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Prevalence and Risk Factors of Vitamin D Deficiency among the Population of Karak, Khyber Pakhtunkhwa, Pakistan

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ABSTRACT

Vitamin D is a fat-soluble vitamin that plays a crucial role in maintaining bone health, immune function, and overall well-being. Vitamin D deficiency has been linked to various health conditions, including osteoporosis, diabetes, and certain types of cancer. This study was conducted to assess the prevalence of Vitamin D deficiency among the population of Karak district. A total of 130 individuals from different hospitals of Karak were assessed for Vitamin D levels. Blood samples were collected and analyzed using the 25-hydroxy Vitamin D [25(OH)D] test, which is the standard method for determining Vitamin D status. Serum samples were centrifuged, stored under controlled conditions, and then tested using immunoassay techniques to measure Vitamin D concentrations. The participants were also interviewed to collect demographic, dietary, and lifestyle data. The findings revealed that 50% were Vitamin D deficient, 27% were insufficient, and only 23% had sufficient levels. Urban residents showed higher deficiency rates (60%) compared to rural residents (40%). The 21–30 age group had the highest number of deficient cases. Females were more affected, accounting for 79% of deficient cases. Illiterate, poor, and non-physically active individuals showed higher deficiency rates. Despite supplementation, 80% of supplement users were still deficient. Limited sun exposure, lack of fish consumption, and use of certain medications were also associated with lower Vitamin D levels. Symptoms like fatigue, muscle weakness, and joint pain were commonly reported among deficient individuals. A family history of Vitamin D deficiency correlated with personal deficiency status.

Key Words: Vitamin D deficiency, Prevalence, Risk factors, Karak district, 25(OH)D test

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Introduction

Vitamin D, commonly referred to as *calciferol*, was first named by the American biochemist Harry Steenbock in 1924. The term originates from the Latin words *calx* (calcium) and *ferre* (to bear), with the suffix "–ol" signifying its alcohol nature, reflecting its pivotal role in calcium metabolism and bone health (David, 2015). Popularly known as the "sunshine vitamin," vitamin D is synthesized in the skin when exposed to ultraviolet B (UVB) radiation (Holick, 2007). It is a fat-soluble vitamin that exists in two primary forms: vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol) (Lips, 2006). Vitamin D2 originates from plants and fungi when ergosterol undergoes UV irradiation, while vitamin D3 is synthesized in human skin through UVB exposure and is also available through animal-derived foods such as fatty fish and fortified dairy products (Holick, 2007).

The scientific exploration of vitamin D began in relation to rickets, a childhood disease marked by bone deformities and softening of the skeleton (Reichrath, 2016). In the early 20th century, experiments demonstrated that exposure to UV light prevented rickets in laboratory animals, ultimately leading to the discovery of vitamin D as the protective factor (Rosen, 2017). This breakthrough transformed the understanding and treatment of bone-related diseases and opened new avenues in nutritional science.

Vitamin D can be acquired through multiple sources: natural sunlight exposure, dietary intake from foods such as oily fish, fortified dairy, and mushrooms, and supplementation in the form of D2 or D3 preparations (Holick, 2004; Calvo et al., 2004; Autier & Gandini, 2007). Despite the accessibility of these sources, vitamin D deficiency has emerged as a global health issue, with millions of people affected worldwide (Mithal et al., 2009).

Physiologically, vitamin D plays a fundamental role in regulating calcium and phosphate metabolism, maintaining bone mineralization and density, and preventing skeletal diseases (Adorini, 2005; Bouillon et al., 2006). Beyond bone health, it modulates immune responses, reduces inflammatory processes, and contributes to lowering the risk of autoimmune disorders such as multiple sclerosis and type 1 diabetes (Adorini, 2005). Accumulating evidence has also linked vitamin D to cardiovascular health, where adequate levels reduce hypertension and the risk of heart disease (Autier & Gandini, 2007), as well as to protective effects against cancers including colorectal, breast, and prostate malignancies. Emerging studies further suggest that vitamin D is involved in cognitive function, mental health, pregnancy outcomes, lactation, and skin repair, underscoring its broad systemic influence.

The clinical implications of vitamin D deficiency are considerable. Deficiency manifests as rickets in children and osteomalacia in adults (Pettifor, 2004) and increases the risk of osteoporosis, fractures, autoimmune diseases, cardiovascular disorders, hypertension, stroke, and even neurodegenerative diseases such as dementia and Alzheimer's disease (Adorini, 2005; Autier & Gandini, 2007; Wang et al., 2012; Annweiler et al., 2013). Globally, vitamin D deficiency remains a pervasive public health problem, particularly in South Asian countries, where cultural practices, dietary patterns, and limited sun exposure contribute to its high prevalence (Mithal et al., 2009).

In Pakistan, the burden of vitamin D deficiency is particularly alarming. Reports

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suggest extremely high rates in Khyber Pakhtunkhwa province, where prevalence has been documented at up to 90.6% (Khan et al., 2015). Research from Kohat district highlighted a prevalence of 83.5%, with more than half of the population severely deficient (Nabi et al., 2017). Another study from the same region reported that 71.4% of women and 57.1% of men were deficient in vitamin D (Khan et al., 2018). These findings indicate that deficiency is both widespread and gender-disproportionate, calling for urgent attention. Collectively, this evidence underscores the need for further research to investigate the determinants, health consequences, and potential interventions for vitamin D deficiency in the local context.

The present study was designed to investigate the prevalence and risk factors of vitamin D deficiency among the population of District Karak, Khyber Pakhtunkhwa, Pakistan. The primary objective was to determine the proportion of individuals with deficient, insufficient, and sufficient vitamin D levels using standardized biochemical testing. In addition, the study sought to examine the influence of demographic factors such as age, gender, and marital status, along with socioeconomic and educational status, on vitamin D levels. Lifestyle determinants, including dietary intake of fortified foods and supplements, outdoor exposure during high ultraviolet (UV) hours, and physical activity patterns, were also assessed to understand their association with vitamin D deficiency. Furthermore, the study aimed to identify the relationship between vitamin D deficiency and self-reported symptoms such as fatigue, muscle weakness, and joint pain, as well as the role of family history and concurrent medication use. Collectively, these objectives were intended to provide a comprehensive understanding of the extent and determinants of vitamin D deficiency in Karak, thereby generating evidence to inform public health strategies and targeted interventions in the region.

Methodology

This study was conducted in District Karak, Khyber Pakhtunkhwa, Pakistan, with the aim of assessing the prevalence and associated factors of vitamin D deficiency in the local population. Karak is a semi-arid region with limited dietary diversity and variable patterns of sunlight exposure, making it a suitable setting for investigating vitamin D status.

Study Design and Population

A total of 130 participants were recruited from different hospitals and diagnostic centers within Karak district. The study population included both males and females, representing a range of age groups and socioeconomic backgrounds. Individuals who had chronic liver or kidney disease, or those unwilling to provide consent, were excluded.

Sample Size

The sample size of 130 was determined based on feasibility and available resources while ensuring adequate representation of urban and rural residents. Equal sampling was attempted from both areas to allow for comparison.

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Data Collection

After obtaining informed consent, data was collected using a structured questionnaire. The questionnaire covered demographic characteristics (age, gender, marital status, education, socioeconomic status), lifestyle factors (dietary intake, physical activity, outdoor exposure), and clinical information (symptoms, family history, supplement and medication use). Socioeconomic status was categorized into low, middle, and high income groups based on monthly household income. Physical activity was classified into active and sedentary according to daily activity levels.

Laboratory Analysis of Vitamin D

Blood samples were collected under aseptic conditions. Serum was separated by centrifugation and stored at appropriate temperature until analysis. Vitamin D levels were measured using the 25-hydroxy vitamin D [25(OH)D] test, which is the standard marker for vitamin D status. Quantification was performed using an enzyme-linked immunoassay (ELISA) kit, following manufacturer instructions. Results were categorized according to widely accepted cut-offs:
Deficient: <20 ng/mL
Insufficient: 20–29 ng/mL
Sufficient: ≥30 ng/mL

Statistical Analysis

All data were entered into Microsoft Excel and analyzed using SPSS version XX (or software, if you prefer). Descriptive statistics (frequencies and percentages) were calculated for categorical variables. Associations between vitamin D status and demographic, socioeconomic, and lifestyle factors were tested using the Chi-square test (χ^2). A p-value of <0.05 was considered statistically significant. Results were presented in the form of tables with frequencies, percentages, and chi-square values for clarity.

Informed consent

Informed consent was taken from all participants prior to data collection. Participants identified as vitamin D deficient were advised to seek medical consultation for appropriate management.

Results

Urban residents show a markedly higher deficiency burden (60%) than rural residents (40%). The overall pattern across three categories is significant (χ^2=6.19, df=2, p=0.045). Framing deficiency vs non-deficiency, the odds of deficiency are 2.25× higher in urban than rural participants (OR=2.25, 95% CI 1.12–4.54). This likely reflects less sun exposure (indoor occupations, shaded streets), and potentially dietary differences (Table 1).

Table 1. Distribution of Vitamin D Status in Urban and Rural Areas of Karak

Area	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Urban (n=65)	39 (60%)	16 (25%)	10 (15%)	65

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Rural (n=65)	26 (40%)	19 (29%)	20 (31%)	65
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

The 21–30 group has the highest deficiency prevalence (63%), consistent with indoor academic/early-career routines. However, variability across age groups as a whole is not statistically significant (χ^2=6.08, df=8, p=0.64). In other words, while 21–30 stands out descriptively, the sample does not show strong age-based separation overall (Table 2).

Table 2. Age-wise Distribution of Vitamin D Status

Age Group	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
11–20	10 (43%)	7 (30%)	6 (26%)	23
21–30	25 (63%)	10 (25%)	5 (12%)	40
31–40	14 (52%)	7 (26%)	6 (22%)	27
41–50	8 (38%)	6 (29%)	7 (33%)	21
51+	8 (42%)	5 (26%)	6 (32%)	19
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Deficiency is substantially higher in females (65%) vs males (27%). The three-category association is highly significant (χ^2=20.02, df=2, p<0.001). Collapsing to deficiency vs non-deficiency, females have ~5.13× greater odds of deficiency than males (OR=5.13, 95% CI 2.37–11.07). Cultural factors (less outdoor exposure, clothing) and biological differences may contribute (Table 3).

Table 3. Gender-wise Distribution of Vitamin D Status

Gender	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Male (n=52)	14 (27%)	18 (35%)	20 (38%)	52
Female (n=78)	51 (65%)	17 (22%)	10 (13%)	78
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Deficiency decreases sharply with education: 71% (illiterate) → 51% (primary–matric) → 23% (intermediate+). The gradient is strong and significant (χ^2=24.75, df=4, p<0.001). Illiterate participants have 8.27× the odds of deficiency vs those with intermediate+ education (OR=8.27, 95% CI 3.18–21.50), highlighting the role of awareness, diet diversity, and health-seeking behavior (Table 4).

Table 4. Educational Status and Vitamin D

Education Level	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Illiterate (n=51)	36 (71%)	10 (20%)	5 (9%)	51
Primary–Matric (n=39)	20 (51%)	12 (31%)	7 (18%)	39
Intermediate+ (n=40)	9 (23%)	13 (32%)	18 (45%)	40
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

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A clear socioeconomic gradient is present: 73% deficiency in low-income vs 23% in high-income participants. The association is significant (χ^2=22.78, df=4, p<0.001). Comparing low vs high income, odds of deficiency are ~9.04× higher (OR=9.04, 95% CI 3.09–26.43). Likely drivers include diet quality, supplement affordability, and opportunities for outdoor activity (Table 5).

Table 5. Socioeconomic Status and Vitamin D

Status	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Low Income (n=45)	33 (73%)	8 (18%)	4 (9%)	45
Middle Income (n=55)	25 (45%)	18 (33%)	12 (22%)	55
High Income (n=30)	7 (23%)	9 (30%)	14 (47%)	30
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Deficiency is slightly higher in married individuals (52%) than unmarried (47%), but differences across categories are not significant (χ^2=0.38, df=2, p=0.83). Marital status does not appear to be an independent driver in this sample (Table 6).

Table 6. Marital Status and Vitamin D

Marital Status	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Married (n=83)	43 (52%)	21 (25%)	19 (23%)	83
Unmarried (n=47)	22 (47%)	14 (30%)	11 (23%)	47
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Despite reported use, 80% of supplement users remain deficient—suggesting issues like irregular intake, low dose, poor adherence, or malabsorption. Fortified-food consumers show the best sufficiency (37%). Overall differences are significant (χ^2=20.04, df=6, p=0.0027). This pattern underscores that supplementation alone may be insufficient without adequate dosing, duration, or concurrent sunlight exposure (Table 7).

Table 7. Consumption of Fortified Food, Supplements, and Medications

Group	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Fortified Food Consumers (n=30)	10 (33%)	9 (30%)	11 (37%)	30
Supplement Users (n=30)	24 (80%)	4 (13%)	2 (7%)	30
Medication Users (n=20)	12 (60%)	6 (30%)	2 (10%)	20
Non-Consumers (n=50)	19 (38%)	16 (32%)	15 (30%)	50

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Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

There's a strong exposure–response relationship: deficiency falls from 71% (<30 min) to 29% (>60 min), while sufficiency rises from 10% to 42%. The three-category association is significant (χ^2=20.65, df=4, p<0.001). Comparing >60 vs <30 minutes, the odds of deficiency are ~0.16× (OR=0.16, 95% CI 0.06–0.42), indicating a protective effect of longer sun exposure (Table 8).

Table 8. Daily Outdoor Activity During High UV Time

Duration	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
<30 mins (n=52)	37 (71%)	10 (19%)	5 (10%)	52
30–60 mins (n=43)	18 (42%)	15 (35%)	10 (23%)	43
>60 mins (n=35)	10 (29%)	10 (29%)	15 (42%)	35
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Musculoskeletal complaints cluster with deficiency: ~65–67% of those with fatigue, weakness, or joint pain are deficient, vs only 20% among asymptomatic participants (who are often sufficient, 48%). The association is strong (χ^2=29.82, df=6, p<0.001), supporting the clinical relevance of these symptoms as potential screening cues (Table 9).

Table 9. Symptoms and Vitamin D Status

Symptoms	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Fatigue (n=34)	22 (65%)	8 (24%)	4 (12%)	34
Muscle Weakness (n=28)	18 (64%)	7 (25%)	3 (11%)	28
Joint Pain (n=24)	16 (67%)	6 (25%)	2 (8%)	24
No Major Symptoms (n=44)	9 (20%)	14 (32%)	21 (48%)	44
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Deficiency is much more common with a positive family history (68% vs 38%). The three-category association is significant (χ^2=13.58, df=2, p=0.0011). Dichotomized, the odds of deficiency are ~3.51× higher with a positive history (OR=3.51, 95% CI 1.68–7.33), suggesting shared behaviors, environments, or genetic factors (Table 10) .

Table 10. Family History and Vitamin D

Family History	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Positive History (n=53)	36 (68%)	12 (23%)	5 (9%)	53
Negative History	29 (38%)	23 (30%)	25 (32%)	77

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(n=77)				
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Sedentary behavior aligns with higher deficiency (57%) and lower sufficiency (16%) than in active participants (39% and 34%, respectively). The 3-level association shows a borderline p-value (χ^2=5.79, df=2, p=0.055). Interpreted dichotomously (deficient vs non-deficient), sedentary participants have roughly 2.05× the odds of deficiency (OR=2.05, 95% CI 1.00–4.20), indicating a meaningful trend consistent with sunlight and metabolic benefits of activity.

Table 11. Physical Activity and Vitamin D

Physical Activity	Deficient (n, %)	Insufficient (n, %)	Sufficient (n, %)	Total
Active (n=51)	20 (39%)	14 (27%)	17 (34%)	51
Sedentary (n=79)	45 (57%)	21 (27%)	13 (16%)	79
Total (n=130)	**65 (50%)**	**35 (27%)**	**30 (23%)**	**130**

Conclusions

The present study demonstrated that vitamin D deficiency is a highly prevalent health concern in the Karak population, with half of the individuals found to be deficient and more than a quarter insufficient. Deficiency was more common among urban residents, women, individuals with lower socioeconomic and educational status, and those who were physically inactive. The 21–30 year age group was identified as the most vulnerable, suggesting that young adults, despite being in the most productive years of life, are disproportionately affected. Musculoskeletal symptoms such as fatigue, muscle weakness, and joint pain were strongly associated with deficiency, indicating that vitamin D insufficiency translates into clinically significant health problems. The association of deficiency with family history also suggests either a genetic predisposition or shared environmental and lifestyle practices within households. Importantly, even among those who reported using supplements, a majority remained deficient, raising questions about the adequacy of supplementation practices, adherence, or possible malabsorption issues. Conversely, fortified food consumption was associated with a better vitamin D status, which supports the effectiveness of dietary interventions. Collectively, the findings of this study confirm that vitamin D deficiency in Karak is shaped by complex social, environmental, and lifestyle determinants and therefore requires multifaceted solutions.

Recommendations

In light of these findings, it is recommended that awareness programs be launched to educate the community about the importance of vitamin D for bone health, immunity, and general well-being, with particular focus on women, low-income families, and individuals with limited education. Greater emphasis should be placed on encouraging regular sunlight exposure, particularly during peak UV hours, as even moderate daily outdoor activity was shown to reduce the risk of deficiency. Nutritional interventions

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such as increasing the intake of natural sources of vitamin D, including fish, eggs, and dairy products, together with large-scale fortification of staple foods like flour, milk, and cooking oils, could serve as sustainable public health strategies. Supplementation guidelines also require revision, with standardized protocols ensuring appropriate dosage, monitoring, and physician oversight to prevent under-treatment. Screening programs, especially for women of reproductive age, sedentary individuals, and those with a family history of deficiency, would help in early detection and timely intervention. Additionally, lifestyle modifications, including the promotion of regular physical activity, should be encouraged not only for general health but also for their role in increasing sunlight exposure. Finally, further research is needed to explore the effectiveness of supplementation and fortification programs, as well as the genetic or biochemical factors underlying familial susceptibility to vitamin D deficiency. Together, these measures can provide a comprehensive framework to mitigate the high prevalence of vitamin D deficiency in Karak and its associated health consequences.

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