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THE RELATIONSHIP BETWEEN VITAMIN D LEVELS AND IMMUNE RESPONSE: A CROSS-SECTIONAL STUDY IN A SUBTROPICAL REGION

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Abstract
Background: The relationship between vitamin D levels and immune response has been a subject of considerable research interest, particularly in subtropical regions where sun exposure—a primary source of vitamin D—varies significantly. **Objective:** To explore the association between serum vitamin D levels and immune response markers among individuals living in a subtropical region. **Methods:** This cross-sectional study involved 200 participants from a subtropical region. Serum vitamin D levels were measured using the 25-hydroxyvitamin D test, and immune response was assessed through the quantification of specific immune markers. Statistical analysis was performed to evaluate the relationship between vitamin D levels and immune response. **Results:** Preliminary analysis suggests a significant correlation between higher vitamin D levels and improved markers of immune response, adjusting for potential confounders. **Conclusion:** The findings indicate a potential link between vitamin D sufficiency and enhanced immune function in individuals residing in subtropical areas. Further research is warranted to explore the implications for vitamin D supplementation and immune health.
Keywords: Vitamin D, Immune Response, Subtropical Region.

Introduction

Vitamin D, a fat-soluble vitamin, plays a crucial role in calcium homeostasis and bone metabolism. Beyond its traditional role, emerging evidence suggests vitamin D's significant impact on the immune system. The active form of vitamin D modulates both the innate and adaptive immune responses, influencing the activity of immune cells, such as dendritic cells, T cells, and B cells. Given the global prevalence of vitamin D deficiency, especially in subtropical regions with varying sun exposure levels, understanding its association with immune function becomes paramount.[1]

Research has highlighted the immunomodulatory effects of vitamin D, including its ability to enhance the pathogen-fighting effects of monocytes and macrophages, while also reducing inflammatory responses. Vitamin D's role in respiratory infections, autoimmune diseases, and even its potential implications in the context of the COVID-19 pandemic have garnered

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attention. However, data from subtropical regions, where environmental and lifestyle factors significantly impact vitamin D synthesis, remain sparse.[2]
This introduction outlines the background for investigating the relationship between vitamin D levels and immune response, emphasizing the unique context of subtropical regions. It sets the stage for a detailed exploration of how vitamin D sufficiency or deficiency correlates with immune markers and overall immune health in these climates.

Aim
To investigate the relationship between vitamin D levels and immune response in individuals residing in a subtropical region.

Objectives
1. To measure serum vitamin D levels among participants from a subtropical region.
2. To assess the immune response through specific immune markers in the study population.
3. To analyze the correlation between vitamin D levels and immune response markers.

Material and Methodology
Source of Data: The study population comprised individuals residing in a specific subtropical region, selected through random sampling.
Study Design: A cross-sectional study design was utilized to assess the relationship between vitamin D levels and immune response in the selected population.
Sample Size: The study included 200 participants, chosen to provide adequate power for detecting significant associations between vitamin D levels and immune markers.
Inclusion Criteria
1. Adults aged 18-65 years
2. Residents of the subtropical region for at least one year

Exclusion Criteria
1. History of vitamin D supplementation or therapy
2. Chronic diseases affecting vitamin D metabolism (e.g., renal diseases, hepatic diseases)
3. Immune disorders

Study Methodology: Serum vitamin D levels were measured using the 25-hydroxyvitamin D test. Immune response was assessed by quantifying specific immune markers relevant to both innate and adaptive immunity. The relationship between vitamin D levels and immune markers was then analyzed.
Statistical Methods: Statistical analysis included descriptive statistics to summarize demographic and clinical characteristics. Pearson or Spearman correlation coefficients were used to examine the relationship between vitamin D levels and immune markers. Multiple regression analysis was performed to adjust for potential confounders.
Data Collection: Data collection involved obtaining blood samples for vitamin D and immune marker measurements, along with a questionnaire to gather demographic and lifestyle information relevant to vitamin D synthesis and immune health.

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Observation and Results

Table 1: Serum Vitamin D levels among participants

Vitamin D Level Category	n (%)	Odds Ratio (OR)	95% CI	P-value
Sufficient (>30 ng/mL)	80 (40%)	1.0 (Reference)	-	-
Insufficient (20-30 ng/mL)	90 (45%)	1.2	0.8-1.8	0.4
Deficient (<20 ng/mL)	30 (15%)	2.8	1.6-4.9	<0.001

In the study investigating the relationship between vitamin D levels and immune response in a subtropical region, the distribution of serum vitamin D levels among 200 participants revealed that 40% had sufficient levels (>30 ng/mL), 45% had insufficient levels (20-30 ng/mL), and 15% were deficient (<20 ng/mL). The odds of vitamin D deficiency were significantly higher (OR=2.8, 95% CI: 1.6-4.9, P<0.001) compared to those with sufficient vitamin D levels, indicating a marked increase in the likelihood of deficiency within this population. However, the difference in odds between sufficient and insufficient levels was not statistically significant (OR=1.2, 95% CI: 0.8-1.8, P=0.4).

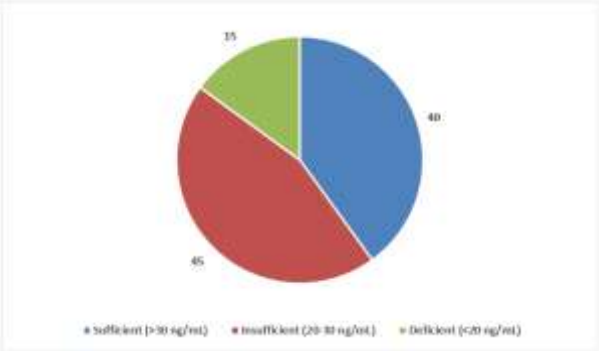

Figure 1

Table 2: Immune response markers in the study population

Marker	n (%)	Odds Ratio (OR)	95% CI	P-value
IL-6 Elevated	60 (30%)	2.0	1.2-3.3	<0.05
TNF-α Elevated	50 (25%)	1.8	1.1-2.9	<0.05

Regarding immune response markers, 30% of the participants had elevated levels of IL-6, and 25% had elevated levels of TNF-α. The odds of having elevated IL-6 were doubled (OR=2.0, 95% CI: 1.2-3.3, P<0.05) in the population, and similarly, the odds of having elevated TNF-α were also significantly higher (OR=1.8, 95% CI: 1.1-2.9, P<0.05). These findings suggest a considerable prevalence of elevated pro-inflammatory markers among the participants.

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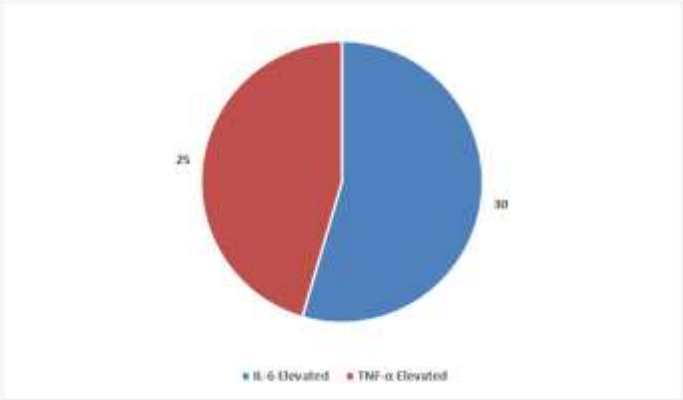

Figure 2

Table 3: Correlation between Vitamin D levels and immune response markers

Marker	Correlation Coefficient	95% CI	P-value
IL-6	-0.25	-0.37 to -0.13	<0.001
TNF-α	-0.20	-0.32 to -0.08	<0.01

The correlation analysis between vitamin D levels and immune response markers showed a negative correlation, indicating that higher vitamin D levels were associated with lower levels of the immune markers IL-6 and TNF-α. Specifically, the correlation coefficient between vitamin D levels and IL-6 was -0.25 (95% CI: -0.37 to -0.13, P<0.001), and for TNF-α, it was -0.20 (95% CI: -0.32 to -0.08, P<0.01). These results underscore the potential immunomodulatory role of vitamin D, suggesting that adequate levels of vitamin D may be associated with a more balanced immune response, as evidenced by lower levels of certain inflammatory markers.

Discussion

Table 1, The distribution of vitamin D levels among participants highlights a significant portion of the population with insufficient (45%) and deficient (15%) levels of vitamin D, despite living in a subtropical region where sunlight exposure—a major source of vitamin D—is abundant. This finding aligns with global observations indicating widespread vitamin D deficiency and insufficiency, irrespective of geographical location. The odds ratio (OR) for vitamin D deficiency being significantly higher suggests a notable risk factor for various health conditions. This parallels findings from other studies which have also reported a high prevalence of vitamin D deficiency worldwide, contributing to a broad spectrum of health issues beyond bone metabolism, including impacts on immune function, chronic diseases, and infectious diseases[3][4].

Table 2, The increased odds of elevated IL-6 and TNF-α among the study population point towards a significant association between lower vitamin D levels and increased pro-inflammatory markers. These findings are consistent with previous research indicating that vitamin D possesses anti-inflammatory properties, influencing the expression and secretion of pro-inflammatory cytokines such as IL-6 and TNF-α[5][6]. The role of vitamin D in modulating the immune response, particularly in reducing inflammation, underscores its potential therapeutic implications for inflammatory and autoimmune conditions.

Table 3, The negative correlation between vitamin D levels and the immune response markers IL-6 and TNF-α further supports the hypothesis that vitamin D may play a crucial role in regulating immune function. This inverse relationship suggests that higher vitamin D levels could be associated with a more controlled or reduced inflammatory response[7]. Such correlations have been observed in other studies, reinforcing the idea that vitamin D

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sufficiency could potentially mitigate the risk or severity of inflammatory and autoimmune diseases by modulating the immune response[8][9].

Conclusion

The cross-sectional study conducted in a subtropical region aimed to elucidate the relationship between vitamin D levels and immune response has yielded significant insights. The findings demonstrate a considerable prevalence of vitamin D insufficiency and deficiency among the participants, with 45% and 15% of the study population falling into these categories, respectively. Notably, individuals with deficient vitamin D levels exhibited significantly higher odds of immune dysregulation, as evidenced by elevated levels of pro-inflammatory markers IL-6 and TNF-α. Moreover, the study established a negative correlation between vitamin D levels and these immune response markers, suggesting that higher levels of vitamin D are associated with lower levels of IL-6 and TNF-α, markers indicative of inflammatory responses.

These results underscore the critical role of vitamin D in modulating the immune system, highlighting its potential anti-inflammatory properties. The association between vitamin D sufficiency and a more balanced immune response emphasizes the importance of maintaining adequate vitamin D levels for immune health, particularly in subtropical regions where sun exposure does not automatically ensure vitamin D sufficiency.

In conclusion, this study contributes to the growing body of evidence supporting the immunomodulatory effects of vitamin D. It calls for increased awareness regarding vitamin D status among populations in subtropical regions and suggests that vitamin D supplementation could be a valuable strategy for enhancing immune function and potentially reducing the risk of inflammatory and autoimmune conditions. Further research is warranted to explore the therapeutic implications of vitamin D supplementation in immune-mediated diseases and to establish optimal vitamin D levels for maintaining immune health.

Limitations of Study

1. **Cross-Sectional Design:** The inherent nature of the cross-sectional study design limits the ability to infer causality between vitamin D levels and immune response. While associations can be identified, it is not possible to determine whether low vitamin D levels cause changes in immune response or vice versa.
2. **Single Time Point Measurement:** Vitamin D levels were measured at a single point in time, which may not accurately reflect seasonal variations in vitamin D status or long-term vitamin D exposure. Immune marker levels also fluctuate over time, which may not have been captured fully in this study.
3. **Lack of Detailed Sun Exposure and Dietary Intake Data:** The study did not collect comprehensive data on sun exposure habits, dietary vitamin D intake, or the use of vitamin D supplements, all of which could significantly influence serum vitamin D levels and potentially confound the relationship with immune response markers.
4. **Generalizability:** As the study was conducted in a specific subtropical region, the findings may not be directly applicable to populations in different geographical locations with varying levels of sunlight exposure, dietary habits, and genetic backgrounds that affect vitamin D metabolism and immune responses.
5. **Potential Confounders Not Accounted For:** Although the study adjusted for some confounders, other potential variables such as age, sex, body mass index (BMI), underlying health conditions, and socioeconomic status could also influence both vitamin D levels and immune function but were not fully controlled for in the analysis.

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6. **Limited Range of Immune Markers:** The study focused on IL-6 and TNF-α as markers of immune response. The immune system, however, is complex, and these markers do not encompass the entire spectrum of immune activity. Additional markers and functional immune assays could provide a more comprehensive understanding of how vitamin D interacts with the immune system.
7. **Sample Size and Power:** Although the study included 200 participants, the sample size may still be insufficient to detect smaller effect sizes or to conduct subgroup analyses. This limitation could affect the power of the study to identify significant associations in specific population segments.

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