RJNMSR
Review Journal of Neurological & Medical Sciences Review

Volume 3, Issue 4, 2025

VITAMIN D DEFICIENCY: A CROSS-SECTIONAL STUDY IN THE POPULATION OF KOHAT, KHYBER PAKHTUNKHWA

Sonia Aslam[1*], Shehzad Zareen[2*], Rimsha[3], Hadia[4], Aleena Ayaz[5], Hina Noor[6]

*[*1]Government Girls Postgraduate College Kohat, KP, Pakistan.*
*[*2]Department of Zoology, Kohat University of Science & Technology, Kohat, KP, Pakistan.*
[3]Government Girls Postgraduate College Kohat, KP, Pakistan.
[4]Government Girls Postgraduate College Kohat, KP, Pakistan.
[5]Government Girls Postgraduate College Kohat, KP, Pakistan.
[6]Government Girls Postgraduate College Kohat, KP, Pakistan.
[1]dua005@yahoo.com, [2]Shehzadzareen1@kust.edu.pk, [3]Shoibfarooq999@gmail.com, [4]Bushra03041998@gmail.com, [5]aleenadoll049@gmail.com, [6]Hinanoor042001@gmail.com

Corresponding Authors: *
Sonia Aslam
Shehzad Zareen

DOI: https://doi.org/

Received	Accepted	Published
15 July, 2025	12 August, 2025	13 August, 2025

ABSTRACT

Vitamin D, a fat-soluble secosteroid, is essential for optimal bone mineralization, immune modulation, and overall physiological homeostasis. Deficiency of this micronutrient has been implicated in a range of chronic conditions, including osteoporosis, metabolic disorders such as type 2 diabetes, and certain malignancies. In the present cross-sectional study, a total of 200 blood samples were collected from multiple hospitals across the Kohat district, Khyber Pakhtunkhwa. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured to determine vitamin D status. Of the total cohort, 50% were classified as vitamin D deficient, 27% as insufficient, and only 23% as sufficient. Urban residents exhibited a markedly higher deficiency rate (60%) compared to rural participants (40%). The highest prevalence of deficiency was observed in the 21–30-year age group, with females comprising 79% of deficient cases. Individuals with lower educational attainment, reduced socioeconomic status, and sedentary lifestyles demonstrated significantly greater deficiency rates ($p < 0.05$). Notably, 80% of individuals who reported regular vitamin D supplementation remained deficient, suggesting possible issues of dosage, compliance, or absorption. Lifestyle and dietary assessments revealed limited sun exposure, minimal fish consumption, and concurrent medication use as significant contributors to low serum vitamin D concentrations. Commonly reported symptoms among deficient individuals included fatigue, myalgia, and arthralgia. A positive family history of vitamin D deficiency was also associated with increased risk. These findings highlight a substantial burden of vitamin D deficiency within the Kohat population, disproportionately affecting urban residents, women, and socioeconomically disadvantaged groups. Public health measures should prioritize targeted nutritional education, promotion of safe sunlight exposure, and fortified food programs to mitigate this pervasive micronutrient deficiency.
Key Words: *Vitamin D deficiency, Prevalence, Kohat, Khyber Pakhtunkhwa, Risk factors*

INTRODUCTION

Vitamin D, also known as *calciferol*, is a fat-soluble secosteroid that plays a fundamental role in human health, particularly in calcium and phosphate metabolism, skeletal integrity, and a broad range of extra-skeletal physiological functions. The name *calciferol*—coined by American biochemist Harry Steenbock in 1924—derives from the Latin *calx* (calcium) and *ferre* (to bear), with the suffix "-ol" signifying its alcohol structure (David, 2015). This nomenclature is particularly fitting, given the compound's indispensable role in promoting calcium absorption and maintaining bone strength. Widely known as the "sunshine vitamin," vitamin D is unique among micronutrients in that it can be synthesized endogenously in the skin following exposure to ultraviolet B (UVB) radiation (Holick, 2007). It occurs in two main bioactive forms: vitamin D_2 (*ergocalciferol*) and vitamin D_3 (*cholecalciferol*) (Lips, 2006). Vitamin D_2 is primarily obtained from plant and fungal sources, produced via ultraviolet irradiation of ergosterol, while vitamin D_3 is generated in the epidermis upon UVB exposure and is also found in certain animal-derived foods such as oily fish, liver, and fortified dairy products (Holick, 2007).

The historical roots of vitamin D research are closely tied to the prevention and treatment of rickets, a debilitating pediatric condition marked by defective bone mineralization and skeletal deformities (Reichrath, 2016). In the early 20th century, studies demonstrated that exposure to sunlight or ultraviolet light could prevent and reverse rickets in animal models, leading to the identification and isolation of vitamin D as the active protective factor (Rosen, 2017). This discovery not only revolutionized the understanding of nutritional deficiencies but also marked a pivotal shift in public health strategies aimed at preventing bone-related disorders. Vitamin D status in humans is influenced by multiple factors, including cutaneous synthesis through sunlight exposure (Holick, 2004), dietary intake from sources such as fatty fish, egg yolks, fortified dairy products, and UV-exposed mushrooms (Calvo et al., 2004), and supplementation in pharmacological forms of vitamin D_2 or D_3 (Autier & Gandini, 2007). Despite these varied sources, deficiency remains one of the most widespread micronutrient insufficiencies globally, affecting diverse populations across different latitudes and socioeconomic settings (Mithal et al., 2009).

Physiologically, vitamin D is a key regulator of calcium and phosphorus homeostasis, critical for optimal bone mineral density and skeletal health (Bouillon et al., 2006). Beyond its classical role in musculoskeletal function, vitamin D exerts profound effects on the immune system, modulating both innate and adaptive immunity, and reducing the risk of chronic inflammation and autoimmune conditions such as multiple sclerosis and type 1 diabetes (Adorini, 2005). It has also been associated with improved cardiovascular outcomes, including regulation of blood pressure, endothelial function, and a reduced incidence of ischemic heart disease (Autier & Gandini, 2007). Additionally, accumulating evidence suggests potential protective effects against certain cancers—such as colorectal, breast, and prostate malignancies—as well as benefits in cognitive performance, mood regulation, pregnancy outcomes, lactation, wound healing, and dermatological health. Conversely, vitamin D deficiency has been implicated in a spectrum of adverse health outcomes. Classical manifestations include rickets in children and osteomalacia in adults (Pettifor, 2004), while chronic insufficiency increases susceptibility to osteoporosis, fragility fractures, autoimmune disorders, cardiovascular disease, hypertension, and cerebrovascular events (Wang et al., 2012). Emerging data have also linked deficiency to an elevated risk of neurodegenerative conditions such as Alzheimer's disease and dementia (Annweiler et al., 2013).

Globally, vitamin D deficiency is recognized as a pressing public health concern, but its burden is particularly pronounced in South Asia (Mithal et al., 2009). In Pakistan, prevalence rates are alarmingly high, especially in the Khyber Pakhtunkhwa province, where Khan et al. (2015) reported deficiency rates up to 90.6%. The Kohat district exemplifies this crisis: Nabi et al. (2017) found that 83.5% of residents had deficient serum vitamin D levels, with more than half exhibiting severe deficiency. Gender disparities are also significant, with Khan et al. (2018) documenting prevalence rates of 71.4% among women and 57.1% among men. These statistics underscore that vitamin D deficiency in Kohat is not only widespread but also influenced by demographic, lifestyle, and possibly genetic factors. Such evidence highlights the urgent need for targeted epidemiological research to investigate its determinants, quantify its health impacts, and inform locally relevant prevention and intervention strategies.

MATERIALS AND METHODS

STUDY AREA

Kohat city is situated at an altitude of 489 meters (1,604 ft) above sea level, covering a total district area of approximately 2,545 km². The climate of Kohat is characterized by long, hot, and humid summers, contrasted with short, mild to cold winters. Annual temperature variation typically ranges from 36 °F to 103 °F, with extremes rarely falling below 31 °F or exceeding 110 °F. These climatic conditions influence sunlight exposure, an important determinant of endogenous vitamin D synthesis.

STUDY DESIGN AND SETTING

This cross-sectional study was conducted to determine the frequency of vitamin D deficiency among individuals attending healthcare facilities in Kohat. Data collection sites included multiple hospitals and diagnostic centers, namely:

- KDA Hospital
- Behram Medical Center
- Doctors Hospital
- Asad Khalil Medical Store Laboratory Unit

The selection of multiple centers ensured a more representative sample of the district's urban and peri-urban population.

SAMPLE SIZE AND SAMPLING TECHNIQUE

A total of 200 individuals were recruited through simple random sampling from patients visiting the selected facilities. Inclusion criteria comprised individuals aged ≥18 years, residing in Kohat district, and willing to provide informed consent. Those with known chronic renal or hepatic diseases, or already under investigation for metabolic bone disorders, were excluded to minimize confounding.

DATA COLLECTION TOOLS AND PROCEDURES

Data were collected using a structured questionnaire administered through face-to-face interviews. The questionnaire captured:

- **Demographic data:** age, gender, education, socioeconomic status, and residential area (urban or rural).
- **Lifestyle factors:** sun exposure, dietary habits, supplement use, and physical activity.
- **Clinical symptoms:** fatigue, muscle weakness, joint pain, osteoporosis history, and other relevant complaints.

BLOOD SAMPLE COLLECTION AND LABORATORY ANALYSIS

Blood samples were collected via standard venipuncture. Using a sterile needle (15–20° angle, bevel upward), approximately 3–5 mL of venous blood was drawn into a serum separator tube (SST). Each tube was labeled with patient ID, date, and time of collection.

Samples were centrifuged at 1,300–1,500 × g for 10–15 minutes to separate serum. The clear serum layer was carefully extracted using a calibrated micropipette (100–200 µL) and transferred into microplate wells.

Quantitative analysis of serum 25-hydroxyvitamin D [25(OH)D] levels was performed using a commercially available ELISA kit following the manufacturer's protocol:

1. **Addition of Reagent:** 100–200 µL of the 25(OH)D test reagent was added to each well containing serum.
2. **Mixing:** Gentle mixing was carried out using a pipette or plate mixer to avoid air bubbles.
3. **Incubation:** Plates were incubated at 37 °C for 10 minutes, covered to prevent evaporation.
4. **Measurement:** Absorbance was read at 450 nm using a calibrated microplate reader.
5. **Calculation:** Concentrations were calculated according to the manufacturer's software and interpreted as:
    - **Deficient:** <20 ng/mL
    - **Insufficient:** 20–29 ng/mL
    - **Sufficient:** ≥30 ng/mL

DATA ANALYSIS

Data were entered and analyzed using IBM SPSS Statistics. Descriptive statistics (frequencies and percentages) were calculated for categorical variables. Continuous variables were summarized as means ± standard deviations where applicable. The results are presented in percentage format to allow straightforward interpretation and facilitate comparison between demographic and clinical subgroups.

RESULTS

VITAMIN D STATUS BY RESIDENTIAL AREA

A total of 200 participants were included in the analysis, of whom 112 (56.0%) resided in urban areas and 88 (44.0%) in rural areas (Table 1). Overall, vitamin D deficiency (<20 ng/mL) was present in 100 participants (50.0%), insufficiency (20–29 ng/mL) in 54 (27.0%), and sufficient levels (≥30 ng/mL) in 46 (23.0%). Urban residents exhibited a markedly higher prevalence of vitamin D deficiency compared to rural participants (60.0% vs. 40.0%). Conversely, sufficiency was more common among rural residents (65.2%) than urban residents (34.8%). The proportion of vitamin D insufficiency was also higher in urban areas (66.7%) compared to rural areas (33.3%). These findings suggest a strong association between residential setting and vitamin D status, with urban living potentially contributing to increased deficiency risk — possibly due to reduced sun exposure, lifestyle factors, or dietary differences.

TABLE 1. DISTRIBUTION OF VITAMIN D STATUS BY RESIDENTIAL AREA

Area	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Urban	60 (60.0%)	36 (66.7%)	16 (34.8%)	112 (56.0%)
Rural	40 (40.0%)	18 (33.3%)	30 (65.2%)	88 (44.0%)
Total	**100 (50.0%)**	**54 (27.0%)**	**46 (23.0%)**	**200 (100%)**

VITAMIN D STATUS BY AGE GROUP

The distribution of vitamin D status across different age groups is presented in Table 2. Among the 200 participants, the highest prevalence of deficiency (<20 ng/mL) was observed in the 21–30-year age group, accounting for 32.0% of all deficient cases. This was followed by the 11–20-year group (21.0%) and the 41–50-year group (20.0%). Notably, no cases of deficiency were recorded in participants aged 61–70 years or in most individuals over 70 years. Vitamin D insufficiency (20–29 ng/mL) was also most prevalent in the 21–30-year age group (24.1%), followed by the 51–60-year group (22.2%) and the 11–20-year group (20.4%). Sufficient vitamin D levels (≥30 ng/mL) were most common in the 21–30-year age group (45.7%), followed by the 11–20-year group (32.0%). Very few individuals aged 71–80 years had sufficient vitamin D levels (5.6%), and no sufficient cases were observed in the 61–70-year age category. The age distribution suggests that young and middle-aged adults, particularly those between 21–30 years, exhibit the highest rates of deficiency and insufficiency, indicating potential lifestyle, occupational, or dietary influences in this demographic.

TABLE 2. DISTRIBUTION OF VITAMIN D STATUS BY AGE GROUP

Vitamin D Level	11–20 yrs	21–30 yrs	31–40 yrs	41–50 yrs	51–60 yrs	61–70 yrs	71–80 yrs	Total
Deficient	21 (21.0%)	32 (32.0%)	18 (18.0%)	20 (20.0%)	9 (9.0%)	0 (0.0%)	0 (0.0%)	100 (50.0%)
Insufficient	11 (20.4%)	13 (24.1%)	10 (18.5%)	5 (9.3%)	12 (22.2%)	0 (0.0%)	3 (5.6%)	54 (27.0%)
Sufficient	15 (32.0%)	21 (45.7%)	3 (6.5%)	3 (6.5%)	4 (8.7%)	0 (0.0%)	0 (0.0%)	46 (23.0%)
Total	**47**	**66**	**31**	**28**	**25**	**0**	**3**	**200 (100%)**

VITAMIN D STATUS BY GENDER

The gender-wise distribution of vitamin D status is presented in Table 3. Out of 200 participants, 141 (70.5%) were female and 59 (29.5%) were male. Vitamin D deficiency (<20 ng/mL) was significantly more prevalent among females, who accounted for 79.0% of all deficient cases, compared to only 21.0% among males. Similarly, vitamin D insufficiency (20–29 ng/mL) was more common in females (68.5%) than males (31.5%). Conversely, sufficient vitamin D levels (≥30 ng/mL) were more frequently observed in males (45.7%) compared to females (54.3%), although the overall proportion of sufficiency in both genders remained relatively low. These findings suggest a marked gender disparity, with females being disproportionately affected by vitamin D deficiency and insufficiency, which may be attributed to sociocultural practices, differences in sun exposure, dietary patterns, and physiological factors.

TABLE 3. DISTRIBUTION OF VITAMIN D STATUS BY GENDER

Gender	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Male	21 (21.0%)	17 (31.5%)	21 (45.7%)	59 (29.5%)
Female	79 (79.0%)	37 (68.5%)	25 (54.3%)	141 (70.5%)
Total	**100 (50.0%)**	**54 (27.0%)**	**46 (23.0%)**	**200 (100%)**

VITAMIN D STATUS BY EDUCATIONAL STATUS

The association between educational attainment and vitamin D status is summarized in Table 4. Of the 200 participants, 112 (56.0%) were literate and 88 (44.0%) were illiterate. Vitamin D deficiency (<20 ng/mL) was equally distributed between literate and illiterate participants, with each group accounting for 50.0% of all deficient cases. However, vitamin D sufficiency (≥30 ng/mL) was notably higher among literate individuals (73.9%) compared to illiterate individuals (26.1%). The prevalence of insufficiency (20–29 ng/mL) was also slightly higher among literate participants (51.9%) than illiterate participants (48.1%). These results indicate that although both groups were equally affected by deficiency, literacy was associated with a greater likelihood of having sufficient vitamin D levels. This may reflect better health awareness, dietary diversity, or lifestyle factors among the literate population.

TABLE 4. DISTRIBUTION OF VITAMIN D STATUS BY EDUCATIONAL STATUS

Educational Status	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Literate	50 (50.0%)	28 (51.9%)	34 (73.9%)	112 (56.0%)
Illiterate	50 (50.0%)	26 (48.1%)	12 (26.1%)	88 (44.0%)
Total	100 (50.0%)	54 (27.0%)	46 (23.0%)	200 (100%)

VITAMIN D STATUS BY SOCIOECONOMIC STATUS

Table 5 presents the distribution of vitamin D status across different socioeconomic groups. Among the 200 participants, the majority (76.5%) belonged to the middle-income category, followed by poor (19.5%) and rich (4.0%) groups. Vitamin D deficiency (<20 ng/mL) was most prevalent among middle-income individuals, accounting for 82.0% of all deficient cases. Poor participants represented 18.0% of deficient cases, while no deficiencies were recorded among the rich group. Insufficiency (20–29 ng/mL) was also more common in the middle-income group (68.5%), followed by the poor group (31.5%), with no cases in the rich group. Conversely, vitamin D sufficiency (≥30 ng/mL) was highest among middle-income participants (73.9%), followed by the rich group (17.4%) and the poor group (8.7%). These results indicate that while deficiency was largely concentrated in the middle-income category, sufficiency was rare among lower-income participants, highlighting the potential role of socioeconomic factors in dietary quality, supplementation, and sun exposure habits.

TABLE 5. DISTRIBUTION OF VITAMIN D STATUS BY SOCIOECONOMIC STATUS

Socioeconomic Status	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Poor	18 (18.0%)	17 (31.5%)	4 (8.7%)	39 (19.5%)
Middle	82 (82.0%)	37 (68.5%)	34 (73.9%)	153 (76.5%)
Rich	0 (0.0%)	0 (0.0%)	8 (17.4%)	8 (4.0%)
Total	100 (50.0%)	54 (27.0%)	46 (23.0%)	200 (100%)

VITAMIN D STATUS BY MARITAL STATUS

The relationship between marital status and vitamin D levels is shown in Table 6. Of the 200 participants, 118 (59.0%) were married and 82 (41.0%) were unmarried. Vitamin D deficiency (<20 ng/mL) was slightly more prevalent among married individuals (52.0%) than unmarried individuals (48.0%). However, the difference in deficiency rates between the two groups was minimal. Insufficiency (20–29 ng/mL) was considerably higher in the married group, accounting for 72.2% of all insufficient cases, compared to 27.8% in the unmarried group. Conversely, sufficient vitamin D levels (≥30 ng/mL) were more common among unmarried individuals (41.3%) compared to married individuals (58.7%), although the married group still represented the majority of sufficient cases in absolute numbers. These findings suggest that marital status may have a subtle influence on vitamin D status, potentially linked to lifestyle patterns, dietary habits, and outdoor activity levels.

TABLE 6. DISTRIBUTION OF VITAMIN D STATUS BY MARITAL STATUS

Marital Status	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Married	52 (52.0%)	39 (72.2%)	27 (58.7%)	118 (59.0%)
Unmarried	48 (48.0%)	15 (27.8%)	19 (41.3%)	82 (41.0%)
Total	100 (50.0%)	54 (27.0%)	46 (23.0%)	200 (100%)

SUPPLEMENT USE, FORTIFIED FOOD CONSUMPTION, AND MEDICATION IN RELATION TO VITAMIN D STATUS

VITAMIN D SUPPLEMENT INTAKE

Among the 200 participants, 114 (57.0%) reported taking vitamin D supplements, while 86 (43.0%) did not (Table 7). Surprisingly, vitamin D deficiency (<20 ng/mL) was more common among supplement users (80.0%) compared to non-users (20.0%). In contrast, sufficient vitamin D levels (≥30 ng/mL) were more prevalent among non-supplement users (73.9%) than supplement users (26.1%). This unexpected pattern may indicate irregular supplement use, incorrect dosage, or underlying health conditions in those already prescribed supplements.

CONSUMPTION OF VITAMIN D–FORTIFIED FOODS

A majority of participants (n=171; 85.5%) reported consuming vitamin D–fortified foods, while 29 (14.5%) did not. Deficiency was notably higher among fortified food consumers (87.0%) compared to non-consumers (13.0%). Similarly, sufficient vitamin D levels were also predominantly found in fortified food consumers (84.8%). This suggests that dietary fortification alone may not be adequate to prevent deficiency in this population, possibly due to insufficient fortification levels or limited bioavailability.

MEDICATION USE

Most participants (n=159; 79.5%) reported taking some form of medication, while 41 (20.5%) did not. Vitamin D deficiency was markedly higher among medication users (83.0%) compared to non-users (17.0%). Conversely, sufficient vitamin D levels were more frequent in non-medication users (39.1%) than in those taking medications (60.9%). The association between medication use and deficiency may reflect underlying chronic illnesses or drug-induced alterations in vitamin D metabolism.

TABLE 7. ASSOCIATION OF SUPPLEMENT USE, FORTIFIED FOOD INTAKE, AND MEDICATION WITH VITAMIN D STATUS

Variable	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Supplement Use				
Yes	80 (80.0%)	22 (40.7%)	12 (26.1%)	114 (57.0%)
No	20 (20.0%)	32 (59.3%)	34 (73.9%)	86 (43.0%)
Fortified Food Consumption				
Yes	87 (87.0%)	45 (83.3%)	39 (84.8%)	171 (85.5%)
No	13 (13.0%)	9 (16.7%)	7 (15.2%)	29 (14.5%)
Medication Use				
Yes	83 (83.0%)	48 (88.9%)	28 (60.9%)	159 (79.5%)
No	17 (17.0%)	6 (11.1%)	18 (39.1%)	41 (20.5%)

TIME SPENT OUTDOORS DURING PEAK SUNLIGHT HOURS AND VITAMIN D STATUS

The association between outdoor exposure during peak sun hours (10 a.m.–3 p.m.) and vitamin D status is presented in Table 8. A majority of participants (n=104; 52.0%) reported rarely spending time outdoors during these hours. This group exhibited the highest prevalence of vitamin D deficiency (62.0%), along with moderate proportions of insufficiency (48.1%) and sufficiency (34.8%). Participants spending 1–2 times per week outdoors (n=54; 27.0%) had a deficiency rate of 15.0%, but were the most represented among those with vitamin D insufficiency (46.3%). Those spending 2–3 times per week outdoors (n=24; 12.0%) demonstrated the highest proportion of sufficient vitamin D levels (26.1%) relative to their group size, with only 9.0% showing deficiency. Daily outdoor exposure during peak sunlight hours (n=18; 9.0%) was associated with the lowest deficiency rate (14.0%) and a relatively low insufficiency rate (0.0%), indicating a clear protective effect of consistent sun exposure. Overall, these findings underscore the strong positive association between frequent sun exposure and adequate vitamin D levels, highlighting limited outdoor activity as a major risk factor for deficiency in this population.

TABLE 8. DISTRIBUTION OF VITAMIN D STATUS BY FREQUENCY OF OUTDOOR EXPOSURE DURING PEAK SUNLIGHT HOURS

Time Outdoors (Peak Sun Hours)	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Daily	14 (14.0%)	0 (0.0%)	4 (8.7%)	18 (9.0%)
2–3 times/week	9 (9.0%)	3 (5.6%)	12 (26.1%)	24 (12.0%)
1–2 times/week	15 (15.0%)	25 (46.3%)	14 (30.4%)	54 (27.0%)
Rarely	62 (62.0%)	26 (48.1%)	16 (34.8%)	104 (52.0%)
Total	100 (50.0%)	54 (27.0%)	46 (23.0%)	200 (100%)

SYMPTOM DISTRIBUTION IN RELATION TO VITAMIN D STATUS

Table 9 illustrates the distribution of self-reported symptoms across different vitamin D status categories. Fatigue was the most frequently reported symptom overall (n=70; 35.0%), with the majority occurring in the insufficient vitamin D group (51.9%), followed by the sufficient (41.3%) and deficient (23.0%) groups. Muscle weakness was predominantly associated with vitamin D deficiency, reported by 31.0% of deficient participants but only 5.6% of insufficient and 8.7% of sufficient individuals. Joint pain was also more common in the deficient group (28.0%)

compared to those with insufficient (20.4%) or sufficient (8.7%) levels. Interestingly, osteoporosis was more prevalent among individuals with sufficient vitamin D levels (26.1%) than among deficient (11.0%) or insufficient (13.0%) participants. This unexpected pattern may be related to pre-existing diagnoses leading to supplementation and improved serum vitamin D levels. Other symptoms, such as general malaise, headaches, or non-specific discomfort, were reported by 9.5% of participants, with slightly higher proportions among those with sufficient vitamin D levels. These findings suggest that while classical musculoskeletal symptoms (e.g., muscle weakness, joint pain) are strongly linked with deficiency, fatigue is more evenly distributed and osteoporosis may be influenced by confounding factors such as medical intervention.

TABLE 9. DISTRIBUTION OF SYMPTOMS BY VITAMIN D STATUS

Symptom	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Fatigue	23 (23.0%)	28 (51.9%)	19 (41.3%)	70 (35.0%)
Muscle weakness	31 (31.0%)	3 (5.6%)	4 (8.7%)	38 (19.0%)
Joint pain	28 (28.0%)	11 (20.4%)	4 (8.7%)	43 (21.5%)
Osteoporosis	11 (11.0%)	7 (13.0%)	12 (26.1%)	30 (15.0%)
Other	7 (7.0%)	5 (9.3%)	7 (15.2%)	19 (9.5%)

ASSOCIATION BETWEEN FAMILY HISTORY AND VITAMIN D STATUS

Table 10 summarizes the relationship between family history of vitamin D deficiency and current vitamin D status among participants. Of the 200 individuals surveyed, 120 (60.0%) reported a positive family history of vitamin D deficiency, while 80 (40.0%) had no such history. Vitamin D deficiency was markedly more prevalent among those with a family history (74.0%) compared to those without (26.0%). Conversely, insufficiency was more common among participants without a family history (63.0%) than among those with a family history (37.0%). Sufficient vitamin D levels were also slightly higher in the family-history group (56.5%) compared to the no-history group (43.5%), suggesting that some individuals with hereditary risk factors may achieve adequate levels through increased awareness, supplementation, or targeted interventions. These results indicate a strong correlation between family history and the likelihood of vitamin D deficiency, underscoring the potential role of genetic predisposition and shared lifestyle factors in determining vitamin D status.

TABLE 10. DISTRIBUTION OF VITAMIN D STATUS BY FAMILY HISTORY

Family History	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Yes	74 (74.0%)	20 (37.0%)	26 (56.5%)	120 (60.0%)
No	26 (26.0%)	34 (63.0%)	20 (43.5%)	80 (40.0%)

RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND VITAMIN D STATUS

Table 11 presents the distribution of vitamin D status in relation to participants' engagement in physical activity. Of the 200 individuals studied, 88 (44.0%) reported regular engagement in physical activity, while 112 (56.0%) were physically inactive. Vitamin D deficiency was substantially more prevalent among physically inactive participants (73.0%) compared to those who engaged in physical activity (27.0%). Conversely, sufficient vitamin D levels were observed in 65.2% of physically active individuals, whereas only 34.8% of inactive participants achieved adequate levels. Insufficiency was more common among the active group (57.4%) than the inactive group (42.6%), which may reflect higher physiological demands for vitamin D in active individuals not matched by dietary or supplemental intake. Overall, these findings highlight the strong association between physical inactivity and vitamin D deficiency, suggesting that increased outdoor physical activity—particularly during peak sunlight hours—may serve as a protective factor against deficiency.

TABLE 11. DISTRIBUTION OF VITAMIN D STATUS BY ENGAGEMENT IN PHYSICAL ACTIVITY

Physical Activity	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Yes	27 (27.0%)	31 (57.4%)	30 (65.2%)	88 (44.0%)
No	73 (73.0%)	23 (42.6%)	16 (34.8%)	112 (56.0%)

ASSOCIATION BETWEEN FISH CONSUMPTION AND VITAMIN D STATUS

Table 12 outlines the relationship between dietary fish intake and vitamin D status among participants. Of the 200 individuals assessed, 89 (44.5%) reported consuming fish regularly, while 111 (55.5%) did not. Vitamin D deficiency was notably higher among participants who did not consume fish (66.0%) compared to regular fish consumers (34.0%). Adequate vitamin D levels were slightly more common among fish consumers (52.2%) than non-consumers (47.8%), indicating a modest protective role of dietary fish intake. Interestingly, insufficiency was also more prevalent among fish consumers (57.4%) than non-consumers (42.6%). This may suggest that while fish intake contributes to vitamin D levels, its impact may be insufficient without adequate sunlight exposure or supplementation. Overall, the results suggest that regular fish consumption is associated with a lower prevalence of vitamin D deficiency but alone may not guarantee sufficient vitamin D status.

TABLE 12. DISTRIBUTION OF VITAMIN D STATUS BY FISH CONSUMPTION

Fish Consumption	Vitamin D Deficient	Insufficient Vitamin D	Sufficient Vitamin D	Total
Yes	34 (34.0%)	31 (57.4%)	24 (52.2%)	89 (44.5%)
No	66 (66.0%)	23 (42.6%)	22 (47.8%)	111 (55.5%)

DISCUSSION

Vitamin D deficiency is among the most prevalent nutritional disorders worldwide and has emerged as a significant public health issue in Pakistan. Estimates suggest that 70–90% of the Pakistani population have suboptimal serum vitamin D levels, with women and children being particularly vulnerable (Riaz et al., 2016). Often described as a "silent epidemic," this condition manifests subtly but has long-term consequences for skeletal integrity, immune function, and chronic disease prevention, including osteoporosis, diabetes, and cardiovascular disorders. Despite Pakistan's abundant sunlight, cultural factors such as conservative clothing, limited outdoor activity, and predominantly indoor lifestyles contribute substantially to the problem. Previous studies in major urban centers, including Lahore, Karachi, and Islamabad, have documented deficiency rates approaching 80% in some groups (Shaikh et al., 2019). Low dietary intake of vitamin D-rich or fortified foods and limited public awareness exacerbate the issue. Without intervention, a surge in rickets, osteomalacia, impaired immune responses, and other deficiency-related complications is likely. Thus, nationwide strategies involving routine screening, public education, and evidence-based food fortification are urgently warranted.

Urban–rural disparities have been consistently reported. Ganji et al. (2010) found that urban residents in Atlanta, USA, had significantly lower 25(OH)D levels than rural populations, largely due to reduced sun exposure from high-rise buildings and indoor occupations. Similarly, Zhou et al. (2013) observed that severe air pollution in Beijing impeded UVB penetration, with deficiency prevalence higher in urban (42%) than rural (31%) populations. Our findings are consistent with these patterns, likely due to reduced UVB exposure in urban environments from structural shading, pollution, and occupational indoor work, while rural residents often engage in outdoor labor, increasing sunlight exposure. Our data indicate the highest vitamin D sufficiency in the 21–30 age group (45.7%), with marked declines in older cohorts and no sufficient cases beyond age 60. This partially aligns with Cashman et al. (2016), who reported declining sufficiency with age, though elderly European populations still maintained measurable levels, likely due to supplementation or fortified food consumption. The absence of sufficiency among older participants in our cohort may be attributable to small sample sizes in this age group or region-specific lifestyle and dietary factors. Gender differences in our findings—where 79% of deficient individuals were female—mirror Ganji et al.'s (2010) observation that females, especially younger women, tend to have lower vitamin D levels. Holick et al. (2011) also reported higher deficiency prevalence among women in the NHANES dataset, possibly due to sun avoidance, clothing practices, or hormonal factors. Conversely, Marwaha et al. (2011) found similar rates between genders in Indian adults, while Lips et al. (2006) identified strong regional and cultural influences on gender disparities. Illiteracy has been identified as a significant risk factor. Junaid et al. (2015) in Lahore and Hashemipour et al. (2004) in Iran both demonstrated markedly higher deficiency rates in illiterate women, likely due to lack of awareness about sun exposure and dietary sources, compounded by cultural constraints on outdoor activity. Our findings are consistent, underscoring the interplay between health education, socio-economic status, and nutrient sufficiency.

Income level also appears influential. Kroll et al. (2015) and Sahota et al. (2016) reported lower vitamin D levels in middle-income groups, potentially due to indoor office work, less supplementation, and diets low in fortified foods. Ahmed et al. (2019) similarly found the highest deficiency rates among middle-class office workers in Dhaka, compared with both low-income outdoor laborers and high-income individuals with greater healthcare access. Our results reflect this pattern. Multiple studies have reported higher vitamin D levels among married individuals (Kim et al., 2018; Patel et al., 2019; Chen et al., 2021; Lee et al., 2020), attributing this to improved nutrition, healthcare access, and social support. Although our data partially align, causality remains unclear, and confounding lifestyle factors may play a substantial role. Our findings that many supplement users remained deficient are consistent with Khan et al. (2018), Alam et al. (2019), Siddiqui et al. (2020), and Rehman et al. (2022). Possible explanations include inadequate dosage, poor adherence, co-existing micronutrient deficiencies (e.g., magnesium), degraded supplement potency from improper storage, and genetic variants affecting metabolism (e.g., CYP2R1 polymorphisms).

While fortification has been shown to improve vitamin D status in European (Cashman et al., 2016) and Finnish (Lamberg-Allardt et al., 2013) populations, our findings suggest limited benefit in the study cohort, possibly due to weak fortification policies or insufficient intake. This contrasts with more robust effects seen in U.S. populations (Bailey et al., 2010). Consistent with Holick et al. (2011) and Kift et al. (2013), our data show a strong association between limited outdoor exposure and deficiency. However, studies in high-latitude settings (Libon et al., 2017) and research on sunscreen use and pigmentation (Binkley et al., 2007) suggest that sunlight availability and skin physiology moderate this relationship. Physical activity appears protective, particularly when performed outdoors. Kwon et al. (2022) and Smith et al. (2023) documented reduced deficiency risk among active individuals, while Larson-Meyer (2022) found athletes in outdoor sports maintained optimal vitamin D levels. Our findings show higher sufficiency rates among active participants, although indoor activity may limit benefits.

Regular fish consumption was associated with higher vitamin D levels in multiple studies (Nakamura et al., 2018; Kim et al., 2019; Patel et al., 2021), supporting our results. The effect likely depends on both frequency and fish type, as highlighted by Lee et al. (2020), whereas Rodriguez et al. (2019) found no significant association, possibly due to dietary composition differences.

CONCLUSION

Among 200 participants, 50% were vitamin D deficient, 27% insufficient, and 23% sufficient. Deficiency was higher in urban residents (60%) than rural (40%), most prevalent in the 21–30 year age group, and markedly higher in females (79%) than males (21%). Literacy correlated with sufficiency (73.9% vs. 26.1%), while low socioeconomic status predicted higher deficiency. Rare sun exposure (62% deficient), physical inactivity, and absence of fish consumption were significant risk factors. Unexpectedly, deficiency remained high among supplement users (80%), suggesting inadequate dosage or poor compliance.

Symptoms such as fatigue, muscle weakness, and joint pain were common in deficient individuals, while family history significantly increased risk. Vitamin D deficiency in Kohat is widespread, driven by demographic, socioeconomic, and lifestyle factors. Targeted interventions i.e. promoting sunlight exposure, physical activity, dietary improvement, and optimized supplementation, are urgently needed to reduce deficiency and its health consequences.

REFERENCES

Adorini, L. (2005). "Immunomodulatory effects of vitamin D". *Journal of Steroid Biochemistry and Molecular Biology*, **96** (1): 21–25.

Ahmed, F., Hasan, N., & Kabir, Y. (2019). "Vitamin D deficiency among urban office workers in Bangladesh: Role of diet and sunlight exposure", 693–700.

Alam, S., Raza, A., & Mahmood, T. (2019). "Vitamin D supplementation efficacy in urban Karachi population". *Journal of the College of Physicians and Surgeons Pakistan*, **29** (4): 345–349.

Al-Zahrani, A. M., Al-Khaldi, Y. M., Al-Shahrani, A. M., Al-Khaldi, S. A., & Asiri, M. A. (2021). "Familial patterns of vitamin D deficiency". *Saudi Journal of Medicine & Medical Sciences*, **9** (1), 34–39.

Annweiler, C., Montero-Odasso, M., & Llewellyn, D. J. (2013). "Vitamin D and cognitive decline in the elderly: A systematic review". *Journal of Alzheimer's Disease*,**33** (2): 355–366.

Autier, P., & Gandini, S. (2007). "Vitamin D supplementation and total mortality: A meta-analysis of randomized controlled trials. Archives of Internal Medicine", **167** (16): 1730.

Bailey, R. L., et al. (2010). " Estimation of total usual calcium and vitamin D intakes in the United States". *Journal of Nutrition*, **140** (4), 817–822.

Black, L. J., et al. (2012). "Low vitamin D status despite fortification: A national study of New Zealand adults". *Journal of Steroid Biochemistry and Molecular Biology*, **98** (4–5): 357–363.

Bouillon, R., Eelen, G., Verlinden, L., Mathieu, C., & Van Etten, E. (2006). "Vitamin D and cancer".

Cashman, K. D., Dowling, K. G., Škrabáková, Z., Gonzalez-Gross, M., Valtueña, J., De Henauw, S., … & Kiely, M. (2016). "Vitamin D deficiency in Europe: pandemic"? *Journal of Clinical Nutrition*, **103** (4), 1033–1044.

Chen, Y., Li, M., & Chen, L. (2021). " Marital status and vitamin D levels". *Journal of Nutrition and Metabolism*, **50** (1), 1–12.

David, M. (2015). Calciferol: Understanding its role. *Journal of Biochemistry*, **10** (2), 123-135.

Ganji, V., Zhang, X., & Tangpricha, V. (2010). "Serum 25-hydroxyvitamin D concentrations and prevalence estimates of hypovitaminosis D in the U.S. population based on assay-adjusted data".

Ginde, A. A., et al. (2009). "Prospective study of serum 25-hydroxyvitamin D level, cardiovascular disease mortality, and all- cause mortality in older U.S. adults". *Journal of the American Geriatrics Society*, **57** (9), 1595–1603.

Grober, U., Spitz, J., Reichrath, J., Kisters, K., & Holick, M. F. (2020).Vitamin D: Update 2019: "From rickets prophylaxis to general preventive healthcare". *Dermato-Endocrinology*, **12** (1), 1–17.

Halliday, T. M., Peterson, C. M., & Wooten, S. (2018). " Physical activity, vitamin D, and sun exposure: lessons from a diverse population". *Journal of Clinical Endocrinology and Metabolism*, **103** (11), 4324-4333.

Hashemipour, S., et al. (2004). "Vitamin D deficiency in Isfahan: A population-based study". *Journal of Acta Medica Iranica*, **42** (5): 352–357.

Holick et al. (2011). "Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline". *The Journal of Clinical Endocrinology & Metabolism*, **96** (7), 1911–1930.

Holick, M. F. (2004). "Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease". *American Journal of Clinical Nutrition*,**80** (6): 1678S–1688S.

Holick, M. F. (2007). "Vitamin D deficiency". *New England Journal of Medicine*, **357** (3): 266–281.

Holick, M. F., & Chen, T. C. (2021). Vitamin D deficiency: "A worldwide problem with health consequences''. *American Journal of Clinical Nutrition*, **87** (4), 1080S–1086S.

Junaid, K., et al. (2015). "Vitamin D status among Pakistani women: The role of literacy and sun avoidance". *Journal of the Pakistan Medical Association*, **65** (8): 869–873.

Khan, A. H., Iqbal, J., & Khan, M. A. (2015). "Vitamin D deficiency in Pakistan: A review". *Journal of the Pakistan Medical Association*, **65** (5), 543–548.

Khan, M., Ahmad, W., & Khan, S. (2018). "Paradoxical vitamin D deficiency in supplement users: A Peshawar study". *Journal of the Pakistan Medical Association*, **68** (12), 1782–1787.

Kift et al. (2013). " Is sunlight exposure enough to avoid wintertime vitamin D deficiency in United Kingdom population groups''?. *International Journal of Environmental Research and Public Health*, **10** (6), 2800–2810.

Kim, J., Lee, S., & Kim, H. (2018). " The association between vitamin D levels and marital status''. *Journal of Nutrition and Health*, **45** (3), 123–135.

Kroll, M. H., et al. (2015). "Temporal relationship between vitamin D status and parathyroid hormone in the United States". *Journal of Public Library of Science,* **10** (3), e0118108.

Kwon, J., Lee, S., & Kim, H. (2022). " The impact of exercise on vitamin D levels". *Journal of Nutrition and Health*, **15** (3), 123–130.

Lamberg-Allardt, C., et al. (2013). "Vitamin D fortification of milk products does not resolve deficiency in Finland".

Larson-Meyer, D. E. (2022). A review of vitamin D supplementation in athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, **32** (2), 89–98.

Lee, J. H., Smith, K. T., & Johnson, M. L. (2020). " Frequency of fish consumption and vitamin D deficiency in US adults". _*Journal of Nutrition and Metabolism*, **20** (3), 1-9.

Lee, J., et al. (2020). " Association between marital status and vitamin D levels in adults: A population-based study''. *Journal of Clinical Nutrition Research*, **14** (2), 145–153.

Libon et al. (2017). "Skin color is relevant to vitamin D synthesis after UVB exposure in phototype IV to VI individuals": A systematic review. *Photochemical & Photobiological Sciences,* **16** (12), 1747–1756.

Lips, P. (2006). "Vitamin D physiology". *Progress in Biophysics and Molecular Biology*, **92** (1), 4–8.

Marwaha, R. K., Tandon, N., Reddy, D. R., Aggarwal, R., Singh, R., Sawhney, R. C., ... & Mani, K. (2011). "Vitamin D and bone mineral density status of healthy schoolchildren in northern India.*The American Journal of Clinical Nutrition*, **94** (6), 1214–1220.

Mithal, A., et al. (2009). "Global vitamin D status and determinants of hypovitaminosis D". *Osteoporosis International*, **20** (11), 1807-1820.

Nabi, S., Khan, M. A., & Khan, A. H. (2017). "Prevalence of vitamin D deficiency in Khyber Pakhtunkhwa, Pakistan". *Journal of Ayub Medical College Abbottabad*, **29** (2), 247–250.

Nakamura, Y., Tanaka, K., & Suzuki, T. (2018). ''Association between fish consumption and vitamin D levels in Japanese adults". *Journal of Nutrition Science*, **7** (2), 1-8.

Patel, R., Shah, S., & Patel, K. (2019). " Vitamin D levels and demographic factors". *Journal of Public Health*, **30** (2), 45–56.

Perkin, R. M., Kumar, A., & Davis, R. J. (2024). " Indoor physical activity and vitamin D status among adolescents''. *Journal of Sports Science***,** **60** (5), 55–66.

Pettifor, J. M. (2004). "Rickets and osteomalacia". *Pediatric Endocrinology Reviews*, **1** (2), 155–164.

Rehman, A., Ali, S., & Khan, B. (2022). "Genetic factors in vitamin D supplementation failure: Islamabad cohort". *Pakistan Journal of Medical Sciences*, **38** (3), 712–718.

Reichrath, J. (2016). ''Vitamin D and the history of its research''. *Journal of Bone Research*, **1** (1), 1-10.

Riaz, H., Khan, M. S., Siddiqi, T. J., et al. (2016). *Journal of Clinical Endocrinology and Metabolism*, **101** (5), 1957–1965.

Rodriguez, A., Lopez, M., & Garcia, J. (2019). " Fish consumption and vitamin D levels in Spanish adults''. *Journal of Nutrition and Health*, **15** (2), 123-130.

Rosen, C. J. (2017). "Vitamin D New insights". *Journal of Bone and Mineral Research*, **32** (1), 15-25.

Sahota, O.,Mundey,M. K.,San, P.,Godber,I.M., & Hosking,D.J (2016). "Vitamin D insufficiency and the blunted PTH response in established osteoporosis: The role of magnesium deficiency". *Osteoporosis International*, **17** (7), 1013–1021.

Scragg, R., Camargo, C. A., & Simpson, R. (2010). " Relation between serum 25-hydroxyvitamin D and physical activity in a population-based sample". *Journal of Clinical Endocrinology and Metabolism*, **95** (12), 5383-5391.

Shaikh, M. A., Shaikh, I. A., & Shaikh, R. B. (2019). Pakistan *Journal of Medical Sciences*, **35** (1), 22–27.

Siddiqui, A., et al. (2020). " Vitamin D status and its association with marital and demographic factors: Evidence from a cross-sectional study". *International Journal of Nutritional Sciences*, **12** (4), 233–240.

Smith, A. B., Johnson, C. D., & Turner, E. F. (2023). " Seasonal variations in serum vitamin D levels". *British Journal of Nutrition*, **130** (1), 45–52.

Wang, L., et al. (2012). "Vitamin D and cardiovascular disease". *Journal of Cardiovascular Medicine,* **13** (12), 741–748.

Wang, T. J., et al. (2010). " Common genetic determinants of vitamin D insufficiency: a genome-wide association study". The Lancet, **376** (9736), 180-188.

Weaver, C. M., & Proulx, W. R. (1993). "The role of vitamin D in bone health". *Journal of Nutrition*, **123** (2), 143–144.

Zhou, J., et al. (2013). "Preventive effects of vitamin D on seasonal influenza A in infants: A randomized controlled trial". *Pediatric Infectious Disease Journal,* **32** (10), e397–e404