

*Original Research Article*

# ASSOCIATION OF COVID-19 PANDEMIC RESTRICTIONS WITH SERUM VITAMIN D3 LEVELS IN UNDERWEIGHT FEMALE ADOLESCENTS AGED 10–20 YEARS

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## ABSTRACT

**Background:** COVID-19 lockdowns and prolonged online schooling markedly reduced outdoor activity and sunlight exposure among adolescents, potentially increasing the risk of vitamin D deficiency. While low vitamin D levels are well documented in individuals with high body mass index (BMI), limited evidence exists regarding its association with low BMI during the pandemic. **Aim:** To evaluate the association of COVID-19 pandemic restrictions with serum vitamin D3 levels in female students aged 10–20 years with low body mass index (BMI)

**Materials and Methods:** This cross-sectional observational study included 144 female students and patients aged 10–20 years, recruited from a tertiary care hospital and an associated university. BMI was calculated using standard methods, and a low BMI was defined as  $<18.5$  kg/m<sup>2</sup>. Serum 25-hydroxyvitamin D [25(OH)D] levels were estimated using a Bio-Rad D10 Analyzer. Vitamin D status was classified as severely deficient ( $<10$  ng/mL), mildly to moderately deficient (10–24 ng/mL), or optimal (25–80 ng/mL). Comparisons between the BMI groups were performed using an unpaired t-test.

**Results:** Fifty percent of the participants were underweight. Severe vitamin D deficiency was observed in 52.7% of the subjects, while 30.5% had mild-to-moderate deficiency. The mean serum vitamin D level was 16.93 ng/mL. Underweight participants had significantly lower vitamin D levels ( $13.12 \pm 1.65$  ng/mL) than those with a normal BMI ( $20.81 \pm 2.80$  ng/mL), with a mean difference of  $7.692 \pm 3.252$  ( $p < 0.05$ ).

**Conclusion:** Female adolescents with low BMI demonstrated significantly reduced vitamin D3 levels following COVID-19 restrictions, highlighting the need for early screening and preventive strategies in this vulnerable population group.

**Keywords:** Vitamin D deficiency; Body mass index; Underweight; Female adolescents; COVID-19 pandemic; India.

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## INTRODUCTION

The COVID-19 pandemic led to prolonged lockdowns and a shift to online schooling in India, resulting in markedly reduced outdoor activity and sunlight exposure among adolescents in India.<sup>[1]</sup> These lifestyle changes have been associated with an increased risk of vitamin D deficiency, a condition already highly prevalent among Indian females.<sup>[2]</sup> While previous studies have extensively documented the association between low serum vitamin D levels and high body mass index (BMI), limited data are available on vitamin D status in adolescents with low BMI during periods of restricted mobility.<sup>[3,4]</sup> Given that underweight individuals may have inadequate

nutritional reserves and limited vitamin D stores, the impact of pandemic-related restrictions on this subgroup warrants focused evaluation in future studies. Therefore, the present study was undertaken to assess serum vitamin D3 levels in female students aged 10–20 years with a low BMI ( $<18.5$  kg/m<sup>2</sup>) following COVID-19 pandemic restrictions and to examine the relationship between reduced physical activity, limited sunlight exposure, and vitamin D deficiency in this vulnerable population.

## MATERIALS AND METHODS

**Study design:** This was a cross-sectional observational study

**Study population:** The study population included 144 female patients from a tertiary hospital and female students in the age group of 10-20 years who presented for routine physical examinations or in the outpatient department.

### Inclusion Criteria

Females between the age groups of 10 and 20 years with low BMI who are:

- Asymptomatic
- Presenting to the outpatient department for musculoskeletal pain
- Having difficulty participating in physical activity.

### Exclusion Criteria

- Females with high BMI
- Females with known chronic kidney disease, rickets, or osteomalacia
- Females on vitamin D3 supplementations
- Females with chronic illnesses or comorbidities.

### Data Collection

Female participants between the ages of 10 and 20 years were recruited from a tertiary hospital and students studying in the associated university who had been diagnosed with low BMI (BMI <18.5 kg/m<sup>2</sup>) according to the World Health Organization (WHO) classification.<sup>[5]</sup>

Collection of blood samples: Informed consent in Hindi and English from patients and subjects was obtained before taking blood samples. The elaborate clinical history, examination to assess all aspects of musculoskeletal pain, and other details such as the height and weight of the patients were taken and attached to the proforma.

### Asymptomatic participants were asked to answer a few questions, including

- Presence of any generalized tenderness
- Presence of any tiredness after travelling from school and college or climbing upstairs in schools and colleges
- Presence of nonspecific aches and pain
- Discomfort in participating in physical activities, such as sports and dancing.

Ethical clearance was obtained from the Institutional Ethics Committee prior to the initiation of the study. Written informed consent was obtained from all participants and their guardians, where applicable.

### Method

Subjects' height and weight were measured in kilograms and meters using the standard methods, and

BMI was calculated with the help of  $BMI = \frac{weight(kg)}{height(m)^2}$

- The cut-off of BMI taken was <18.5 kg/m<sup>2</sup> for underweight, based on the WHO classification,<sup>[6]</sup> according to which

Underweight = <18.5 kg/m<sup>2</sup>

Normal = 18.5-24.9 kg/m<sup>2</sup>

Overweight = 25-29.9 kg/m<sup>2</sup>

Obese 1 = 30-34.9 kg/m<sup>2</sup>

Obese 2 = 35-39.9 kg/m<sup>2</sup>

Obese 3 = Above 40 kg/m<sup>2</sup>

The reference ranges for total serum 25-hydroxyvitamin D [25(OH)D], as per Mayo Medical Laboratories,<sup>[7]</sup> are as follows:

Severely deficient	<10 ng/mL
Mild to Moderate deficient <sup>b</sup>	10-24 ng/mL
Optimal <sup>c</sup>	25-80 ng/mL
Possible toxicity <sup>d</sup>	>80ng/mL

Although BMI-for-age Z-scores are recommended for adolescents, adult BMI cut-offs were used for uniformity across the 10–20-year age range and due to feasibility constraints.

A blood sample (2 ml) was collected, and vitamin D3 levels in the serum were analyzed using a Bio-Rad D10 analyzer.

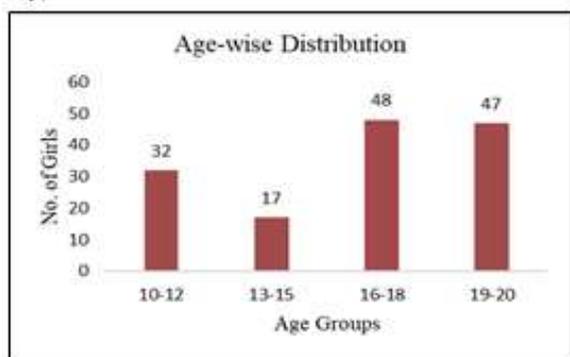
To change 25(OH)D readings to nmol/L, multiply by 2.496. b could be linked to osteomalacia or rickets, c could be linked to secondary hyperparathyroidism and/or osteoporosis, and d levels found in healthy people.<sup>[8]</sup>

**Statistical Analysis:** Statistical analyses were performed using SPSS. Continuous variables are expressed as mean ± SEM. An unpaired t-test was used to compare vitamin D levels between BMI groups. Correlation analysis between BMI and serum vitamin D levels was performed using Pearson's correlation coefficient. Statistical significance was set at p < 0.05.

## RESULTS

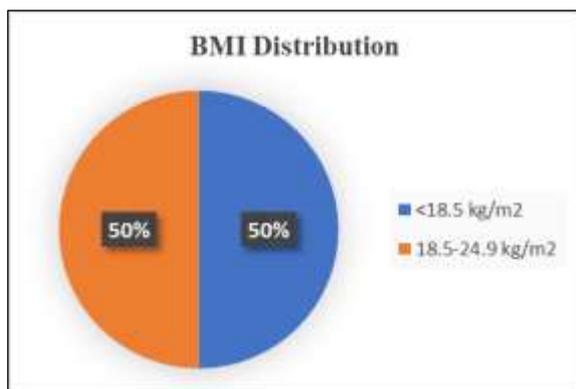
The total number of participants in the study was 144. The distribution of the study population based on age is shown in Table 1. The age-wise distribution of body mass index and serum vitamin D levels among the study participants is illustrated in Figure 1.

**Figure 1**  
Age wise distribution



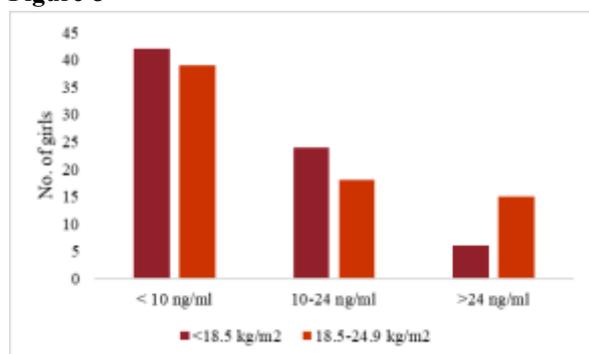
The entire population based on BMI is shown in Figure 2. The number of female students enrolled in the study who had a BMI less than 18.5 kg/m<sup>2</sup> was 50%, while the rest, 50%, had a BMI between 18.5 and 24.9 kg/m<sup>2</sup>.

**Figure 2**  
The BMI percentage wise distribution



The overall distribution of serum vitamin D levels among the study participants across different deficiency categories is depicted in Figure 3.

**Figure-3**



**Table 1: Age-wise distribution of body mass index and serum vitamin D levels among study participants**

Age Group	BMI (kg/m <sup>2</sup> ) (Mean ± SEM)	Vitamin D level (ng/mL) (Mean ± SEM)
10-12	18.52 ± 0.4073	18.97 ± 4.629
13-15	18.89 ± 0.5012	20.65 ± 5.794
16-18	18.78 ± 0.2826	13.66 ± 1.790
19-20	18.58 ± 0.3138	17.64 ± 2.859

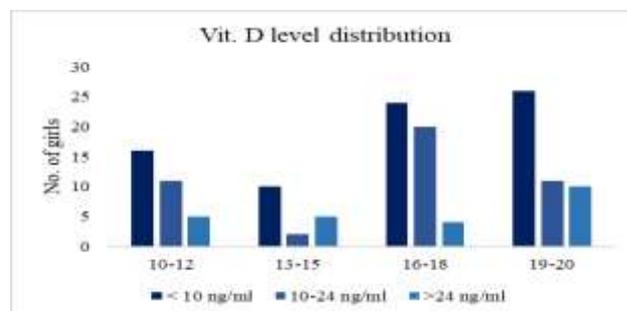
The distribution of serum vitamin D levels according to body mass index categories is presented in Table 2.

**Table 2. Distribution of serum vitamin D levels according to body mass index categories**

BMI	Vitamin D level (ng/mL)		
	< 10 ng/mL	10-24 ng/mL	>24 ng/mL
<18.5 kg/m <sup>2</sup>	42(58.35%)	24(33.3%)	6 (8.3%)
18.5 – 24.9 kg/m <sup>2</sup>	39(54.2%)	18(25%)	15(20.8%)

Majority of the study population that is 52.7% girl students had severely deficient levels of vitamin D<sub>3</sub>, 30.5% fell in the mild to moderate deficient group while rest 16.6% had optimal and above as shown in Table-3 and Figure-4.

**Figure 4**

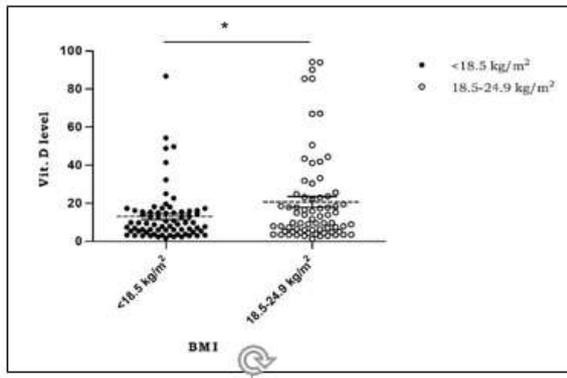


	< 10 ng/mL	10-24 ng/mL	>24 ng/mL
10-12	16(50%)	11(34.4%)	5(15.6%)
13-15	10(58.8%)	2(11.8%)	5(29.4%)
16-18	24(50%)	20(41.7%)	4(8.3%)
19-20	26(55.3%)	11(23.4%)	10(21.3%)

Although the mean value of vitamin D<sub>3</sub> of the whole study population was found to be 16.93 ng/mL, which falls in the mild to moderate group, the majority of girls with a BMI <18.5 kg/m<sup>2</sup> were found to have very low vitamin D<sub>3</sub> levels (<10 ng/mL). On further analysis of the data, the study group had one-third of students in the age bracket of 16-18 years. In the 16–18-year age group, 24 students (50%) had severely deficient vitamin D<sub>3</sub> levels, and in the mild-to-moderately deficient group, there were 11 (22.9%), with the rest having optimal levels.

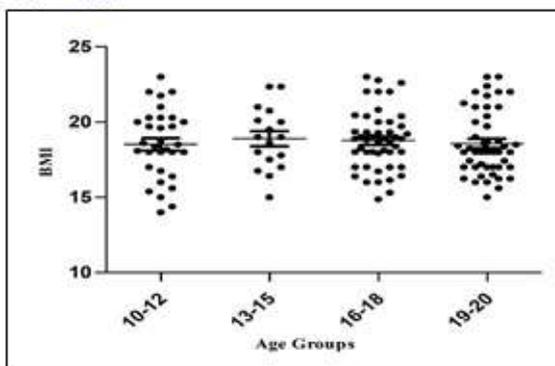
An unpaired t-test was applied between groups with a BMI <18.5 kg/m<sup>2</sup> (underweight) and 18.5-24.9 kg/m<sup>2</sup>, and a significant difference of  $7.692 \pm 3.252$  was found between both groups. The underweight group girls had significantly low ( $13.12 \pm 1.650$ ) vitamin D levels compared to the healthy group ( $20.81 \pm 2.802$ ), as shown in the scatter plot in Figure 5.

Figure 5



An additional graphical representation summarizing the relationship between body mass index categories and serum vitamin D levels among the study participants is shown in Figure 6.

Figure 6 :



## DISCUSSION

The present study evaluated the impact of COVID-19 pandemic-related restrictions on serum vitamin D3 levels in female adolescents with a low body mass index (BMI). The findings demonstrate a high prevalence of vitamin D deficiency in this population, with more than half of the participants exhibiting severe deficiency and significantly lower mean vitamin D levels in underweight participants compared with those with normal BMI. These results suggest that a low BMI does not confer protection against vitamin D deficiency, particularly during periods of restricted mobility and reduced sunlight exposure.

Previous studies have consistently reported an inverse relationship between vitamin D levels and high BMI,

attributing lower circulating vitamin D concentrations in obese individuals to sequestration of the fat-soluble vitamin in adipose tissue.<sup>[3,9]</sup> However, evidence regarding the vitamin D status of individuals with low BMI is limited. Our findings indicate that adolescents with a low BMI are equally, if not more, vulnerable to vitamin D deficiency, especially in the context of pandemic-related lifestyle changes. Reduced outdoor activity, prolonged indoor confinement, and limited sun exposure during lockdowns likely contributed to the impaired cutaneous synthesis of vitamin D in this group.<sup>[4,10]</sup>

Additionally, underweight adolescents may have inadequate dietary intake and limited vitamin D reserves, further predisposing them to vitamin D deficiency. The observed association between low BMI and significantly reduced serum vitamin D levels highlights the combined effects of nutritional insufficiency and environmental factors. The highest proportion of severe deficiency was noted in the 16–18-year age group, a critical period of growth and bone mineralization, emphasizing the potential long-term skeletal implications if left unaddressed.<sup>[11,12]</sup>

These findings underscore the importance of recognizing low-BMI adolescents as a vulnerable group for vitamin D deficiency, particularly during periods of restricted physical activity. Routine screening and early preventive strategies, including dietary counseling, supplementation, and safe sunlight exposure, are warranted in this population.

The limitations of this study include its single-center design, lack of quantitative assessment of dietary intake and sunlight exposure, and absence of seasonal variation analysis. Despite these limitations, this study provides valuable insights into an underexplored subgroup and highlights the need for further large-scale, multicenter studies.

## CONCLUSION

The present study demonstrates a high prevalence of vitamin D deficiency among female adolescents with low body mass index following COVID-19 pandemic-related restrictions. Underweight participants had significantly lower serum vitamin D3 levels than those with a normal BMI, indicating that a low BMI does not confer protection against vitamin D deficiency. Reduced sunlight exposure, limited physical activity, and possible nutritional inadequacy during prolonged lockdowns may have contributed to these effects. Further multicenter studies are warranted to explore the underlying mechanisms and guide preventive strategies in this vulnerable population.

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