presenting with:

- Obesity
- Type 2 diabetes mellitus
- Metabolic syndrome
- Dyslipidemia
- Unexplained anemia
- Chronic inflammatory disorders

Vitamin D supplementation remains the standard treatment for deficiency. Current clinical guidance emphasizes individualized supplementation based on baseline vitamin D status, risk factors, and underlying health conditions. While supplementation clearly benefits skeletal health, evidence for consistent improvements in metabolic and hematological outcomes remains variable and requires further high-quality randomized trials.

8. Future Perspectives

Future research should focus on:

- Large multicenter prospective studies
- Standardized vitamin D deficiency cut-off values
- Long-term supplementation trials
- Gene–vitamin D interactions
- Biomarkers predicting treatment response
- Relationships between vitamin D status and hematological disorders in diverse adult populations

Improved understanding of these associations may support more personalized prevention and treatment strategies.

9. CONCLUSION

Vitamin D deficiency is highly prevalent among adults and has important implications extending beyond skeletal health. Current evidence indicates significant associations between low serum vitamin D concentrations and adverse metabolic parameters, including obesity, insulin resistance, dyslipidemia, and metabolic syndrome. Emerging evidence also supports a relationship between vitamin D deficiency and hematological abnormalities such as anemia,

lower hemoglobin concentrations, and impaired iron metabolism. Although causal relationships are not fully established, routine assessment of vitamin D status in at-risk adults may facilitate early identification and management of deficiency. Integrating vitamin D evaluation into comprehensive metabolic and hematological assessment could contribute to improved patient care and preventive health strategies.

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