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Original Article

Relation between Thyroid Function and Iron Deficiency Anemia in Primary School-Age Children: A Controlled Cross-Sectional Study

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ABSTRACT

Background: Iron deficiency anemia [IDA] is a very common medical condition affecting primary school-age children, with several unfavorable consequences. There are some reports pointing to a possible effect of IDA on thyroid gland function.

Aim of the work: To assess thyroid function in primary school age children in Damietta Governorate, Egypt with iron deficiency anemia and to investigate potential related risk factors.

Patients and Methods: A controlled cross-sectional study included 100 primary school age children [age: 6-12 years]; 50 children with iron deficiency anemia [case group], and 50 healthy age- and sex-matched children [control group]. Complete blood count, serum iron, serum ferritin and thyroid hormone profile [thyroid stimulating hormone [TSH], free triiodothyronine [FT3] and free thyroxine [FT4] were analyzed for all children.

Results: In the case group, compared to the control group, there was a significantly higher TSH level [2.77±1.30 vs. 2.10±1.11; P=0.006] and lower FT3 [3.22±0.82 vs. 3.61±0.69; P=0.011]. The frequency of hypothyroid status [both overt and subclinical] was elevated in the case group [24% vs. 6%; P=0.02]. There was a significant negative correlation between TSH with both serum iron [P=0.019] and ferritin [P=0.009].

Conclusion: Iron deficiency anemia, especially when serum ferritin and iron are very low, in primary school children is associated with liability to get subclinical hypothyroidism.

Keywords: Thyroid; Primary school age; Egyptian; Iron deficiency; Anemia

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* Main subject and any subcategories have been classified according to the research topic

INTRODUCTION

The condition of iron deficiency [ID] and subsequent iron deficiency anemia [IDA] are common medical disorders that occur almost in every country in the world [1].

Iron deficiency anemia affects about 40% of children within the school age in developing countries [2]. It is a major health problem in Egypt, as the prevalence of iron deficiency anemia among school children reported as 35.3% [3].

There is a growing body of evidence that iron deficiency can result in symptoms and signs unrelated to anemia itself and can be associated with a diversity of diseases [4]. One of the major concerns is the effect of IDA on thyroid function [5].

The function of the thyroid gland is critical for the control of metabolic activity within the human body [6]. In addition, it plays an essential role in the growth and development of children as well as, in the maturation of the central nervous system [7]. Adequate thyroid function relies on the existence of many trace elements, which are necessary for the production and metabolism of thyroid hormones

In patients with IDA, thyroid function may be affected through several mechanisms; iron deficiency can impair thyroid metabolism [9] that can be attributed to the iron-dependent haem-containing thyroid peroxidase [TPO] enzyme [10], which is accountable for the oxidation of iodide into iodine, and its organification into tyrosine residues of thyroglobulin to form Mono-Iodotyrosine [MIT] or Di-Iodotyrosine [DIT] [11]. Furthermore, TPO is a principal for the formation of T_3 [by the coupling of one molecule of MIT and one molecule of DIT], and T_4 [by the coupling of two DIT molecules] [12].

Several studies have investigated the association between thyroid function with iron status among school children, with conflicting results [12-15]. Although iodine nutrition continues to improve worldwide, thyroid dysfunction is still frequently reported in school-age children [13].

AIM OF THE WORK

Since ID and IDA are highly prevalent among school-age children, assessment of thyroid function is critical to avoid the potential consequences on cognitive and intellectual function of these children.

The aim of the present study is to look for the possible effects of iron deficiency on thyroid function in primary school children in Damietta governorate, and to investigate potential risk factors for thyroid dysfunction.

PATIENTS AND METHODS

A comparative cross-sectional study that included 100 primary school-age [6-12 years] children recruited from Pediatric outpatient clinic of Al-Azhar University Hospital [New Damietta]. Included children divided into two groups; 50 children with iron deficiency anemia [case group], and 50 age- and sex-matched apparently healthy children [control group]. The study was conducted during the period from April 2020 until end of December 2020.

Anemia was diagnosed in this age group when hemoglobin [HB] is < 11.5 gm/dl. Iron deficiency was diagnosed when there is microcytic [mean corpuscular volume [MCV] < 76 fl] hypochromic [mean corpuscular hemoglobin [MCH] < 25 pg] anemia, simultaneously with serum ferritin < 20 µg/l and/or serum iron < 40 µg/dl [16].

Children with other associated anemia, with acute illness or chronic diseases, having a recent history of blood transfusion or iron therapy during the past four months, children with known thyroid disorder, receiving thyroid hormones, or having family history of thyroid diseases were excluded from the study.

A systematic approach to symptoms of thyroid gland dysfunction was employed. Considered symptoms of hypothyroid dysfunction include weight gain, cold intolerance, easy fatigability, hoarseness of voice, constipation and mood impairment [17].

The following investigations were done: complete blood count, serum iron, serum ferritin, thyroid stimulating hormone [TSH], free thyroxine [FT_4], free triiodothyronine [FT_3].

Laboratory analysis

Blood samples [3 ml of venous blood] were collected under complete aseptic conditions. The sample was divided to 2 portions; an aliquot was added to EDTA tube for the measurement of complete blood count, and the other part left to clot for 30 minutes, then centrifugation was allowed for 15 minutes at 3000 rpm, then stored at -20°C till time of biochemical analysis. Complete blood count [CBC] was analyzed using a coulter MAXM [Coulter Corporation]. Serum iron, ferritin and total iron-binding capacity [TIBC] were analyzed using Cobas C311 analyzer [Roche, Switzerland].

For analysis of thyroid function tests, a commercially available ELISA kit was used. Serum FT_3 and FT_4 were analyzed by using “solid phase competitive assay method”. TSH was analyzed using “a solid phase sandwich assay

method". All thyroid function tests were equipped by [Calbiotech Inc., Austin Dr, CA].

The normal reference range for TSH=0.4–4.0 µIU/mL, for FT3=1.71-4.8 pg/mL and for FT4= 0.89–1.76 ng/dl. Primary [overt] hypothyroidism defined as TSH > 4.0 µIU/ml [0.4–4.0] and free thyroxine [FT_4] levels < 0.89 ng/dl [0.89–1.76 ng/dl]. Subclinical hypothyroidism is defined when there is an elevated TSH with normal free T_4 [18].

Ethical considerations: Oral consent was obtained from the parents of all Patients of the study. The study had been approved by the local ethics committee on research involving human subjects of Damietta Faculty of Medicine, Al-Azhar University. The approval of IRB was obtained.

Statistical analysis: The data were evaluated using "statistical package for social sciences version 19 [SPSS Inc, Chicago, USA]", running on IBM compatible computer. Normality tests were checked using "Shapiro-Wilk's test". "Chi-square test" or "Fisher's exact test" were used for comparing categorical variables. "Independent two-sample t –test" or "Mann-Whitney-U test" were applied to compare continuous variables. Pearson's r correlation co-efficient was used for correlating parametric continuous variables. Spearman's ρ [rho] correlation co-efficient was used for correlating ordinal and non-parametric variables. For all tests, P values < 0.05 were considered significant.

RESULTS

No significant difference between both groups as regards demographic features and anthropometric measures. The most frequent clinical findings among the case group were easy fatigability, mood impairment and constipation. The frequency of easy fatigability was significantly higher among the case group [28% vs. 10%; P=0.039] [table 1].

Hematological profile proved the existence of IDA among the case group. Regarding thyroid hormones, there was a statistically significant higher TSH level [2.77±1.30 vs. 2.10±1.11; P=0.006] and lower FT_3 [3.22±0.82 vs. 3.61±0.69; P=0.011] in the case group, compared to the control group. Mean FT4 was lower in the case group, but without a statistically significant difference [1.29±0.45 vs. 1.42±0.25; P=0.082] [table 2].

The frequency of hypothyroidism [both overt and subclinical] was significantly elevated in the case group [24% vs. 6%; P=0.02] [table 3].

There was no relation between thyroid status and any of the studied demographic [age, sex and residence] and anthropometric data [weight and height]. There was a significant increase in the frequency of easy fatigability [58% vs. 18%; P=0.022] and mode impairment [50% vs. 16%; P=0.024] among children with hypothyroidism, compared to euthyroid children. Furthermore, serum iron and ferritin were significantly lower among children with hypothyroidism, compared to children with euthyroidism [for ferritin: 15.45±4.16 ng/ml vs. 11.58±5.19 ng/ml; P= 0.011; for iron: 31.09±12.78 µg/dl vs. 21.45±8.41 µg/dl; P= 0.018] [table 4].

There was significant negative correlation between TSH with both serum iron [r: - 0.33, P= 0.019] and ferritin [r: -0.37, P= 0.009]. In addition, free T_3 had a significant positive correlation with serum ferritin [r: 0.29, P= 0.042] [table 5] and figure [1].

Table [1]: Comparison of demographic and clinical data between the study groups

Variables		Case group [n=50]	Control group [n=50]	P value
Age [years] [Mean ± SD]		8.21±1.75	8.24±1.98	0.94
Sex	Male	27 [54%]	30 [60%]	0.69
	Female	23 [46%]	20 [40%]	
Residence	Rural	31 [62%]	34 [68%]	0.67
	Urban	19 [38%]	16 [32%]	
Heart rate [beat/min] [Mean ± SD]		91.8 ± 16.5	86.2 ± 13.1	0.063
Weight percentiles [Mean ± SD]		52.5±23.6	48.4±21.3	0.38
Height percentiles [Mean ± SD]		45.1±19.7	39.6±17.2	0.14
Easy fatigability		14 [28%]	5 [10%]	0.039*
Mood impairment		12 [24%]	4 [8%]	0.054
Constipation		8 [16%]	3 [6%]	0.2
Disturbed sleep		4 [8%]	3 [6%]	1
Weight gain		4 [8%]	2 [4%]	0.68
Cold intolerance		3 [6%]	2 [6%]	1

*** = significant**

Table [2]: Comparison of laboratory findings between the study groups

Variables	Case group [n=50] Mean ± SD	Control group [n=50] Mean ± SD	P value
White blood cells [×10³/cm³]	8.24±2.12	7.79±1.95	0.27
Platelets [×10³/mmol]	264±85	239±101	0.18
Hemoglobin [g/dL]	9.25 ± 1.58	12.14 ± 1.13	**< 0.001***
Hematocrit [%]	28.76±4.04	35.51±3.56	**< 0.001***
MCV [fl]	64.12±5.32	79.24±3.14	**< 0.001***
MCH [pg/cell]	23.02±2.91	27.83±2.22	**< 0.001***
RDW [%]	16.26±2.45	13.78±1.22	**< 0.001***
Serum iron [µg/dl]	28.16±9.30	50.81±18.52	**< 0.001***
Ferritin [ng/mL]	14.18±4.47	43.12±15.04	**< 0.001***
TIBC [µg/dL]	433.1±48.2	310.6±52.9	**< 0.001***
TSH [µIU/ml]	2.77±1.30	2.10±1.11	**0.006***
Free T_3 [pg/ml]	3.22±0.82	3.61±0.69	**0.011***
Free T_4 [ng/dl]	1.29±0.45	1.42±0.25	0.082

* = significant; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; RDW, Red cell distribution width; TIBC, total iron-binding capacity; TSH, thyroid stimulating hormone.

Table [3]: Thyroid function status among the study groups

Thyroid status	Case group [n=50]	Control group [n=50]	P value
Euthyroidism	38 [76%]	47 [94%]	**0.02***
Hypothyroidism	12 [24%]	3 [6%]	
Hypothyroidism [n=12]			
Overt hypothyroidism	2 [4%]	0 [0%]	0.49
Subclinical hypothyroidism	10 [20%]	3 [6%]	0.071

* = significant

Table [4]: Comparison of demographic, clinical and laboratory data in relation to thyroid status among the case group

Variables		Euthyroidism [n=38]	Hypothyroidism [n=12]	P value
Age [years] [Mean ± SD]		8.34±1.65	7.94±2.17	0.50
Sex	Male	22 [58%]	5 [42%]	0.51
	Female	16 [42%]	7 [58%]	
Residence	Rural	22 [58%]	9 [75%]	0.33
	Urban	16 [42%]	3 [25%]	
Heart rate [beat/min] [Mean ± SD]		95.3 ± 16.7	86.4 ± 22.9	0.14
Weight percentiles [Mean ± SD]		50.4±28.3	59.8±20.1	0.29
Height percentiles [Mean ± SD]		46.9±23.7	43.5±17.4	0.65
Easy fatigability		7 [18%]	7 [58%]	**0.022***
Mood impairment		6 [16%]	6 [50%]	**0.024***
Constipation		5 [13%]	3 [25%]	0.38
Hemoglobin [g/dL] [Mean ± SD]		9.37 ± 1.52	8.84 ± 1.79	0.32
MCV [fl] [Mean ± SD]		67.05±6.17	`64.42±7.01	0.22
MCH [pg/cell] [Mean ± SD]		23.04±2.93	22.95±2.86	0.92
RDW [%] [Mean ± SD]		16.21±2.87	17.02±3.17	0.41
Serum iron [µg/dl] [Mean ± SD]		31.09±12.78	21.45±8.41	**0.018***
Ferritin [ng/mL] [Mean ± SD]		15.45±4.16	11.58±5.19	**0.011***
TIBC [µg/dL] [Mean ± SD]		425.6±51.3	458.4±62.5	0.07

* = significant; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; RDW, Red cell distribution width; TIBC, total iron-binding capacity.

Table [5]: Correlation between thyroid hormones with various demographic and laboratory variables

Variables	TSH		FT_4		FT_3	
	r/ρ	P	r/ρ	P	r/ρ	P
Age [years]	- 0.12	0.39	0.089	0.54	0.082	0.57
Heart rate [beat/min]	- 0.22	0.12	0.11	0.47	0.14	0.33
Hemoglobin [g/dl]	- 0.19	18	0.22	0.1	0.23	0.09
MCV [fl]	- 0.15	0.3	0.27	0.06	0.25	0.08
MCH [pg/cell]	- 0.20	0.16	0.13	0.39	0.17	0.23
RDW [%]	0.26	0.067	- 0.057	0.69	- 0.15	0.3
Serum iron [µg/dl]	- 0.33	**0.019***	0.23	0.09	0.27	0.06
Ferritin [ng/ml]	- 0.37	**0.009***	0.25	0.074	0.29	**0.042***
TIBC [µg/dL]	0.26	0.07	- 0.21	0.13	- 0.25	0.077

*: significant; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; RDW, Red cell distribution width; TIBC, total iron-binding capacity; TSH, thyroid stimulating hormone.

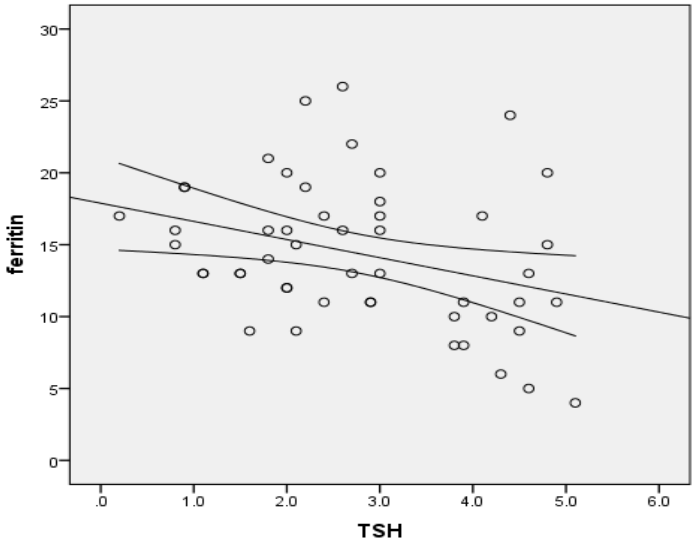

Figure (1): Correlation between serum ferritin and TSH among the case group

DISCUSSION

Both iron deficiency anemia and thyroid dysfunction have adverse consequences on cognitive function and may impair the learning abilities and acquisition of new skills, especially during childhood. The co-occurrence of both diseases in children will negatively impact their capabilities. An Egyptian study demonstrated that poor total intelligence quotient [IQ] in children with iron deficiency anemia was significantly correlated with thyroid dysfunction [5].

Health supervision and global screening programs are still major concerns in the developing world. Many children are out of reach proper medical care. There is an increasing need for addressing frequent medical issues, especially those with adverse impacts on the individual and national health, through conducting scientific research and establishing the current medical dilemmas within the community. Iron deficiency anemia and thyroid dysfunction are among the major concerns within the pediatric population and the relationship between them should be explored [19].

The age of studied children ranged from 6-12 years, and the mean age was 8.2 years. This mean shows a trend toward the lower limits of the range, which points to the association between IDA and early childhood [20].

Regarding sex distribution, males were more frequent [54%] than females, which agree with many reports. In the study by Khatiwada *et al.* [13], 55.5 % of studied iron-deficient anemic primary school children were males and 44.5 % were females. Also, El-Masry *et al.* [12] reported that, among 60 children, 34 were males [57%] and 26 [43%] were females. The majority of studied children were rural residents [62%], which come to an agreement with Al Ghwass *et al.* [21] who reported that rural areas were significant risk factors [P = 0.026] for IDA in Egypt.

The main finding of the study was illuminating the association between IDA and thyroid dysfunction. In the case group, there was statistically a significant higher TSH levels and lower FT3. Furthermore, the frequency of hypothyroid status [both overt and subclinical] was elevated in the case group with statistical significant difference.

An initial report has shown that iron therapy in children with goiter and IDA has been proved to enhance the effect of iodized oil intake, resulting in a gland reduction [22]. Likewise, Azizi *et al.* [23] found a relation between the frequency of goiter and low serum ferritin level among Iranian school children and stated that the occurrence of goiter was related to ID. In Egypt, Metwalley *et al.* [5] compared thyroid functions between 60 primary school children with IDA and 20 healthy children. In their study, TT_3 and TT_4 were significantly lower while TSH was higher in children with IDA compared to control. A cross-sectional study conducted among 227 children aged 6-12 years in Nepal, reported that 1.3% of children had overt hypothyroidism and 16.3% had subclinical hyperthyroidism. The relative risks of hypothyroidism in IDA and ID were 5.5 and 1.9, respectively. In a larger cohort of Nepali school children, low urinary iodine excretion was common in children with ID and IDA [24]. On the other hand, Tienboon and Unachak [14] reported no difference in thyroid hormone levels in children with IDA anemia before versus after iron therapy. Recently, Thapa *et al.* [15] found that the difference between the median TSH levels in children with IDA and iron sufficient group was not significant.

Iron deficiency can modify the production of thyroid hormones by several mechanisms; ID causes inefficient erythropoiesis, therefore decreasing oxygen transport to body tissues needed for various enzyme reactions [25]. ID also increases in-vitro hepatic reverse T_3 deiodination, suggesting the presence of inactivating metabolic routes for thyroid hormones [26]. Also, ID may lower TPO activity, interfering with the production of thyroid hormones [10]. Given the lack of TSH response due to a decrease in peripheral hormones, a recent study had suggested the implications of further hypothalamic pituitary mechanism [27]. For an explanation of our results, a combination of mechanisms may be relevant, as there is no other mechanism that fully explains the results found in our study.

In the present study, the occurrence of hypothyroidism was related to the severity of iron deficiency. Likewise, Khatiwada *et al.* [13] reported that hemoglobin level was negatively correlated with TSH [$P < 0.001$], but weakly correlated with FT_3 [$P= 0.249$] and FT_4 [$P= 0.787$]. Similar results are obtained by El-Masry *et al.* [12]. In contrast, Akhter *et al.* [28] demonstrated that serum ferritin had non-significant correlation with serum TSH. Also, both serum FT_4 and FT_3 revealed a non-significant positive correlation with serum ferritin.

In this work, children with hypothyroidism demonstrated higher frequency of easy fatigability and mode impairment. Thus, we suggest special caution for the observation for the presence of these symptoms among children with iron deficiency anemia. The need for a simple screening evaluation is of great importance in developing countries, where many people lack ease of access to continuous medical care.

The main limitation of the present study was the cross-sectional nature of the analyses, so we cannot infer causal mechanisms; however, the results may have clinical implications on the cognitive function of the included children. Also, we could not explore the effect of iron supplementation on the outcome of thyroid function. Furthermore, we did not analyze the total T_3 and Total T_4, thus the relationship between IDA and thyroid hormone binding could not be clarified.

CONCLUSION

The present study emphasized the association between IDA and thyroid dysfunction, especially the occurrence of subclinical hypothyroidism, and pointed to the potential influence of anemia severity on the incidence of thyroid dysfunction. These results warrant special attention to those children in order to avoid potential adverse consequences on cognitive and learning abilities.

Financial and Non-financial Relationships and Activities of Interest

None

REFERENCES

1. Camaschella C. New insights into iron deficiency and iron deficiency anemia. Blood Rev. 2017 Jul;31[4]:225-233. DOI: 10.1016/j.blre.2017.02.004.

2. Darlan DM, Ananda FR, Sari MI, Arrasyid NK, Sari DI. Correlation between iron deficiency anemia and intestinal parasitic infection in school-age children in Medan. Earth Environment Sci. 2018;125:012959. DOI :10.1088/1755-1315/125/1/012059.

3. Tawfik AA, Hanna ET, Abdel-Maksoud AM. Anemia and iron deficiency anemia in Egypt. IOSR J Pharm. 2015;5[4]:30-4.

4. DeLoughery TG. Iron Deficiency Anemia. Med Clin North Am. 2017 Mar;101[2]:319-332. DOI: 10.1016/j.mcna.2016.09.004.

5. Metwalley KA, Farghaly HS, Hassan AF. Thyroid status in Egyptian primary school children with iron deficiency anemia: Relationship to intellectual function. Thyroid Res Pract. 2013 Sep 1;10[3]:91-5. DOI:10.4103/0973-0354.116131.

6. Homuth G, Lietzow J, Schanze N, Golchert J, Köhrle J. Endocrine, Metabolic and Pharmacological Effects of Thyronamines [TAM], Thyroacetic Acids [TA] and Thyroid Hormone Metabolites [THM] - Evidence from in vitro, Cellular, Experimental Animal and Human Studies. Exp Clin Endocrinol

Diabetes. 2020 Jun;128[6-07]:401-413. DOI: 10.1055/a-1139-9200.

7. Davies KL, Camm EJ, Atkinson EV, Lopez T, Forhead AJ, Murray AJ, Fowden AL. Development and thyroid hormone dependence of skeletal muscle mitochondrial function towards birth. J Physiol. 2020 Jun;598[12]:2453-2468. DOI: 10.1113/JP279194.

8. Kravchenko VI, Andrusyshyna IM, Luzanchuk IA, Polumbryk MO, Tarashchenko YM. Association Between Thyroid Hormone Status and Trace Elements in Serum of Patients with Nodular Goiter. Biol Trace Elem Res. 2020 Aug;196[2]:393-399. DOI: 10.1007/s12011-019-01943-9.

9. Bobbili TKN, Kartheek VAS. Anaemia in patients with thyroid dysfunction. J Evid Based Med Healthc. 2020;7[47]:2757-2761. DOI: 10.18410/jebmh/2020/566.

10. Zhang Y, Huang X, Chen Z, Yang Q, Li X, Zhang R, *et al.* Iron Deficiency, a Risk Factor for Thyroid Autoimmunity during Second Trimester of Pregnancy in China. Endocr Pract. 2020 Jun 2;26[6]:595-603. DOI: 10.4158/EP-2019-0220.

11. Sachdeva A, Singh V, Malik I, Roy PS, Madaan H, Nair R. Association between serum ferritin and thyroid hormone profile in hypothyroidism. Int J Med Sci Public Health. 2015 Jun 1;4:863-5. DOI: 10.5455/ijmsph.2015.24012015174.

12. El-Masry H, Hamed AM, Hassan MH, Fayed HM, Abdelzaher MH. Thyroid Function among Children with Iron Deficiency Anaemia: Pre and Post Iron Replacement Therapy. J Clin Diagn Res. 2018 Jan 1;12[1]: BC01-BC05. DOI: 10.7860/JCDR/2018/32762.11023.

13. Khatiwada S, Gelal B, Baral N, Lamsal M. Association between iron status and thyroid function in Nepalese children. Thyroid Res. 2016 Jan 27;9:2. DOI: 10.1186/s13044-016-0031-0.

14. Tienboon P, Unachak K. Iron deficiency anaemia in childhood and thyroid function. Asia Pac J Clin Nutr. 2003;12[2]:198-202. PMID: 12810411.

15. Thapa S, Lamsal M, Sah SK, Chaudhari RK, Gelal B, Kunwar S, Baral N. Impact of Iron Status on Thyroid Function: A Community Based Cross-Sectional Study in Eastern Nepal. J College Med Sci-Nepal. 2019 May 21;15[1]:18-21. DOI: 10.3126/jcmsn.v15i1.21022.

16. Mantadakis E, Chatzimichael E, Zikidou P. Iron Deficiency Anemia in Children Residing in High and Low-Income Countries: Risk Factors, Prevention, Diagnosis and Therapy. Mediterr J Hematol Infect Dis. 2020 Jul 1;12[1]:e2020041. DOI: 10.4084/MJHID.2020.041.

17. Chaker L, Bianco AC, Jonklaas J, Peeters RP. Hypothyroidism. Lancet. 2017 Sep 23;390[10101]:1550-1562. DOI: 10.1016/S0140-6736[17]30703-1.

18. Leung AKC, Leung AAC. Evaluation and management of the child with hypothyroidism. World J Pediatr. 2019 Apr;15[2]:124-134. DOI: 10.1007/s12519-019-00230-w.

19. Wood SK, Sperling R. Pediatric Screening: Development, Anemia, and Lead. Prim Care. 2019 Mar;46[1]:69-84. DOI: 10.1016/j.pop.2018.10.008.

20. Oatley H, Borkhoff CM, Chen S, Macarthur C, Persaud N, Birken CS, *et al*. Screening for Iron Deficiency in Early Childhood Using Serum Ferritin in the Primary Care Setting. Pediatrics. 2018;142[6]:e20182095. DOI: 10.1542/peds.2018-2095.

21. Al Ghwass MM, Halawa EF, Sabry SM, Ahmed D. Iron deficiency anemia in an Egyptian pediatric population: a cross-sectional study. Ann Afr Med. 2015 Jan-Mar;14[1]:25-31. DOI: 10.4103/1596-3519.148725.

22. Zimmermann M, Adou P, Torresani T, Zeder C, Hurrell R. Iron supplementation in goitrous, iron-deficient children improves their response to oral iodized oil. Eur J Endocrinol. 2000 Mar;142[3]:217-23. DOI: 10.1530/eje.0.1420217.

23. Azizi F, Mirmiran P, Sheikholeslam R, Hedayati M, Rastmanesh R. The relation between serum ferritin and goiter, urinary iodine and thyroid hormone concentration. Int J Vitam Nutr Res. 2002 Oct;72[5]:296-9. DOI: 10.1024/0300-9831.72.5.296.

24. Khatiwada S, Lamsal M, Gelal B, Gautam S, Nepal AK, Brodie D, Baral N. Anemia, Iron Deficiency and Iodine Deficiency among Nepalese School Children. Indian J Pediatr. 2016 Jul;83[7]:617-21. DOI: 10.1007/s12098-015-1924-y.

25. Camaschella C, Nai A, Silvestri L. Iron metabolism and iron disorders revisited in the hepcidin era. Haematologica. 2020 Jan 31;105[2]:260-272. DOI: 10.3324/haematol.2019.232124.

26. Smith SM, Johnson PE, Lukaski HC. In vitro hepatic thyroid hormone deiodination in iron-deficient rats: effect of dietary fat. Life Sci. 1993;53[8]:603-9. DOI: 10.1016/0024-3205[93]90268-8.

27. Maldonado-Araque C, Valdés S, Lago-Sampedro A, Lillo-Muñoz JA, Garcia-Fuentes E, Perez-Valero V, *et al*. Iron deficiency is associated with Hypothyroxinemia and Hypotriiodothyroninemia in the Spanish general adult population: Di@bet.es study. Sci Rep. 2018 Apr 26;8[1]:6571. DOI: 10.1038/s41598-018-24352-9.

28. Akhter S, Nahar ZU, Parvin S, Alam A, Sharmin S, Arslan MI. Thyroid status in patients with low serum ferritin level. J Med Biochem. 2012;5[1]:5-11. DOI: 10.3329/bjmb.v5i1.13424.

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