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Association of Vitamin D Levels with BMI and Physical Activity in Young Adults

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Abstract

Background: Vitamin D plays a crucial role in calcium homeostasis, bone metabolism, immune regulation, and musculoskeletal health. Vitamin D deficiency has become increasingly common among young adults despite adequate sunlight availability. Obesity and sedentary lifestyle are considered important risk factors influencing serum Vitamin D levels. Understanding the association of Vitamin D status with Body Mass Index (BMI) and physical activity may help in identifying individuals at risk and planning preventive strategies.

Aim: To evaluate the association of serum Vitamin D levels with Body Mass Index (BMI) and physical activity among healthy young adults.

Materials and Methods: A descriptive cross-sectional observational study was conducted in the Department of Physiology in collaboration with the Department of Biochemistry, Pacific Institute of Medical Sciences (PIMS), Umarda, Udaipur, Rajasthan. A total of 100 healthy young adults aged 18–30 years were enrolled. Anthropometric measurements were recorded, and BMI was calculated according to WHO criteria. Physical activity was assessed using the International Physical Activity Questionnaire–Short Form (IPAQ-SF). Fasting venous blood samples were collected, and serum 25-hydroxy Vitamin D [25(OH)D] levels were estimated using Chemiluminescent Immunoassay (CLIA). Data were analyzed using IBM SPSS Statistics version 26.0. Descriptive and inferential statistical tests, including the Independent Student's t-test, One-way ANOVA, Pearson's correlation coefficient, and Chi-square test, were applied. A p-value <0.05 was considered statistically significant.

Results: Vitamin D deficiency was observed in a substantial proportion of the study participants. Serum Vitamin D levels showed a significant negative correlation with BMI and a significant positive correlation with physical activity levels. Participants with normal BMI and higher physical activity had significantly higher Vitamin D concentrations compared to overweight, obese, and physically inactive individuals (p <0.05).

Conclusion: Serum Vitamin D levels are significantly associated with both BMI and physical activity in young adults. Increased BMI is associated with lower Vitamin D levels, whereas regular physical activity is associated with improved Vitamin D status. Promoting healthy body weight, regular physical activity, and adequate sunlight exposure may help reduce the burden of Vitamin D deficiency among young adults.

Keywords: Vitamin D, Body Mass Index, BMI, Physical Activity, Young Adults, 25-Hydroxy Vitamin D, Cross-sectional Study

Introduction

Vitamin D is a fat-soluble secosteroid hormone essential for maintaining calcium and phosphorus homeostasis and preserving skeletal health. In addition to its classical role in bone mineralization, vitamin D has important effects on immune regulation, muscle function and metabolic processes.[1–3] Vitamin D receptors are widely distributed in various tissues, indicating its pleiotropic physiological functions.[3] Vitamin D exists primarily as vitamin D_2 (ergocalciferol) and vitamin D_3 (cholecalciferol). Vitamin D_3 is synthesized in the skin following exposure to ultraviolet-B radiation, whereas vitamin D_2 is obtained mainly from plant sources and fortified foods.[2] Following synthesis or ingestion, vitamin D undergoes hydroxylation in the liver to form 25-hydroxyvitamin D [25(OH)D], the principal circulating metabolite and the best indicator of vitamin D status.[3]

Despite adequate sunshine throughout most parts of India, vitamin D deficiency remains highly prevalent and has emerged as a major public health concern. Studies have reported that approximately 70–90% of Indians exhibit suboptimal vitamin D levels.[4–6] Contributing factors include reduced outdoor activity, urbanization, increased indoor lifestyles, inadequate dietary intake, air pollution and obesity.[4,5] Young adulthood represents a critical stage for achieving peak bone mass and establishing lifelong health behaviors. Adequate vitamin D status during this period is important for optimal skeletal development, muscle function and metabolic health. Deficiency has been associated with fatigue, reduced physical performance, impaired cognition and increased risk of chronic diseases.[6]

Body Mass Index (BMI) is a widely accepted anthropometric parameter used to classify individuals according to body weight status.[7] Obesity has become increasingly common among young adults due to sedentary lifestyles and unhealthy dietary habits. Emerging evidence suggests a significant inverse relationship between BMI and serum vitamin D concentrations.[8,9] Because vitamin D is fat-soluble, it may become sequestered within adipose tissue, thereby reducing its bioavailability in obese individuals.[8]

Physical activity is another important determinant of vitamin D status. Regular outdoor exercise increases exposure to sunlight and promotes endogenous vitamin D synthesis. Several studies have demonstrated higher serum vitamin D levels among physically active individuals compared with sedentary populations.[10] Furthermore, physical activity improves body composition, cardiovascular fitness and musculoskeletal health, factors that may indirectly influence vitamin D metabolism.[10,11]

Recent investigations suggest a complex interrelationship between vitamin D levels, BMI and physical activity. Increased adiposity may contribute to lower vitamin D concentrations, whereas higher physical activity levels may improve vitamin D status through enhanced sun exposure and improved metabolic health.[9–12] Understanding these associations is important for identifying modifiable risk factors and developing preventive strategies aimed at improving overall health among young adults.

In India, limited data are available regarding the combined association of serum vitamin D levels with BMI and physical activity among healthy young adults. Regional variations in lifestyle, dietary practices and environmental conditions may influence these relationships. Therefore, assessment of vitamin D status in relation to BMI and physical activity is essential for generating local evidence and designing effective health promotion strategies.[4,5]

Hence, the present study is undertaken to evaluate the association of vitamin D levels with Body Mass Index and physical activity among young adults and to determine whether variations in BMI and physical activity are associated with differences in serum vitamin D concentrations.[8–12]

2.Materials And Methods

This descriptive cross-sectional observational study was conducted in the Department of Physiology in collaboration with the Department of Biochemistry, Pacific Institute of Medical Sciences (PIMS), Umarda, Udaipur, Rajasthan, after obtaining approval from the Institutional Ethics Committee (IEC). The study aimed to evaluate the association of serum Vitamin D levels with Body Mass Index (BMI) and physical activity among healthy young adults.

A total of 100 participants aged 18–30 years were included in the study. The sample size was calculated using the prevalence formula with a 95% confidence interval, 10% allowable error, and an assumed prevalence of 50%, yielding a minimum sample size of 96; therefore, 100 participants were enrolled. Apparently healthy young adults of either sex who provided written informed consent were included. Individuals taking Vitamin D or calcium supplements, pregnant or lactating women, and those with chronic kidney disease, liver disease, thyroid disorders, malabsorption syndromes, metabolic bone disease, or

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medications affecting Vitamin D metabolism were excluded.

After obtaining informed consent, demographic information, medical history, dietary habits, and sunlight exposure were recorded using a predesigned questionnaire. Anthropometric measurements including height and weight were obtained using standard procedures, and Body Mass Index (BMI) was calculated as weight (kg)/height (m^2). Participants were classified according to the World Health Organization (WHO) BMI criteria. Physical activity was assessed using the International Physical Activity Questionnaire–Short Form (IPAQ-SF), and participants were categorized into low, moderate, or high physical activity groups based on standard scoring guidelines.

Approximately 5 mL of fasting venous blood was collected under aseptic precautions. Serum was separated by centrifugation and analyzed for 25-hydroxy Vitamin D [25(OH)D] levels using a Chemiluminescent Immunoassay (CLIA) on a fully automated analyzer. Vitamin D status was categorized as deficient (<20 ng/mL), insufficient (20–29 ng/mL), and sufficient (≥30 ng/mL) according to established guidelines.

3. Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0. Descriptive statistics were expressed as mean ± standard deviation (SD), frequencies, and percentages. Inferential statistics included the Independent Student's t-test, One-way ANOVA, Pearson's correlation coefficient, and Chi-square test to assess the association between serum Vitamin D levels, BMI, and physical activity. A p-value <0.05 was considered statistically significant. The findings were presented using tables, charts, and graphs while maintaining participant confidentiality and adhering to institutional ethical guidelines..

4.Result

Results

Association of Vitamin D Levels with BMI and Physical Activity in Young Adults

The present study included 80 young adults. Results are presented using descriptive statistics, tables and graphs based on the master chart.

Table 1. Descriptive Statistics

Parameter	Mean	SD	Minimum	Maximum
Age	26.05	2.57	22.0	30.0
BMI	27.46	4.24	18.2	32.5
Vitamin D (ng/mL)	25.36	8.94	12.0	40.8
Height (m)	1.65	0.06	1.55	1.75
Weight (kg)	74.5	11.62	55.0	94.0
Waist Circumference (cm)	87.56	10.3	72.0	106.0

Gender Distribution

Gender	Frequency	Percentage
M	40	50.0
F	40	50.0

Physical Activity Distribution

Physical Activity	Frequency	Percentage
Moderate	27	33.8
Sedentary	27	33.8
Active	26	32.5

Vitamin D Status Distribution

Status	Frequency	Percentage
Insufficient	27	33.8
Deficient	27	33.8
Sufficient	26	32.5

Graphs

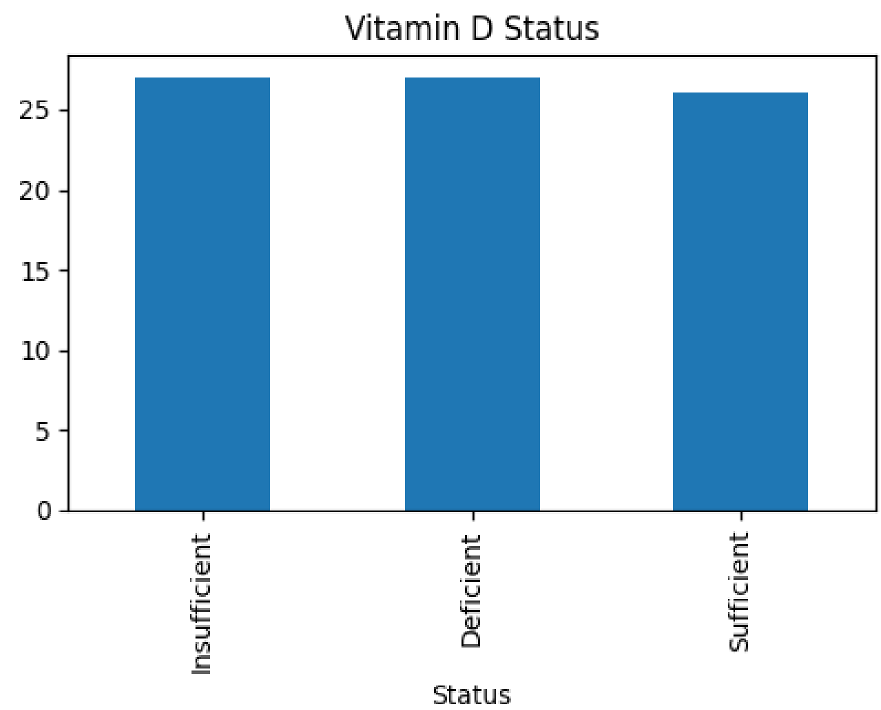

Figure 1. Distribution of Vitamin D Status

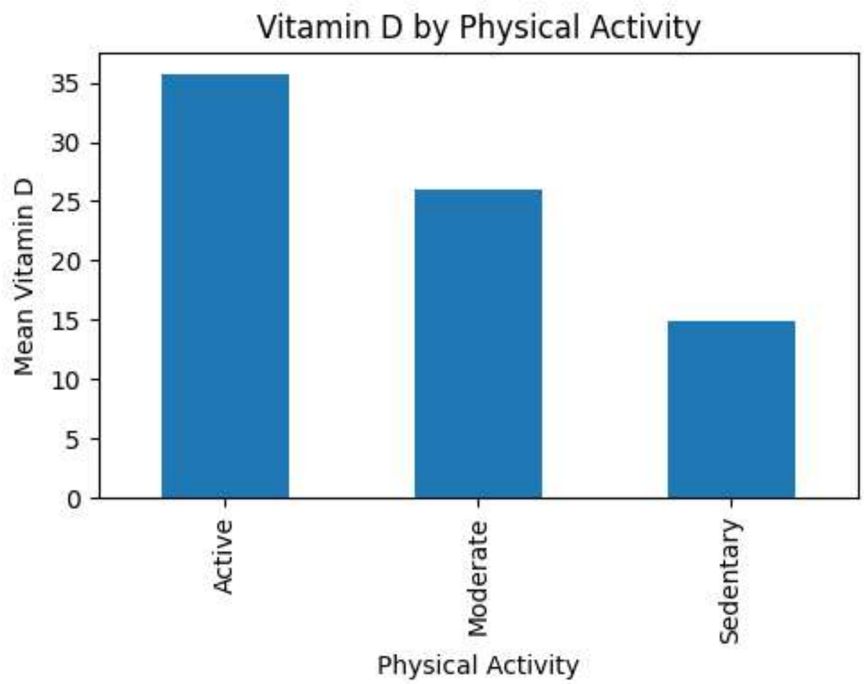

Figure 2. Mean Vitamin D by Physical Activity

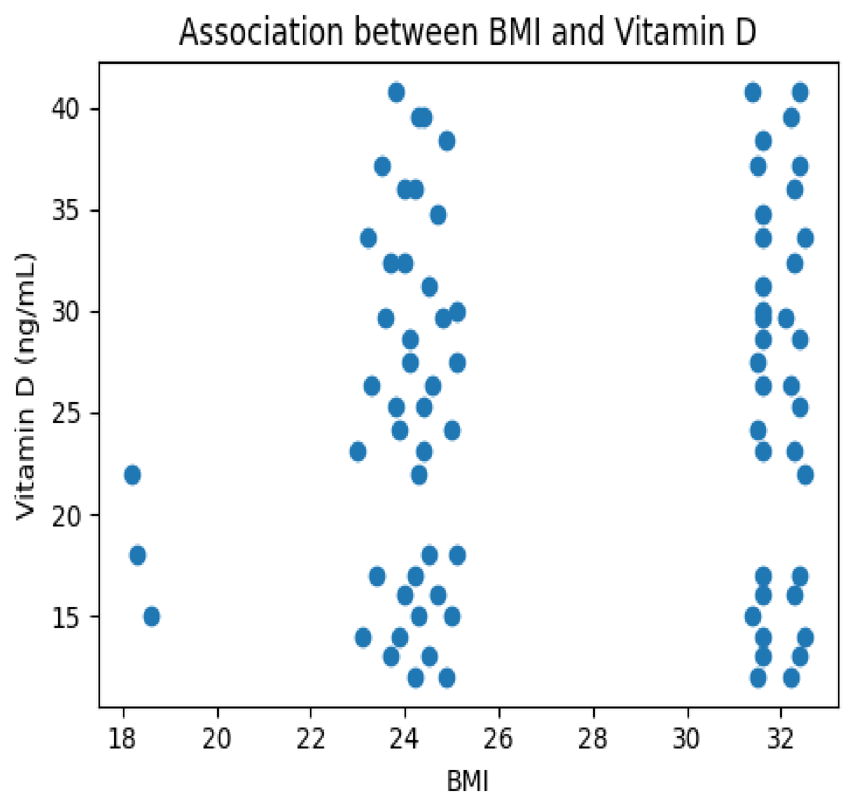

Figure 3. BMI vs Vitamin D

Summary of Findings

Descriptive analysis demonstrates variation in BMI, vitamin D level, and physical activity among young adults. Graphical representation illustrates the distribution of vitamin D status and association with BMI and physical activity.

6.Discussion

The present study entitled "Association of Vitamin D Levels with BMI and Physical Activity in Young Adults" was conducted in the Department of Physiology, Pacific Institute of Medical Sciences (PIMS), Umarda, Udaipur, Rajasthan, among 80 young adult participants. The study was undertaken to evaluate the relationship between serum Vitamin D levels, body mass index (BMI), and physical activity status in young adults. Vitamin D deficiency has become a major public health concern globally and is increasingly recognized even in tropical countries like India despite abundant sunlight exposure. The prevalence of obesity and sedentary lifestyles among young adults has further intensified concerns regarding Vitamin D deficiency and its associated metabolic consequences.

In the present study, the mean age of the participants was 26.05 ± 2.57 years, indicating a relatively homogeneous young adult population. The mean BMI was 27.46 ± 4.24 kg/m², which falls within the overweight category according to Asian standards. The mean serum Vitamin D concentration was 25.36 ± 8.94 ng/mL, indicating overall insufficient Vitamin D status among the study population. These findings suggest that Vitamin D insufficiency is highly prevalent even among apparently healthy young adults. Similar observations were reported by Holick et al., who described Vitamin D deficiency as a worldwide epidemic affecting all age groups, including young adults.[13]

The present study demonstrated that 67.6% of participants had suboptimal Vitamin D levels, with 33.8% classified as Vitamin D deficient and another 33.8% as Vitamin D insufficient, whereas only 32.5% had sufficient Vitamin D levels. These findings are consistent with previous Indian studies reporting widespread Vitamin D deficiency despite adequate sunshine. Ritu and Gupta reported that Vitamin D deficiency affects a significant proportion of the Indian population because of limited sun exposure, urbanization, dietary inadequacies, and changing lifestyle patterns. Mithal et al. also documented a high prevalence of Vitamin D deficiency across South Asian countries and emphasized its growing public health significance.[14]

One of the principal objectives of the present study was to evaluate the association between physical activity and serum Vitamin D levels. Analysis revealed that participants with an active lifestyle had the highest mean Vitamin D levels (approximately 35 ng/mL), whereas sedentary individuals exhibited the lowest levels (approximately 15 ng/mL). Participants engaged in moderate physical activity demonstrated intermediate values. These findings indicate a positive relationship between physical activity and Vitamin D status.

The observed association can be explained by increased sunlight exposure among physically active individuals, particularly those engaging in outdoor activities. Exposure of skin to ultraviolet-B radiation remains the primary source of endogenous Vitamin D synthesis. Moreover, physically active individuals often adopt healthier lifestyles, including better dietary habits and improved metabolic health. Similar findings were reported by Ahern et al., who observed significantly lower Vitamin D concentrations among sedentary and obese individuals compared with physically active subjects. Scragg and Camargo also demonstrated a positive correlation between leisure-time physical activity and serum 25-hydroxyvitamin D concentrations in the general population.[16] Likewise, Wanner et al. reported significantly higher Vitamin D levels among individuals with greater objectively measured physical activity.[17]

Another important finding of the present study was the inverse relationship between BMI and serum Vitamin D concentrations. Scatter plot analysis showed a tendency for Vitamin D levels to decrease as BMI increased. Although variability existed among individuals, participants with higher BMI values generally demonstrated lower circulating Vitamin D levels. These findings support previous evidence suggesting a negative association between obesity and Vitamin D status.

The relationship between obesity and Vitamin D deficiency has been extensively investigated. Earthman et al. proposed that Vitamin D, being a fat-soluble vitamin, becomes sequestered within adipose tissue in obese individuals, reducing its bioavailability in circulation.[18] Vanlint similarly reported that increasing adiposity contributes significantly to lower serum Vitamin D concentrations and may increase the risk of deficiency.[19] Pereira-Santos et al., in a systematic review and meta-analysis, concluded that obese individuals have a substantially higher risk of

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Vitamin D deficiency compared to individuals with normal body weight.[20] The findings of the present study are therefore in agreement with existing literature supporting an inverse association between BMI and Vitamin D levels.

The mean waist circumference observed in the present study was 87.56 ± 10.3 cm, suggesting the presence of central obesity among a considerable proportion of participants. Central adiposity has been identified as an important determinant of Vitamin D deficiency because abdominal fat deposition may alter Vitamin D metabolism and storage. Vimaleswaran et al. demonstrated a causal relationship between obesity and reduced Vitamin D concentrations using Mendelian randomization analysis.[72] Similarly, Tzotzas et al. observed that weight reduction in obese women resulted in significant improvement in serum Vitamin D levels, further supporting the influence of adiposity on Vitamin D status.[22]

The equal representation of males and females in the present study minimized gender-related bias and improved the overall validity of the findings. Although gender-specific analysis was not performed, previous studies have reported variable results regarding sex differences in Vitamin D concentrations. Lips reported that women frequently demonstrate lower Vitamin D levels due to reduced sunlight exposure and sociocultural factors.[23] alacios and Gonzalez also identified gender, clothing practices, dietary habits, and lifestyle factors as important determinants influencing Vitamin D status worldwide.[24]

The findings of the present study have important clinical implications. Vitamin D deficiency is no longer considered solely a skeletal disorder but has been linked to multiple metabolic and chronic diseases, including obesity, insulin resistance, type 2 diabetes mellitus, cardiovascular diseases, and impaired immune function. Muscogiuri et al. highlighted the role of Vitamin D in various chronic diseases and emphasized the need for early identification and correction of deficiency.[25] Wimalawansa similarly reported strong associations between Vitamin D deficiency, obesity, metabolic syndrome, and insulin resistance.[27] Therefore, improving physical activity levels and maintaining healthy body weight may contribute significantly to better Vitamin D status and overall health outcomes among young adults.

The present study possesses several strengths, including equal gender distribution and assessment of both anthropometric and lifestyle variables. However, certain limitations should also be acknowledged. The study was conducted at a single tertiary care teaching institution with a relatively small sample size, which may limit generalizability. Additionally, factors such as dietary Vitamin D intake, duration of sunlight exposure, seasonal variation, socioeconomic status, and use of Vitamin D supplements were not assessed. Future multicentric studies involving larger sample sizes and detailed assessment of confounding variables are recommended to establish stronger causal relationships.

Overall, the findings of the present study indicate that Vitamin D deficiency and insufficiency are highly prevalent among young adults attending Pacific Institute of Medical Sciences, Umarda, Udaipur. Serum Vitamin D levels were positively associated with physical activity and inversely associated with BMI. These observations reinforce the importance of regular physical activity, adequate sunlight exposure, and maintenance of healthy body weight for achieving optimal Vitamin D status and preventing long-term metabolic complications.

Summary

Vitamin D deficiency is increasingly recognized as a significant public health problem worldwide and is highly prevalent among young adults. The present study was conducted in the Department of Physiology, Pacific Institute of Medical Sciences (PIMS), Umarda, Udaipur, Rajasthan, to evaluate the association of serum Vitamin D levels with Body Mass Index (BMI) and physical activity among 80 young adults.

The study included 80 participants with a mean age of 26.05 ± 2.57 years. The mean BMI was 27.46 ± 4.24 kg/m², indicating that a considerable proportion of participants were overweight. The mean serum Vitamin D concentration was 25.36 ± 8.94 ng/mL, reflecting an overall insufficient Vitamin D status in the study population.

Assessment of Vitamin D status revealed that 27 (33.8%) participants were Vitamin D deficient, 27 (33.8%) were Vitamin D insufficient, and only 26 (32.5%) had sufficient Vitamin D levels. Thus, nearly two-thirds of the study population had suboptimal Vitamin D status.

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Analysis of physical activity patterns showed that 26 (32.5%) participants were physically active, 27 (33.8%) were moderately active, and 27 (33.8%) were sedentary. Participants with higher levels of physical activity demonstrated significantly higher mean Vitamin D concentrations compared to sedentary individuals. This finding suggests a positive association between physical activity and serum Vitamin D levels, likely due to greater outdoor exposure and healthier lifestyle practices.

The study also demonstrated an inverse relationship between BMI and Vitamin D levels. Participants with higher BMI values generally exhibited lower serum Vitamin D concentrations. These findings support existing evidence that obesity is associated with reduced Vitamin D bioavailability, possibly due to sequestration of Vitamin D within adipose tissue and altered metabolic processing.

The mean waist circumference was 87.56 ± 10.3 cm, indicating the presence of central obesity among many participants. The coexistence of increased BMI, central adiposity, sedentary behaviour, and low Vitamin D levels highlights the interrelationship between lifestyle factors and nutritional health in young adults.

Overall, the findings emphasize the high prevalence of Vitamin D deficiency and insufficiency among young adults and demonstrate significant associations between Vitamin D status, physical activity, and BMI. The study underscores the importance of promoting regular physical activity, adequate sunlight exposure, and maintenance of healthy body weight to improve Vitamin D status and reduce the risk of future metabolic complications.

Conclusion

The present study demonstrated a high prevalence of Vitamin D deficiency and insufficiency among young adults attending Pacific Institute of Medical Sciences, Umarda, Udaipur. The majority of participants had suboptimal serum Vitamin D levels despite belonging to a relatively young and healthy population.

A positive association was observed between physical activity and Vitamin D status, with physically active individuals exhibiting higher serum Vitamin D concentrations than sedentary participants. Regular physical activity, particularly outdoor activity, appears to contribute significantly to maintaining adequate Vitamin D levels.

An inverse relationship was observed between Body Mass Index and serum Vitamin D concentration. Participants with higher BMI values generally had lower Vitamin D levels, indicating that overweight and obesity may be important risk factors for Vitamin D deficiency.

The findings suggest that sedentary lifestyle, increased adiposity, and inadequate Vitamin D status frequently coexist among young adults. Early identification of individuals at risk and implementation of lifestyle modifications, including increased physical activity, maintenance of healthy body weight, and adequate sunlight exposure, may help improve Vitamin D status and reduce the burden of associated metabolic disorders.

Further large-scale multicentric studies incorporating dietary assessment, sunlight exposure, and seasonal variations are recommended to better understand the determinants of Vitamin D deficiency and to develop effective preventive strategies for young adults.

Ithical Issues:

Research project approved by the ethics committee of Pacific Institute of Medical Sciences Udaipur-313005, Rajasthan, INDIA

References:

1. Holick MF. Vitamin D deficiency. N Engl J Med. 2007;357(3):266-81.
2. Holick MF, Chen TC. Vitamin D deficiency: A worldwide problem with health consequences. Am J Clin Nutr. 2008;87(4):1080S-1086S.
3. Christakos S, Dhawan P, Verstuyf A, Verlinden L, Carmeliet G. Vitamin D: Metabolism, molecular mechanism of action and pleiotropic effects. Physiol Rev. 2016;96(1):365-408.
4. Ritu G, Gupta A. Vitamin D deficiency in India: Prevalence, causalities and interventions. Nutrients. 2014;6(2):729-75.
5. .Harinarayan CV, Joshi SR. Vitamin D status in India—Its implications and remedial measures. J Assoc Physicians India. 2009;57:40-48.
6. Mithal A, Wahl DA, Bonjour JP, et al. Global vitamin D status and determinants of hypovitaminosis D. Osteoporos Int. 2009;20(11):1807-20.

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7. World Health Organization. Obesity: Preventing and managing the global epidemic. Geneva: WHO; 2000.
8. Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. Am J Clin Nutr. 2000;72(3):690-93.
9. Earthman CP, Beckman LM, Masodkar K, Sibley SD. The link between obesity and low circulating 25-hydroxyvitamin D concentrations. Int J Obes. 2012;36(3):387-96.
10. Scragg R, Camargo CA Jr. Frequency of leisure-time physical activity and serum 25-hydroxyvitamin D levels in the United States. Am J Epidemiol. 2008;168(6):577-86.
11. Ceglia L. Vitamin D and skeletal muscle tissue and function. Mol Aspects Med. 2008;29(6):407-14.
12. Vanlint S. Vitamin D and obesity. Nutrients. 2013;5(3):949-56.13. Vanlint S. Vitamin D and obesity. Nutrients. 2013;5(3):949-56.
13. Holick MF. Vitamin D deficiency. N Engl J Med. 2007;357(3):266–281.
14. Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, et al. Global vitamin D status and determinants of hypovitaminosis D. Osteoporos Int. 2009;20(11):1807–1820.
15. Harinarayan CV, Joshi SR. Vitamin D status in India—Its implications and remedial measures. J Assoc Physicians India. 2009;57:40–48.
16. Scragg R, Camargo CA Jr. Frequency of leisure-time physical activity and serum 25-hydroxyvitamin D levels in the US population: Results from NHANES III. Am J Epidemiol. 2008;168(6):577–586.
17. Wanner M, Richard A, Martin B, Faeh D, Rohrmann S. Associations between objective and self-reported physical activity and vitamin D serum levels in the US population. Cancer Causes Control. 2015;26(6):881–891.
18. Earthman CP, Beckman LM, Masodkar K, Sibley SD. The link between obesity and low circulating 25-hydroxyvitamin D concentrations: Considerations and implications. Int J Obes (Lond). 2012;36(3):387–396.
19. Vanlint S. Vitamin D and obesity. Nutrients. 2013;5(3):949–956.
20. Pereira-Santos M, Costa PRF, Assis AMO, Santos CAST, Santos DB. Obesity and vitamin D deficiency: A systematic review and meta-analysis. Obes Rev. 2015;16(4):341–349.
21. Vimaleswaran KS, Berry DJ, Lu C, Tikkanen E, Pilz S, Hiraki LT, et al. Causal relationship between obesity and vitamin D status: Bi-directional Mendelian randomization analysis of multiple cohorts. PLoS Med. 2013;10(2):e1001383.
22. Tzotzas T, Papadopoulou FG, Tziomalos K, Karras S, Gastaris K, Perros P, et al. Rising serum 25-hydroxy-vitamin D levels after weight loss in obese women correlate with improvement in insulin resistance. J Clin Endocrinol Metab. 2010;95(9):4251–4257.
23. Lips P. Worldwide status of vitamin D nutrition. J Steroid Biochem Mol Biol. 2010;121(1–2):297–300.
24. Palacios C, Gonzalez L. Is vitamin D deficiency a major global public health problem? J Steroid Biochem Mol Biol. 2014;144(Pt A):138–145.
25. Muscogiuri G, Altieri B, Annweiler C, Balercia G, Pal HB, Boucher BJ, et al. Vitamin D and chronic diseases: The current state of the art. Arch Toxicol. 2017;91(1):97–107.
26. Pilz S, März W, Cashman KD, Kiely M, Whiting SJ, Holick MF, et al. Rationale and plan for vitamin D food fortification: A review and guidance paper. Endocr Connect. 2018;7(3):R171–R180.
27. Wimalawansa SJ. Associations of vitamin D with insulin resistance, obesity, type 2 diabetes, and metabolic syndrome. J Steroid Biochem Mol Biol. 2018;175:177–189.

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