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Physiological Association: Vitamin D, Ferritin, TSH and Diffuse Hair Loss in Tarhouna, Libya: A Cross-sectional Study

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العلاقة الفسيولوجية بين فيتامين د والفيريتين والهرمون المحفز للغدة الدرقية (TSH) وتساقط الشعر المنتشر في مدينة ترهونة، ليبيا: دراسة مقطعية

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Abstract

Background: From January to June of 2025, this study was conducted in Tarhuna laboratories with the aim of evaluating biochemical markers and their relationship to hair loss.

Materials and Methods: There were 414 intravenous blood samples taken from patients who participated in this study, and the device (I-Chromma II analyser, Boditech Med, South Korea, 2017) was used to measure TSH, while S. ferritin and vitamin D were measured by the device (Mindray CL-900i analyser, China, 2022). Data was analyzed using Microsoft Excel 2010 and SPSS version 27. A questionnaire was used to gather additional data.

Results: The study found that participants' iron stores decreased by 49.3%, or roughly 204 cases, and that patients' vitamin D levels were insufficient by 85.5%, or roughly 354 cases, of the total number of cases. Additionally, the study revealed that an average of 4.3% (18 cases out of 414 study participants) had a thyroid hormone deficiency.

Conclusion: The majority of patients have normal thyroid function, but there is a high prevalence of iron and vitamin D deficiencies. Ferritin, vitamin D, and TSH levels did not significantly correlate with diffuse hair loss in women.

Recommendations: According to the study, trichoscopic or biopsy-based evaluations should be used in longitudinal studies to track changes in hair loss over time. Additionally, it recommends measuring, zinc, cortisol, and androgen levels; determining the causes of hair loss; assessing the effects of genetic and environmental factors; and researching blood hormone levels.

Keywords: Thyroid stimulating hormone, Vitamin D, S. ferritin, and diffuse hair loss.

الملخص

الخلفية :أُجريت هذه الدراسة في مختبرات مدينة ترهونة خلال الفترة من يناير إلى يونيو 2025 بهدف تقييم بعض المؤشرات الكيميائية الحيوية ودراسة علاقتها بتساقط الشعر.

المواد وطرق البحث :شملت الدراسة 414 عينة دم وريدي جُمعت من المرضى المشاركين في الدراسة. تم قياس مستوى الهرمون المحفز للغدة الدرقية (TSH) باستخدام جهاز (I-Chroma II Analyzer, Boditech Med, South Korea, 2017)، بينما تم قياس مستوى الفيريتين المصلي وفيتامين د باستخدام جهاز (Mindray CL-900i Analyzer, China, 2022). جرى تحليل البيانات باستخدام برنامجي Microsoft Excel 2010 و SPSSالإصدار 27، كما استُخدمت استبانة لجمع البيانات الإضافية المتعلقة بالمشاركين.

النتائج :أظهرت نتائج الدراسة انخفاض مخزون الحديد لدى 49.3% من المشاركين، أي ما يعادل 204 حالات تقريباً، كما تبين وجود نقص في مستوى فيتامين د لدى 85.5% من المشاركين، أي ما يعادل 354 حالة من إجمالي العينة. كذلك أوضحت النتائج أن 4.3% من المشاركين في الدراسة (18 حالة من أصل 414) كانوا يعانون من قصور في إفراز هرمونات الغدة الدرقية.

الاستنتاج :أظهرت الدراسة أن معظم المرضى يتمتعون بوظيفة طبيعية للغدة الدرقية، في حين وُجد انتشار مرتفع لنقص الحديد ونقص فيتامين د. كما لم تُظهر مستويات الفيريتين وفيتامين د والهرمون المحفز للغدة الدرقية (TSH) ارتباطاً ذا دلالة إحصائية مع تساقط الشعر المنتشر لدى النساء.

التوصيات :توصي الدراسة بإجراء دراسات طولية تعتمد على الفحص بالترايكوسكوبي (Trichoscopy) أو الخزعات الجلدية لمتابعة التغيرات في تساقط الشعر مع مرور الوقت. كما توصي بقياس مستويات الزنك والكورتيزول والهرمونات الأندروجينية، وتحديد الأسباب المختلفة لتساقط الشعر، وتقييم تأثير العوامل الوراثية والبيئية، بالإضافة إلى إجراء مزيد من الدراسات حول مستويات الهرمونات في الدم وعلاقتها بتساقط الشعر.

الكلمات المفتاحية: الهرمون المحفز للغدة الدرقية (TSH)، فيتامين د، الفيريتين المصلي، تساقط الشعر المنتشر.

Introduction:

The intricate biochemical mechanisms governing hair development and loss encompass oxidative stress, immunological dysfunction, hormonal abnormalities, and stem cell regulation. Recent investigations (2023–2025) have identified critical biomarkers linked to androgenetic alopecia (AGA) and alopecia areata (AA) (1,2). Elevated levels of biomarkers, including paraoxonase, ceruloplasmin, and malondialdehyde, have been observed in both AGA and AA, suggesting sustained oxidative damage to dermal papilla cells and hair follicle stem cells (3-6). This oxidative stress contributes to follicular miniaturization, a hallmark of progressive hair loss. Furthermore, individuals with AGA exhibit increased accumulation of advanced glycation end products (AGEs) and activation of the receptor for advanced glycation end products (RAGE) signaling cascades, which exacerbate chronic inflammation and hasten follicular regression (7-9). Additionally, insulin resistance, elevated dihydrotestosterone (DHT) levels,

and diminished sex hormone-binding globulin (SHBG) are strongly correlated with AGA pathogenesis (10-13). In AA, abnormal cysteine metabolism dysregulates keratin production, leading to structural fragility of the hair shaft and increased shedding (14,15). Signaling molecules, such as FGF5 and BMP4, also play pivotal roles in hair cycle control; overexpression of FGF5 shortens the anagen phase, while BMP4 dysregulation impairs follicular differentiation and regeneration (16-20). Due to a lack of research on its biochemical causes, diffuse hair loss, a common dermatological condition affecting women, is underdiagnosed and undertreated in MENA regions. Empirical evidence on the connection between micronutrients and hormonal factors, including vitamin D, serum ferritin, and thyroid-stimulating hormone, and diffuse hair loss in women is lacking in Libya, especially in Tarhouna City. Being the first to investigate the biochemical correlates of diffuse hair loss in Tarhouna women, this study will help clinicians develop more focused diagnostic and treatment plans, raise awareness of endocrine and nutritional health issues, and open the door for more longitudinal and interventional research in the future. The study investigates the relationship between diffuse hair loss in women from Tarhouna City, Libya, and various serum levels, including ferritin, vitamin D, and thyroid-stimulating hormone (TSH). It assesses the extent of hair loss by comparing it to normal levels while also evaluating potential risk factors such as age, marital status, diabetes, hypertension, Coronavirus exposure, and medication usage. The study posits several hypotheses: the null hypotheses suggest no significant relationships between serum vitamin D, ferritin, nor TSH levels and the incidence of diffuse hair loss, while the alternative hypotheses propose that low serum levels of vitamin D and ferritin, along with abnormal TSH levels, are significantly linked to hair loss in this population.

Materials and Methods: The purpose of this study is to measure the levels of S. ferritin, vitamin D, and thyroid gland hormones in patients in Tarhuna, Libya. Age, marital status, diabetes, hypertension, surgery, Coronavirus, and medication were among the dependent variables in the analytical cross-sectional study, which ran from 10-2-2025 to 30-6-2025. Vitamin D, S. ferritin, and TSH were independent factors. Males were not included in the study, but all females were. The following formula was used to determine the sample size: $N = Z^2 * P (1 – P) / /d2$. In contrast, d^2 is the degree of accuracy based on expected prevalence, P is the expected prevalence from prior studies, Z is the normal distribution of 1.96 at 0.95 confidence, and N is the sample size. When the expected or imposed value of P equals 0.5. The variables in the study are described in the document and include dependent and independent variables. The dependent variables are age, marital status, diabetes mellitus, hypertension, surgical operations, coronavirus and medication status. The independent variables, on the other hand, are TSH, vitamin D and serum ferritin levels. The criteria of the study are well categorized into inclusion and exclusion criteria. The inclusion criteria state that all females are eligible to participate in the study, while the exclusion criteria explicitly exclude all males from participation. This framework ensures that for the data being analysed, the study looks only at a female population. There were 414 intravenous blood samples taken, drawn and put in plain tubes devoid of anticoagulants. Through direct interviews and targeted questionnaires, the study sought to gather information on all female patients between the ages of 06 and 56 years old.

Procedure of Thyroid Gland Hormones Test:

It was measured as the following: The blood sample was taken from a vein, and then it was placed in a plain tube (no anticoagulant) and left to clot for one hour. It was then separated by a centrifuge (Md-C8, China, 2021) for 5 minutes, and the test was measured by the device (I-Chromma II analyzer, BoditechMed, South Korea, 2017) according to the method followed in

the analysis steps. Results were reported: thyroid gland hormones as µIU/mL, compared to the international standard level, as follows: TSH levels were in the normal range for females (0.35 - 5.1 µIU/mL)

Procedure of Vitamin D and S. Ferritin Tests:

It was measured as the following: The blood sample was taken from a vein, and then it was placed in a plain tube (no anticoagulant) and left to clot for one hour. It was then separated by a centrifuge (Md-C8, China, 2021) for 5 minutes, and the test was measured by the device (Mindray, CL-900i analyzer, China, 2022) according to the method followed in the analysis steps.

Results were reported:

S. ferritin levels were in the normal range for females (12 to 135 ng/ml).

The study used statistical packages for social sciences (SPSS) version 22 to analyze the data, ensuring a significant level of P-value ≤ 0.05. Ethical considerations were taken into account, and patients were informed about the study's objectives and asked to sign an agreement. The questionnaire was filled out by answering the researchers' questions and clarifying them, and any patient who refused to participate was excluded from the study.

Results:

With an emphasis on the correlation between the prevalence of diffuse hair loss and specific biochemical markers, including serum ferritin, vitamin D levels, and thyroid-stimulating hormone (TSH), this study attempts to provide insight into the health and demographic characteristics of a sample of women taking part in a medical study. Age, marital status, medical history, and levels of various biochemical indicators were among the data gathered from 414 cases. Finding out if there is a statistically significant correlation between these biochemical markers and hair loss a prevalent condition that can have a major impact on women's quality of life is the aim of this analysis.

Table 1: Distribution of study cases by age group:

Ages	Frequency	Percent %
Less than 20	126	30.4%
20 to 40	222	53.7%
41 to 60	66	15.9%
Total	**414**	**100%**

Table (1) displays the distribution of study cases across four age groups, illustrating the absolute frequency and proportion of cases within each group. Of the (414 cases) analyzed, we found that the predominant age group (20 to 40 years) is the most prominent in this study, with individuals aged (20 to 40) representing 53.7% (222 cases) of the total participants. This indicates that nearly half of the study sample belongs to this age group. The middle age group (41 to 60 years) follows, representing 15.9% (66 cases) of the study participants. Underrepresented group (under 20 years) The under-20 age group is the least represented, accounting for only 30.4% (126 cases) of the total. This indicates that the study focuses primarily on the adult population.

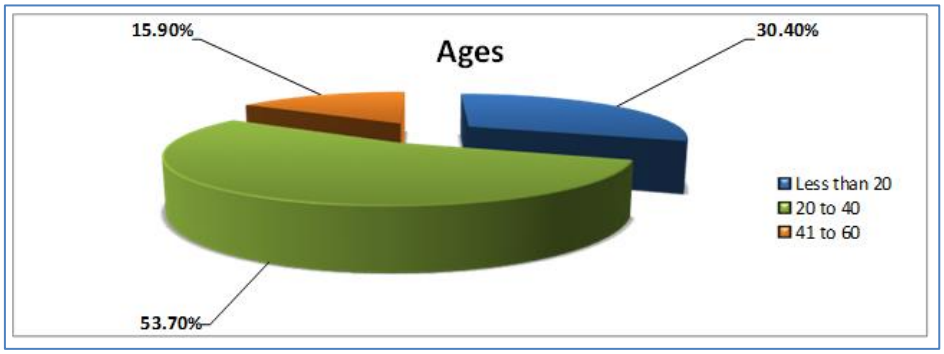

Figure 1: Distribution of study cases by age group.

Table 2: Distribution of study samples according to social status:

Marital status	Frequency	Percent %
single	288	69.6%
married	126	30.4%
Total	**414**	**100%**

Table 4.2 shows the distribution of study participants by marital status. Of the 414 individuals, the majority (288 individuals, equivalent to 69.6%) were single. In contrast, a smaller percentage (126 individuals, equivalent to 30.4%) were married.

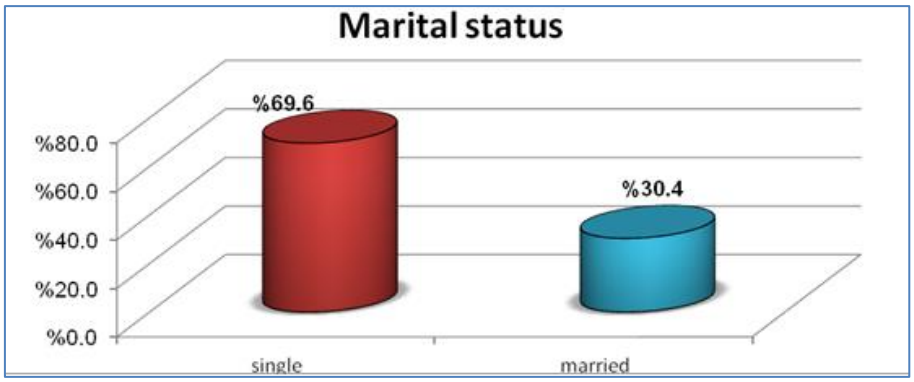

Figure 2: Distribution of study cases according to social status**.**

Table 3: Distribution of patients with and without co-morbidities (diabetes, hypertension, and COVID-19), surgeries, and treatments used:

Variables	Responded	Frequency	Percent %
Diabetes	Yes	6	1.4%
	No	408	98.6%
Blood Pressure	Yes	6	1.4%
	No	408	98.6%
COVID-19	Yes	42	10.1%
	No	372	89.9%
Previous Surgeries	Yes	6	1.4%
	No	408	98.6%
Treatments Used	Yes	18	4.3%
	No	396	95.7%
N*		**414**	**100%**

* Size of samples.

Table 3 illustrates the distribution of patients based on the presence of specific comorbidities (diabetes, hypertension, and COVID-19), previous surgeries, and use of medications. The total number of patients included in this analysis was 414. Diabetes and Hypertension: A very small percentage of patients, 1.4% (6 individuals), reported having either diabetes or hypertension. This suggests that these specific co morbidities are not highly prevalent within the patient population studied. The vast majority, 98.6%, do not suffer from these conditions. COVID-19 is more prevalent than diabetes or hypertension, affecting 10.1% (42 individuals) of patients. This suggests that a significant proportion of the sample had a history of COVID-19. As with diabetes and hypertension, only a small percentage of patients, 1.4% (6 individuals), had undergone previous surgeries. This suggests that the study sample was largely comprised of individuals with no history of surgical interventions, with 4.3% (18 individuals) of patients reporting using treatments. This figure is higher than the prevalence of diabetes, hypertension, and previous surgery, but it still represents a minority. The high proportion of patients not using treatments (95.7%) may indicate that a significant proportion of the study group may have been newly diagnosed, in the early stages of their condition, or were managing their health without specific interventions at the time of data collection. Overall, the data suggest that the majority of patients in the study sample were relatively healthy with respect to the specific co morbidities mentioned (diabetes and hypertension) and previous surgical history. The most common "positive" outcome among these variables was the presence of COVID-19, although it still affected a minority. The low rate of "treatments used" may indicate that the group is either in overall excellent health, in the early stages of their condition, or managing their health without pharmacological treatment or other specific interventions.

Table 4: Distribution of patients according to TSH level, vitamin D level, and serum ferritin level

Variables	Range value	Frequency	Percent %
TSH levels	Normal	396	95.7
	Low	18	4.3
	High	-	-
vitamin D levels	Normal	60	14.5
	Deficiency	354	85.5
S. ferritin levels	Normal	210	50.7
	Low	204	49.3
	High	-	-
N		**414**	**100%**

Table 4 reveals the distribution of patients according to TSH, vitamin D, and serum ferritin levels. The total number of patients included in this analysis was 414.

- **TSH Level:** The vast majority of patients (396 individuals, 95.7%) had normal TSH levels. This indicates that thyroid function was within the healthy range for most individuals in the study sample. A small percentage (18 individuals, 4.3%) showed low TSH levels. Low TSH may indicate hyperthyroidism or may be caused by other factors. Given the small size of this percentage, it suggests that overt hyperthyroidism is not a common problem in this group. No patients had elevated TSH levels, as elevated TSH usually indicates hypothyroidism.
- **Vitamin D Levels:** A striking finding was the high prevalence of low vitamin D levels, affecting 354 individuals (85.5%). This indicates widespread vitamin D deficiency within the

study sample. Only a small percentage (60 individuals, 14.5%) had normal vitamin D levels, while no patients were recorded with elevated vitamin D levels, which is expected given the rarity of vitamin D toxicity resulting from diet or sun exposure.

❖ **Serum ferritin level:** The distribution of serum ferritin levels was roughly evenly divided between normal and low. Normal serum ferritin levels were observed in 210 individuals (50.7%), while low serum ferritin levels were found in 204 individuals (49.3%). None of the patients had elevated serum ferritin levels. Low serum ferritin is a strong indicator of iron deficiency, which can lead to iron deficiency anemia. The low serum ferritin levels in nearly half of the study sample are an important finding, as they indicate the widespread prevalence of iron deficiency. This may have various effects on patients' health, including fatigue, impaired cognitive function, and decreased physical performance. The absence of elevated ferritin levels indicates the absence of iron overload in this sample.

Table 5: The relationship between specific biochemical parameters (vitamin D, serum ferritin, and thyroid-stimulating hormone) and the incidence of diffuse hair loss in women.

Variables	Statistics	TSH	Vit. D	S. ferritin	Hair Loss
TSH	Pearson Correlation	1	-0.173**	0.007	-0.067
	Sig. (2-tailed)	—	0.000	0.889	0.173
	N	414	414	414	414
Vit. D	Pearson Correlation	-0.173**	1	-0.022	0.054
	Sig. (2-tailed)	0.000	—	0.662	0.277
	N	414	414	414	414
S. ferritin	Pearson Correlation	0.007	-0.022	1	-0.004
	Sig. (2-tailed)	0.889	0.662	—	0.943
	N	414	414	414	414
Hair Loss	Pearson Correlation	-0.067	0.054	-0.004	1
	Sig. (2-tailed)	0.173	0.277	0.943	—
	N	414	414	414	414

Note: Correlation is significant at the 0.01 level (2-tailed).
Sample size (N) = 414.

Table 5 discovered Pearson's correlation coefficients and their significances (P-values) to assess the linear relationship between TSH, vitamin D, serum ferritin levels, and diffuse hair loss in women. The total sample size for this analysis was 414.

❖ **TSH and Hair Loss:** Pearson's correlation coefficient (r): -0.067, significance/ P-value = 0.173, There is a very weak negative association between TSH levels and hair loss. However, this association is not statistically significant (P-value = 0.173 > 0.05) This suggests that, in this study sample, differences in TSH levels are not significantly associated with the rate of diffuse hair loss.

❖ **Vitamin D and Hair Loss:** Pearson's correlation coefficient (r): 0.054, significance/P-value = 0.277, There is a very weak positive association between vitamin D levels and hair loss. Importantly, this association is not statistically significant (P-value = 0.277 > 0.05) This finding contradicts many published studies that suggest a relationship between vitamin D deficiency and hair loss. For this particular study group, the results do not support a statistically significant linear relationship between vitamin D levels (as a continuous variable) and the presence of diffuse hair loss.

❖ **Serum ferritin and hair loss:** Pearson's correlation coefficient (r): -0.004, significance/P-value = 0.943, There is a very weak, insignificant, negative association between serum ferritin levels and hair loss. This association is not statistically significant (P-value = 0.943 > 0.05). This suggests that serum ferritin levels are not significantly associated with the incidence of diffuse hair loss in this group. This finding also contradicts some studies that suggest a link between iron deficiency (low ferritin) and hair loss.

Based on the above, we note the following:

✓ **TSH levels and hair loss:** With this result, the null hypothesis (H_{03}) is accepted, which states that there is no statistically significant correlation between TSH levels and hair loss prevalent among women in the city of Tarhuna, and the alternative hypothesis (H_{13}) is rejected, which states that abnormal TSH levels are closely related to hair loss prevalent among women in the city of Tarhuna.

✓ **Serum vitamin D levels and hair loss:** With this result, the null hypothesis (H_{01}) is accepted, which states that there is no statistically significant correlation between serum vitamin D levels and hair loss prevalent among women in the city of Tarhuna, and the alternative hypothesis (H_{11}) is rejected, which states that the low level of serum vitamin D is closely related to hair loss prevalent among women in the city of Tarhuna.

✓ **Serum ferritin levels and hair loss:**With this result, the null hypothesis (H_{02}) is accepted, which states that there is no statistically significant correlation between serum ferritin levels and hair loss prevalent among women in the city of Tarhuna, and the alternative hypothesis (H_{11}) is rejected, which states that the low level of serum ferritin is closely related to hair loss prevalent among women in the city of Tarhuna.

Discussion: The study investigated the relationship between selected biochemical markers thyroid-stimulating hormone (TSH), vitamin D, and serum ferritin and the incidence of diffuse hair loss in a cohort of 414 women. The primary objective was to evaluate the potential correlation between these markers and the prevalence of hair loss among women in Tarhuna, Libya. While these biomarkers are physiologically integral to the hair follicle cycle, statistical analysis through Pearson's correlation revealed no significant linear relationship between these markers and the incidence of hair loss in this cohort. This finding necessitates a deep exploration into the demographic profile of the participants, the biological thresholds of these markers, and the potential multifactorial nature of alopecia. The study population was predominantly characterised by women in their prime reproductive and professional years, with 53.7% of participants aged between 20 and 40 years. This demographic trend is consistent with global clinical observations where women in this age group are more likely to seek medical consultation for hair loss due to the high psychosocial impact and the associated decrease in quality of life (21). Interestingly, the majority of the sample (69.6%) were single, which might suggest a heightened concern regarding aesthetic health and its social implications within this subgroup. Regarding the general health profile, the low prevalence of chronic comorbidities such as diabetes (1.4%) and hypertension (1.4%) indicates that the participants were relatively healthy from a systemic perspective. However, a significant 10.1% of the sample reported a history of COVID-19. Emerging literature has frequently cited "telogen effluvium" as a common post-viral sequela following COVID-19 infection, often occurring 2–3 months after recovery (22). While this study did not find a direct biochemical correlation, the historical presence of viral stress could be a confounding factor in the reported hair loss that transcends simple mineral or vitamin deficiencies. Despite the physiological significance of TSH, vitamin D, and ferritin, none of these biomarkers demonstrated a statistically significant linear

correlation with diffuse hair loss in the current sample. TSH levels showed a weak, non-significant negative correlation (r = -0.067, P-value = 0.173), suggesting that minor variations within the euthyroid range may not substantially impact hair cycles, consistent with findings by Rasheed et al. (23). Regarding vitamin D, although 85.5% of participants were deficient, the correlation was statistically insignificant (r = 0.054, P-value = 0.277), contradicting prior studies (24, 25). This discrepancy may arise from the lack of vitamin D receptor (VDR) analysis, which is more critical at the follicular level (26). Similarly, serum ferritin showed a negligible association (r = -0.004, P-value = 0.943), despite 49.3% of the sample having low levels. This aligns with recent evidence suggesting that ferritin must fall below 15–20 ng/mL to demonstrably impair hair growth (27-29). One of the most striking findings in this study was the overwhelming prevalence of vitamin D deficiency, affecting 85.5% of the participants. Despite this widespread deficiency, the correlation with hair loss was statistically insignificant (P-value = 0.277), leading to the acceptance of the null hypothesis (H_{01}). This result presents a paradox when compared to several international studies that have linked low vitamin D levels to various forms of alopecia, including telogen effluvium and female pattern hair loss (30, 31). Several factors may explain this lack of correlation. First, vitamin D deficiency is known to be endemic in North African and Middle Eastern regions due to factors such as limited sun exposure, dietary habits, and traditional clothing styles (32). Furthermore, recent molecular research suggests that the Vitamin D Receptor (VDR) expression at the follicular level is more critical for the hair growth cycle than the circulating serum levels of 25-hydroxyvitamin D (33). Similarly, the analysis of serum ferritin revealed a high prevalence of low iron stores, with 49.3% of the participants falling below the normal range. Iron deficiency is a well-documented cause of impaired hair growth, as iron is a cofactor for ribonucleotide reductase (27). However, this study found no significant correlation between ferritin levels and hair loss (P-value = 0.943), resulting in the acceptance of the null hypothesis (H_{02}). This finding aligns with evidence suggesting that hair loss only manifests when ferritin levels drop below a specific "critical threshold". While many laboratories define the lower limit of normal ferritin at 10–15 ng/mL, several dermatological studies suggest that a level of at least 70 ng/mL is required for optimal hair regrowth (29, 28). Moreover, the body prioritises iron distribution to essential functions like erythropoiesis over non-essential appendages like hair, meaning hair loss might be a late-stage symptom (34). The thyroid function analysis showed that 95.7% of the participants were euthyroid. The weak and insignificant negative correlation (r = -0.067, P-value = 0.173) led to the acceptance of the null hypothesis (H_{03}). Thyroid hormones (T3 and T4) are known to directly stimulate hair follicle proliferation and pigmentation (35). Since the vast majority of the sample maintained normal TSH levels, it is logical that thyroid dysfunction was not a primary driver of hair loss in this specific group. This suggests that for the women of Tarhuna, hair loss is likely driven by non-hormonal factors or pathways not involving the thyroid gland, such as hyperandrogenism or elevated cortisol due to stress (36). The lack of linear correlation suggests that alopecia in this cohort is likely multifactorial. Beyond the markers studied, other variables such as zinc deficiency, biotin levels, protein-energy malnutrition, and psychological stress must be considered (37). The findings of this cross-sectional study present a significant clinical paradox: while there is an exceptionally high prevalence of vitamin D deficiency (85.5%) and iron depletion (49.3%) among women in Tarhouna, these biochemical markers showed no statistically significant correlation with the incidence of diffuse hair loss. This lack of association, which contradicts several international studies, necessitates a deeper interpretation considering the unique regional, environmental, and lifestyle-related factors specific to the Libyan population. The overwhelming prevalence

of Vitamin D deficiency (85.5%) suggests that low serum levels have become a "population baseline" in Tarhouna rather than a distinguishing variable. In such a homogenous sample where the vast majority are deficient, the statistical power to detect a correlation with hair loss is significantly diminished a phenomenon known as the "ceiling effect" in epidemiological research (38). From a regional perspective, the sunny climate of Libya does not necessarily translate to adequate vitamin D synthesis. In Tarhouna and similar Libyan cities, cultural and religious practices, specifically the use of the hijab and conservative clothing, drastically limit the skin's surface area exposed to UV-B radiation (39). Furthermore, the extreme heat during summer months encourages an indoor-centric lifestyle and the avoidance of direct sunlight during peak hours. Studies in neighbouring regions have shown that even among women with normal outdoor activities, the dietary intake of vitamin D is insufficient to compensate for limited cutaneous synthesis, leading to chronic subclinical deficiency that may not be the primary trigger for acute hair shedding in this specific cohort (40). The high rate of low serum ferritin (49.3%) underscores a critical public health issue. In Libya, dietary habits play a central role; the high consumption of black tea immediately after meals—a common social practice—is known to inhibit non-heme iron absorption due to the high tannin content (41). Despite this, the lack of correlation ($P = 0.943$) between ferritin and hair loss suggests that the hair follicle in this population might be adapted to lower iron stores or that other compensatory mechanisms are at play. Another interpretation is that diffuse hair loss in these women might be more closely linked to "Chronic Telogen Effluvium" (CTE), which often persists regardless of iron correction if the underlying trigger is multifactorial, such as emotional stress or rapid changes in metabolic state (42). The physiological stress induced by the recent COVID-19 pandemic (reported by 10.1% of our sample) could be a more dominant, albeit transient, driver of hair loss that masks the effects of nutritional deficiencies. The genetic landscape of the Libyan population cannot be overlooked. Libya has one of the higher rates of consanguineous marriages in the region, which increases the prevalence of polygenic traits, including Female Pattern Hair Loss (FPHL) (43). If a significant portion of the "diffuse hair loss" reported is actually early-stage FPHL, its progression is driven primarily by androgen sensitivity and genetic susceptibility rather than TSH or vitamin D levels. This would explain why correcting nutritional markers often fails to arrest hair thinning in some clinical settings in Libya (44). Environmental stressors specific to Tarhouna may also contribute to the results. The quality of domestic water in Libya, often characterized by high salinity and mineral content (hard water), can physically damage the hair shaft and increase breakage, which patients may perceive as "hair loss" from the root (45). Furthermore, the dry, semi-arid climate of the region can lead to increased hair fragility. In such cases, the "hair loss" is exogenous rather than a systemic physiological result of low ferritin or vitamin D, further explaining the lack of biochemical correlation found in our study (46).

- **Strengths and Limitations:** A major strength of this study is the large sample size (N= 414), which provides significant statistical power to the findings. However, the study is limited by its cross-sectional design, which captures only a snapshot in time. Longitudinal studies would be more effective in tracking how changes in vitamin D or ferritin levels over time influence the hair cycle. Additionally, the study did not include a control group of women without hair loss, which would have allowed for a more robust comparative analysis.

Conclusion: In light of the findings derived from this study of 414 women in Tarhuna, Libya, it can be concluded that while biochemical deficiencies—specifically vitamin D (85.5%) and

serum ferritin (49.3%)—are remarkably prevalent, they do not function as isolated primary predictors of diffuse hair loss in this cohort. The demographic analysis reveals a relatively robust health profile among participants, with over 95% of the sample maintaining a status free from chronic metabolic comorbidities such as diabetes and hypertension. However, the notable 10.1% prevalence of COVID-19 history suggests a potential post-viral influence that may contribute to the clinical presentation of alopecia independently of nutrient status. Furthermore, the absence of a statistically significant linear correlation between thyroid function (TSH), vitamin D, or ferritin levels and the incidence of hair loss leads to the acceptance of the null hypotheses. This suggests that the pathophysiology of diffuse hair loss in this population is inherently multifactorial and likely involves complex biological mechanisms that transcend simple serum concentrations. The low rate of pharmacological intervention (4.3%) further underscores that many cases may be in early stages or managed through non-clinical pathways, emphasizing the need for a more nuanced understanding of how endemic deficiencies interact with other physiological and environmental triggers. Our results suggest that while Vitamin D and ferritin are vital for overall health, they are not the sole or primary determinants of hair loss in the women of Tarhouna. The "normalcy" of deficiency in this region suggests that clinicians must look beyond standard blood panels. A holistic approach that includes genetic screening, psychological assessment, and an evaluation of environmental exposures (like water quality and hair care habits) is essential for effective management.

Recommendations: To address the complexities identified in this study and to optimize clinical outcomes, the following recommendations are proposed:

- Integrated Diagnostic Paradigms: Clinical practitioners should move beyond traditional supplementation-based models. A holistic diagnostic approach is essential, incorporating comprehensive hormonal profiling, nutritional screenings, and detailed patient histories that account for systemic stressors or prior viral infections.
- Methodological Advancements in Research: Future investigations should prioritize prospective longitudinal designs to monitor the dynamic interplay between biomarkers and hair follicle cycles over time. The integration of objective diagnostic tools, such as trichoscopy or histopathological biopsy, is crucial to quantify hair density and shedding more accurately.
- Refinement of Clinical Thresholds: There is a critical need to re-evaluate standard laboratory "normal" ranges for ferritin and vitamin D in the context of dermatology. Establishing more specific, evidence-based thresholds for hair health would enhance the sensitivity and specificity of clinical assessments.
- Expansion of the Biomarker Spectrum: Research should be broadened to encompass a wider array of potential contributors, including trace elements (zinc, copper), vitamins (B12, biotin), and stress-related hormones (cortisol, androgens), to map the complete biochemical landscape of alopecia.
- Environmental and Genetic Synthesis: Further exploration into the genetic predispositions and environmental factors unique to the Libyan context is warranted. Investigating the molecular role of the Vitamin D Receptor (VDR) may provide the missing link between widespread serum deficiency and its varied clinical manifestations in hair health.

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Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.