Current Science International
Volume: 14 | Issue: 01| Jan. - March| 2025

EISSN:2706-7920 ISSN: 2077-4435
DOI: 10.36632/csi/2025.14.1.3
Journal homepage: www.curresweb.com
Pages: 26-38

Zinc and Ferritin Deficiency in Children with Attention Deficit Hyperactivity Disorder

Walaa A. Shams[1], Thanaa A. Elkholy[1], Nagwan M. Madbouly[2] and Asmaa A. El-Sayed Faramawy[1]

[1]Department of Nutrition and Food Science, Faculty of Home Economic, Al-Azhar University, Egypt.
[2]Department of Psychiatry, Faculty of Medicine, Cairo University, Egypt.

Received: 05 Jan. 2024 **Accepted:** 15 Feb. 2025 **Published:** 10 Mar. 2025

ABSTRACT

Background: Insufficient nutritional supply and deficiency of trace elements and other components including various minerals have been suggested to play a role in the development of attention deficit hyperactivity disorder (ADHD) symptoms. Zinc and ferritin in particular were found to be deficient in patients with ADHD compared with healthy controls, so it was concluded that zinc and ferritin deficiency might play a role in the etiopathogenesis of ADHD. **Aim of work**: Compare serum zinc and ferritin levels between children with ADHD and controls, trying to investigate the association of serum zinc and ferritin levels with ADHD diagnosis, its symptom domains, and severity. **Patients and Methods:** A cross-sectional case control descriptive study conducted on 90 participants of both sexes with age limit from7to 14 years. The study was divided into two groups (45 participants in each group): Group A included 45 children with ADHD, recruited from the Child outpatient clinic located in Kasr Al Ainy Psychiatric and Addiction Hospital, were diagnosed according to Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) criteria, using the Arabic version of Kiddie Schedule for Affective Disorders and Schizophrenia for School Age Children Present and Lifetime version (K-SADS-PL). Conner's Parent Rating Scale −Revised −Long version (CPRS-R-L) used to assess ADHD symptoms severity. Group B included 45 healthy children as controls, recruited from healthy children attending with their parents in other clinics of Kasr Al Ainy hospital as well as children of employees, workers and nurses working in the same hospital. Serum zinc level using atomic absorption spectroscopy and serum ferritin level using enzyme-linked immunosorbent assay (ELISA) were measured in all children in both groups. All children and their parents interviewed by the researcher individually for socioeconomic status scale (SES). **Results**: There were no significant differences regarding age, sex, birth order, residence, and socioeconomic level between children with ADHD and controls. Our results point to serum zinc levels, there were no significant differences between both groups regarding serum zinc levels. However; 24.4% of children with ADHD (n=45) had frank zinc deficiency with serum zinc levels less than 60 µg/dl in compared with 11.1% of controls(n=45). Among children with ADHD, it is found that hyperactivity-impulsivity, inattention DSM-IV index, and ADHD DSM-IV index subscales were higher in zinc deficient cases than non-zinc deficient cases. Also, serum zinc levels were negatively correlated with cognitive problems and inattention DSM-IV index. Regarding serum ferritin levels, there were no significant differences between children with ADHD and controls. However, (66.7%) of children with ADHD had low serum ferritin levels <30 ng/ml in contrast to (55.6%) of controls. It is worth nothing that there was no correlation between serum ferritin levels and CPRS-R-L subscales scores among children with ADHD. **Conclusion:** Serum zinc levels were associated with ADHD symptom domains and its severity in contrast to serum ferritin levels.

Keywords: ADHD, serum zink levels, serum ferritin levels, frank zinc deficiency

Corresponding Author: Walaa A. Shams, Department of Nutrition and Food Science, Faculty of Home Economic, Al-Azhar University, Egypt.

1. Introduction

ADHD is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development**,** it is more common in boys than in girls (Hussein *et a*l., 2025). The etiology of ADHD is complex and has not yet been completely understood, but findings support multifactorial hypotheses. Various neurochemical, neuroanatomical, genetic, and environmental factors have been reported to play a role in the development of this disorder (Razavinia *et al*.,2024).

Diet and nutrition have been proposed to be involved in the pathophysiology and management of ADHD, as nutrition play a role in brain development and functioning (Lange *et al*., 2023). Several studies have shown that nutrition is a strong mediator and/or moderator of ADHD symptoms (Yorgidis *et al*.,2021). Nutrient deficiency has potential roles in it the pathogenesis of ADHD (Ryu *et al*., 2022). Zinc is an essential trace element, required for cellular functions related to the metabolism of neurotransmitters, melatonin, and prostaglandins. Altered levels of zinc have been related with the aggravation and progression of ADHD **(**Granero *et al*., 2021), lower levels of zinc may significantly contribute to the severity of ADHD symptoms (Skalny *et al*., 2020). Also, iron is an essential cofactor required for several functions, such as neurotransmitter metabolism, particularly dopamine production, which is a core factor in ADHD (Granero *et al*., 2021). Lower iron concentration is associated with changes in myelin structure, followed by changes in cortical fibers function, and dopaminergic system, dopamine is known as a key element in the pathogenesis of ADHD. Therefore, iron storage in the brain may be effective on dopamine-dependent functions and ADHD symptoms (Tohidi *et al*., 2021).

2. Subjects and Methods

2.1. Study setting and design

Cross-sectional case control descriptive study was conducted on 90 participants. The study was divided into two groups. Group A: (45) children suffering from ADHD recruited from the Child outpatient clinic located in Kasr Al Ainy Psychiatric and Addiction Hospital.

Group B: (45) healthy children as controls recruited from healthy children attending with their parents in other clinics of Kasr Al Ainy hospital as well as children of employees, workers, and nurses working in the same hospital.

2.2. Sampling and sample size

The sample size calculation (45 participants in each group) was done using G*Power software version 3.1.9.2, considering α error = 0.05 and power = 0.8 to detect an effect size of 0.48 adopted from a previous study (Chou *et al*., 2018).

2.3. Data collection tools

Demographic and socioeconomic data assessed by valid and reliable socioeconomic status scale (SES) for health research in Egypt, with permission of the original author. SES has seven domains with a total score 84, the socioeconomic status was classified according to the quartiles of the score into very low, low, middle, and high levels (El-Gilany *et al.,* 2012).

Blood sample (3 ml) was withdrawn through venipuncture in the arm of children in both groups. Samples were taken by a nurse at child outpatient clinic located in Kasr Alainy Psychiatric and Addiction Hospital (El-Bakry *et al*., 2019). The sample was taken then centrifugation was done for serum separation. The tubes were coded for identification and packed into box then collected sample stored at -5 C until analysis (Karam *et al*., 2019).

Serum zinc levels was assayed using atomic absorption spectroscopy in the Laboratory of the Department of Occupational and Environmental Medicine, Cairo University. Based on serum zinc, zinc deficiency < 80 µg/dl and frank zinc deficiency less than 60 µg/dl were considered (El-Bakry *et al*., 2019). Serum ferritin level was assayed using (ELISA) (Nyakundi *et al*., 2022). Low serum ferritin level was defined as ferritin <30 ng /ml, a measure used in previous study (Abou-Khadra *et al*., 2013).

CPRS-R-L was used to assess ADHD symptoms severity as reported by parents **(**Conners, 2001). It includes 80 items grouped into different subscales: oppositional, cognitive problems/inattention, hyperactivity, anxious-shy, ADHD index, perfectionism, social problems, psychosomatic, conners global index, conners global emotional index, conners global total index, inattention DSM-IV index hyperactivity-impulsivity DSM-IV index, and ADHD DSM-IV index. The CPRS-R-L in Arabic was developed by translation and back-translation with permission of the original author. Reliability analysis showed that Cronbach's alpha was 0.95 (Abou-Khadra *et al*., 2013).

2.4. Statistically analysis:

The collected data were organized and entered on Excel sheet and statistically analyzed using SPSS software statistical computer package for Windows, version 25 (IBM Corp., Armonk, N.Y., USA). The Shapiro-Wilk for normality test was performed to assess the distribution of the numerical data. Normally distributed parametric quantitative data were represented by mean and SD. Abnormally distributed nonparametric quantitative data were represented by median and interquartile ranges. Qualitative data was summarized in numbers and percentage. The Chi square test was applied to test the association between categorical variables in two independent samples. Mann Whitney test was applied for quantitative nonparametric variables comparing the median between two or more independent samples respectively. Spearman's rho correlation coefficient was used to investigate the association between two ordinal data and numerical or categorial data respectively. A significant P-value was considered when P is less than 0.05.

3. Results

Table (1) shows demographic and socioeconomic characteristics of the studied children (children with ADHD and controls). There were no significant differences between the children in both groups in terms of age, age groups, sex, birth order, socioeconomic level, and residence.

Table 1: Demographic and Socioeconomic characteristics of the studied children in both groups (n=90).

	Group A (n=45) Children with ADHD		**Group B (n=45) Controls**		**Sig. test**	**P value**
	N	**%**	**N**	**%**	**$\chi 2$**	
Age of children						
≤ 7-10 Years	22	48.9%	19	42.2%		
>10-14 years	23	51.1%	26	57.8%	0.403	0.525
Mean ± SD	10.034 ±	1.572	10.516 ±	1.624	t = -1.429	0.156
Sex						
Male	35	77.8	35	77.8	0.001	1
Female	10	22.2	10	22.2		
Birth order						
First	14	31.1%	16	35.6%	1.208	0.547
Second	11	24.4%	14	31.1%		
The last	20	44.4%	15	33.3%		
Socioeconomic level						
Low	24	53.3%	22	48.9%	$\chi 2$ =0.178	0.673
Middle	21	46.7%	23	51,15		
Residence						
Urban	32	71.1%	33	73.3%	$\chi 2$ =0.055	0.814
Rural	13	28.9%	12	26.7%		

SD= Standard Deviation **$\chi 2$**= chi square test **t** =independent sample t test

Table (2) compares serum zinc levels between children with ADHD and controls. There were no significant differences between both groups according to serum zinc levels. However; there were (24.4%) of children with ADHD had frank zinc deficiency in contrast to (11.1%) of controls.

Table 2: Comparison of serum zinc levels between children with ADHD and controls(n=90).

	Group A (n=45) Children with ADHD			**Group B(n=45) Controls**			**Sig. Test**	**P value**
	N		**%**	**N**		**%**		
Serum zinc levels								
Mean ± SD	77.56	±	21.01	78.40	±	17.57	t=-0.205	0.838
No zinc deficiency	20		44.4	18		40.0		
Marginal zinc deficiency	14		31.2	22		48.9	$\chi2$ =4.133	0.127
Frank zinc deficiency	11		24.4	5		11.1		

χ2 =chi square **t**= independent sample t test **SD**= standard deviation

Table (3) compares serum ferritin levels between children with ADHD and controls. There were no significant differences between both groups according to serum ferritin levels. However; there were (66.7%) of children with ADHD had low serum ferritin levels <30 ng/ml in contrast to (55.6%) of controls.

Table 3: Comparison of serum ferritin levels between children with ADHD and controls(n=90).

	Group A (n=45) Children with ADHD			**Group B (n=45) Controls**			**Sig. Test**	**P value**
	N		**%**	**N**		**%**		
Serum ferritin levels								
Mean ± SD	27.59	±	17.45	28.96	±	17.99	U=949.500	0.611
Above cut off value (30 ng /ml)	15		33.3	20		44.4	$\chi2$ =1.169	**0.280**
Below cut off value (30 ng/ml)	30		66.7	25		55.6		

χ2 =chi square **U**= man Whitney test **SD**= standard deviation

Table (4) shows that there were statistically significant differences between non- zinc deficient cases and zinc deficient cases among children with ADHD as regards hyperactivity-impulsivity, inattention DSM-IV index, and ADHD DSM-IV index subscales, with (P value=0.034), (P=0.017), (P=0.04), respectively.

Table (5) shows that there were no statistically significant differences between non- ferritin deficient cases and ferritin deficient cases among children with ADHD as regards CPRS-R-L subscales scores.

Table (6) and Figures (1), (2) shows correlation between serum zinc levels and CPRS-R-L subscales scores among children with ADHD. There is significant negative correlation between serum

EISSN: 2706-7920 ISSN: 2077-4435 **DOI: 10.36632/csi/2025.14.1.3**

zinc levels and cognitive problems (P =0.020). Similarly, there is significant negative correlation between serum zinc levels and inattention DSM-IV index (P = 0.004).

Table (7) shows no correlation between serum ferritin levels and CPRS-R-L subscales scores among children with ADHD.

Table 4: Comparison of CPRS-R-L subscales scores between zinc deficient cases and non-zinc deficient cases among children with ADHD(n=45)

Conners subscales		Serum zinc levels		Mann Whitney	P value
		Non- Zinc deficient cases	Zinc deficient cases		
Conduct disorder -oppositional	Mean ± SD	68.29 ± 9.744	71.91 ±7.70		
	Median (IQR)	68(48-85)	73(54-82)	t=-1.120	0.269
Cognitive problems	Mean ± SD	67 ± 7.793	72.73±10.412		
	Median (IQR)	65(55-88)	72.00(58-90)	t=115.500	0.059
Hyperactivity-impulsivity	Mean ± SD	72.76±10.689	80.91±9.843		
	Median (IQR)	74.00(56-90)	84.00(64-90)	107.000	0.034*
Anxious -shy	Mean ± SD	55.94 ±10.22	65.91±17.947		
	Median (IQR)	55.00(41-87)	66.00(39-90)	132	0.145
Perfectionism/OCD	Mean ± SD	48.82±7.830	48.91±9.214		
	Median (IQR)	48.00(40-80)	45 (40-71)	171.500	0.681
Social problems	Mean ± SD	62.85±12.346	66.82±15.478		
	Median (IQR)	61.00(45-89)	65.00(45-90)	157	0.427
Psychosomatic	Mean ± SD	54.32±11.819	57.64±15.194		
	Median (IQR)	51.50(42-83)	53.00(42-87)	163.5	0.533
ADHD index	Mean ± SD	67.06±7.631	71.45±8.407		
	Median (IQR)	65(56-90)	70.00(61-81)	130	0.133
Conners global ADHD index	Mean ± SD	70.71±8.537	75.45±9.256		
	Median (IQR)	70.50(57-90)	70.00(67-90)	143	0.244
Conners global emotional index	Mean ± SD	67.74±9.362	74.64±13.299		
	Median (IQR)	68.50(46-90)	77.00(49-90)	t =-1.911	0.063
Conners global total index	Mean ± SD	71.26±8.088	77.36±9.542		
	Median (IQR)	70.00(56-90)	76.00(65-90)	113	0.058
Inattention DSM-IV index	Mean ± SD	64.94±7.269	72.91±10.511		
	Median (IQR)	64.00(56-88)	73 (58-88)	115.500	0.017*
Hyperactivity-impulsivity DSM-IV index	Mean ± SD	72.62±10.534	77.36±9.179		
	Median (IQR)	73.00(56-90)	76.00(62-90)	140	0.213
ADHD DSM-IV index	Mean ± SD	69.53±8.921	75.91±9.659		
	Median (IQR)	70.00(56-90)	75.00(64-90)	t =-2.022	0.049*

U= man Whitney test **t**= independent sample t test **SD**= standard deviation

EISSN: 2706-7920 ISSN: 2077-4435 **DOI: 10.36632/csi/2025.14.1.3**

Table 5: Comparison of CPRS-R-L subscales scores between ferritin deficient cases and non-ferritin deficient cases among children with ADHD (n=45)

Conners subscales		Serum ferritin levels		Sig U	P value
		Non-ferritin deficient cases	Ferritin deficient cases		
Conduct disorder -oppositional	Mean ± SD	71.20±8.479	68.17±9.713		
	Median (IQR)	68(59-85)	71(48-82)	t=1.028	0.310
Cognitive problems	Mean ± SD	68.07±8.481	68.57±9.005		
	Median (IQR)	68(57-88)	68.5(55-90)	t=-0.179	0.859
Hyperactivity-impulsivity	Mean ± SD	76.27±9.422	74±11.739	197.5	
	Median (IQR)	78(56-90)	74(56-90)		0.507
Anxious -shy	Mean ± SD	60.33±13.589	57.40±12.896		0.440
	Median (IQR)	58(45-90)	55(39-85)	193	
Perfectionism/OCD	Mean ± SD	48.60±5.616	48.97±9.152	202.5	
	Median (IQR)	49(40-59)	47(40-80)		0.586
Social problems	Mean ± SD	61.67±14.681	64.90±12.366		
	Median (IQR)	59(45-88)	62.5(45-90)	187	0.359
Psychosomatic	Mean ± SD	58±15.123	53.70±11.176	197.5	0.506
	Median (IQR)	53(42-87)	53(42-83)		
ADHD index	Mean ± SD	68.07±8.413	68.17±7.874		
	Median (IQR)	65(61-90)	65(56-89)	219	0.885
Conners global ADHD index	Mean ± SD	73.47±7.328	71.07±9.541		
	Median (IQR)	71(63-90)	69(57-90)	173.5	0.214
Conners global emotional index	Mean ± SD	68±12.851	70.13±9.648		
	Median (IQR)	70(46-90)	71(56-88)	t=-0.625	0.535
Conners global total index	Mean ± SD	73.20±7.664	72.53±9.380	212.5	0.763
	Median (IQR)	71(64-90)	71(56-90)		
Inattention DSM-IV index	Mean ± SD	65.87±8.442	67.40±9.012		
	Median (IQR)	64(58-88)	65(56-88)	204	0.612
Hyperactivity-impulsivity DSM-IV index	Mean ± SD	76.07±9.989	72.63±10.467		
	Median (IQR)	78(56-90)	73(58-90)	178.500	0.262
ADHD DSM-IV index	Mean ± SD	72±9.181	70.63±9.647		
	Median (IQR)	70(56-90)	70(56-90)	t=0.455	0.651

U= man Whitney test **t**= independent sample t test **SD**= standard deviation

Table 6: Correlation between serum zinc levels and CPRS -R-L subscales scores among children with ADHD (n=45).

Correlation		Serum zinc levels
Conduct disorder -oppositional	r_s	-0.101
	P	0.510
Cognitive problems	r_s	-0.347
	P	0.020*
Hyperactivity-impulsivity	r_s	-0.230
	P	0.129
Anxious -shy	r_s	-0.166
	P	0.275
Perfectionism/OCD	r_s	-0.027
	P	0.858
Social problems	r_s	-0.049
	P	0.749
Psychosomatic	r_s	-0.128
	P	0.402
ADHD index	r_s	-0.223
	P	0.141
Conners global ADHD index	r_s	-0.238
	P	0.116
Conners global emotional index	r_s	-0.195
	P	0.199
Conners global total index	r_s	-0.272
	P	0.070
Inattention DSM-IV index	r_s	-0.419
	P	0.004*
Hyperactivity-impulsivity DSM-IV index	r_s	-0.145
	P	0.343
ADHD DSM-IV index	r_s	-0.271
	P	0.072

rs: Correlation coefficient of spearman Correlation **p:** probability value *****: statistically significant

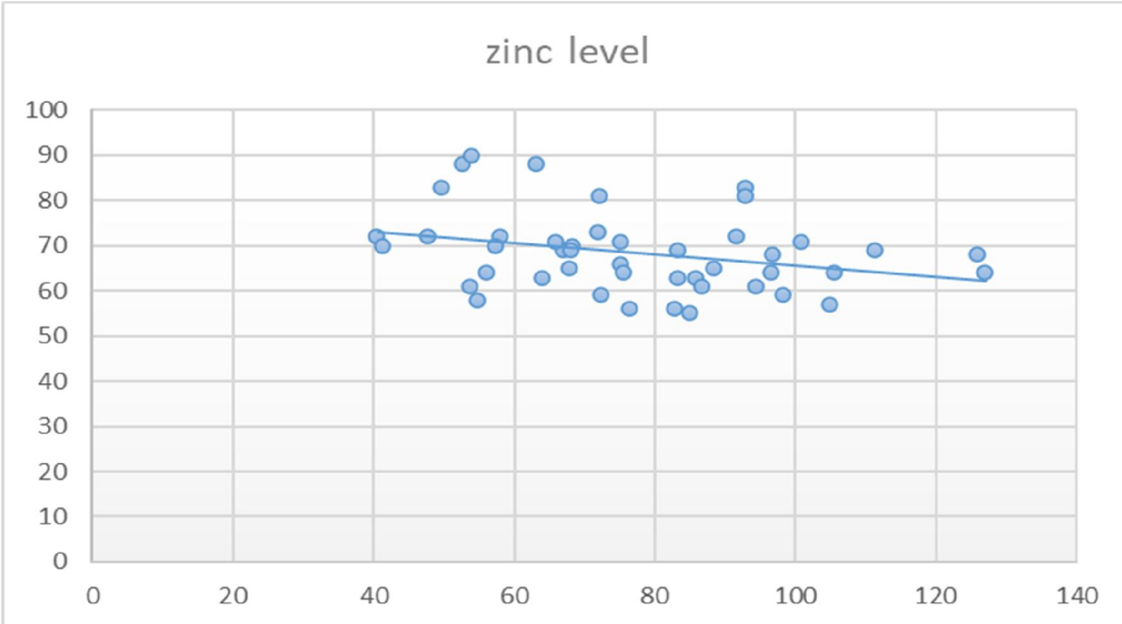

Fig. 1: Correlation between serum zinc levels and cognitive problems among children with ADHD

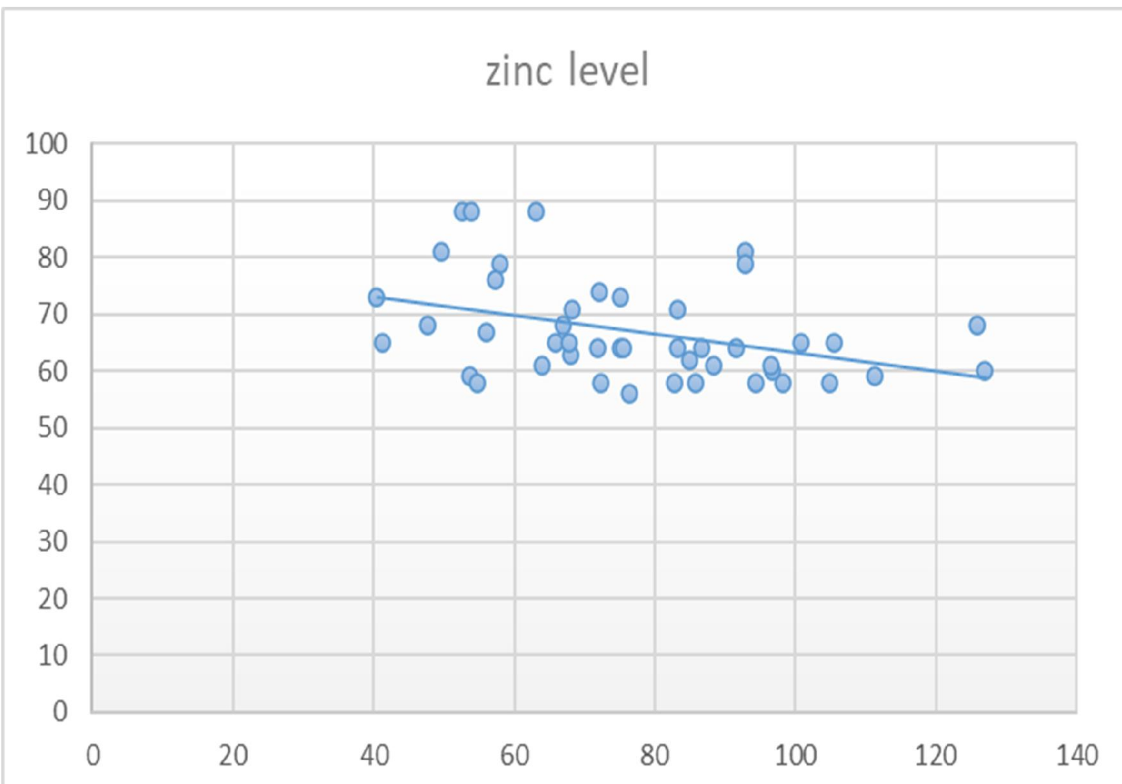

Fig. 2: Correlation between serum zinc levels and inattention DSM-IV index among children with ADHD

Table 7: Correlation between serum ferritin levels and CPRS-R-L subscales scores among children with ADHD(n=45).

Correlation		Serum ferritin levels
Conduct disorder -oppositional	r_s	0.185
	P	0.224
Cognitive problems	r_s	-0.139
	P	0.362
Hyperactivity-impulsivity	r_s	0.071
	P	0.641
Anxious -shy	r_s	0.070
	P	0.649
Perfectionism/OCD	r_s	-0.032
	P	0.836
Social problems	r_s	-0.046
	P	0.762
Psychosomatic	r_s	0.109
	P	0.475
ADHD index	r_s	-0.704
	P	0.630
Conners global ADHD index	r_s	0.150
	P	0.325
Conners global emotional index	r_s	-0.008
	P	0.956
Conners global total index	r_s	0.047
	P	0.761
Inattention DSM-IV index	r_s	-0.169
	P	0.267
Hyperactivity-impulsivity DSM-IV index	r_s	0.117
	P	0.443
ADHD DSM-IV index	r_s	-0.014
	P	0.929

rs: Correlation coefficient of spearman Correlation **p:** probability value

4. Discussion

In this study, both groups were matched by age, gender, race, and socioeconomic status. The age of the study sample (45 children with ADHD and 45 controls) ranged from 7 –14 years with mean age of (10.034±1.572), (10.516± 1.624) years, respectively. From the researcher point of view; 7 years was selected due to at this age, children begin to engage and interact more clearly with the external environment, and thus they develop different dietary tendencies and habits separate from their families. Moreover, 14 years were the upper age limit for children in Child outpatient clinic located in Kasr Alainy Psychiatric and Addiction hospital where the study sample was taken.

As regards to sex each group consisted of 35 males (77.8%) and 10 females (22.2%), at a ratio ~ of 3.5:1. which is consistent with sex differences reported in the literature for patients with ADHD. Sex differences in the rate of ADHD diagnoses are well documented in literature, with male-to-female prevalence ratios varying within the range of 2:1 to 10:1 across studies (Al-Wardat *et al.*,2024). In particular, our results come in line with a study found that the male-to-female ratio of ADHD in childhood was 3:1 (Da Silva *et al*., 2020). Our results also, consistent with studies found that the male-to-female ratio of ADHD in childhood was 4:1 (Martin,2024; Abdelnour *et al*., 2022). These results can be explained by females are more likely to present with symptoms of inattention than hyperactivity and less likely to exhibit disruptive behaviors, causing their symptoms to be less noticeable in childhood (Huynh *et al*., 2024).

Concerning to child birth order, the current study showed that there were no significant differences between both groups. However; the study found that the prevalence of the ADHD was higher if the child was the last one in the family followed by first birth order, which is consistent with study done by Mohamed *et al*. (2023).

For socioeconomic level, as mentioned earlier we matched socioeconomic level in both groups. So, there were no significant differences between both groups according to: Residence, educational level, occupation of mothers and fathers, health care level, and socioeconomic level.

In particularly, among children with ADHD (n=45), 32 of those children living on Urban area and 24 of them had low socioeconomic status, this result consistent with research that identified a correlation between lower socioeconomic status and higher ADHD prevalence rates, as well as a link between urban living and increased ADHD prevalence (Sadr-Salek *et a*l., 2023).

Regarding serum ferritin levels, our result showed that there were no statistically significant differences regarding serum ferritin levels between children with ADHD and controls. The result of this study is in line with data from previous studies (Donfrancesco *et al*., 2012; Wang *et al*., 2017). Despite this result, serum ferritin levels found to be lower in children with ADHD than healthy controls. This result consistent with the study of Wang *et al*. (2017). Among children with ADHD, regarding the correlation between serum ferritin levels and CPRS-R-L subscales, there was no correlation between serum ferritin level and CPRS-R-L subscales scores. Also, it is found that no statistically significant differences between non- ferritin deficient cases ≥30 ng/ml and ferritin deficient cases <30 ng/mL as regards CPRS-R-L subscales ($p > 0.05$), This results consistent with study conducted by Abou-Khadra *et al*. (2013).

Our result point to serum zinc levels, it is found that there were no statistically significant differences regarding serum zinc levels between children with ADHD and controls. The result of this study consistent with studies conducted by (Ghoreishy *et al*., 2021; Liu *et al*., 2020). Whereas, the result of this study contradicted with a study done by Karam *et al*. (2019) who stated that there was a highly significant difference between children with ADHD and controls regarding serum zinc levels. In particularly, according to serum zinc levels among children with ADHD (n=45), 55, 6% of them (n=25) were below the laboratory reference range, which was 80–130 μg/dl, denoting prevalent zinc deficiency among children with ADHD, where (14) children had marginal zinc deficiency, with serum zinc levels ranging between 60 and 80 μg/dl and (11) children had frank zinc deficiency, with serum zinc levels less than 60 μg/dl. These results are in line with previous study suggesting that many children with ADHD have lower than average zinc levels (El-Bakry *et al*., 2019).

Several studies have previously reported that lower levels of zinc may significantly contribute to the severity of ADHD symptoms (Skalny *et al*., 2020). Among children with ADHD our results concluded statistically significant differences between non- zinc deficient cases ≥80–130 μg/dl and zinc deficient cases < 80 μg/dl as regards hyperactivity-impulsivity, inattention DSM-IV index, and ADHD DSM-IV index. Where zinc deficient cases have higher scores in these subscales than non-zinc deficient cases ($p < 0.05$). This result is in line with data from previous study suggesting that low zinc levels was associated with high conner parent rating scale (CPRS) hyperactivity score (Oner *et al*., 2010). Also, this result consistent with previous study suggesting that serum zinc concentration has negative correlation with parent-teacher-rated inattention (Arnold *et al*., 2005). Our findings also, showed an association between serum zinc levels and ADHD DSM-IV index, and this result consistent with previous study suggesting significant beneficial effect of zinc supplementation on ADHD total scores (Talebi *et al*., 2022). These results contradicted with a study done by Karam *et al*. (2019) who stated that there was no statistically significant difference between zinc deficient cases and non-zinc deficient cases as regards conners subscales scores.

Furthermore, an association between low serum zinc levels and high score of both cognitive problems and inattention DSM- IV index scores has been ound among children with ADHD. As mentioned earlier we found that serum zinc concentration has negative correlation with parent-teacher-rated inattention (Arnold *et al*. 2005). The association between serum zinc levels and cognitive problems, can explained through, zinc plays an important role in many physiological and pathological processes in normal mammalian brain development, especially in the development of the Central nervous system (CNS). Zinc deficiency can lead to neurodegenerative diseases, mental abnormalities, sleep disorders, tumors, vascular diseases, and other pathological conditions, which can cause cognitive impairments. Zinc is important for the brain to function normally. So, zinc deficiency is closely related to cognitive impairment, memory impairment, and other diseases (Sun *et al*., 2022).

5. Conclusion

In conclusion, nutritional deficiency may significantly contribute to the severity of ADHD symptoms. In particular, lower serum zinc levels were positively associated with ADHD symptoms and its severity such as cognitive problems, hyperactivity-impulsivity, inattention, and ADHD DSM-IV index.

Conflict of Interest

The authors reported no conflict of interest.

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