Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 2, 591-603
2026
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v10i2.12167

Vitamin D status among healthy adults in Albania aged 18–35 years: Associations with biological and seasonal factors

Silvi Bozo[1*], Eftiola Pojani[1], Irida Ikonomi Hoxha[2], Bertina Hoxha Lami[3], Dhurata Bozo[3]
[1]Department of Chemical-Pharmaceutical and Biomolecular Technologies, Faculty of Pharmacy, Catholic University "Our Lady of Good Counsel", Tirana, Albania. s.bozo@unizkm.al (S.B.) e.pojani@unizkm.al (E.P.).
[2]Department of Medical Technical Sciences, Faculty of Professional Studies, "Aleksandër Moisiu" University, Durrës, Albania; iridaikonomi@uamd.edu.al (I.I.H.).
[3]Department of Health and Physical Activity, Sport Research Institute, Sport University of Tirana, Tirana, Albania; bhoxha@ust.edu.al (B.H.L.) dhbozo@ust.edu.al (D.B.).

Abstract: Vitamin D insufficiency remains a global public health concern, and population-based data from Albania are scarce, particularly among young adults. This study aimed to assess vitamin D status and serum 25-hydroxyvitamin D [25(OH)D] concentrations among healthy Albanian young adults and to examine associations with age, gender, and season of sampling. A cross-sectional study was conducted between January 2023 and January 2025, including 467 healthy adults aged 18–35 years. Serum 25(OH)D concentrations were measured using standardized laboratory procedures in an ISO-certified laboratory. Vitamin D status was classified using a cutoff value of <20 ng/mL. Statistical analyses were performed using SPSS version 27.0. The mean serum 25(OH)D concentration was 25.16 ± 10.30 ng/mL. Overall, 31.7% of participants had concentrations below the study cutoff. Males showed significantly higher mean 25(OH)D levels than females ($p < 0.001$), while no association was observed with age. Significant seasonal variation was noted, with higher levels in summer and autumn and lower levels in winter and spring ($p < 0.001$). A considerable proportion of healthy young adults in Albania exhibit suboptimal vitamin D status. Gender and seasonal factors significantly influence serum 25(OH)D concentrations, underscoring the need for targeted public health interventions.
Keywords: *Albania, Seasonal differences, Serum 25(OH)D, Vitamin D status, Young adults.*

1. Introduction

Vitamin D is a secosteroid pro-hormone essential for calcium and phosphorus metabolism, bone mineralization, and involved in other non-skeletal functions. In the human body, both inactive forms of vitamin D, D2 (ergocalciferol) and D3 (cholecalciferol), undergo enzymatic reactions to become biologically active [1].

The first hydroxylation occurs primarily in the liver at the C-25 position. This reaction produces 25-hydroxyvitamin D [25(OH)D], the major circulating form of vitamin D [2]. The second hydroxylation is mediated by 25-hydroxyvitamin D-1α-hydroxylase in the kidney. This step converts 25(OH)D into the biologically active form, 1,25-dihydroxyvitamin D [$1,25(OH)_2D$] [3].

Serum 25(OH)D concentration is the most reliable and widely used marker for assessing vitamin D status. However, there is no universal consensus on cut-off values for vitamin D deficiency. According to the National Institutes of Health (NIH) Office of Dietary Supplements (ODS), serum 25(OH)D concentrations below 30 nmol/l (<12 ng/mL) are associated with an increased risk of deficiency [4]. The Endocrine Society Task Force on Vitamin D considers a concentration of 50 nmol/l (>20 ng/mL) sufficient for the general health of the population [5]. Overall, there is broad agreement that serum 25(OH)D concentrations of 30–50 nmol/L (12–20 ng/mL) indicate

History: Received: 24 November 2025; Revised: 19 January 2026; Accepted: 23 January 2026; Published: 17 February 2026
* Correspondence: s.bozo@unizkm.al

insufficiency, values below 30 nmol/L (<12 ng/mL) indicate deficiency, and concentrations above 50 nmol/L (>20 ng/mL) indicate sufficiency [5-8].

The prevalence of vitamin D deficiency from 2000 to 2024 has emerged as a significant global concern, prompting many countries to evaluate their population's vitamin D status [6, 9]. Approximately one billion people worldwide are affected by vitamin D deficiency; around 50% of the global population has insufficient levels [10, 11]. In Europe, about 40% of the population has been found to have vitamin D deficiency, with 13% experiencing severe deficiency, particularly among adolescents, pregnant women, and older adults [12, 13].

In addition to its crucial role in skeletal homeostasis, recent evidence shows that vitamin D exerts multidirectional effects. It affects the immune system, glucose metabolism, oxidative stress, and nerve cell growth and differentiation [14]. For instance, vitamin D deficiency has been associated with an increased risk of developing several types of cancer, cardiovascular and autoimmune diseases, as well as acute conditions [15-17].

Vitamin D synthesis and status are influenced by several intrinsic and extrinsic factors, such as age, skin pigmentation, seasonal variation, lifestyle, and dietary habits [18, 19]. Dermal synthesis upon UVB light exposure and diet are the main sources of this vitamin for the human body. Therefore, appropriate sunlight exposure and a healthy, balanced diet providing both plant and animal sources of this vitamin (D2 and D3 sources, respectively) are essential to prevent deficiencies of this vitamin [20].

Despite limited population-based data on vitamin D status, certain subgroups are known to be particularly vulnerable to deficiency, including individuals with darker skin pigmentation and those living at higher latitudes [21].

Besides dietary sources of vitamin D, exposure to sunlight (UVB photons) is a determinant for the skin to convert pre-vitamin D_3 (pre-cholecalciferol) into the active form, cholecalciferol [22]. The intensity of UVB radiation depends on latitude, season, and time of day. Experts suggest that 5–30 minutes of sun exposure, daily or at least twice weekly, is necessary to maintain adequate serum 25(OH)D concentrations [23].

Albania (latitude: 41° 09' 10.46" N) is located in Southeastern Europe and belongs to the Mediterranean climatic zone. Despite an average of approximately 300 sunny days per year, limited available evidence suggests a high prevalence of suboptimal vitamin D status in Albania, with insufficiency or deficiency observed in 72% of young adults and 74% of pregnant women [24, 25].

As for some neighboring regions, such as Kosovo and Greece, they both lack national surveillance data on vitamin D status. However, there are notable differences in the scope and population coverage of the studies conducted. For instance, Greece has conducted broader investigations, including multi-year studies with nationally distributed samples, providing a more robust foundation for public health policy. In contrast, research conducted in Kosovo has limited representativeness, with a few cross-sectional studies conducted on specific subpopulations [26, 27].

The prevalence of vitamin D deficiency has significantly increased in recent years and is recognized as a global public health issue. Thus, ongoing research is essential to uncover the broader implications of vitamin D deficiency and to emphasize the need for prioritizing its prevention and management [28]. Through coordinated public health efforts, including enhanced awareness about the importance of maintaining adequate serum 25(OH) concentration and targeted interventions, it is possible to mitigate the burden of this deficiency and improve population health outcomes.

The present study aims to assess vitamin D status and mean serum 25(OH)D concentrations among healthy Albanian young adults, and to examine their associations with age, gender, and season of sampling, in the absence of vitamin D supplementation and other external influencing factors.

This investigation addresses the limited availability of population-based data on vitamin D status in Albania, reflecting a broader global lack of accurate epidemiological evidence on vitamin D levels.

2. Design and Methods

2.1. Study Design and Sample Size

A cross-sectional study was conducted between January 2023 and January 2025 to assess serum 25(OH)D concentrations among healthy Albanian adults aged 18–35 years. This age group is generally associated with a lower prevalence of chronic diseases and a relatively favorable overall health status on a global scale [10, 29-31]. Therefore, to ensure internal validity, individuals with known chronic diseases affecting vitamin D metabolism (renal insufficiency, malabsorption disorders, or chronic diarrhea), pregnant/lactating women, as well as individuals taking vitamin D or multivitamin supplements, were excluded.

Laboratory analyses for testing serum 25(OH)D concentration were performed in an accredited and certified medical laboratory (ISO 9001-2015) located in an urban area of Albania. Ethical approval for the study was obtained from the Ethics Committee for Scientific Research of the University of Sports of Tirana on 02/10/2024, with reference number Prot.N.2602/2. Participants were recruited voluntarily during routine laboratory testing. Individuals meeting the inclusion criteria were invited to participate and screened for eligibility before enrollment. Oral consent was obtained from all participants before inclusion in the study, in the presence of a study team member, who served as a witness to ensure that consent was properly obtained.

The collected demographic data included age, gender, and the month of sample collection. Months were categorized into four seasons: Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November), and Winter (December, January, February).

The minimum required sample size was determined to be 384 participants, ensuring an adequate sample size for this population subgroup. The sample size formula used was: $(Z^2 \times p \times (1-p)) / E^2$, where Z is the standard normal deviation (1.96 for a 95% confidence level), p is the estimated proportion of individuals with vitamin D deficiency, and E is the margin of error (0.05). To enhance representativeness and ensure robust results, a total of 467 participants were enrolled in the study.

2.2. Sample Collection

The serum 25(OH)D concentration was assessed on blood taken from the cubital vein of all 467 participants, in the fasting state, around 8–9 am in the morning. Blood samples were collected in gel tubes and processed within two hours of collection. Serum was separated by centrifugation at 3000 RPM for 10 minutes. If processing within two hours was not possible, serum samples were stored at -80°C and processed within five days. The collection was performed during various months throughout the year to account for the seasonal distribution of estimated serum 25(OH)D concentration [32].

2.3. Measurement of Serum 25-Hydroxyvitamin D

The serum 25(OH)D concentration was measured using the automated COBAS® E 411 system, which employs the electrochemiluminescence (ECL) technique. Calibration and quality control procedures were periodically performed according to the manufacturer's guidelines following the DEQAS scheme [32]. This system, manufactured by Roche Diagnostics® and approved by the Food and Drug Administration (FDA), is internationally recognized for its reliability and validated methods for accurate measurements [33]. Although different consensus recommendations exist regarding vitamin D cut-off values, for our analyses serum 25(OH)D concentrations were categorized as follows: sufficiency (> 20 ng/mL), insufficiency (12–20 ng/mL), deficiency (< 12 ng/mL), in accordance with international recommendations from the NIH, Endocrine Society, EFSA and SACN [5-8, 34]. In addition, a cut-off value of <20 ng/mL was used to define suboptimal vitamin D status, encompassing both vitamin D insufficiency and deficiency. From this point forward, serum 25(OH)D concentrations are expressed in nanograms per milliliter (ng/mL).

2.4. Data Collection and Analysis

The data were exported to Microsoft Excel and analyzed using the Statistical Package for Social Sciences (SPSS, Version 27.0, IBM). Descriptive statistics, including means and standard deviations, were used to summarize continuous variables, while frequencies and percentages were calculated for categorical variables. Comparisons of continuous variables between two independent groups (females and males) were performed using independent samples t-tests, with Welch's correction applied when equality of variances was not assumed. Differences in mean 25(OH)D concentrations across more than two groups, such as seasonal distribution, were assessed using one-way ANOVA. Associations between continuous variables, such as age and serum 25(OH)D concentrations, were evaluated using Pearson's correlation coefficient (r). A two-way ANOVA was conducted to examine the independent effects of gender and season of sampling on serum 25(OH)D concentrations and to test for a possible interaction between these factors. A p-value <0.05 was considered statistically significant.

3. Results

3.1. Characteristics of the Study Population

During the study period, a total of 467 samples were analyzed, each from a unique participant, with no duplicate measurements recorded. Participant characteristics and the seasonal distribution of sampling are presented in Table 1. The study population included 339 females (72.6%) and 128 males (27.4%). The overall mean age was 26.51 ± 4.24 years, with no significant age difference observed between females and males ($p = 0.157$).

Blood sampling was conducted throughout all four Mediterranean seasons. The largest proportion of samples was collected during autumn (30.4%), followed by summer (25.3%), winter (24.8%), and spring (19.5%). Every month, the highest proportions of samples were collected in December (11.1%) and August (10.7%).

Table 1.
Demographic characteristics and seasonal distribution of blood sampling by gender.

Variable	Total	Females	Males
	n (%)	**n (%)**	**n (%)**
Gender	467 (100)	339 (72.6)	128 (27.4)
Age range (years)	18–35	18–35	18–35
Age (years), mean ± SD	26.51 ± 4.24	26.69 ± 4.07	26.03 ± 4.64
Season of sampling			
Spring	91 (19.5)	61 (18.0)	30 (23.4)
Summer	118 (25.3)	85 (25.2)	33 (25.8)
Autumn	142 (30.4)	109 (32.1)	33 (25.8)
Winter	116 (24.8)	84 (24.7)	32 (25.0)

3.2. Serum 25(OH)D Concentrations, Vitamin D Status, and Demographic Associations

Serum 25(OH)D concentrations ranged from 3.59 to 79.39 ng/mL, with a mean concentration of 25.16 ± 10.30 ng/mL in the total study population. A significant difference in mean serum 25(OH)D levels was observed between females and males ($t = -4.31$, $p < 0.001$), with lower concentrations in females (23.92 ± 9.47 ng/mL) compared with males (28.44 ± 11.65 ng/mL). Additionally, Pearson correlation analysis showed no significant association between age and serum 25(OH)D concentrations ($r = 0.040$, $p = 0.387$).

The assessment of vitamin D status in the study population identified distinct patterns of sufficiency, insufficiency, and deficiency. The majority of participants (68.3%) had sufficient vitamin D levels (>20 ng/mL), while 24.2% were classified as insufficient (12–20 ng/mL) and 7.5% as deficient (<12 ng/mL). Overall, nearly one-third of the participants (31.7%) presented serum 25(OH)D concentrations below the study cut-off (<20 ng/mL).

Gender-specific differences were observed. A higher proportion of males had sufficient vitamin D levels compared with females (77.3% vs. 64.9%), whereas deficiency and insufficiency were more frequent among females (8.3% vs. 5.5% and 26.8% vs. 17.2%, respectively). Accordingly, serum 25(OH)D concentrations below the cut-off were observed in 35.1% of females and 22.7% of males. The distribution of vitamin D status differed significantly between genders (p = 0.036) (Table 2).

Table 2.
Serum 25(OH)D concentrations and vitamin D status by gender.

		Serum 25(OH)D concentration (ng/mL)				
Season	**Participants**	**Range**		**Mean ± Std. Deviation**	**95% CI Lower Bound**	**95% CI Upper Bound**
	n (%)	**Minimum**	**Maximum**			
Spring	91 (19.5)	3.59	50.81	21.45 ± 10.52	19.26	23.64
Summer	118 (25.3)	7.92	76.5	27.63 ± 9.68	25.86	29.39
Autumn	142 (30.4)	5.68	79.39	28.03 ± 10.91	26.22	29.84
Winter	116 (24.8)	7.87	45.4	22.02 ± 8.05	20.54	23.5
Total	467 (100)	3.59	79.39	25.15 ± 10.30	24.22	26.09

Note: a. Independent samples t-test for mean serum 25(OH)D concentration differences between females and males: $t = -4.31$, $p < 0.001$.
b. Pearson χ^2 test for vitamin D status distribution between females and males: $\chi^2(2) = 6.654$, $p = 0.036$.
c. Cut-off corresponds to serum 25(OH)D <20 ng/mL, combining insufficiency and deficiency.

3.3. Vitamin D Status and Seasonal Association

The distribution of serum 25(OH)D concentrations according to season of sampling is presented in Table 3.

Table 3.
Serum 25(OH)D distribution by season.

Gender	**Serum 25(OH)D[a] (mean ± SD)**	**Sufficiency (>20 ng/mL)[b]**	**Below cut-off (<20 ng/mL)[c]**	**Insufficiency (12–20 ng/mL)**	**Deficiency (<12 ng/mL)**	**Total n (%)**
		n (%)	**n (%)**	**n (%)**	**n (%)**	
Females	23.92 ± 9.47	220 (64.9)	119 (35.1)	91 (26.8)	28 (8.3)	339 (100)
Males	28.44 ± 11.65	99 (77.3)	29 (22.7)	22 (17.2)	7 (5.5)	128 (100)
Total	25.16 ± 10.30	319 (68.3)	148 (31.7)	113 (24.2)	35 (7.5)	467 (100)

The largest proportion of participants was examined in autumn (30.4%), followed by summer (25.3%), winter (24.8%), and spring (19.5%). Mean serum 25(OH)D concentrations were highest among samples collected in autumn (28.03 ± 10.91 ng/ml) and summer (27.63 ± 9.68 ng/ml), and lower among those collected in winter (22.02 ± 8.05 ng/ml) and spring (21.45 ± 10.52 ng/ml). The distribution of serum 25(OH)D concentrations by season of sampling in the total study population is illustrated in Figure 1, while the distributions stratified by gender are shown in Figure 2.

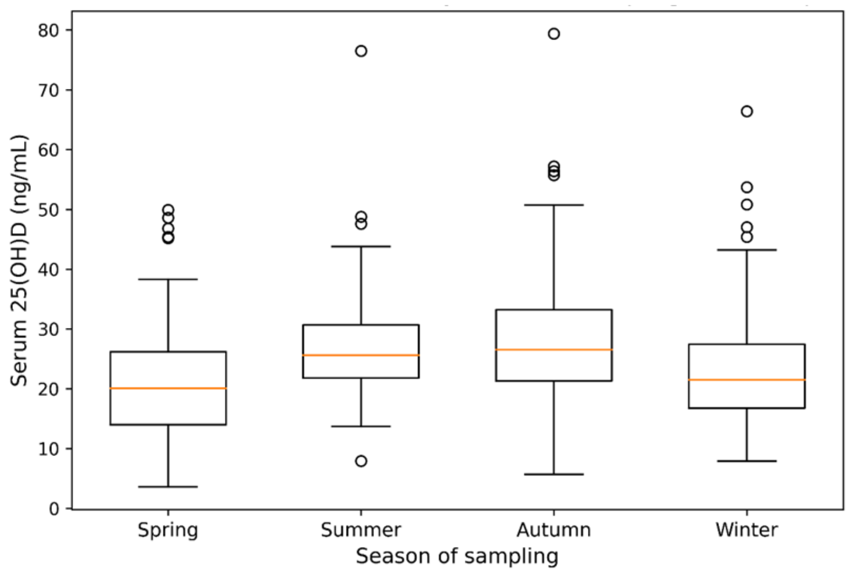

Figure 1.
Distribution of serum 25(OH)D concentrations according to season of sampling in the total study population.

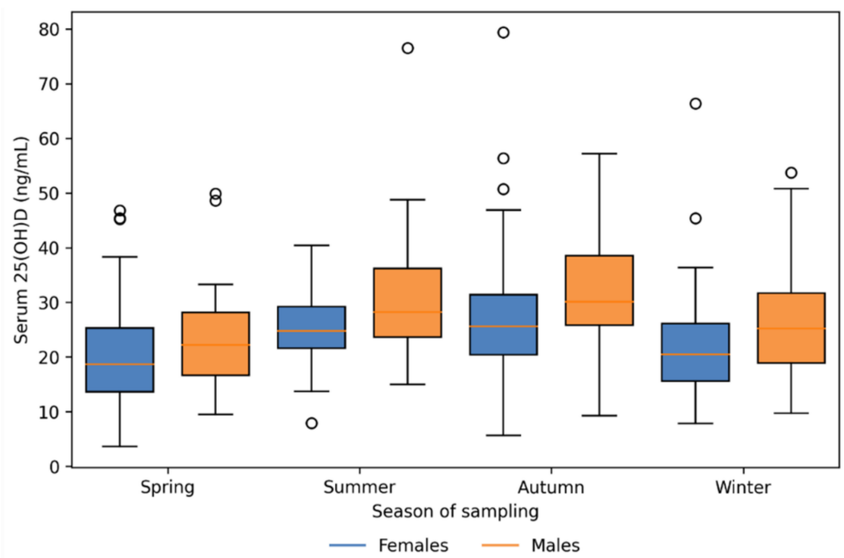

Figure 2.
Distribution of serum 25(OH)D concentrations according to season of sampling and gender.

Consistent with the overall gender difference, mean serum 25(OH)D concentrations were higher in males than females in each season. The two-way ANOVA revealed no significant interaction between gender and season of sampling ($p = 0.880$), indicating similar seasonal patterns in serum 25(OH)D concentrations in both genders.

One-Way ANOVA confirmed a statistically significant association between season of sampling and serum 25(OH)D concentrations ($F = 14.626$, $p < 0.001$). Post hoc analysis using Tukey's Honestly Significant Difference (HSD) test further revealed significant differences between seasons (Table 4).

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 2: 591-603, 2026
DOI: 10.55214/2576-8484.v10i2.12167

Table 4.
Post-hoc analysis of mean serum 25(OH)D differences between seasons[a]

Comparison	Mean difference in 25(OH)D conc. (ng/mL)	Std. Error	p-value[b]	95% CI Lower bound	95% CI Upper bound
Spring – Summer	−6.18	1.38	**<0.001**	−9.73	−2.62
Spring – Autumn	−6.58	1.33	**<0.001**	−10.00	−3.16
Spring – Winter	−0.57	1.38	0.976	−4.14	2.99
Summer – Autumn	−0.40	1.23	0.988	−3.58	2.77
Summer – Winter	5.60	1.29	**<0.001**	2.27	8.93
Autumn – Winter	6.01	1.24	**<0.001**	2.82	9.19

Note: a. Post-hoc pairwise comparisons were conducted using Tukey's Honestly Significant Difference (HSD) test following one-way ANOVA.
b. Bold p-values indicate statistically significant differences ($p < 0.05$)

Specifically, serum 25(OH)D concentrations in spring were significantly lower than in summer and autumn, with mean differences of 6.18 ng/mL ($p < 0.001$) and 6.58 ng/mL ($p < 0.001$), respectively. Furthermore, concentrations were significantly higher in summer than in winter (mean difference 5.60 ng/mL, $p < 0.001$) and in autumn compared to winter (mean difference 6.01 ng/mL, $p < 0.001$). In contrast, no significant differences were observed between summer and autumn (mean difference = -0.40 ng/mL, $p = 0.988$) or between spring and winter (mean difference = -0.57 ng/mL, $p = 0.976$).

4. Discussion

Vitamin D deficiency remains a widespread global health issue, with substantial variation across different populations due to factors such as age, gender, ethnicity, lifestyle, and geographical location.

In this context, the present study provides a comprehensive evaluation of vitamin D status among healthy young adults in Albania, highlighting the role of demographic characteristics and seasonal factors associated with serum 25(OH)D concentrations.

The mean serum 25(OH)D concentration observed in this study was 25.16 ± 10.30 ng/mL. This value is higher than that reported in a previous Albanian study among postmenopausal women (21.4 ± 12.0 ng/mL), although direct comparison is limited by differences in age group and physiological status between the study populations [35]. Compared with neighboring regions, serum 25(OH)D concentrations in our study were higher than those reported in Southern European countries, including Spain (15.6 ng/mL), Italy (11.2 ng/mL), and Greece (10 ng/mL), while Eastern European countries typically report mean levels below 20 ng/mL [12].

Regarding vitamin D status, 68.3% of participants had sufficient 25(OH)D levels, while 24.2% were insufficient, and 7.5% were deficient. Overall, nearly one-third of the study population (31.7%) showed serum 25(OH)D concentrations below the study cut-off (<20 ng/mL). When placed in a broader context, a large systematic review and meta-analysis including 7.9 million participants worldwide reported a global prevalence of vitamin D deficiency of 15.7%, with a prevalence of 10.2% in upper-middle-income countries and values ranging from 14.9% to 18.2% among younger adults [9]. In neighboring Kosovo, serum 25(OH)D concentrations below the cut-off (<20 ng/mL) were observed in 23.2% of younger adults (20–39 years) [36]. In contrast, much higher proportions of serum 25(OH)D concentrations below the cut-off (<20 ng/mL) have been reported in Bosnia and Herzegovina (82%) [37]. Differences observed between neighboring countries may be influenced by variations in lifestyle factors such as time spent outdoors, dietary habits, and supplementation practices. For example, Albania and Kosovo share a Mediterranean diet rich in vitamin D–containing foods and similar cultural habits promoting outdoor activity, which may contribute to their similar proportions of serum 25(OH)D concentrations below the cut-off [38]. In contrast, dietary patterns and sun exposure behaviors in Bosnia and Herzegovina may differ, potentially leading to higher proportions of serum 25(OH)D concentrations below the cut-off [39]. Disparities in healthcare policies, public health efforts, and supplementation awareness further influence vitamin D status across these populations. In Albania and Kosovo, limited professional awareness and inconsistent supplementation are partially offset by favorable lifestyle and dietary habits, which may help reduce the proportion of individuals with serum 25(OH)D concentrations below the cut-off [26]. Conversely, limited public health strategies in Bosnia and Herzegovina, combined with the above-mentioned factors, may contribute to a higher burden of low vitamin D status.

Conversely, the deficiency rate observed in our study is lower than the European average prevalence of 13% but similar to the 7.4% reported in Canada, while substantially lower rates have been documented in the United States (5.9%) [13]. In contrast, countries in the Middle East and South Asia report substantially higher burdens of low vitamin D status. For example, studies conducted in Saudi Arabia, Pakistan, and Iraq have reported prevalences exceeding 50–70%, particularly among younger adults and women, likely reflecting reduced sun exposure, cultural clothing practices, sedentary behavior, and dietary factors [40-42].

Beyond overall prevalence, gender differences in vitamin D status remain an important consideration in nutritional epidemiology. In the present study, males showed significantly higher serum 25(OH)D concentrations than females, both in terms of mean levels and the proportion reaching recommended thresholds. This finding is consistent with previous research reporting a higher prevalence of vitamin D deficiency among females [43, 44].

Several factors may contribute to the observed gender disparities in vitamin D status. One important factor is sun exposure, as men are often more engaged in outdoor occupational and recreational activities, which facilitate greater cutaneous synthesis of 25(OH)D. In Albania, this pattern may be partly explained by labor market differences, where the employment rate among individuals over 15 years of age is 74.9% for men compared to 61.9% for women, potentially reflecting differences in lifestyle and daily sun exposure [45].

Physiological differences also play a crucial role in metabolism and storage of vitamin D. For instance, women often have higher body fat percentages, which can influence the bioavailability of vitamin D [46]. Vitamin D tends to accumulate in adipose tissue, potentially leading to lower serum levels of the active form in females, despite adequate dietary intake or sun exposure [47]. Additionally, Trifan *et al.* discussed how variations in endocrine function and metabolic pathways between genders may further complicate the understanding of vitamin D status, adding to the complexities of gender disparity [48]. However, findings remain inconsistent, as some studies suggest that vitamin D deficiency in women is more pronounced in older age groups, while others report no significant correlation between gender and serum 25(OH)D levels [49, 50].

Regarding age, correlation analysis did not reveal a statistically significant relationship with serum 25(OH)D concentrations. This lack of significance is likely attributable to the relatively narrow age range of the study population, which limits the ability to detect age-related differences in serum 25(OH)D concentrations.

Furthermore, the seasonal variations observed in this study reinforce the strong link between sun exposure and 25(OH)D synthesis. Mean serum 25(OH)D concentrations were significantly higher in autumn (28.03 ng/mL) and summer (27.63 ng/mL), with lower levels in winter and spring. These findings are consistent with evidence indicating that UVB radiation intensity decreases substantially during colder months, an effect further influenced by Albania's geographical latitude, which results in reduced sun exposure during these seasons [23]. Similar seasonal trends have been reported in Switzerland and Turkey, where lower serum 25(OH)D concentrations were observed during winter and spring [51, 52].

Finally, the lack of a significant difference between summer and autumn observed in Albania, despite the decline in winter and spring, may be attributed to several local factors. Albania's Mediterranean climate provides prolonged sunlight exposure extending into early autumn, supporting sustained cutaneous 25(OH)D synthesis beyond the summer peak [53]. Cultural habits such as regular outdoor activity during the warmer months, adherence to a Mediterranean diet rich in vitamin

D-containing foods, and generally clear atmospheric conditions with favorable UVB availability may all contribute to maintaining elevated levels [54, 55].

4.1. Recommendations

Although the prevalence of serum 25(OH)D concentrations below the study cut-off was lower than that reported in several other regions, nearly one-third of participants exhibited suboptimal vitamin D status, underscoring the need for targeted public health interventions even among healthy young adults. Strategies such as dietary supplementation, promotion of safe sun exposure, and lifestyle modifications may help mitigate potential long-term health risks associated with low vitamin D levels, particularly in physically active individuals and other at-risk subgroups [56].

Gender-specific interventions are necessary, as males in our study exhibited significantly higher serum 25(OH)D concentrations than females. Public health campaigns could focus on educating women about the importance of vitamin D and ways to improve intake, especially considering factors like reduced sun exposure and higher body fat percentages, which may affect vitamin D metabolism.

Seasonal patterns observed in this study further highlight the importance of seasonally tailored strategies. In particular, vitamin D supplementation and monitoring may be especially beneficial during winter and spring, when reduced sun exposure limits endogenous vitamin D synthesis. Implementing seasonal recommendations could support the maintenance of adequate serum 25(OH)D concentrations throughout the year.

Lifestyle factors such as smoking and alcohol consumption have been reported in the literature to influence vitamin D status; however, these factors were not directly assessed in the present study [57, 58]. Future research in the Albanian population should investigate the potential impact of these behaviors on serum 25(OH)D concentrations, especially among groups with higher exposure, to better inform targeted prevention strategies.

Currently, Albania lacks national guidelines or structured public health programs addressing vitamin D status. The findings of this study provide evidence that may support the development of national supplementation policies, community- and school-based awareness campaigns, and the integration of vitamin D assessment into primary healthcare services. These measures could contribute to a coordinated national approach to improving vitamin D status across different population groups.

4.2. Strengths and Limitations

To our knowledge, this is the first study conducted in Albania to assess serum 25(OH)D concentrations among healthy young adults aged 18–35 years, providing novel data on vitamin D sufficiency, insufficiency, and deficiency in this population subgroup. Key strengths of the study include a rigorous methodological approach, with biochemical analyses performed in an ISO-certified laboratory, standardized procedures for sample collection, and an adequate sample size for this specific age group. Additionally, the evaluation of serum 25(OH)D concentrations according to gender and season of sampling allowed for a more comprehensive characterization of vitamin D status.

Several limitations should also be acknowledged. First, the absence of data on dietary vitamin D intake, sun exposure, and supplementation limits the ability to fully assess determinants of serum 25(OH)D concentrations. Second, the restricted age range limits the generalizability of the findings to older populations, who may be at greater risk of vitamin D deficiency. Additionally, the unequal distribution between female and male participants may represent a limitation, as the smaller proportion of male participants may limit the robustness of gender-stratified analyses.

5. Conclusions

This study provides the first comprehensive assessment of serum 25(OH)D concentrations among healthy young adults in Albania. Despite favorable climatic conditions, a substantial proportion of participants showed suboptimal vitamin D status, with nearly one-third presenting serum 25(OH)D concentrations below the established cut-off. Vitamin D status differed significantly by gender, with lower concentrations observed among females, while no significant association with age was identified within this age group. Seasonal patterns were evident, with higher serum 25(OH)D concentrations during summer and autumn and lower levels during winter and spring. Overall, these findings highlight that vitamin D insufficiency remains a relevant public health concern even in young, apparently healthy populations.

Funding:
This research was funded by the National Agency for Scientific Research and Innovation (NASRI), Albania, within the framework of the National Research and Development Projects 2024-2025.

Institutional Review Board Statement:
Ethical approval for the study was obtained from the Ethics Committee for Scientific Research of the University of Sports of Tirana on 02/10/2024, with reference number Prot.N.2602/2. The study was conducted in accordance with the Declaration of Helsinki.

Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Acknowledgments:
The authors sincerely thank all the participants for their valuable contribution to this study. We also wish to acknowledge MSc. Entela Kostrista for her expertise and support in performing the statistical analysis.

References
[1] W. B. Grant, S. J. Wimalawansa, P. Pludowski, and R. Z. Cheng, "Vitamin D: Evidence-based health benefits and recommendations for population guidelines," *Nutrients*, vol. 17, no. 2, p. 277, 2025. https://doi.org/10.3390/nu17020277
[2] O. Trummer *et al*., "Genetic components of 25-hydroxyvitamin D increase in three randomized controlled trials," *Journal of Clinical Medicine*, vol. 9, no. 2, p. 570, 2020. https://doi.org/10.3390/jcm9020570
[3] N. Alonso, S. Zelzer, G. Eibinger, and M. Herrmann, "Vitamin D metabolites: Analytical challenges and clinical relevance," *Calcified Tissue International*, vol. 112, no. 2, pp. 158-177, 2023. https://doi.org/10.1007/s00223-022-00961-5
[4] O. o. D. S. National Institutes of Health, "Vitamin D: Fact sheet for health professionals," 2025. https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/
[5] M. F. Holick, "The vitamin D deficiency pandemic: Approaches for diagnosis, treatment and prevention," *Reviews in Endocrine and Metabolic Disorders*, vol. 18, no. 2, pp. 153-165, 2017. https://doi.org/10.1007/s11154-017-9424-1
[6] A. Giustina *et al*., "Consensus statement on vitamin D status assessment and supplementation: Whys, whens, and hows," *Endocrine Reviews*, vol. 45, no. 5, pp. 625-654, 2024.
[7] J.-L. Bresson *et al*., "Dietary reference values for vitamin D," *EFSA Journal*, vol. 14, no. 10, pp. e04547-e0692, 2016. https://dx.doi.org/10.2903/j.efsa.2016.4547
[8] C. Liu, X. Zhan, B. Qin, L. Sun, and R. Zhai, "Assessment of vitamin D nutritional status among adults in Lu'an, China, based on serum 25-hydroxyvitamin D measured by LC-MS/MS," *Frontiers in Nutrition*, vol. 12, p. 1695862, 2025. https://doi.org/10.3389/fnut.2025.1695862
[9] A. Cui, T. Zhang, P. Xiao, Z. Fan, H. Wang, and Y. Zhuang, "Global and regional prevalence of vitamin D deficiency in population-based studies from 2000 to 2022: A pooled analysis of 7.9 million participants," *Frontiers in Nutrition*, vol. 10, p. 1070808, 2023. https://doi.org/10.3389/fnut.2023.1070808

[10] K. D. Cashman, "100 YEARS OF VITAMIN D: Global differences in vitamin D status and dietary intake: A review of the data," *Endocrine Connections*, vol. 11, no. 1, 2022. https://doi.org/10.1530/EC-21-0282
[11] J. Kaur, S. Khare, O. Sizar, and A. Givler, *Vitamin D deficiency. In StatPearls*. Treasure Island, FL: StatPearls Publishing, 2025.
[12] P. Lips *et al.*, "Current vitamin D status in European and Middle East countries and strategies to prevent vitamin D deficiency: A position statement of the European Calcified Tissue Society," *European Journal of Endocrinology*, vol. 180, no. 4, pp. P23-P54, 2019. https://doi.org/10.1530/EJE-18-0736
[13] K. Amrein *et al.*, "Vitamin D deficiency 2.0: An update on the current status worldwide," *European Journal of Clinical Nutrition*, vol. 74, no. 11, pp. 1498-1513, 2020. https://doi.org/10.1038/s41430-020-0558-y
[14] M. J. Anwar, S. K. Alenezi, and A. H. Alhowail, "Molecular insights into the pathogenic impact of vitamin D deficiency in neurological disorders," *Biomedicine & Pharmacotherapy*, vol. 162, p. 114718, 2023. https://doi.org/10.1016/j.biopha.2023.114718
[15] Y. Sunami, V. Boeker, and J. Kleeff, "Targeting and reprograming cancer-associated fibroblasts and the tumor microenvironment in pancreatic cancer," *Cancers*, vol. 13, no. 4, p. 697, 2021. https://doi.org/10.3390/cancers13040697
[16] W. B. Grant, B. J. Boucher, R. Z. Cheng, P. Pludowski, and S. J. Wimalawansa, "Vitamin D and cardiovascular health: A narrative review of risk reduction evidence," *Nutrients*, vol. 17, no. 13, p. 2102, 2025. https://doi.org/10.3390/nu17132102
[17] P.-J. Martens, C. Gysemans, A. Verstuyf, and C. Mathieu, "Vitamin D's effect on immune function," *Nutrients*, vol. 12, no. 5, p. 1248, 2020. https://doi.org/10.3390/nu12051248
[18] A. B. Morales-Villar *et al.*, "Determinants of vitamin D status in healthy young adults from Mexico City," *Archives of Medical Research*, vol. 55, no. 3, p. 102968, 2024. https://doi.org/10.1016/j.arcmed.2024.102968
[19] J. J. Neville, T. Palmieri, and A. R. Young, "Physical determinants of vitamin D photosynthesis: A review," *Journal of Bone and Mineral Research Plus*, vol. 5, no. 1, p. e10460, 2021. https://doi.org/10.1002/jbm4.10460
[20] J. R. Raymond-Lezman, S. I. Riskin, and J. Lezman, "Benefits and risks of sun exposure to maintain adequate vitamin D levels," *Cureus*, vol. 15, no. 5, p. e38578, 2023. https://doi.org/10.7759/cureus.38578
[21] N. Balachandran, G. Salibi, and N. Tzenios, "The prevalence of vitamin D deficiency among different population groups and its impact on health outcomes," *Special Journal of the Medical Academy and other Life Sciences.*, vol. 2, no. 7, 2024. https://doi.org/10.58676/sjmas.v2i7.85
[22] N. Uçar and M. F. Holick, "Illuminating the connection: Cutaneous Vitamin D3 synthesis and its role in skin cancer prevention," *Nutrients*, vol. 17, no. 3, p. 386, 2025. https://doi.org/10.3390/nu17030386
[23] S. B. Srivastava, "Vitamin D: Do we need more than sunshine?," *American Journal of Lifestyle Medicine*, vol. 15, no. 4, pp. 397-401, 2021. https://doi.org/10.1177/15598276211005689
[24] M. Rumano, "Vitamin D status and its relationship with age, gender and parathyroid hormone," presented at the International Conference on General Health Science, 2021.
[25] E. Kapllani, "Assessment of vitamin D status deficiency in Albanian pregnant women," in *Proc. 27th Balkan Clinical Laboratory Federation & 30th National Biochemistry Congress of TBS, Antalya, Turkey*, 2019.
[26] E. Krasniqi, A. Boshnjaku, A. Ukëhaxhaj, K.-H. Wagner, and B. Wessner, "Association between vitamin D status, physical performance, sex, and lifestyle factors: a cross-sectional study of community-dwelling Kosovar adults aged 40 years and older," *European Journal of Nutrition*, vol. 63, no. 3, pp. 821-834, 2024. https://doi.org/10.1007/s00394-023-03303-9
[27] S. E. Xyda, K. Kotsa, A. Doumas, E. Papanastasiou, A. A. Garyfallos, and G. Samoutis, "Could the majority of the Greek and Cypriot population be vitamin D deficient?," *Nutrients*, vol. 14, no. 18, p. 3778, 2022. https://doi.org/10.3390/nu14183778
[28] R. Tønnesen, P. H. Hovind, L. T. Jensen, and P. Schwarz, "Determinants of vitamin D status in young adults: Influence of lifestyle, sociodemographic and anthropometric factors," *BMC Public Health*, vol. 16, no. 1, p. 385, 2016. https://doi.org/10.1186/s12889-016-3042-9
[29] C. Hajat and E. Stein, "The global burden of multiple chronic conditions: A narrative review," *Preventive Medicine Reports*, vol. 12, pp. 284-293, 2018. https://doi.org/10.1016/j.pmedr.2018.10.008
[30] T. Vos *et al.*, "Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019," *The Lancet*, vol. 396, no. 10258, pp. 1204-1222, 2020. https://doi.org/10.1016/S0140-6736(20)30925-9
[31] N. Garin *et al.*, "Global multimorbidity patterns: a cross-sectional, population-based, multi-country study," *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, vol. 71, no. 2, pp. 205-214, 2016. https://doi.org/10.1093/gerona/glv128
[32] C. T. Sempos *et al.*, "Assessment of serum total 25-hydroxyvitamin D assays for Vitamin D External Quality Assessment Scheme (DEQAS) materials distributed at ambient and frozen conditions," *Analytical and Bioanalytical Chemistry*, vol. 414, no. 2, pp. 1015-1028, 2022. https://doi.org/10.1007/s00216-021-03742-5

[33] Roche Diagnostics, "Roche receives FDA clearance on its digital pathology solution for diagnostic use," 2024. https://diagnostics.roche.com/global/en/news-listing/2024/roche-receives-fda-clearance-on-its-digital-pathology-solution-for-diagnostic-use.html

[34] Scientific Advisory Committee on Nutrition (SACN), "Report on vitamin D and health," 2016. https://assets.publishing.service.gov.uk/media/5a804e36ed915d74e622dafa/SACN_Vitamin_D_and_Health_report.pdf

[35] E. Hoxhaj and A. Mitre, "An Evaluation of Vitamin D and Bone Turnover Markers Levels in Postmenopausal Women in Albania," *Athens Journal of Mediterranean Studies*, vol. 11, pp. 1-11, 2025.

[36] Z. Baruti-Gafurri, A. Kafexholli, B. Dervishi, R. Sylaj, K. Shabani, and D. Musliu, "Prevalence of vitamin d deficiency and insufficiency in kosovo population," *Open Access Macedonian Journal of Medical Sciences*, vol. 10, no. A, pp. 1-6, 2022. https://doi.org/10.3889/oamjms.2022.8808

[37] S. Sokolovic, R. Alimanovic-Alagic, L. Dzananovic, S. Cavaljuga, N. Beslic, and E. Ferhatbegovic-Opankovic, "Vitamin D status in Bosnia and Herzegovina: the cross-sectional epidemiological analysis," *Osteoporosis International*, vol. 28, no. 3, pp. 1021-1025, 2017. https://doi.org/10.1007/s00198-016-3831-0

[38] S. Gicevic *et al.*, "Fueling an epidemic of non-communicable disease in the Balkans: A nutritional survey of Bosnian adults," *International Journal of Public Health*, vol. 64, no. 6, pp. 873-885, 2019. https://doi.org/10.1007/s00038-019-01222-3

[39] S. Gicevic *et al.*, "Demographic and socio-economic predictors of diet quality among adults in Bosnia and Herzegovina," *Public Health Nutrition*, vol. 22, no. 17, pp. 3107-3117, 2019. https://doi.org/10.1017/S1368980019001988

[40] K. H. Farhat, M. A. Arafa, D. M. Rabah, H. S. Amin, and N. K. Ibrahim, "Vitamin D status and its correlates in Saudi male population," *BMC Public Health*, vol. 19, no. 1, p. 211, 2019. https://doi.org/10.1186/s12889-019-6527-5

[41] S. Arshad and S. J. A. Zaidi, "Vitamin D levels among children, adolescents, adults, and elders in Pakistani population: a cross-sectional study," *BMC Public Health*, vol. 22, no. 1, p. 2040, 2022. https://doi.org/10.1186/s12889-022-14526-6

[42] M. A. Abdulrahman, S. Y. Alkass, and N. I. Mohammed, "Total and free vitamin D status among apparently healthy adults living in Duhok Governorate," *Scientific Reports*, vol. 12, p. 1778, 2022. https://doi.org/10.1038/s41598-022-05775-x

[43] N. Poudel, S. S. Dhakal, R. Sukhupayo, and D. B. Karki, "Vitamin D deficiency among patients visiting a tertiary care hospital: A descriptive cross-sectional study," *Journal of the Nepal Medical Association*, vol. 58, no. 231, p. 839, 2020. https://doi.org/10.31729/jnma.5645

[44] S. C. Biswasarma *et al.*, "Prevalence and determinants of vitamin d deficiency: A comprehensive analysis from the measured vitamin d level at chemiluminescence immunoassay (CLIA) laboratory of National Institute of nuclear medicine and Allied sciences (NINMAS), Dhaka," *Bangladesh Journal of Nuclear Medicine*, vol. 27, no. 1, pp. 89-94, 2024. https://doi.org/10.3329/bjnm.v27i1.71523

[45] Instituti i Statistikave (INSTAT), "Employment and unemployment," 2024. https://www.instat.gov.al/en/themes/labour-market-and-education/employment-and-unemployment-from-lfs/#tab2

[46] G. Muscogiuri, L. Verde, C. Vetrani, L. Barrea, S. Savastano, and A. Colao, "Obesity: A gender-view," *Journal of Endocrinological Investigation*, vol. 47, no. 2, pp. 299-306, 2024. https://doi.org/10.1007/s40618-023-02196-z

[47] C. Y. Park and S. N. Han, "The role of vitamin D in adipose tissue biology: Adipocyte differentiation, energy metabolism, and inflammation," *Journal of Lipid and Atherosclerosis*, vol. 10, no. 2, p. 130, 2021. https://doi.org/10.12997/jla.2021.10.2.130

[48] D. F. Trifan *et al.*, "Involvement of vitamin D3 in the aging process according to sex," *Cosmetics*, vol. 10, no. 4, p. 114, 2023. https://doi.org/10.3390/cosmetics10040114

[49] Y. Hu *et al.*, "Vitamin D status and associated factors of older adults in the cross-sectional 2015–2017 survey," *Nutrients*, vol. 15, no. 20, p. 4476, 2023. https://doi.org/10.3390/nu15204476

[50] D. A. Tangoh *et al.*, "Vitamin D status and its associated risk factors among adults in the southwest region of Cameroon," *Journal of Nutrition and Metabolism*, vol. 2018, no. 1, p. 4742574, 2018. https://doi.org/10.1155/2018/4742574

[51] I. Guessous *et al.*, "Vitamin D levels and associated factors: A population-based study in Switzerland," *Swiss Medical Weekly*, vol. 142, 2012. https://doi.org/10.4414/smw.2012.13719

[52] E. P. Hataysal, B. Saraçlıgil, S. Abuşoğlu, A. Ünlü, and H. Vatansev, "Prevalence of vitamin D deficiency in healthy adults," *Turkish Journal of Family Medicine and Primary Care*, vol. 13, no. 3, pp. 335-341, 2019. https://doi.org/10.21763/tjfmpc.451729

[53] A. Bucaj, P. Sourtzi, P. Galanis, A. Kalokerinou, and E. Velonakis, "Dietary habits of Albanian immigrants living in Greece in comparison to Albanians living in their country," *Mediterranean Journal of Nutrition and Metabolism*, vol. 6, no. 1, pp. 39-44, 2012. https://doi.org/10.3233/s12349-012-0114-y

[54] I. Mone *et al.*, "Adherence to a predominantly Mediterranean diet decreases the risk of gastroesophageal reflux disease: a cross-sectional study in a South Eastern European population," *Diseases of the Esophagus*, vol. 29, no. 7, pp. 794-800, 2016. https://doi.org/10.1111/dote.12384
[55] R. Vitt *et al.*, "UV-Index climatology for Europe based on satellite data," *Atmosphere*, vol. 11, no. 7, p. 727, 2020. https://doi.org/10.3390/atmos11070727
[56] D. Bozo, B. Hoxha-Lami, S. Bozo, E. Pojani, and I. Ikonomi-Hoxha, "Dietary supplement use and their role in fitness and sports performance," *South Eastern European Journal of Public Health*, pp. 2603–2612, 2024.
[57] L. Yang *et al.*, "Smoking behavior and circulating vitamin D levels in adults: A meta-analysis," *Food Science & Nutrition*, vol. 9, no. 10, pp. 5820-5832, 2021. https://doi.org/10.1002/fsn3.2488
[58] O. Ogunsakin, T. Hottor, A. Mehta, M. Lichtveld, and M. McCaskill, "Chronic ethanol exposure effects on vitamin D levels among subjects with alcohol use disorder," *Environmental Health Insights*, vol. 10, p. EHI. S40335, 2016. https://doi.org/10.4137/EHI.S40335