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Serum 25-hydroxyvitamin D is associated with body fat percentage and skeletal muscle mass in adults: A cross-sectional study

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ABSTRACT

Background: Vitamin D is widely recognized for its role in bone and musculoskeletal health, yet accumulating evidence suggests it may also influence body composition through regulatory effects on adipose and skeletal muscle tissues. This study aimed to evaluate the association between serum vitamin D status and body composition parameters in adults. Methods: A cross-sectional study was conducted in 77 adults. Serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured using an enzyme-linked immunosorbent assay (ELISA), while body composition (percent body fat and skeletal muscle mass) was assessed using bioelectrical impedance analysis (BIA). Participants were categorized based on vitamin D status, and group comparisons as well as Pearson correlation analyses were performed. Results: The mean age of participants was 35.8 ± 9.6 years, and 40.2% were men. The prevalence of vitamin D deficiency (<20 ng/mL) was 36%, while 68% of participants had suboptimal vitamin D levels (deficiency or insufficiency). Individuals with vitamin D deficiency showed significantly higher body fat percentage and lower skeletal muscle mass compared with the non-deficient group ($p < 0.05$). Serum 25(OH)D was moderately inversely correlated with body fat percentage ($r = -0.41$, $p = 0.018$) and positively correlated with skeletal muscle mass ($r = 0.29$, $p = 0.012$). Conclusion: Lower vitamin D status was associated with increased adiposity and reduced skeletal muscle mass in adults. These findings highlight the potential importance of maintaining adequate vitamin D levels as part of strategies supporting healthier body composition. Longitudinal and interventional studies are needed to clarify causality and clinical implications.

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INTRODUCTION

Vitamin D deficiency represents a significant public health problem (up to 1 billion people worldwide are estimated to be affected) and the burden of disease is high, also in developing countries where rickets still occurs (Marti et al., 2024). In addition to its traditional function of calcium/phosphate metabolism and skeletal health, vitamin D has emerged as a multifaceted steroid hormone with constructive actions in distant organs such as adipocyte or muscle This broader biological impact is justified by the fact that vitamin D receptor (VDR) signaling exists in non-skeletal tissues; suggesting a possibility that a similar, endocrine-like action mechanism may underlie metabolic and body composition regulation induced by vitamin D (Park & Han, 2021). he "vitamin D paradox" is due to a combination of indoor lifestyles, reduced UVB exposure during peak sunlight hours, air pollution and sun-avoidance behaviour (Siddiqee et al., 2021). even though there maybe abundant sunshine in much tropical country; circulating 25-hydroxyvitamin D [25(OH)D] levels are still low throughout much of the tropics. Similarly, the worldwide prevalence rates of overweight and obesity that have risen globally have increased attention on nutritional biomarkers potentially implicated in adiposity and lean tissue physiology (Bennour et al., 2022).

A consistent observation across epidemiological studies is the inverse association between serum 25(OH)D levels and adiposity-related outcomes, including higher body fat percentage and greater central fat accumulation among individuals with low vitamin D status (Lu & Cao, 2023). Mechanistic explanations for this relationship include adipose sequestration of fat-soluble vitamin D and volumetric dilution across a larger body mass, which may lower measurable circulating 25(OH)D concentrations in individuals with excess adiposity (Szymczak-Pajor et al., 2022). Moreover, obesity has been proposed not only as a correlate but potentially a causal contributor to vitamin D deficiency through combined physiological and behavioral pathways (Angelino et al., n.d.). While the vitamin D–adiposity relationship is widely reported, evidence linking vitamin D status to skeletal muscle parameters remains less consistent, particularly among working-age adults (Angelino et al., n.d.; Bennour et al., 2022). Skeletal muscle is a major metabolic organ responsible for glucose disposal and energy expenditure, and vitamin D signaling has been implicated in muscle cell differentiation, calcium handling, and mitochondrial bioenergetics (Angelino et al., n.d.). Experimental and translational studies suggest that VDR activity may directly influence mitochondrial function in skeletal muscle, providing biological plausibility for associations between vitamin D status and muscle-related phenotypes (Salles et al., 2022). Nevertheless, population findings differ across studies, potentially due to variations in measurement approaches, confounding by physical activity and adiposity, and the frequent use of broad lean mass estimates rather than muscle-specific indicators (Angelino et al., n.d.; Bennour et al., 2022).

Given the concurrent high prevalence of hypovitaminosis D and suboptimal body composition profiles, clarifying the relationship between vitamin D status and fat–muscle distribution in adults remains clinically and public health relevant (Zhang & Li, 2024). Notably, data from working age adults in Southeast Asia, where sunlight exposure is abundant yet vitamin D inadequacy persists, remain underrepresented in the current literature on vitamin D and body composition. Many previous studies have emphasized BMI or generalized lean mass measures, which may mask clinically meaningful variation in fat muscle distribution and its relationship with vitamin D status (Angelino et al., n.d.; Bennour et al., 2022). By integrating serum 25(OH)D assessment with bioelectrical impedance-based evaluation of percent body fat and skeletal muscle mass, the present study offers a more granular description of body composition correlates of vitamin D in adults. These findings may provide practical implications for early screening and targeted interventions aimed at reducing adiposity and preserving metabolically active muscle tissue in populations at risk of hypovitaminosis D (Al Argan et al., 2026). Previous studies leave key gaps by often focusing on bone health or examining fat and muscle separately, rather than body composition as a whole. Most evidence is cross-sectional, limiting insight into causality, and many studies use inconsistent measurement methods or overlook important factors such as age, sex, and physical activity. These gaps highlight the need for research that examines the integrated relationship between vitamin D status, fat mass, and muscle mass (Faradisa, Muhammad and Girindraswari, 2022, 2022; Madusanka *et al.*, 2023). This research contributes by broadening the understanding of vitamin D beyond bone health, showing its potential role in regulating both muscle and fat mass. The findings help clarify how micronutrient status may influence overall body composition. In practice, the study highlights the importance of monitoring and addressing vitamin D deficiency, particularly in adults at risk of obesity or muscle loss, and supports its consideration as part of simple, preventive health strategies. Therefore, this study aimed to examine the association between serum 25(OH)D concentration and body composition parameters specifically percent body fat and skeletal muscle mass in an adult population assessed using standardized biochemical and bioelectrical impedance approaches. We hypothesized that higher 25(OH)D levels would be associated with lower adiposity and greater skeletal muscle mass, supporting the potential value of vitamin D adequacy for favorable body composition in adults.

RESEARCH METHOD

A cross-sectional study was conducted to examine the association between vitamin D status and body composition in adults. A total of 77 men and women aged 20–60 years were recruited. Participants were eligible if they were apparently healthy, had no major chronic diseases (e.g., uncontrolled diabetes, severe renal/hepatic disease, or active malignancy), and had not consumed vitamin D supplements within the previous 3 months. Exclusion criteria included pregnancy, use of medications affecting bone or mineral metabolism, and conditions that could compromise bioelectrical impedance measurements. All participants provided written informed consent. The study protocol was approved by the Universitas Sumatera Utara Ethics Committee and conducted in accordance with the Declaration of Helsinki.

Demographic and health information (age, sex, medical history, supplement use, and self-reported physical activity) were collected using a structured questionnaire. Body weight and height were measured using calibrated equipment, and BMI was calculated. Body composition, including percent body fat and skeletal muscle mass, was assessed using bioelectrical impedance analysis (BIA). Serum 25-hydroxyvitamin D [25(OH)D] was measured at Prodia Laboratory using a quantitative ELISA method. Vitamin D status was categorized as deficient (<20 ng/mL), insufficient (20–29 ng/mL), and sufficient (≥30 ng/mL). For selected comparisons, participants were grouped as vitamin D-deficient versus non-deficient (insufficient and sufficient combined).

Continuous variables were assessed for normality using the Kolmogorov–Smirnov test and presented as mean ± SD, while categorical variables were reported as frequency and percentage. Group differences between vitamin D-deficient and non-deficient participants were evaluated using independent-samples t-tests and chi-square tests, as appropriate. Associations between serum 25(OH)D and body composition parameters were examined using Pearson correlation coefficients. Statistical significance was defined as $p < 0.05$ (two-tailed), and all analyses were performed using SPSS version 26.

RESULTS AND DISCUSSIONS

A total of 77 adult patients, 31 males (40.2%) and 46 females (59.7%), mean age: 35.8 ±9.6 years, (range:22–58 years) were included in this study. The average values of the BMI, body fat and skeletal muscle mass were 25.1 ± 4.3 kg/m² (range:20.8–29.4 kg/m²), 24.87 ± 5.62% (range:15.70–36.60%) and 28.77 ± 2.56 kg (range:19 .20-35.10kg) respectively among these subjects., The mean value of serum vitamin D level was 24.5 ± 9.1 ng/mL (range: 15.4–33.6 ng/mL). BMI classification showed 43 participants (55.8%) to be of normal weight, 21 (27.2%) to be overweight, seven (9.09%) obese and six (7.7%) underweight. For 28 participants (36%) the overall vitamin D level was deficient (<20 ng/mL), for 25 (32%) it was insufficient (20–29 ng/mL) and only 24 (31%) had a sufficient overall vitamin D status (≥30 ng/mL), which means that in the total study population, 68% presented with an unsatisfactory vitamin D status.

Table 1. Participant characteristics and body composition (N=77)

Variable	n	Mean ± SD	Min–Max
Gender			
Man	31(40.2%)		
Women	46 (59.7%)		
Age (years)		35.8 ± 9.6	22–58
BMI (kg/m²)		25.1 ± 4.3	20.8–29,4
Percent Body Fat (%)		24.87±5.623	15.70-36.60
Skeletal Muscle Mass (kg)		28.77 ± 2.56	19.20–35.10
Vitamin D (ng/mL)		24.5 ± 9.1	15.4–33.6

Table 2. BMI category

BMI	n	%
Underweight (BMI<18.5)	6	7.7
Normal (BMI 18.5-24.9)	43	55.8
Overweight (BMI 25–29.9)	21	27.2
obese (BMI ≥ 30)	7	9.09

Table 3. Vitamin D status distribution

Vitamin D status	n	%
Deficiency (<20 ng/mL)	28	36
Insufficiency (20–29 ng/mL)	25	32
Sufficiency (≥30 ng/mL)	24	31

The current results indicate the high prevalence of vitamin D insufficiency in these adults, the majority of whom are deficient2 or insufficient even though their mean age is young (Siddiqee et al., 2021). This observation is consistent with another study reporting hypovitaminosis D to be still prevalent in working-age populations as a result of the lack of outdoor activity, indoor occupation or low consumption of dietary vitamin-rich products (Kelly et al., 2024). Importantly, the sample's mean BMI was classified as overweight and around one-third of participants were overweight or obese; this distribution may be of clinical interest considering that higher adiposity is often linked with lower plasma vitamin D concentrations. Data of the current study imply that vitamin D screening and targeted lifestyle interventions might be useful for obese adults with either high adiposity or suboptimal levels of vitamin D (Aris et al., 2020; Augustine et al., 2021).

Vitamin D reduction at high fat mass attaches to visceral dilution and storage of vitamin D in adipose tissue, lowering bioavailable circulating levels (Szymczak-Pajor et al., 2022). which may vary with the study design. Lastly, the contribution of vitamin D on skeletal muscle also includes - along with VDR expression in muscles tissue- its role in calcium handling and muscle protein metabolism (Pojednic & Ceglia, 2014). While the average muscle mass was preserved in relation to age, the incredibly high proportion of individuals with vitamin D insufficiency might have implications on both muscle quality and future strength and metabolic health (Bollen et al., 2022; Md Salleh et al., 2025). Of note, the inclusion of fat mass% and skeletal Muscle mass in addition to BMI gives a more detailed body composition profile, effectively enhancing the evidence for assessing Vitamin D status not only according to body size but also with respect to fat muscle distribution (Magalhães et al., 2024; Sutherland et al., 2023). The average percent body fat was also significantly higher in the vitamin D deficient group (30.2 ± 7.8%) compared with the non-deficient participants (25.6 ± 6.5%, p = 0.004). Furthermore, the absolute skeletal muscle mass was significantly lower in Vitamin D deficient than Vitamin D non-deficient group individuals as assessed by BIA (mean 24.1 ± 5.4 kg vs 26.8 ± 5.9 kg, p = 0.019).

Table 3. Vitamin D status distribution

Body Composition Parameter	Vitamin D Deficient Group	Vitamin D Non-Deficient Group	p-value
Percent Body Fat (%)	30.2 ± 7.8	25.6 ± 6.5	0.004
Skeletal Muscle Mass (kg)	24.1 ± 5.4	26.8 ± 5.9	0.019

Table 4. Correlation vitamin D and body composition parameter

Body Composition Parameter	r	p-value
Body Fat Percentage	-0.41	0.018
Skeletal Muscle Mass	0.29	0.012

Serum 25(OH)D concentration were significantly associated with body composition parameters. There existed a significant negative correlation between 25(OH)D and percent body fat (Pearson r = –0.41, p=0.018), suggesting that those with higher vitamin D status exhibited less adiposity. Serum 25(OH)D also exhibited a positive association with skeletal muscle mass (r = 0.29, p = 0.012). These associations persisted in partial correlation analysis when adjusting for age and sex. We observed vitamin D status had a significant association with body composition in our present study. Lower serum 25(OH)D values were associated with increased body fat and decreased muscle mass, as we hypothesized (Khwanchuea & Punsawad, 2022; Latham et al., 2021) These results are in line with other studies which have recommended that vitamin D acts on both adipose and muscle tissues (Jonasson et al., 2020). A recent cross-sectional study in Korean adults also found total 25(OH)D levels to be negatively associated with percent fat mass and positively related to lean mass and muscle strength (Kim et al., 2025). Our findings support these associations in a general adult population, providing further evidence that sufficient vitamin D status is associated with a more favourable body composition profile.

The association of low vitamin D and increased adiposity is biologically feasible, and other studies reported similar findings. Vitamin D is a fat-soluble vitamin and may be sequestered in adipose tissue, resulting in reduced circulating concentrations among overweight individuals. Hypertrophied adipocytes in obesity could serve as a storage depot for vitamin D, rendering it less bioavailable. This latter hypothesis of the sequestration theory would account for a vitamin D deficiency as a result from an increased fat mass. On the other hand, there are mechanistic reasons why vitamin D deficiency per se might lead to increased adiposity. Vitamin D receptors are expressed in adipose tissue, and the biologically active form of this vitamin (1,25-dihydroxyvitamin D), stimulates lipolysis, inhibits mature adipocytes development and also decreases fat storage (Jonasson et al., 2020). These regulatory effects are diminished in deficiency states and may therefore predispose to increased fat deposition. The inverse 25(OH)D–body fat relationship that we found overlaps both views and is consistent with conclusions of other observational studies reporting associations between low vitamin D status and increased BMI, waist girth, and central fat accumulation. It should be noted that in our data, vitamin D levels were more closely related to percent fat than BMI which emphasizes the importance of including body composition variables in addition to BMI (Campa et al., 2021; Dai et al., 2025).

In the present study, vitamin D status was related to muscle mass as well as adiposity. We observed that higher 25(OH)D levels were modestly but significantly associated with higher Skeletal Muscle Mass. This is consistent with the hypothesis that vitamin D adequacy might be good for muscle health (Latham et al., 2021; Shoemaker et al., 2022). Several pathways influence muscle function and vitamin D. Muscle fibers also have vitamin D receptors, which can be activated by calcitriol to promote muscle protein synthesis and mitochondrial function. Vitamin D has also been implicated in regulating muscle cell calcium handling, a process that is essential for muscle contraction and strength (Conzade et al., 2019; Sutherland et al., 2023). An additional prospective cohort study reported that older adults with 25(OH)D insufficiency were associated with higher risk of developing low muscle mass and sarcopenia in comparison to normal (Shin & Kim, 2025). Our cross-sectional findings in a younger adult cohort mirror these patterns to some extent: deficient individuals had reduced muscle mass relative to their peers. The association remained significant after adjusting for basic confounders, though it was partly attenuated by controlling for overall body size (BMI), suggesting that some of the vitamin D–muscle link might be indirect (Kim et al., 2025).

Some studies have reported sex-specific or age-specific differences in the vitamin D and muscle relationship (Shin & Kim, 2025). Men generally have higher muscle mass and possibly greater outdoor activity on average, which might amplify detectable associations in cross-sectional data (Jeong et al., 2023). Additionally, hormonal differences and vitamin D receptor expression could play a role. Age is another factor, our relatively young to middle-aged cohort might not exhibit as pronounced muscle deterioration as older populations do. Thus, the consequences of vitamin D deficiency on muscle might manifest more strongly with advancing age or in the context of sarcopenia risk (Conzade et al., 2019; Umer et al., 2025).

Our findings contribute to the ongoing discussion of whether improving vitamin D status can favorably alter body composition. While observational data consistently show associations, the causality is not fully established (Jonasson et al., 2020). It could be that people with healthier lifestyles both have better vitamin D status (through diet or sun exposure) and maintain fitter body compositions. Randomized trials of vitamin D supplementation have yielded mixed results regarding body composition outcomes. Some intervention studies demonstrate that vitamin D supplementation, especially when combined with resistance exercise or protein intake, can modestly increase lean mass or improve muscle function in deficient individuals (Ganapathy & Nieves, 2020; Martínez-Rodríguez et al., 2023). For instance, a meta-analysis indicated vitamin D supplementation alone did not significantly boost muscle mass in older adults, but combined strategies (vitamin D with exercise and nutrition) showed more promise (Fuentes-Barría et al., 2025; Zhang & Li, 2024). On the adiposity side, a few trials suggest that correcting vitamin D deficiency might aid weight loss or reduce fat mass, though results are not uniform (Chang, 2022; Dai et al., 2025; Ganapathy & Nieves, 2020; Umer et al., 2025). Given these nuances, our cross-sectional study underscores an association but cannot prove causation. Longitudinal studies are needed to see if low vitamin D precedes changes in body composition, and well-controlled trials can determine if addressing vitamin D deficiency leads to measurable improvements in muscle or fat metrics.

Strengths of our study include the use of direct measurements for both vitamin D (serum 25(OH)D via ELISA and body composition via BIA, allowing quantification of fat and muscle compartments. The study is novel in focusing on an adult population with a broad age range, contributing to literature that has often focused either on elderly cohorts or specific groups (Durak & Safer, 2025; Umer et al., 2025; Zhang & Li, 2024). However, several limitations should be noted. First, the sample size is relatively modest, which may limit generalizability and statistical power to detect smaller effects or subgroup differences. Second, BIA, while convenient and non-invasive, is an indirect method of assessing body composition and may be less accurate than gold-standard techniques like DEXA. we mitigated this with standardized measurement conditions, but some measurement error is possible. Third, we did not measure functional outcomes such as muscle strength or physical performance, which are important aspects of body composition's impact on health. Including like handgrip strength or gait tests could strengthen future analyses, as vitamin D might relate more strongly to function than mass in some cases. Finally, as an observational cross-sectional study, we cannot infer causality or directionality. Despite these limitations, our study provides a snapshot consistent with the hypothesis that better vitamin D status aligns with healthier body composition.

CONCLUSION

Our findings indicate that vitamin D status is closely associated with body composition, with deficient individuals tending to have higher body fat and lower muscle mass. This suggests that adequate vitamin D may support a healthier muscle–fat balance, extending its relevance beyond bone health to broader metabolic well-being. Although causality cannot be established from this study, the results underscore the potential importance of addressing vitamin D deficiency, particularly in adults at risk of obesity or muscle loss. Future longitudinal studies and clinical trials are needed to clarify whether improving vitamin D status can directly enhance muscle mass or reduce fat accumulation. From an academic perspective, this study contributes to a more integrated understanding of vitamin D in body composition regulation and encourages further mechanistic research. Practically, the findings support the consideration of vitamin D screening and correction as part of preventive health strategies and evidence-based clinical and public health policies.

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