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VITAMIN D STATUS AMONG ADOLESCENT VISITING AT TERTIARY CARE HOSPITAL

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ABSTRACT

Background: Deficiency of vitamin D among adolescents is becoming a significant issue to the general population and has been linked to poor skeletal growth, metabolic imbalances, and poor health effects. The hypovitaminosis D still is very common in South Asian countries, and little is known about vitamin D levels of Pakistani adolescents.

Objective: To establish the vitamin D status of adolescents visiting the pediatric clinic and to compare the prevalence in boys and girls.

Methods: The cross-sectional study was carried out in the Adolescent Clinic, Department of Pediatrics, Bilawal Medical College for Boys, CDF hospital, Hyderabad over a period of 3 months from June 2026 to August 2026. Non-probability consecutive sampling was used to recruit 138 adolescents who were between 10 - 18 years of age. A structured proforma was used to gather the information on demographic factors, parental education, family income, sun exposure, physical activity, vitamin D supplementation, and clinical symptoms. All participants had their serum vitamin D rates measured and analysed with the help of SPSS version 26. The Chi-square test or Fisher exact test was used to assess the associations and multivariate logistic regression was used to determine the independent predictors of vitamin D deficiency. A p-value ≤ 0.05 was considered statistically significant.

Results: The mean age of the sample was 14.3±2.1 years and the mean serum vitamin D level was 22.4±8.6 ng/mL serum. A prevalence of 44.2 was found to be 61 vitamin D deficient participants. Girls were much more likely to be deficient than boys (53.9% vs. 32.3% p=0.011), and females had 2.46 greater odds of deficiency. Inadequate sun exposure (OR=2.74, p=0.004), lack of vitamin D supplementation (OR=3.79, p=0.002), obesity (OR=2.51, p=0.039), low paternal educational status (OR=2.58, p=0.009), physical inactivity (OR=2.58, p=0.007), and low family income (OR=4.25, p=0.002) were significantly associated with vitamin D deficiency. The logistic regression established that female gender (AOR=2.21, p=0.029), lack of sun exposure (AOR=2.68, p=0.008), lack of supplementation in vitamin D (AOR=3.41, p=0.007), obesity (AOR=2.12, p=0.047), low family income (AOR=3.03, p=0.016), low level of paternal education (AOR=2.11, p=0.046) and physical inactivity (AOR=2.18, p=0.038) to be independent predictors of vitamin D deficiency.

Conclusion: Vitamin D deficiency was very common among teenagers and strongly linked to female gender, insufficient sunlight exposures, obesity, low socioeconomic status, physical inactivity, and a deficiency of vitamin D supplement.

KEYWORDS: Adolescents; Vitamin D deficiency; Hypovitaminosis D; Serum vitamin D; Sun exposure; Physical activity; Pakistan; Risk factors.

INTRODUCTION

Vitamin D is a secosteroid fat-soluble hormone, which is essential in calcium homeostasis, skeletal growth and immunology during adolescence, which is a phase of intense body growth and nutritional requirements (Swailem et al., 2025). Adolescence is a period of intense growth of bone minerals, and almost 40-60% of bone mass is gained during the period, so proper status of vitamin D is the key to musculoskeletal health in the long run (Ravindra et al., 2026). In addition to the classical impact of vitamin D on bone metabolism, it has been associated with cellular differentiation, insulin secretion, inflammatory reactions, and cardiovascular regulation, indicating its pleiotropic physiological effects (Wu et al., 2023). It has been reported that lack of vitamin D leads to rickets, osteomalacia, retarded growth, low bone mineral density and heightened predisposition to chronic diseases in later life (Nagata et al., 2022). There is also the emerging evidence that hypovitaminosis D is associated with obesity, metabolism syndrome and impaired cognitive and psychological well-being in adolescents that hypovitaminosis D has broader public health consequences. As a result, vitamin D status measurement in adolescence has become a valuable concern in preventive medicine and nutrition epidemiology (Swailem et al., 2025).

Deficiency in vitamin D has become a universal health issue with an estimated one billion people in the world and children and adolescents forming very vulnerable groups (Holick, 2007). A cross-country systematic review approximated about 13% of the world population to have serum 25-hydroxyvitamin D levels less than 30 nmol/L,

and about 40% with levels less than 50 nmol/L (Sozaeva et al., 2026). North American and European studies have indicated that the prevalence of vitamin D insufficiency is up to 20-70% among adolescents depending on ethnicity, season, and latitude (Koirala and Shah, 2025). In the United States, studies revealed that about 61% of adolescents were not getting adequate amounts of vitamin D and almost nine% of them were deficient (Swailem et al., 2025). In a comparable study, the prevalence rates have been reported to be above 80% even with sufficient sunlight in Middle Eastern nations, indicating that the behavioral and cultural aspects play a significant role in determining vitamin D status (Abuhamad et al., 2024). Hypovitaminosis D has also been shown to be common in Asian population with its prevalence estimates being 50-90% among school-aged children and adolescents (Miftah et al., 2023).

Many biological, environmental and socioeconomic factors are familiar to variations in vitamin d status between teenagers belonging to a variety of populations (Khadilkar et al., 2022). One of the main causes of vitamin D deficiency is reduced cutaneous synthesis caused by limited exposure to sunlight especially in urban dwellers and those who majorly live indoors (Badiu et al., 2024). Lack of exercise has been continually linked to reduced levels of circulating vitamin D due to sequestration of the vitamin in adipose tissue and changes in the metabolic processes (Liu et al., 2023). It has also been demonstrated that the ethnical variations in skin pigmentation can affect the process of vitamin D synthesis by lowering the cholecalciferol production in individuals with darker skin through ultraviolet B radiation (Motlagh et al., 2023). Serum 25-hydroxyvitamin D levels are also highly influenced by the season and the geographical latitude, with decreased amounts being reported during winter and in areas with a greater distance to the equator (Koirala and Shah, 2025). These complicated interactions are crucial in determining effective prevention measures and interventions based on targeting to enhance the health outcomes of adolescents (Kowalcze et al., 2024).

Studies reported that Pakistan belongs to the list of the countries where the prevalence of vitamin D deficiency is high despite the high levels of sunlight and climatic conditions during most of the year (Ali et al., 2022). Around 53 to 93% of the Pakistani population is deficient in vitamin D, with adolescents and females showing the highest susceptibilities (Ashraf et al., 2024). Hypovitaminosis D has been identified as a significant problem in Pakistan due to rapid urbanization and reduced physical activities, air and water pollution, dietary inadequacy, and sociocultural habits (Zahoor et al., 2025). Existing literature on other provinces has shown that prevalence estimates are often very heterogeneous, making it necessary to have region-specific data and new epidemiological evidence (Abbas et al., 2025). There is also the need to have reliable local evidence to guide the policy-makers and medical care providers to come up with specific nutritional and population health strategies to apply to vulnerable groups. Consequently, the current study will evaluate the vitamin D levels among adolescents in Pakistan to present context-specific evidence that can be used to inform effective prevention and management strategies.

METHODOLOGY

A cross-sectional study was conducted in Adolescent Clinic, Department of Pediatrics, Bilawal Medical College for Boys, CDF Hospital, Hyderabad over a period of 3 months from June 2026 to August 2026. The study commenced after obtaining approval from the College of Physicians and Surgeons Pakistan. The research sample used included teens who were visiting the pediatric outpatient clinic at the time of the research. The sample size of 138 participants was determined based on a 95% confidence, margin of 7%, and prevalence of 22.7% of vitamin D deficiency among the adolescents. The participants were recruited using non-probability consecutive sampling method to make sure all eligible subjects who were making presentations during the period of data collection were included.

The sample used consisted of healthy teenagers between the ages of 10 to 18 who have regularly attended the pediatric clinic. Adolescents who came with symptoms like generalized body pain, weakness, loss of hair and lethargy were also deemed eligible regardless of gender. Only the participants whose parents or legal guardians have written informed consent having been informed properly about the study were allowed to participate. Teenagers with musculoskeletal disorders, endocrine disorders, infectious diseases, chronic kidney disease, malnutrition, hepatic disorders, or any other severe systemic illness were not involved in the research. Moreover, past antiepileptic drug users were not enrolled because it was aimed at minimizing the possible confounding factors on vitamin D metabolism.

Data Collection

The eligible participants were recruited sequentially provided that they met the selection criteria that were pre-established. Enrollment Pre-enrollment informed consent was given by the parents or guardians after the objectives and procedures of the study were explained. Data on demographic and clinical factors, such as age, sex, height, weight, body mass index, educational status of both parents, monthly household income, ethnicity, sunlight exposure, and vitamin D supplementation were obtained using a structured and predesigned proforma. All the enrolled participants were sampled with the aim of assessing serum vitamin D levels in their blood. The expenses related to laboratory investigations were borne by the hospital.

Data Analysis

Data collected were processed and analysed in Statistical Package for Social Sciences (SPSS) 26 version. The analysis of the distribution of continuous variables, such as age, height, weight, body mass index, sun exposure duration, and serum vitamin D levels, was performed by using the Shapiro–Wilk test. Variables with a normal

distribution were summarized as mean and standard deviation and non-normally distributed variables as median and range. Categorical variables that comprise: gender, parental education level, monthly family income, and sufficiency of sun exposure were expressed in frequencies and percentages. The chi-square test was used to test the association between vitamin D status and vitamin D supplementation. Stratified analyses were then done based on age, gender, body mass index, hours spent under the sun, parent education level and monthly income status. After stratification, the chi-square or the Fisher exact test was used, respectively, to analyze the vitamin D status of adolescents who took vitamin D supplements and those who did not. The p-value was taken as being statistically significant below 0.05.

Ethical Considerations

It was carried out with the permission of the College of Physicians and Surgeons Pakistan. All participants were enrolled with a written informed consent being signed by the parent or legal guardians. Informed consent was ensured to the study participants regarding the objectives and steps of the study and confidentiality of the information gathered was fully upheld during the research period. Participation was free of cost and all the laboratory studies needed to carry out the study were offered without any cost to the participants since the hospital was to cover the costs.

RESULTS

A total of 138 adolescents were included in the study. The average age of the participants was 14.3±2.1 years, mean age of mothers and fathers was 39.7±5.8 and 45.2±6.9 years, respectively. A small majority of the study population was female (55.1%), compared to males (44.9%). The majority of families were in the middle-income range (21,000-50,000 PKR), which comprised 42.8% of the respondents. The fathers most commonly had secondary education with 34.1% being of fathers who had secondary education.

Table 1. Demographic Characteristics of Adolescents Included in the Study (n = 138)

Variables	Mean ± SD / n (%)
Age of child (years)	14.3 ± 2.1
Age of mother (years)	39.7 ± 5.8
Age of father (years)	45.2 ± 6.9
Height (cm)	156.8 ± 10.4
Weight (kg)	51.7 ± 12.5
Body mass index (kg/m²)	21.1 ± 3.8
Male	62 (44.9)
Female	76 (55.1)
Monthly family income ≤20,000 PKR	41 (29.7)
Monthly family income 21,000–50,000 PKR	59 (42.8)
Monthly family income >50,000 PKR	38 (27.5)
Father illiterate	22 (15.9)
Primary education	29 (21.0)
Secondary education	47 (34.1)
Graduate and above	40 (29.0)

Of the registered teens, only 26.1% were taking vitamin D supplements, unlike 60.9% who reported a lack of sunshine. The mean serum vitamin D level was 22.4±8.6ng/ml. In total, 61 adolescents were found to be vitamin D deficient and this translates to a prevalence of 44.2%. Half of the participants reported symptoms of generalized body pain and weakness, 41.3% and 31.2% reported lethargy and hair loss, respectively.

Table 2. Clinical Characteristics of Study Participants (n = 138)

Variables	n (%) / Mean ± SD
Sufficient sun exposure (Yes)	54 (39.1)
Sufficient sun exposure (No)	84 (60.9)
Vitamin D supplementation (Yes)	36 (26.1)
Vitamin D supplementation (No)	102 (73.9)
Regular physical activity (Yes)	58 (42.0)
Regular physical activity (No)	80 (58.0)
Serum vitamin D level (ng/mL)	22.4 ± 8.6
Vitamin D deficiency (<20 ng/mL)	61 (44.2)
Normal vitamin D level (≥20 ng/mL)	77 (55.8)
History of body pain/weakness	69 (50.0)
Hair loss	43 (31.2)

Lethargy	57 (41.3)
Mean duration of sun exposure (minutes/day)	34.6 ± 16.7

The Shapiro-Wilk test showed that the age, height, weight, and parental ages were normally distributed (p>0.05), but the body mass index, the period of sun exposure, and serum vitamin D were not normally distributed (p=0.05). Thus, normally distributed variables were reported using means and standard deviation and skewed variables were reported using median and range. Configurative analyses were done with Chi-square or Fisher exact tests depending on the frequency of the cells, as the principal outcome variable was categorical (vitamin D deficiency).

Table 3. Assessment of Normality of Continuous Variables Using Shapiro-Wilk Test (n = 138)

Variable	Shapiro-Wilk Statistic	p-value
Age of child	0.984	0.098
Height	0.977	0.061
Weight	0.971	0.052
BMI	0.964	0.019
Duration of sun exposure	0.953	0.004
Vitamin D level	0.949	0.002
Age of mother	0.982	0.085
Age of father	0.986	0.114

Bivariate analysis revealed that the deficiency of vitamin D was greatly related to the gender of the patients who were females, high body mass index, lack of sufficient exposure to sunlight, lack of vitamin D supplementation, low monthly family income, low levels of paternal education and physical activity. Female teens were 2.46 times more likely to be vitamin D deficient, compared to males (95% CI: 1.22-4.96, p=0.011). Adequate levels of vitamin D were found in adolescents who did not receive any vitamin D supplements and those who did not receive a sufficient amount of sun exposure (about 2.7- and 3.8-times higher odds, respectively). Socioeconomic status was another factor of importance, with adolescents who lived in households with 20,000 PKR or less having a more than fourfold higher probability of having vitamin D deficiency as compared to the adolescents who lived in households with an income above 50,000 PKR. On the contrary, age group failed to show statistically significant correlation with the vitamin D deficiency (p=0.063).

Table 4. Comparison of Vitamin D Deficiency Between Male and Female Adolescents (n = 138)

Variables	Vitamin D Deficiency Present n (%)	Vitamin D Deficiency Absent n (%)	OR (95% CI)	p-value
Gender				
Male (n=62)	20 (32.3)	42 (67.7)		
Female (n=76)	41 (53.9)	35 (46.1)	2.46 (1.22–4.96)	0.011
Age Group				
≤14 years (n=69)	25 (36.2)	44 (63.8)		
>14 years (n=69)	36 (52.2)	33 (47.8)	1.92 (0.96–3.85)	0.063
Body Mass Index				
<25 kg/m² (n=109)	43 (39.4)	66 (60.6)		
≥25 kg/m² (n=29)	18 (62.1)	11 (37.9)	2.51 (1.04–6.07)	0.039
Sun Exposure				
Sufficient (n=54)	16 (29.6)	38 (70.4)		
Insufficient (n=84)	45 (53.6)	39 (46.4)	2.74 (1.34–5.59)	0.004
Vitamin D Supplement Use				
Yes (n=36)	8 (22.2)	28 (77.8)		
No (n=102)	53 (52.0)	49 (48.0)	3.79 (1.59–9.04)	0.002
Monthly Family Income				
>50,000 PKR (n=38)	11 (28.9)	27 (71.1)		
21,000–50,000 PKR (n=59)	24 (40.7)	35 (59.3)	1.68 (0.70–4.02)	0.242
≤20,000 PKR (n=41)	26 (63.4)	15 (36.6)	4.25 (1.62–11.14)	0.002
Regular Physical Activity				
Yes (n=58)	18 (31.0)	40 (69.0)		
No (n=80)	43 (53.8)	37 (46.2)	2.58 (1.28–5.19)	0.007

Stratified analysis showed that vitamin D deficiency had a significant relationship with gender, and body mass index, time spent in the sun, paternal education status and family income. Women adolescents were 2.46 times

more likely to be deficient than men (95% CI: 1.22-4.96, p=0.011). Young people lacking in enough sun exposure were found to have 2.74 times higher chances of being deficient in vitamin D compared to young people with sufficient sun exposure (95% CI: 1.34-5.59, p=0.004). In the same way, deficient levels of vitamin D were highly correlated with obesity, low level of paternal education and lower family income. No statistically significant correlation was found between age category and vitamin D deficiency (p=0.063).

Table 5. Stratified Analysis of Factors Associated with Vitamin D Deficiency (n = 138)

Variable	Vitamin D Deficient n (%)	Normal n (%)	OR (95% CI)	p-value
Age ≤14 years (n=69)	25 (36.2)	44 (63.8)		
Age >14 years (n=69)	36 (52.2)	33 (47.8)	1.92 (0.96–3.85)	0.063
Male (n=62)	20 (32.3)	42 (67.7)		
Female (n=76)	41 (53.9)	35 (46.1)	2.46 (1.22–4.96)	0.011
BMI ≥25 kg/m² (n=29)	18 (62.1)	11 (37.9)	2.49 (1.03–6.02)	0.039
BMI <25 kg/m² (n=109)	43 (39.4)	66 (60.6)		
Sun exposure sufficient (n=54)	16 (29.6)	38 (70.4)		
Sun exposure insufficient (n=84)	45 (53.6)	39 (46.4)	2.74 (1.34–5.59)	0.004
Father's education ≤Primary (n=51)	30 (58.8)	21 (41.2)	2.40 (1.18–4.86)	0.015
Secondary or above (n=87)	31 (35.6)	56 (64.4)		
Income ≤20,000 PKR (n=41)	25 (61.0)	16 (39.0)	2.87 (1.27–6.49)	0.009
Income >20,000 PKR (n=97)	36 (37.1)	61 (62.9)		

The correlation analysis revealed that a number of clinical and lifestyle factors were considerably connected with the vitamin D deficiency in adolescents. The odds ratio of deficiency among the participants who were not supplemented with vitamin D were 3.79 times higher than those who were supplemented (95% CI: 1.59-9.04, p=0.002). Likewise, the lack of sunlight exposure was also linked with a 2.74-fold higher risk of vitamin D deficiency (95% CI: 1.34-5.59, p=.004). The vitamin D deficiency was found to be about 2.6 times higher among adolescents who did not exercise regularly compared to physically active individuals (OR=2.58, 95% CI: 1.28-5.19, p=0.007). Other symptoms such as body pain, loss of hair and lethargy were significantly related with deficiency of vitamin D, implying that such symptoms were more predominant in deficient adolescents. Moreover, the low socioeconomic status and obesity became the significant predictors, whereas adolescents living in the families with lower income had and showed more than four-fold higher odds of deficiency than their counterparts living in the relatively higher-income families.

Table 6. Association Between Vitamin D Supplementation and Vitamin D Deficiency (n = 138)

Variables	Vitamin D Deficiency Present n (%)	Vitamin D Deficiency Absent n (%)	OR (95%CI)	p-value
Vitamin D Supplementation				
Yes (n=36)	8 (22.2)	28 (77.8)		
No (n=102)	53 (52.0)	49 (48.0)	3.79 (1.59–9.04)	0.002
Sun Exposure				
Sufficient (n=54)	16 (29.6)	38 (70.4)		
Insufficient (n=84)	45 (53.6)	39 (46.4)	2.74 (1.34–5.59)	0.004
Regular Physical Activity				
Yes (n=58)	18 (31.0)	40 (69.0)		
No (n=80)	43 (53.8)	37 (46.2)	2.58 (1.28–5.19)	0.007
Body Pain / Weakness				
Present (n=69)	38 (55.1)	31 (44.9)	2.20 (1.10–4.37)	0.024
Absent (n=69)	23 (33.3)	46 (66.7)		
Hair Loss				
Present (n=43)	27 (62.8)	16 (37.2)	2.96 (1.37–6.40)	0.005

Absent (n=95)	34 (35.8)	61 (64.2)		
Lethargy				
Present (n=57)	34 (59.6)	23 (40.4)	2.75 (1.36–5.58)	0.004
Absent (n=81)	27 (33.3)	54 (66.7)		
BMI Category				
≥25 kg/m² (n=29)	18 (62.1)	11 (37.9)	2.51 (1.04–6.07)	0.039
<25 kg/m² (n=109)	43 (39.4)	66 (60.6)		
Monthly Family Income				
≤20,000 PKR (n=41)	26 (63.4)	15 (36.6)	4.25 (1.62–11.14)	0.002
>20,000 PKR (n=97)	35 (36.1)	62 (63.9)		

A multivariate logistic regression analysis revealed that female gender, obesity, insufficient sunlight exposure, lack of vitamin D supplementation, lower family income, lower paternal education level and lack of regular exercise were independent variables of vitamin D deficiency among adolescents. Female adolescents were 2.21 times more likely to be vitamin D deficient than males (AOR=2.21, 95% CI: 1.08-4.54, p=0.029). Deficiency was found in approximately 3.4 times more in adolescents who never used vitamin D supplements compared to those who used the supplements (AOR=3.41, 95% CI: 1.39-8.35, p=0.007). In the same way, the lack of sun exposure was also found to be strongly related to vitamin D deficiency even after controlling the impact of possible confounders by a 2.68-fold probability (95% CI: 1.29-5.57). The odds of deficiency were three times in participants inhabiting low-income families than in participants inhabiting higher-income families (AOR=3.03, 95% CI: 1.23-7.48, p=0.016). Hair loss, lethargy, body pain, age (above 14 years) was also found to have higher odds of vitamin D deficiency but this was not statistically significant after the adjustment.

Table 7. Multivariable Logistic Regression Analysis of Independent Predictors of Vitamin D Deficiency Among Adolescents (n = 138)

Variables	Adjusted Odds Ratio (AOR)	95% Confidence Interval	p-value
Female gender	2.21	1.08–4.54	0.029
Age >14 years	1.56	0.76–3.23	0.223
BMI ≥25 kg/m²	2.12	1.01–4.45	0.047
Insufficient sun exposure	2.68	1.29–5.57	0.008
No vitamin D supplementation	3.41	1.39–8.35	0.007
Low family income (≤20,000 PKR)	3.03	1.23–7.48	0.016
Father's education ≤Primary	2.11	1.01–4.42	0.046
Lack of regular physical activity	2.18	1.04–4.56	0.038
Hair loss	1.87	0.88–3.98	0.103
Lethargy	1.64	0.79–3.40	0.183
Body pain/weakness	1.48	0.72–3.04	0.284

DISCUSSION

The objectives of the current study were to find out the vitamin D status of adolescents visiting the pediatric clinic and compare the occurrence of vitamin D deficiency between boys and girls. The results indicated an average age of the participants 14.3±2.1 years and that 61 respondents out of 138 adolescents were affected by vitamin D deficiency with a prevalence of 44.2 being detected. Mean serum vitamin D concentration was 22.4±8.6 ng/mL, which implies that quite a large percentage of adolescents had an inappropriate amount of vitamin D. These results can be compared with those of Lal et al., (2025) who have found that 61% of 60 children surveyed in the India had vitamin D insufficiency (Lal et al., 2025). In a similar vein, in a cross-sectional study, Pala et al., (2023) found prevalence rates between 30% and 80% among 70 Indian adolescents. It also showed that some 40% of the global population was below the serum 25-hydroxyvitamin D levels of 50 nmol/L, which is very near the prevalence in the current study (Pala et al., 2023). The high prevalence in this study also lends credence to the fact that hypovitaminosis D is a significant nutritional and a public health issue among adolescents regardless of geographic differences in the exposure to sunlight. Thus, the results highlight the importance of regular evaluation and preventive measures against vitamin D deficiency in this age group, which is at risk.

The current research determined a strong gender gap where vitamin D deficiency was observed among 53.9% girls versus 32.3% boys and female adolescents were found to be 2.46 times more likely to have vitamin D deficiency than boys (OR=2.46, 95% CI: 1.224.96, p=0.011). This observation has been confirmed by the evidence that female adolescents are especially vulnerable to the lack of vitamin D because of decreased physical activity and sunlight exposure. Ara et al., (2023) conducted a multicenter study with 300 adolescents in Bangladesh and found modest but statistically significant lower serum vitamin D levels in girls compared to boys, with deficiency rates of nearly 73% in girls (Ara et al., 2023). On the same note, Haripriya et al., (2025) noted that vitamin D deficiency existed in 81.0% of adolescent females and 67.2% of males in 169 participants in India. It also showed

that also showed that female gender was always linked with low vitamin D levels across various groups. The observed higher risk in girls could be explained by sociocultural practice, lack of outdoor activities and hormonal effects on metabolism of vitamin D in the reality (Haripriya et al., 2025). Therefore, the current results support the role of gender-specific interventions to enhance the status of the female adolescents in regard to vitamin D.

The other significant result of the current study was that lifestyle factors are correlated with the lack of vitamin D, as 60.9% adult teens lacked sufficient sun exposure and 73.9% did not take vitamin D supplements. Teenagers who received insufficient amounts of sun exposure showed a much greater possibility of vitamin D deficiency (OR=2.74, 95% CI: 1.3455.59, p=0.004), whereas those who were not taking any vitamin D supplement showed a 3.79-fold greater risk of deficiency (95% CI: 1.599.04, p=0.002). The biologic plausibility of these findings is that under normal physiological conditions, cutaneous synthesis supplies about 80-90% of vitamin D needs (Holick, 2007). The same results were observed by Weng et al. (2007) who found considerably lower levels of serum vitamin D in children with little outdoor activities in a cohort of 740 children. According to a study undertaken by Neyestani et al. (2012) on 2,869 Iranian adolescents, insufficient sun exposure and non-supplementation were significant predictors of insufficiency in vitamin D, the prevalence of which was over 70%. Similarly, a systematic review by Cashman et al. (2016) showed that low vitamin D had one of the strongest determinants as low ultraviolet-B exposure on a global scale. These findings provide important insights into the importance of lifestyle modification and nutritional supplementation in the prevention of vitamin D deficiency in adolescents as they are consistent with earlier evidence. Thus, the load of hypovitaminosis D in this population can significantly be decreased by introducing public health interventions promoting outdoor activities and proper intake of vitamin D.

The current research also proved a significant relationship between vitamin D and obesity and physical inactivity with adolescents with a body mass index of 25kg/m2 and above having odds of deficiency 2.51 times (95% CI: 1.046.07, p=0.039). Additionally, the respondents who were physically inactive were also found to have 2.58-fold higher odds of vitamin D deficiency than physically active adolescents (95% CI: 1.28 5.19, p=0.007). Such results confirm the hypothesis that excess adipose tissue stores vitamin D and decreases bioavailability, therefore, decreases the levels in the circulation (Lin et al., 2025). Lin et al., (2025) studied 1,222 children in the Taiwan and have found that obesity predicted a considerable decrease in serum vitamin D among children and adolescents. In the same way, Jaiswal et al., (2024) found that there is a strong negative correlation between body mass index and serum vitamin D levels in 384 Bangladeshi adolescents. It also found out that obese patients were at risk of developing vitamin D deficiency about 35 times as much as non-obese populations (Jaiswal et al., 2024). The high level of correlation between lack of exercise and deficiency as is witnessed in the present study could also indicate the lack of open-air activities and poor lifestyle habits.

Socioeconomic status was also a significant contributor to vitamin D status in the present study with adolescents in a family earning a ≤20,000 PKR income showing 4.25-fold increase in the likelihood of being vitamin D deficient (95% CI: 1.62 to 11.14, p=0.002) and low level of paternal education increasing the risk by 2.58-fold (95% CI: 1.26 to 5.26, p=0.009). These results suggest that socioeconomic disadvantage can determine the quality of diet, health education, and nutrition supplementation. Bhonsle et al., (2026) have reported that in a cross-sectional study of 277 participants in India, serum vitamin D levels were substantially lower in children with a lower socioeconomic background than in those with a higher socioeconomic background and prevalence of deficiency in children was over 90% in a cohort of lower socioeconomic status children (Bhonsle et al., 2026). Similarly, research in China among 19,283 healthy children has also shown greater prevalence of vitamin D deficiency in economically disadvantaged groups and families that are less educated (Shen et al., 2026). Therefore, the measures to enhance health literacy and access to preventive healthcare services can be important in alleviating the impact of vitamin D deficiency, among adolescents.

The multivariate logistic regression analysis indicated that the independent predictors of vitamin D deficiency were female gender (AOR=2.21, p=0.029), obesity (AOR=2.12, p=0.047), insufficient exposure to the sun (AOR=2.68, p=0.008), lack of vitamin D supplementation (AOR=3.41, p=0.007), low family income (AOR=3.03, p=0.016), low paternal education (AOR=2.11, p=0.046), and physical inactivity (AOR=2.18, p=0.038). Conversely, age (over 14 years), loss of hair, lethargy, and pain of the body were not found to be statistically significant after accounting the confounding factors. This provisional evidence suggests that the nutrient deficiency of vitamin D in adolescents is a complex phenomenon affected by biological, behavioral and socioeconomic factors. Tugrul et al., (2023) found similar conclusions among 376 Turkish children and highlighted that the vitamin D deficiency is the complex of environmental, nutritional and genetic factors. The authors also found female gender, lack of sunlight, and socioeconomic status to be the most reliable predictors of low vitamin D levels (Tugrul et al., 2023). These factors were also found to explain a significant difference in vitamin D levels among populations according to Khadilkar et al., (2024). The agreement of the results with the study among 203 Indian children enhances the external validity of the study and validates the reliability of the conducted associations (Khadilkar et al., 2024).

There are a number of constraints that one needs to take into account when interpreting the results obtained during this research. To begin with, the cross-sectional design did not allow developing any causal connections between the vitamin D deficiency and the risk factors linked to it. Second, the research was carried out at one tertiary care center, which might narrow down the applicability of the results to the overall adolescent community of Pakistan. Third, the sample size of 138 is relatively small and it could have diminished the statistical power to detect weaker

associations. In addition, data about exposure to sunlight, physical activities, and supplementation of vitamin D were self-reported and thus vulnerable to recall bias. They did not assess seasonal changes and dieting vitamin D, which could have affected serum concentrations of vitamin D, and genetic factors of vitamin D metabolism. Although these factors are limiting, the study has valuable preliminary evidence about the burden and determinants of vitamin D deficiency among Pakistani adolescent.

CONCLUSION

This study established that vitamin D deficiency is a significant health issue in adolescents that visit the pediatric clinic with 44.2% of participants having low levels of vitamin D and a median serum vitamin D level of 22.4±8.6 ng/mL. The adolescent females were notably more affected than males and inadequate exposure to sun, lack of vitamin D supplements, obesity, low family income, low educational level of the father and inactivity were all found to be important predictors of deficiency. Multivariate analysis showed that a number of them had independent effect on the vitamin D status showing multifactorial nature of hypovitaminosis D in adolescents. These results highlight the importance of regular screening, education on health, encouragement of outdoor physical activity, and the proper strategy of vitamin D supplementation to minimize the burden of vitamin D deficiency and enhance the state of adolescence health in Pakistan.

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