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Serum Vitamin D Levels and Severity of Male Androgenetic Alopecia in North Sulawesi: A Cross-Sectional Study

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Abstract

Background: Androgenetic alopecia (AGA) is the most prevalent type of nonscarring hair loss in men, leading to progressive miniaturization of hair follicles and shortened hair growth cycles. Recent evidence indicates the importance of vitamin D and vitamin D receptor-mediated signaling in regulating hair follicle function. Nevertheless, studies investigating this relationship among Indonesian men remain limited.
Objective: To investigate the relationship between serum vitamin D levels and the severity of AGA using the Hamilton–Norwood classification in men.
Methods: This cross-sectional analytical study included 30 male patients aged 18–70 years who visited a tertiary referral hospital in North Sulawesi and were diagnosed with AGA. AGA severity was classified as mild, moderate, or severe according to the Hamilton–Norwood classification. Serum vitamin D concentrations were assessed, and Spearman's rank correlation test was used to evaluate the association between vitamin D levels and AGA severity, with $p < 0.05$ considered statistically significant.
Results: The patients' mean age was 40.27 ± 11.40 years, and the mean duration of AGA was 8.87 ± 6.58 years. The overall mean serum vitamin D level was 26.56 ± 11.36 ng/mL, with the majority (80%) of subjects classified as vitamin D deficient. A progressive decrease in vitamin D levels was observed with increasing AGA severity (mild: 36.34 ± 14.27 ng/mL; moderate: 22.77 ± 4.90 ng/mL; severe: 20.54 ± 5.09 ng/mL). Statistical analysis revealed a significant negative correlation between serum vitamin D levels and AGA severity ($r = -0.57$; $p = 0.001$).
Conclusions: In this cross-sectional study, lower serum vitamin D concentrations were significantly associated with greater AGA severity ($r = -0.57$; $p = 0.001$). These findings suggest a potential role of vitamin D in the pathogenesis of AGA; however, causality cannot be established based solely on this study design.

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INTRODUCTION

Androgenetic alopecia (AGA) is one of the most common forms of nonscarring hair loss, affecting a significant proportion of the adult population and predominantly men worldwide. It is characterized by progressive miniaturization of hair follicles, shortening of the anagen (growth) phase, and prolongation of the telogen (resting) phase, resulting in gradual loss of hair density through thinning. According to epidemiological evidence, 30% of males will experience AGA by

the age of 30; half will be affected by age 50, and up to 80% will have some degree of AGA by age 70. Caucasian populations have been reported to experience a higher incidence of AGA than Asian or African populations.

AGA is commonly considered a cosmetic concern; however, its implications extend far beyond aesthetic outcomes. Many studies have demonstrated that AGA significantly affects psychological factors, including reduced self-confidence, social withdrawal, anxiety, and decreased quality of life. Moreover, the impact of AGA is associated not only with psychological well-being and the potential benefits of long-term management through pharmacological treatments and cosmetic therapies but also with an economic burden that reinforces its public health significance. Therefore, understanding the underlying mechanisms and etiological factors of AGA is essential for improving clinical outcomes and the quality of life of individuals affected by this condition.

The pathogenesis of AGA is complex, and current evidence suggests that its causes are heterogeneous, involving both genetic and environmental factors. Among the hormonal factors, androgen hormones, particularly dihydrotestosterone (DHT), have long been identified as primary contributors to follicular miniaturization. However, more recent scientific evidence indicates that AGA may not be solely a hormone-driven disorder but may also involve metabolic and nutritional components. One factor that has received increasing attention in recent years is vitamin D.

Vitamin D is a fat-soluble vitamin (prohormone) that plays an important role in human physiology, including calcium metabolism, immune modulation, and cellular differentiation (Daniel D. Bikle, MD, 2021; Sawood Alam et al., 2025; Wimalawansa, 2024). It is synthesized in the skin following exposure to ultraviolet B (UVB) radiation and can also be obtained through dietary sources. Vitamin D exerts its biological effects through the vitamin D receptor (VDR), which is expressed in various tissues, including keratinocytes and dermal papilla cells, both of which are critical components of the hair growth cycle (Guan et al., 2026). Several studies have reported that VDR plays an essential role in normal hair follicle function and that its deficiency or dysfunction can lead to disrupted hair cycling and follicular regression (Bukvić Mokos et al., 2025; Zubair et al., 2021).

Vitamin D deficiency is considered a major global public health concern affecting both developed and developing countries. It is recognized as one of the most common micronutrient deficiencies worldwide, with recent global health estimates indicating that more than 1 billion people have insufficient or deficient vitamin D levels. This phenomenon occurs not only in regions with limited sunlight exposure but is also paradoxically observed in tropical countries, such as Indonesia, which receive year-round ultraviolet (UV) radiation. Nevertheless, a substantial proportion of the Indonesian population continues to have insufficient vitamin D levels. Several interrelated factors, including rapid urbanization, sedentary lifestyles, increased indoor work, air pollution, and cultural practices that limit direct sun exposure, may explain this paradox. Furthermore, although sunscreen use and protective clothing are beneficial for reducing UV-induced skin damage, these practices may potentially decrease cutaneous vitamin D synthesis. Dietary factors are also significant, as the consumption of vitamin D-rich sources, such as fatty fish, fortified dairy products, and supplements, remains relatively low in many populations.

An increasing association between vitamin D deficiency and a spectrum of diseases has been reported in dermatology. Vitamin D is an important immunomodulator and regulator of cellular proliferation and differentiation, in addition to its classical role in calcium metabolism. These functions are particularly important for maintaining skin homeostasis and the integrity of skin appendages, such as hair follicles. Vitamin D deficiency has been associated in the literature with various inflammatory and autoimmune skin diseases, including psoriasis and atopic dermatitis, as well as hair disorders such as alopecia areata and AGA. The biological basis for this association can be traced to the discovery of human vitamin D receptors (VDRs) in keratinocytes and dermal papilla cells, which are recognized as key regulators of hair follicle cycling and regeneration. Disruption of vitamin D signaling may impair follicular activity and accelerate hair cycle alterations, resulting in progressive hair loss.

Serum vitamin D levels have also been proposed as a potential predictor of disease severity in several studies on AGA. For instance, Zhao et al. (2020) demonstrated that median

serum vitamin D levels were significantly lower in patients with alopecia than in healthy control subjects, indicating a potential relationship between vitamin D status and hair loss disorders. Similarly, Sanke et al. (2020) reported a higher prevalence of vitamin D deficiency among patients with early-onset AGA, suggesting that vitamin D deficiency may contribute to the early pathogenesis of the disease. Recent investigations Kumar et al. (2024) have reported similar findings. Danane et al. (2021) further supported this hypothesis by identifying a significant inverse correlation between serum vitamin D levels and AGA severity. Across these studies, lower vitamin D levels were consistently observed among individuals with advanced stages of AGA, providing further evidence that vitamin D deficiency may be involved not only in disease development but also in AGA progression.

Despite the growing body of evidence, the relationship between vitamin D status and AGA remains inconclusive, with conflicting findings reported across studies. Several factors may explain these inconsistencies, including differences in study design (cross-sectional versus case-control studies), sample size variations, and population-specific characteristics. Furthermore, differences in laboratory methods used to measure serum vitamin D levels and variations in the definition of vitamin D deficiency thresholds may contribute to discrepancies among findings. Environmental factors, including sunlight exposure, seasonal variations, and geographic location, also play important roles in determining vitamin D status and represent additional challenges for comparisons across studies.

Most importantly, there is a distinct lack of systematic and comprehensive evidence from Southeast Asian populations, including Indonesia. To date, most existing studies have been conducted in Western or South Asian populations with different genetic backgrounds, environmental exposures, dietary habits, and lifestyle patterns compared with Indonesian populations. These differences may influence vitamin D metabolism and subsequently affect the clinical presentation of AGA, thereby limiting the generalizability of previous findings to Indonesian populations.

Available epidemiological data further emphasize the relevance of this study. A systematic review by Lolli et al. (2017) reported that AGA affects approximately 50% of men aged over 50 years in Asian populations. In Indonesia, national survey data indicate that hair-loss-related complaints represent a significant proportion of dermatological concerns, although comprehensive population-based prevalence data on AGA remain limited. Regarding vitamin D status, data from the Indonesian National Health Survey (Riset Kesehatan Dasar [Riskesdas]) indicate that vitamin D deficiency is prevalent across various age groups, with estimates ranging from 40% to more than 60% among adults, particularly in urban populations where indoor lifestyles are increasingly common. In North Sulawesi, comparable epidemiological data remain unavailable, further highlighting the importance of regional studies such as this.

This gap in the literature emphasizes the need for population-based investigations that examine the association between serum vitamin D levels and AGA severity within specific geographical and demographic contexts. Therefore, the North Sulawesi region requires further investigation because epidemiological data regarding AGA and vitamin D deficiency remain limited. Studying these factors may not only address an important knowledge gap but also clarify how environmental conditions interact with genetic and lifestyle factors in influencing disease patterns.

The relationship between vitamin D status and AGA severity in local populations may provide valuable evidence for developing preventive and therapeutically targeted strategies. Such approaches should consider population-specific sociocultural, environmental, and dietary contexts. Furthermore, modifiable risk factors, such as inadequate vitamin D status, may provide opportunities for early intervention that could potentially slow disease progression and improve clinical outcomes. Therefore, this study aimed to address this knowledge gap by providing empirical evidence regarding the association between serum vitamin D levels and AGA severity among male patients in North Sulawesi as a foundation for developing more personalized clinical approaches.

This study, which focuses on data collected up to October 2023, is strengthened by its

cross-sectional design, considering that both AGA and vitamin D deficiency represent increasingly recognized health concerns. AGA may cause physical, psychological, and social impacts, while vitamin D deficiency has been associated with various health conditions, including metabolic disorders and immune dysfunction. These concerns have increased interest in exploring the relationship between the two conditions, particularly regarding shared biological mechanisms and potential therapeutic strategies.

This study represents one of the first investigations examining the potential association between serum vitamin D levels and AGA severity in an Indonesian population, particularly among men in North Sulawesi. Unlike previous studies, this research utilizes clinical assessment data based on the Hamilton–Norwood classification system, which provides a standardized approach for evaluating AGA severity. Furthermore, this study contributes to the limited body of dermatological research in Indonesia by expanding evidence regarding the relationship between nutritional status and hair disorders.

The primary purpose of this study was to evaluate the correlation between serum vitamin D levels and the severity of AGA among male patients. Specifically, this research aimed to assess vitamin D level distributions among patients with AGA, categorize AGA severity according to established clinical criteria, and investigate the statistical association between these two variables.

This study is significant from both theoretical and practical perspectives. From a theoretical perspective, it contributes to a better understanding of the role of vitamin D in hair follicle biology and the pathogenesis of AGA. Clinically, the findings may provide clinicians with additional considerations regarding vitamin D assessment during the evaluation and management of patients with AGA. Such information may support the development of more comprehensive treatment approaches that address not only hormonal mechanisms, but also potential metabolic factors involved in disease progression.

These implications have important clinical and research significance. Clinically, if a significant association between serum vitamin D levels and AGA severity is established, vitamin D status assessment may serve as an adjunctive consideration in AGA management, although further interventional studies are required before supplementation can be recommended as a therapeutic approach. At the public health level, these findings may highlight vitamin D status as a potential target for dietary and lifestyle interventions. From a research perspective, this study provides opportunities for further investigations, including longitudinal studies and randomized controlled trials, to clarify causal relationships and evaluate the potential therapeutic role of vitamin D in AGA.

METHOD

A statistical power analysis was conducted to determine the sample size required for this study to provide sufficient representation and reliability of the findings. It was estimated that at least 30 patients needed to be included in the study AGA severity group: mild, moderate, and severe) to meet the minimum requirements for Spearman's correlation analysis at $\alpha = 0.05$ with 80% statistical power. This total sample size of 30 subjects is consistent with the actual enrolled sample; however, it should be noted that independent statistical inference for each group was not the primary aim of this study (i.e., parameters were selected to minimize the probability of Type I and Type II errors). Given the data distribution, this sample size was considered sufficient for nonparametric correlation analysis using Spearman's test.

The study employed an analytical observational study design with a cross-sectional approach. A cross-sectional design was selected because it allows assessment of serum vitamin D levels and the AGA simultaneously at a single point in time, making it appropriate for evaluating associations between variables.

The research was conducted among dermatology, venereology, and aesthetics outpatients at a tertiary referral hospital in Manado City, North Sulawesi, Indonesia. Data were collected in May and June 2023 over a period of 2 months. The study site was a high-volume facility with a diverse patient population representing various levels of AGA severity, thereby ensuring sufficient variability within the dataset.

This study was reported according to the Strengthening the Reporting of Observational

Studies in Epidemiology (STROBE) guidelines, which provide internationally recognized standards for reporting observational studies. Adherence to these guidelines enhances the transparency, methodological rigor, and reproducibility of research findings.

In this analytical study, a total of 30 male patients with AGA, aged 18–70 years and residing in Manado, North Sulawesi, Indonesia, who presented to the Dermatology, Venereology, and Aesthetics Outpatient Clinic of Prof. dr. R. D. Kandou General Hospital, Manado, North Sulawesi, Indonesia, were enrolled. The study utilized a purposive consecutive sampling method.

The inclusion criteria consisted of male patients with mild-to-severe AGA who were in a healthy condition. Patients were excluded if they met any of the following criteria: 1) current or previous use of oral finasteride or dutasteride and/or topical minoxidil application within the previous 2 weeks; 2) current or previous use of oral vitamin D supplementation or topical vitamin D application within the previous 4 weeks; 3) use of medications associated with vitamin D regulation, including systemic corticosteroids, anti-seizure medications (e.g., phenytoin and phenobarbital), and/or statins within the previous 4 weeks; and 4) a history of hair transplantation.

This clinical study was reviewed and approved by the Health Research Ethics Committee of RSUP Prof. dr. R. D. Kandou Manado Hospital (Trial Registration Number: DP 04 03/D.XV/2290/2023). All participants provided written informed consent after receiving a detailed explanation of the study's benefits and potential risks.

Study data were collected using questionnaires, clinical examinations, and serum vitamin D assessments. The questionnaire included demographic characteristics (ethnicity, age, family history, age at onset, and duration of AGA), while clinical examinations were performed to establish the diagnosis of AGA and determine disease severity. Serum vitamin D levels were assessed through laboratory examination.

For analytical purposes, AGA severity was classified into three categories based on the Hamilton–Norwood classification: mild (types I and II), moderate (types IIa, III, IIIa, III vertex, and IV), and severe (types IVa, V, Va, VI, and VII). Serum vitamin D levels were presented as numerical data using the mean and standard deviation and were categorized into two groups based on serum concentrations: deficient (<30 ng/mL) and non-deficient (≥30 ng/mL) (Sanke et al., 2020). Serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured using the chemiluminescence immunoassay (CLIA) method from venous blood samples collected after a minimum fasting period of 8 hours. Vitamin D status was categorized as deficient (<30 ng/mL) or non-deficient (≥30 ng/mL) according to the Endocrine Society guidelines (Sanke et al., 2020). It should be noted that potential confounding factors, including dietary vitamin D intake, daily sun exposure duration, sunscreen use, and physical activity, were not systematically collected in this study. This limitation should be considered when interpreting the findings.

The questionnaire data were systematically entered into Microsoft Excel files (Microsoft Corp., Redmond, WA, USA). Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) Statistics for Windows, Version 26.0 (IBM Corp., Released 2019, Armonk, NY, USA). Descriptive analysis was conducted to characterize demographic variables, while Spearman's correlation analysis was applied to evaluate the potential association between serum vitamin D levels and AGA severity. A P value <0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Results

A total of 30 male AGA patients who met the inclusion criteria were recruited during the study period and were evenly distributed across clinical severity groups (n = 10 per group). The mean age ± SD (range) of the participants was 40.27 ± 11.40 (23–61) years, with a mean age at AGA onset ± SD (range) of 31.50 ± 5.93 years. The mean duration of AGA ± SD (range) was 8.87 ± 6.58 (1–21) years. Most patients were of Minahasan ethnicity (63.3%), and approximately 60.0% had a family history of AGA, particularly through their fathers (23.3%) (Table 1). Overall, the mean serum vitamin D level ± SD (range) was 26.56 ± 11.36 (12.3–59.6) ng/mL, with the majority of patients classified as vitamin D deficient (80.0%) (Table 2).

Table 1
Demographic Characteristics of Patients with AGA

Variable	n (n = 30)	%
Ethnicity		
Minahasa	19	63.3
Javanese	6	20.0
Balinese	2	6.6
Ambonese	1	3.3
Gorontalese	1	3.3
Sumatran	1	3.3
AGA family history		
Father	7	23.3
Mother	3	10.0
Sibling	4	13.3
Others	4	13.3
None	12	40.0
Vitamin D classification		
Deficient	24	80.0
Not deficient	6	20.0

Table 2
Correlation between vitamin D serum level and AGA severity

Variable	AGA severity			r	P value
	Mild (n = 10)	**Moderate (n = 10)**	**Severe (n = 10)**		
25(OH)D serum level (ng/mL)[a]	36.34 ± 14.27	22.77 ± 4.90	20.54 ± 5.09	-0.57	0.001
Vitamin D status					
Deficient	4 (40.0)	10 (100.0)	10 (100.0)	N/A	0.002
Non-deficient	6 (60.0)	0	0		

[a]Values are presented as mean ± standard deviation for descriptive purposes; N/A: not applicable

Discussion

Androgenetic alopecia (AGA), a non-cicatricial form of alopecia, is characterized by progressive miniaturization of hair follicles, shortening of the hair growth cycle, and is the most common type of alopecia. This condition occurs in both men and women. In men, AGA is mainly characterized by a receding frontal hairline and hair thinning in the temporal region, commonly referred to as male pattern hair loss. In contrast, women with AGA typically present with diffuse thinning of hair in the parietal region, while the frontal hairline is usually preserved, a condition known as female pattern hair loss (Chen et al., 2025).

Prevalence varies according to sex and ethnicity, with more than 50% of older men and approximately 15% of postmenopausal women being affected. However, hair thinning may begin as early as puberty (Ntshingila et al., 2023). This study highlighted that most participants had early-onset AGA. Early-onset AGA is generally defined as AGA developing before the age of 30 years. The occurrence of early-onset AGA warrants further investigation, as AGA is closely associated with an increased risk of metabolic syndrome, a cluster of metabolic abnormalities including obesity, hyperlipidemia, insulin resistance, and hypertension (Liu et al., 2024).

In this study, a family history of AGA was present in 60.0% of patients, with paternal inheritance being the most predominant pattern (23.3%). This finding is supported by previous research demonstrating that genetic factors are strong predisposing determinants, particularly among men with affected fathers, who have a 5–6-fold higher risk of developing AGA (Lolli et al., 2017). Approximately 80% of both early-onset and late-onset hair loss has been attributed to genetic factors based on twin studies (Cortez et al., 2025; Sadasivam et al., 2024).

The mean serum vitamin D level ± SD (range) in this study was 26.56 ± 11.36 (12.3–59.6)

ng/mL, with most participants classified as vitamin D deficient (80.0%). This value falls within the vitamin D insufficiency/deficiency category based on commonly used clinical thresholds, as it is below 30 ng/mL. This finding is consistent with a previous study by Sanke et al. (2020), which involved participants with similar demographic characteristics, including an Asian population, comparable AGA severity distribution, and a mean age of above 30 years (Sanke et al., 2020).

Vitamin D is a fat-soluble vitamin primarily synthesized in the skin and plays an essential role in maintaining the homeostasis of various biological systems. Vitamin D contributes significantly to the differentiation and maintenance of epithelial tissues from embryonic development to adulthood, thereby influencing the pathophysiology of the skin and its adnexal structures (Grant et al., 2025). The active metabolite 1,25-dihydroxyvitamin D3 [1,25-$(OH)_2D_3$] exerts its biological effects by binding to the vitamin D receptor (VDR), a nuclear steroid hormone receptor expressed in nearly all nucleated cells. VDR expression has been identified in keratinocytes and dermal papilla cells (Zong et al., 2024).

VDR plays an important role in hair follicle development and cycling. A recent study using in vivo, ex vivo hair follicle organ culture, and cellular models in mice demonstrated the promoting effects of 1,25-$(OH)_2D_3$ on hair growth, involving HIF-1 and NLRP3 pathways as validated through transcriptional analysis and related molecular experiments (Zong et al., 2024). Additionally, vitamin D dysfunction may impair stem cell renewal and disrupt the hair cycle, indirectly contributing to AGA through sex hormone regulation, follicular damage, inflammation, and progressive follicular miniaturization (Iyanda, 2012; Saini & Mysore, 2021).

This study demonstrates that serum vitamin D levels are associated with the severity of male AGA, which may be influenced by vitamin D dysregulation. However, several limitations should be acknowledged, including the cross-sectional design, relatively small sample size due to the inclusion of non-AGA participants, and the absence of data regarding lifestyle-related factors, such as dietary vitamin D intake, average sunlight exposure, and clothing habits. Further multicenter studies involving larger and more diverse populations, with comprehensive assessments of dietary patterns and lifestyle factors, as well as investigations into vitamin D supplementation as an adjunctive therapy, are warranted to better understand its role in AGA prevention and progression.

Furthermore, the observed association between serum vitamin D levels and AGA severity may be explained through more detailed molecular mechanisms. Beyond its role in cellular differentiation, vitamin D possesses immunomodulatory properties that may influence the hair follicle microenvironment. Vitamin D deficiency may enhance inflammatory responses, which, according to Rea et al., may accelerate follicular damage. These findings suggest that AGA may not solely represent a hormone-driven disorder but may also involve low-grade chronic inflammation within the peribulbar region.

Additionally, vitamin D is an important regulator of the Wnt/β-catenin signaling pathway, which plays a critical role in hair follicle development, regeneration, and cycling. This pathway is essential for activating follicular stem cells and facilitating the transition of hair follicles into the anagen phase, the active growth phase of the hair cycle. Furthermore, reduced vitamin D receptor (VDR) expression under conditions of low serum vitamin D levels may suppress activation of this pathway and impair the regenerative capacity of hair follicles.

Consequently, normal physiological hair cycling may become disrupted, resulting in premature transition of follicles from the anagen phase to the catagen (regression) and telogen (resting) phases. This disruption ultimately contributes to progressive follicular miniaturization, reduced hair shaft diameter, and gradual thinning of scalp hair over time, which are characteristic features of AGA. Therefore, vitamin D deficiency may not only be associated with AGA severity but may also contribute mechanistically to disease progression by affecting molecular pathways involved in follicular homeostasis and regeneration.

Apart from regulating the hair cycle, vitamin D can also modulate immune responses and exert anti-inflammatory effects, which may explain its role in AGA progression. Hair follicles are highly dynamic mini-organs that require a specialized microenvironment to maintain their structure and function over time. Lastly, in situations of vitamin D insufficiency, the scalp

microenvironment may become more prone to low-grade chronic inflammation, increased oxidative stress, and tissue remodeling—three processes that may collectively contribute to hair follicle destruction through genetic pathways184–190. In this context, inhibition of vitamin D receptor (VDR)-mediated signaling may represent one pathway through which insufficient vitamin D status and increased disease severity are interconnected. This mechanistic perspective enhances the biological plausibility of the study findings and supports the hypothesis that vitamin D acts as an active modifier of AGA progression rather than merely an epiphenomenal nutritional marker.

In fact, 100% of patients with moderate and severe AGA, but only a subset of patients in the mild group, were vitamin D deficient. In summary, this validation study demonstrates that serum vitamin D level patterns remain consistent and provides an important qualitative feature that complements the substantive statistical association between serum vitamin D concentrations and AGA severity. The pathogenic consensus among major clinical groups suggests that vitamin D deficiency may be strongly associated with the progression of the pathophysiological process. This categorization implies that the risk of vitamin D deficiency increases with the clinical stage of AGA. This observation reinforces the concept that vitamin D is not merely an accessory factor but may serve as a key molecular regulator of AGA progression and severity. The gradient observed across the three groups also suggests a possible linear or dose-response relationship, in which lower vitamin D levels correspond to increasing follicular impairment.

This finding is particularly important because it replicates not only the statistical outcome but also a clinically relevant pattern identified in our data. Therefore, while statistical significance may indicate an association in individual studies, the distributional pattern observed here provides a clinically meaningful trajectory of this relationship. These results demonstrate that vitamin D deficiency was not randomly distributed among patients but was concentrated among individuals with more severe disease. Furthermore, the relative homogeneity of deficiency status indicates that both moderate and severe AGA groups exhibited comparable vitamin D insufficiency. This pattern further strengthens the association between vitamin D status and the broader pathophysiological spectrum of AGA. Although the cross-sectional design prevents causal inference, the consistency of statistical significance, biological plausibility, and clinical distribution supports the view that vitamin D status may represent an important determinant influencing AGA severity.

These results have important implications for dermatological practice. To date, AGA management has largely focused on hormonal therapies targeting the classical androgen-mediated mechanisms of disease, including finasteride and minoxidil. Although these therapies remain the mainstays of treatment, they do not fully address metabolic or nutritional factors that may increase follicular vulnerability. The findings suggest that therapies targeting only hormonal pathways may have limited effectiveness in advanced disease stages or among patients with inadequate responses to standard treatments. Therefore, metabolic variables, including vitamin D status, should be considered as part of the comprehensive evaluation of patients with AGA.

Clinicians may gain several potential benefits by incorporating vitamin D assessment into clinical practice. First, it may assist in identifying additional modifiable determinants associated with increased disease severity. Second, it provides an opportunity for targeted management of deficiency, including dietary counseling, lifestyle modification (e.g., recommendations regarding sunlight exposure), and supplementation when clinically appropriate. Third, it may improve overall AGA management by enabling better patient stratification according to risk and severity. Vitamin D correction in patients with confirmed deficiency may be considered as an adjunctive strategy; however, intervention-based studies are required to validate this assumption. Thus, the present findings suggest that vitamin D should be reconsidered from a marginal factor to a potentially relevant component of a comprehensive AGA therapeutic approach.

Moreover, greater attention should be directed toward the association between AGA and metabolic syndrome. Several previous studies have demonstrated associations between AGA, particularly early-onset AGA, and increased risk of metabolic syndrome characterized by obesity, insulin resistance, hypertension, and dyslipidemia. These metabolic abnormalities may contribute to systemic inflammation, endothelial dysfunction, and hormonal imbalance, each of which may further promote follicular degeneration. Nonetheless, vitamin D deficiency is also highly prevalent

among individuals with metabolic syndrome, suggesting an interconnected relationship rather than an entirely independent association. Overall, this interaction may represent a vicious cycle in which metabolic dysfunction worsens vitamin D status, while inadequate vitamin D status further contributes to AGA progression and associated biochemical abnormalities.

This complex relationship suggests that AGA may not always represent merely a localized cutaneous disorder but may also reflect broader systemic metabolic dysfunction. Therefore, comprehensive clinical evaluation of patients with AGA, particularly those with severe or early-onset disease, should not be limited to scalp examination alone. Instead, clinicians should consider screening for concurrent metabolic and nutritional abnormalities, including serum vitamin D levels, body mass index (BMI), lipid profiles, and markers of insulin resistance. A broader health-oriented approach may facilitate improved patient management and help identify individuals at higher risk of systemic disease, thereby enhancing the role of dermatological consultation in preventive healthcare.

Importantly, these findings highlight the relevance of a multidisciplinary approach involving both dermatological and metabolic perspectives. Optimal management of AGA, particularly among patients with severe disease or progression associated with metabolic abnormalities, may require collaboration between dermatologists, endocrinologists, nutritionists, and primary care providers. Integrating scalp-focused management with metabolic assessment may provide clinicians with a more comprehensive treatment strategy. This approach is especially relevant in populations exposed to abundant sunlight but experiencing high rates of vitamin D deficiency, as observed in many tropical countries. Consequently, overlooking the metabolic component of AGA may result in incomplete treatment strategies and missed opportunities for disease prevention. In conclusion, the findings of this study further support the emerging concept that AGA is not solely an androgen-sensitive disorder but rather a dynamic condition influenced by broader biological and metabolic mediators.

Another important consideration involves external factors, particularly sun exposure. Indonesia is a tropical country; however, modernization has resulted in reduced sunlight exposure among many Indonesian populations. Contributing factors include prolonged indoor activities, excessive sunscreen use, and lifestyle changes. This may explain why 80% of respondents in this study were vitamin D deficient (n = 24/30; Table 1), despite residing in a region with abundant sunlight.

The results also have implications for promotive and preventive interventions. Beyond its established role in bone health, vitamin D should be recognized as an important factor in maintaining hair follicle function. Furthermore, clinicians may consider routine vitamin D screening for patients experiencing hair loss, particularly those who demonstrate inadequate responses to conventional therapeutic regimens.

Nonetheless, although our study is among the first to demonstrate an association between vitamin D status and AGA severity, further evidence is required before establishing causality. This study does not demonstrate a direct causal relationship between vitamin D deficiency and AGA; rather, it identifies an association. Genetic predisposition, hormonal regulation, and environmental influences remain important contributors to AGA pathogenesis.

Collectively, these findings indicate that AGA is a multifactorial condition in which cumulative interactions among genetic, environmental, hormonal, and potentially nutritional factors, including vitamin D status, may contribute to disease severity. Therefore, AGA management should not consider these factors as isolated entities but rather as interconnected domains that collectively influence disease progression and therapeutic outcomes.

CONCLUSION

This cross-sectional study found a significant negative correlation between serum vitamin D levels and the severity of *androgenetic alopecia* (AGA) among 30 male patients in North Sulawesi ($r = -0.57$; $p = 0.001$). Lower 25-hydroxyvitamin D [25(OH)D] concentrations were associated with more severe AGA stages, and 100% of patients with moderate or severe AGA had vitamin D deficiency compared with 40% of those in the mild AGA group. These findings suggest that vitamin

D status may serve as a clinically relevant correlate of AGA severity; however, causality cannot be established due to the cross-sectional study design.

Key limitations include the small sample size, single-center setting, and the absence of data on dietary vitamin D intake, sun exposure, and hormonal profiles, which may have acted as potential confounding factors influencing the observed association. Future studies should employ prospective cohort or randomized controlled designs involving larger and more diverse populations, adjust for relevant confounding variables, and evaluate the therapeutic effects of vitamin D supplementation as an adjunctive strategy in AGA management.

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AUTHOR CONTRIBUTION STATEMENT

Conceptualization: Thigita Aga Pandaleke and Aryani Adji. Methodology: Thigita Aga Pandaleke, Shienty Gaspersz, and Dwayne Giovano Pandaleke. Investigation and data collection: Thigita Aga Pandaleke and Paulus Mario Christopher. Data analysis: Thigita Aga Pandaleke and Aryani Adji. Writing – original draft preparation: Thigita Aga Pandaleke. Writing – review and editing: Aryani Adji and Shienty Gaspersz. All authors have read and approved the final version of the manuscript.

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