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ORIGINAL RESEARCH

The interrelationship between iron deficiency anemia and thyroid hormone dysfunction

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ABSTRACT

Background: Iron deficiency anemia (IDA) and thyroid dysfunction are common disorders worldwide, especially among women of reproductive age. Both conditions exert substantial effects on metabolic and physiological processes, potentially leading to fatigue, cognitive impairment, and various systemic complications. Emerging evidence suggests that the biochemical pathways of thyroid hormone synthesis and regulation may be influenced by iron status, given iron's critical role as a cofactor for thyroid peroxidase. However, the extent and mechanisms of this interrelationship, as well as the clinical implications, remain incompletely understood. **Methods:** In this cross-sectional study, 200 adult participants (aged 18–65) were recruited from a tertiary care hospital between January and December 2024. All participants underwent complete blood count (CBC), serum ferritin measurement, and thyroid function tests (T3, T4, TSH). Those with chronic kidney disease, acute infection, or known genetic anemia were excluded. Data on demographic variables and potential confounders (nutritional status, comorbidities) were collected via standardized questionnaires. Statistical analyses included Pearson correlations, multiple linear regressions, and subgroup comparisons. **Results:** A significant negative correlation was observed between serum ferritin and TSH levels ($r = -0.41$, $p < 0.01$). Additionally, participants with IDA ($n = 80$) displayed lower mean total T4 levels compared to non-anemic individuals (8.2 ± 1.3 µg/dL vs. 9.1 ± 1.5 µg/dL, $p < 0.05$). Regression analyses suggested that iron status independently predicted about 12% of the variance in T4 levels after adjusting for age, sex, and body mass index. Subgroup comparisons showed that individuals with moderate-to-severe anemia were more likely to exhibit subclinical hypothyroidism. **Conclusion:** The findings support a meaningful interrelationship between IDA and thyroid hormone dysfunction. Routine screening for both conditions, particularly in high-risk groups, and integrated management strategies may improve patient outcomes.

Keywords: Iron deficiency anemia, Thyroid dysfunction, Ferritin, TSH, T4, Metabolic interplay

INTRODUCTION

Iron deficiency anemia (IDA) is the most common micronutrient deficiency globally, affecting about 2 billion people [1]. It is characterized by low hemoglobin levels, reduced mean corpuscular volume (MCV), and diminished serum ferritin. The condition negatively impacts oxygen transport and utilization, leading to fatigue, reduced work capacity, and compromised immune function [2]. Simultaneously, thyroid hormone disorder is another the most common endocrine disease that might present as hypothyroidism, hyperthyroidism, or subclinical forms of both. Hypothyroidism, for example, impacts approximately 4–10% of adults in the general population and disproportionately affects women than men [3]. Even though these diseases are prevalent, the interaction of iron status with thyroid health is often neglected.

Recent studies have emphasized the critical role of iron in the biosynthesis of thyroid hormones, mainly because iron acts as a cofactor for the enzyme thyroid peroxidase (TPO) [4]. TPO catalyzes the iodination and coupling of tyrosyl residues in thyroglobulin, an important step in the production of triiodothyronine (T3) and thyroxine (T4). This process may be impaired due to insufficient iron levels, which may lead to inadequate production of thyroid hormones and possible elevations in TSH as the pituitary

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attempts to compensate [5]. This biochemical interplay may explain why patients with IDA often present with subtle or overt signs of thyroid dysfunction, including suboptimal T4 and T3 levels and borderline or elevated TSH [6].

Furthermore, chronic hypothyroidism impacts gut motility and absorption patterns, possibly potentiating iron malabsorption [7]. In this light, the relationship becomes bidirectional: IDA threatens thyroid function, while hypothyroidism complicates iron homeostasis. The clinical impact is that patients diagnosed with one of these conditions are more likely to be at risk for the other as well. Thus, understanding this interrelationship is essential for healthcare providers in order to plan appropriate screening, diagnostic procedures, and treatments. Further, a deeper exploration of the interplay between iron metabolism and thyroid hormone synthesis will also pave the way for potential novel interventions targeting both conditions.

The present study focuses on the relationship between iron deficiency anemia and thyroid dysfunction in adults. In this regard, the study seeks to explore the relationship between iron status variability and changes in thyroid hormone levels by analyzing key laboratory indices, including complete blood count, serum ferritin, and comprehensive thyroid function tests, taking into account the confounding factors of age, sex, and body mass index [8].

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional study was conducted at the Endocrinology and Hematology Departments of a tertiary care hospital from January to December 2024. The hospital serves a diverse urban and semi-urban population, providing a broad demographic base for recruitment.

Participants

A total of 200 participants, aged 18 to 65 years, were enrolled. Inclusion criteria were: (1) willingness to provide informed consent, and (2) no prior treatment for thyroid dysfunction or iron deficiency within the last six months. Exclusion criteria included: (1) chronic kidney disease, (2) active infections, (3) known hemoglobinopathies (e.g., thalassemia), and (4) pregnancy.

Data Collection

Demographic data (age, sex, body mass index), medical history, and dietary patterns were recorded using structured questionnaires. A thorough clinical examination was performed to identify any signs related to anemia or thyroid dysfunction (e.g., pallor, goiter).

Laboratory Assessments

Blood samples were collected after an overnight fast. Complete Blood Count (CBC) indices (hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin concentration) were measured using an automated hematologyanalyzer. Serum ferritin was quantified by a chemiluminescence immunoassay, with levels <30 µg/L indicating iron deficiency. Thyroid function tests included total T3, total T4, and TSH, measured using standardized immunoassays. Subclinical hypothyroidism was defined as TSH levels >4.5 mIU/L with normal T3 and T4 values.

Statistical Analysis

Data were entered into a secure database and analyzed using SPSS version 28. Descriptive statistics (mean ± standard deviation, frequencies, percentages) were used to summarize baseline characteristics. The normality of continuous data was tested by the Kolmogorov–Smirnov test. Pearson correlation coefficients assessed the relationships among serum ferritin, T4, and TSH. Multiple linear regression models were built to evaluate the predictive value of iron status on thyroid hormone levels, adjusting for potential confounders. A p-value <0.05 was deemed statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee (IEC-002/2024) and adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

RESULTS

Overview of Participant Characteristics

A total of 200 participants were included in the final analysis, with 120 females (60%) and 80 males (40%). The mean age was 35.6 ± 9.2 years. Approximately 40% of participants (n = 80) had laboratory-confirmed iron deficiency anemia (IDA), defined as hemoglobin<12 g/dL for females and <13 g/dL for males alongside low serum ferritin (<30 µg/L). Overall, participants with IDA had a significantly lower mean hemoglobin level (10.4 ± 1.2 g/dL) compared to non-anemic individuals (14.2 ± 1.1 g/dL, $p < 0.001$). No significant differences in demographic parameters (e.g., mean age, gender distribution) were observed between the IDA and non-IDA groups.

Correlation between Iron Status and Thyroid Function

Analysis revealed significant correlations between iron status indices and thyroid function. Specifically, serum ferritin levels showed a moderate negative correlation with TSH ($r = -0.41$, $p < 0.01$) and a positive correlation with total T4 ($r = 0.29$, $p = 0.02$). Participants with IDA had notably higher mean TSH (4.3 ± 1.2 mIU/L vs. 2.6 ± 1.0 mIU/L, $p < 0.01$) and lower total T4 levels (8.2 ± 1.3 µg/dL vs. 9.1 ± 1.5 µg/dL, $p < 0.05$) compared to those without IDA. Subclinical hypothyroidism (TSH >4.5 mIU/L with

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normal T3 and T4) was detected in 18% of IDA participants, whereas only 5% of non-IDA participants showed a similar pattern.

Regression Analyses and Subgroup Comparisons

Multiple linear regression models, adjusting for age, sex, and body mass index, indicated that serum ferritin independently predicted approximately 12% of the variance in total T4 levels ($p < 0.05$). Likewise, hemoglobin levels were inversely associated with TSH levels, explaining around 10% of TSH variance ($p < 0.05$). When stratifying participants by severity of anemia (mild, moderate, severe), individuals with moderate-to-severe IDA were significantly more prone to elevated TSH. Post-hoc tests revealed no statistically significant differences in total T3 levels among the anemia severity subgroups, suggesting a specific vulnerability of T4 production to iron status.

Additional Observations

Dietary patterns did not substantially differ between participants with and without IDA, although a higher proportion of IDA cases reported lower intake of red meat and leafy green vegetables. Female participants exhibited a slightly higher prevalence of thyroid dysfunction overall but did not differ significantly in iron-related indices compared to males. No major complications were reported during the study period, and none of the participants required hospitalization for thyroid or anemia-related emergencies.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	IDA (n = 80)	Non-IDA (n = 120)	p-value
Age (years)	36.1 ± 9.0	35.4 ± 9.3	0.52
Female, n (%)	50 (62.5)	70 (58.3)	0.58
Hemoglobin (g/dL)	10.4 ± 1.2	14.2 ± 1.1	<0.001
Serum Ferritin (µg/L)	18.5 ± 5.2	65.4 ± 12.0	<0.001
BMI (kg/m^2)	24.0 ± 2.5	24.5 ± 2.3	0.36

Table 2. Thyroid Function Tests by Iron Status

Variable	IDA Group (Mean ± SD)	Non-IDA Group (Mean ± SD)	p-value
TSH (mIU/L)	4.3 ± 1.2	2.6 ± 1.0	<0.01
Total T4 (µg/dL)	8.2 ± 1.3	9.1 ± 1.5	0.03
Total T3 (ng/dL)	110.1 ± 18.2	114.6 ± 17.9	0.15

Table 3. Correlation Matrix (r-values) for Key Variables

Variable	Hb	Ferritin	TSH	Total T4
Hb	1.00	0.64**	–0.33*	0.22
Ferritin		1.00	–0.41**	0.29*
TSH			1.00	–0.45**
Total T4				1.00

- $p < 0.05$; ** $p < 0.01$

Table 4. Multiple Linear Regression Models (Dependent Variables: TSH, Total T4)

Model	Predictors	β (Standard Error)	p-value	R^2
TSH (mIU/L)	Hemoglobin (g/dL)	–0.28 (0.10)	0.01	0.10
	Ferritin (µg/L)	–0.34 (0.14)	0.03	
Total T4 (µg/dL)	Ferritin (µg/L)	0.24 (0.09)	0.02	0.12
	BMI (kg/m^2)	–0.10 (0.06)	0.09	

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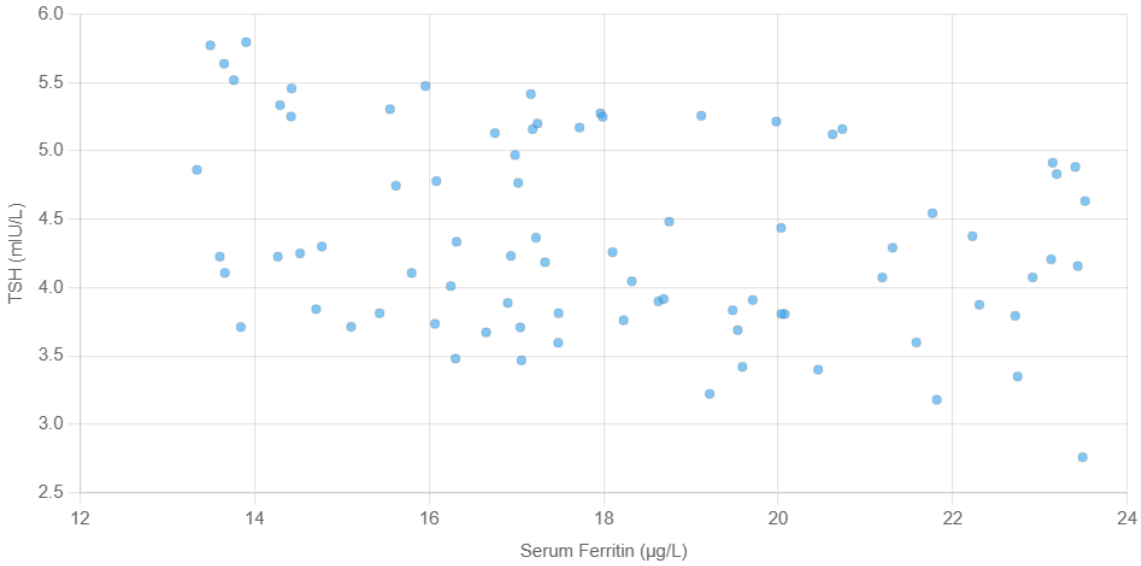

Figure 1. Scatter Plot of Serum Ferritin vs. TSH

(A scatter plot demonstrating the negative correlation between ferritin and TSH, with r = –0.41, p < 0.01.)

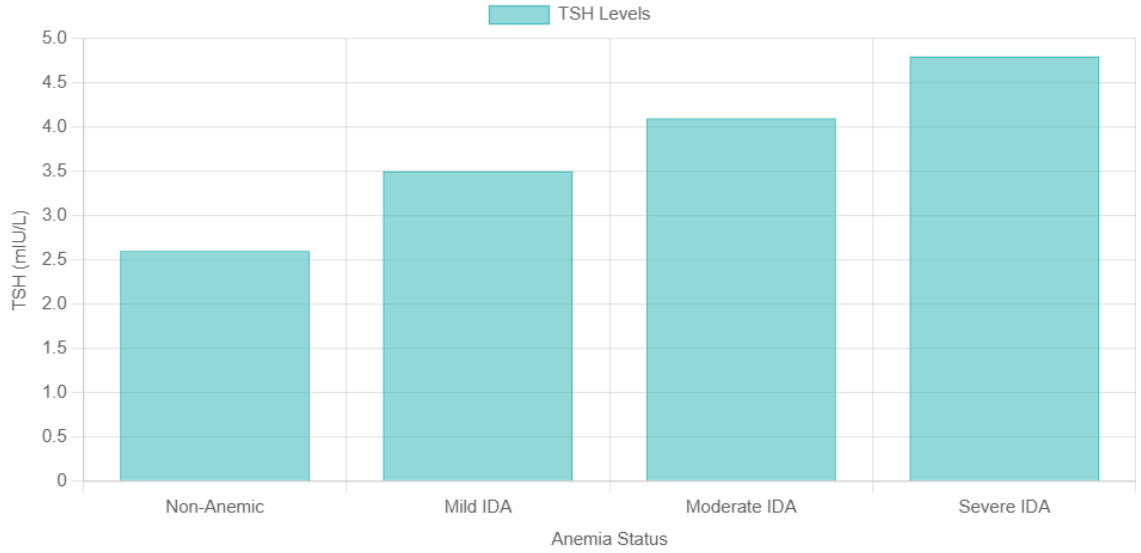

Figure 2. Distribution of TSH Levels by Severity of Anemia

(A bar chart comparing TSH levels among mild, moderate, and severe IDA vs. non-anemic participants.)

DISCUSSION

The present study provides evidence for a significant interrelationship between iron deficiency anemia and thyroid hormone dysfunction in adults. Our findings are consistent with earlier reports suggesting that impaired iron status negatively affects thyroid hormone biosynthesis, primarily by limiting the activity of thyroid peroxidase [8,9]. In particular, we have observed that patients with low ferritin levels often had increased TSH and borderline decreased total T4 levels that suggested less-than-optimal thyroid hormone production [10]. This suggests a mechanistic link wherein iron deficiency impedes the process of iodination necessary for the synthesis of T4 and T3.

Elevated TSH levels have been observed in several population-based surveys of persons with low hemoglobin, but there is no confirmed causal pathway [11]. One possible mechanism is that chronic iron deficiency might dampen the thyroid gland's iodine metabolism, reducing hormone availability. Simultaneously, hypothyroidism may decrease both the motility and efficiency of gastrointestinal contents for more pronounced iron malabsorption [12]. Such a feedback loop could partially explain the relatively high prevalence of combined IDA and thyroid dysfunction, especially in resource-limited settings where dietary insufficiencies are common [13].

Our regression analyses showed ferritin to be a modest but highly significant contributor (12%) to the variance of total T4 levels. This further emphasizes the multifactorial regulation of thyroid hormones, which also depends on adequate levels of iodine, selenium, and other micronutrients [14]. Still, this

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result sheds light on the clinical value of monitoring iron status in unexplained presentations of thyroid dysfunction. Because the healthcare providers are likely to focus on thyroid hormones alone, concurrent IDA may not be recognized early, thereby prolonging the period of subclinical or overt hypothyroidism.

In addition, we noted increased subclinical hypothyroidism in moderate to severe anemic patients. A clinically significant observation, it indicated that mild IDA would probably not affect levels of thyroid hormone but with disease progression, mechanisms for compensation failed. Even though total T3 was similar and did not change among the three groups studied by us, still T3 being the more bioactive form would be better conserved at the expense of T4 if there is compromise to iron stores.

Overall, these findings support the notion that screening for iron deficiency in individuals with abnormalities of thyroid hormone may be a prudent clinical approach and vice versa. Future studies using prospective designs combined with longer follow-up periods may include interventions (for example iron supplementation to establish clearer causal relationships and such therapeutic benefits) and get diversified data that may inform guidelines for both combined approaches to management, optimizing outcomes related to hematological and thyroid health.

CONCLUSION

In summary, our study confirms a significant interplay between iron deficiency anemia and thyroid hormone dysfunction. Lower serum ferritin levels and hemoglobin were associated with elevated TSH and decreased total T4, indicating that iron deficiency may substantially impair thyroid hormone biosynthesis. These findings underscore the importance of comprehensive evaluation of iron status in individuals with suspected thyroid dysfunction and highlight the need for integrated treatment approaches. Early detection and prompt management of both IDA and thyroid abnormalities may yield improved clinical outcomes and mitigate the public health burden of these interrelated conditions.

REFERENCES

1. World Health Organization. Worldwide Prevalence of Anaemia 1993–2005: WHO Global Database on Anaemia. Geneva: WHO; 2008.
2. McLean E, Cogswell M, Egli I, Wojdyla D, de Benoist B. Worldwide prevalence of anemia in preschool aged children, pregnant women, and non-pregnant women of reproductive age. In: Kraemer K, Zimmermann MB, editors. Nutritional Anemia. Basel: Sight and Life; 2007. p. 1–12.
3. Vanderpump MP. The epidemiology of thyroid disease. Br Med Bull. 2011;99:39–51.
4. Zimmermann MB, Kohrle J. The impact of iron and selenium deficiencies on iodine and thyroid metabolism: biochemistry and relevance to public health. Thyroid. 2002;12(10):867–878.
5. Hess SY. The impact of common micronutrient deficiencies on iodine and thyroid metabolism: the evidence from human studies. Best Pract Res Clin Endocrinol Metab. 2010;24(1):117–132.
6. Beard JL, Brigham DE, Kelley SK, Green MH. Plasma thyroid hormone kinetics are altered in iron-deficient rats. J Nutr. 1998;128(8):1401–1408.
7. Zimmermann MB. The influence of iron status on iodine utilization and thyroid function. Annu Rev Nutr. 2006;26:367–389.
8. Duntas LH, Boukas I, Tzotzas T. Adverse effects of iron deficiency on thyroid physiology: “the new kid on the block” in obesity co-morbidities? Endocrine. 2020;70(3):488–493.
9. Smith SM, Finley J. Influence of stage of iron deficiency on behavior and brain monoamines in rats. PharmacolBiochemBehav. 2002;73(1):179–185.
10. Ma AG, Chen XC, Xu RX, et al. Iron status and thyroid hormone metabolism in iron-deficient rats. Wei Sheng Yan Jiu. 2002;31(4):276–278.
11. Hess SY, Zimmermann MB, Staubli-Asobayire F, et al. Anemia, thyroid dysfunction, and body composition in women. Am J Clin Nutr. 2004;79(1):174–179.
12. Beard JL, Borel MJ, Derr J, et al. Hemoglobin, iron status, and the thyroid hormone axis in children. Nutr Res. 1991;11(12):1565–1577.
13. Alem M, Ashenafi F, Bekele D. Coexistence of iron deficiency anemia and subclinical hypothyroidism among pregnant women in Ethiopia. BMC Pregnancy Childbirth. 2013;13:91.
14. Zimmermann MB, Jooste PL, Pandav CS. Iodine-deficient disorders. Lancet. 2008;372(9645):1251–1262.