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Original Research Article

Exploring the Impact of Nutritional Deficiencies on ADHD Symptoms in Children

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Abstract

Background: ADHD (attention deficit hyperactivity disorder) is a prevalent neurodevelopmental disorder among children, with both genetic and environmental risk factors, including nutritional deficiencies. Previous research has suggested that micronutrients like vitamin D and iron play important roles in cognitive function and brain development, potentially affecting ADHD symptoms. However, the specific impact of nutritional deficiencies on ADHD symptoms, particularly in children, remains inadequately explored.

Aim: This study aims to explore the relationship between nutritional deficiencies, specifically serum ferritin and vitamin D levels, and ADHD symptoms in children. It seeks to assess whether children with ADHD exhibit lower levels of these micronutrients compared to healthy controls.

Methodology: A case-control study was conducted involving 35 children diagnosed with ADHD and 35 healthy controls. ADHD was diagnosed using the INCLEN diagnostic tool, and serum levels of ferritin and vitamin D were measured using the Enzyme-Linked Fluorescent Assay (ELFA). Data were statistically analysed using SPSS version 22, with comparisons made between the two groups and ADHD subtypes.

Results: The research showed that children diagnosed with ADHD exhibited notably lower serum ferritin levels in comparison to the control group (p=0.037). In the study, low serum ferritin was observed in 45.71% of ADHD cases, whereas it was present in 22.86% of the control group. No statistically significant difference was observed in serum vitamin D levels between the groups (p=0.573). Both groups exhibited a significant prevalence of vitamin D deficiency, with 71.43% of ADHD cases and 65.71% of controls presenting with low levels.

Conclusion: According to this study, low serum ferritin levels, a sign of iron deficiency, may exacerbate children's ADHD symptoms. Despite being common, vitamin D deficiency does not seem to significantly affect ADHD. These results highlight how crucial it is to take nutritional status into account while managing ADHD and indicate that more study is required to evaluate the possible advantages of dietary treatments.

Keywords: ADHD, Children, Iron Deficiency, Nutritional Deficiencies, Serum Ferritin and Vitamin D.

Introduction

One of the most common psychological health issues among school-aged kids in India is ADHD (attention deficit hyperactivity disorder), which affects a probable 11.32% of primary school kids [1]. This disorder is typically detected in children and frequently continues to maturity. This disease can significantly impair academic and social functioning and is associated with unfavourable long-term social and emotional consequences. Moreover, ADHD frequently coexists with comorbidities, including various psychiatric, behavioural, and developmental diseases, such as autism spectrum disorders and developmental delays, complicating diagnosis and management.

ADHD is thought to be caused by the brain's neurotransmitters, particularly serotonin and dopamine, being depleted [2]. The precise explanation remains complex, involving intricate interactions between hereditary and environmental risks. Genetic connections with genes encoding neurotransmitters, such as serotonin (e.g., 5HTR1B and 5HTT) and dopamine (e.g., DRD5, DAT1, and DRD4), have been substantiated. Ecological risk aspects encompass drug misuse, exposure to pollutants, maternal stress, and psychosocial adversity such as Lead, polychlorinated biphenyls, or organophosphate insecticides, as well as dietary elements, such as surpluses and deficits in certain nutrients, such as Artificial food colouring or too much sugar [3].

Micronutrients play an essential role in neurological function, especially in the production of neurotransmitters. In India, a prevalent factor contributing to anaemia is iron deficiency. A reduction in iron levels can interfere with standard brain operations, resulting in alterations in the conduction of cortical fibers and impacting the dopaminergic systems and serotonergic, along with myelin formation [4]. This deficiency negatively influences cognitive and behavioural functions and is associated with symptoms including diminished attention and hyperactivity. Iron functions as a coenzyme for tyrosine hydroxylase, playing a crucial role in the degradation and synthesis of dopamine. Research indicates a correlation between iron deficiency and a reduction in the expression of D4 and D2 receptors, as well as the dopamine transporter within the brain. The alterations in neurotransmitter levels, coupled with dysfunction within the basal ganglia, are thought to contribute to the aetiology of ADHD [5].

Vitamin D functions as multifaceted hormone, significantly influencing bone metabolism and calcium while also contributing to psychological, immunological, endocrine, and cardiovascular conditions. The neuroprotective and neurotropic effects are crucial for optimal cerebral function and cognitive processes. The significance of cerebral function is paramount, and its absence could have a role in the aetiology of ADHD. Vitamin D influences monoamine concentrations and neurotrophic factors, enhancing oxidative stress responses and inducing alterations in neurotransmitter levels. Lack of Vitamin D consequently leads to alterations in dopamine regulation, thereby establishing a connection to its involvement in the etiopathogenesis of ADHD [6]. The active form of Vitamin D is synthesized through the action of 1α-hydroxylase enzyme and vitamin D receptors, which are extensively present in the central nervous system, especially in hypothalamus, substantia nigra, cingulated gyrus, hippocampus, and prefrontal cortex's neural cells. A large number of these areas have been linked to the pathogenesis of ADHD [7].

Currently, pharmacotherapy is the primary therapeutic modality. Nonetheless, there are constraints in pharmacological therapies. For example, 30 percent of kids with ADHD do not react to pharmacological management. Enhanced treatment modalities and strategies are required to manage the condition [8]. In recent years, researchers have increasingly focused on the significance of the environment, particularly diet, in the treatment and prevention of illness symptoms. Dietary therapy is a straightforward and cost-effective approach that can be easily embraced by parents and followed by children. The significance of nutrition therapy, particularly regarding vitamins and supplements, is quite evident. The impact of micronutrients, including iron, zinc, and omega-3 fatty acids, on the avoidance and control of signs has been thoroughly researched. Nevertheless, the significance of vitamin D has garnered comparatively little focus. This syndrome persists even though vitamin D insufficiency is linked to psychiatric disorders such as depression, schizophrenia, and autism. This vitamin is implicated in the regulation of serum calcium and bone metabolism, and it also significantly affects several body organs [9].

As a result, it has been suggested that pregnant mothers and their unborn children have their vitamin levels examined. A lack of vitamin D during pregnancy is the cause of several postpartum psychiatric problems [10]. Furthermore, it has been advocated that insufficient levels of vitamin D during post-natal and fetal periods may negatively impact the growth of brain structure and function. This study aims to investigate the variations in Serum Vitamin D and Serum ferritin levels, as well as their association with ADHD, given the implications of both Vitamin D and iron absences in the aetiology of the disorder.

Methodology

Study Design

This study was a case-control study carried out over a duration of one year. It aimed to investigate the relationship between ADHD and serum ferritin and vitamin D levels. A total of 70 children were selected for the study and they were divided into 2 groups: 35 cases (children with ADHD) and 35 controls (healthy children of comparable sex and age).

Study Area

The study was conducted at the Department of Pediatrics, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India

Inclusion Criteria

- Children aged 6–15 years.
- Children are diagnosed with ADHD.
- Children attending regular schools.

Exclusion Criteria

- Children with seizures, acute febrile illness, intellectual or neurological impairments, or other psychiatric disorders.
- Children with chronic systemic diseases or stimulant medication.
- Children treated for rickets or taking iron or vitamin D supplements.

Procedure

The diagnosis of ADHD was established through a two-step process: initially, the CBCL (Child Behaviour Checklist) was employed to exclude other behavioural issues, followed by the use of the INDT-ADHD (INCLEN diagnostic tool for ADHD) for final confirmation. Informed consent was obtained from parentage, along with assent from kids over 12 years of age, prior to studying. Blood samples were collected from both cases and controls using aseptic techniques to measure serum ferritin and vitamin D levels. The analysis of the samples was conducted using the Enzyme-Linked Fluorescent Assay (ELFA) technique via the VIDAS system.

Statistical Analysis

Data were entered into MS Excel and subsequently analysed using SPSS version 22. A one-sample Kolmogorov Smirnov test was conducted to assess the data distribution's normality. Parametric tests were utilised for data demonstrating a normal distribution, while non-parametric tests were applied to data that exhibited deviations from normality. Descriptive statistics were employed to compute frequencies and percentages for categorical variables. For categorical data, the Fisher's exact test or chi-square test was used, whereas the Student's T-test was used for quantitative data. A p-value is considered statistically significant if it is less than 0.05.

Result

Table 1 displays the demographic profiles of children classified by age group and gender, contrasting control and case groups, each comprising 35 participants. In the 13–15 age group, 2.86% of cases were female and 8.57% were male. In the 10–12 age group, females represented 14.29% of cases, while males accounted for 17.14%. The 6–9 age group exhibited a significant disparity, with females representing 22.86% and males 34.29% of cases. In contrast, controls displayed no females and 5.71% males in the oldest group, 8.57% females and 17.14% males in the middle group, and 11.43% females and 57.14% males in the youngest group. Males exhibited greater prevalence across all groups, particularly in the younger age categories.

Table 1: Demographical Profiles of children

Age Group (Years)	Gender	Controls (n=35)		Cases (n=35)	
		No.	**Percent**	**No.**	**Percent**
13–15	Female	0	0%	1	2.86%
	Male	2	5.71%	3	8.57%
10–12	Female	3	8.57%	5	14.29%
	Male	6	17.14%	6	17.14%
6–9	Female	4	11.43%	8	22.86%
	Male	20	57.14%	12	34.29%

Table 2 presents the results of ADHD subtypes with the INCLEN tool. Of the overall instances, 34.29% (12 cases) were categorized as the inattention subtype, whereas 31.43% (11 cases) were recognized as exhibiting hyperactivity. The mixed subtype, encompassing both inattention and hyperactivity, constituted 34.29% (12 instances). This indicates that inattention and combination subtypes are equally widespread, each constituting a greater proportion of cases than hyperactivity alone.

Table 2: ADHD outcome with the INCLEN tool

Subtype of ADHD	No. of Cases	Percentage
Inattention	12	34.29%
Hyperactivity	11	31.43%
Combined	12	34.29%

Table 3 compares the serum ferritin levels between two groups: controls and cases, each comprising 35 individuals. In the control group, 62.86% (22 individuals) exhibited normal serum ferritin levels, whereas 54.29% (19 individuals) in the case group displayed normal levels. Low blood ferritin levels were noted in 22.86% (8 individuals) of the control group, in contrast to a significantly higher 45.71% (16 individuals) in the case group. High serum ferritin was observed in 14.29% (5 people) of the control group, however none (0%) were discovered in the case group. A P-value of 0.037 signifies that the differences in serum ferritin levels between the two groups are statistically significant.

Table 3: Levels of serum ferritin in both patients controls and Cases					
Serum Ferritin	**Controls (n=35)**		**Cases (n=35)**		**P-value**
	No. of Cases	**Percentage**	**No. of Cases**	**Percentage**	
Normal	22	62.86%	19	54.29%	0.037
Low	8	22.86%	16	4.71%	
High	5	14.29%	0	0%	
Total	**35**		**35**		

Table 4 comparison of vitamin D levels in ADHD patients and a control group. In a study of 35 ADHD patients, 10 (28.57%) exhibited normal vitamin D levels, whereas 25 (71.43%) presented low levels. In the control group, 12 participants (34.29%) exhibited normal levels, while 23 participants (65.71%) displayed low levels. The two groups' vitamin D levels do not appear to differ statistically significantly, according to the P-value of 0.573.

Table 4: Levels of vitamin D in both patients' controls and cases with ADHD			
Serum Vitamin D	**Cases with ADHD (n=35)**	**Controls (n=35)**	**P-value**
Normal	10 (28.57%)	12 (34.29%)	0.573
Low	25 (71.43%)	23 (65.71%)	
Total	**35**	**35**	

Table 5 shows the average serum levels of Vitamin D and ferritin across three ADHD subtypes: Combined type, Hyperactive type, and Inattentive type. The mean values for Vitamin D are 40.15 ± 16.75 nmol/L in the Combined type, 38.89 ± 14.23 nmol/L in the Hyperactive type, and 36.23 ± 17.98 nmol/L in the Inattentive type, with no significant differences observed among the groups (P=0.812). The mean ferritin levels are 38.60 ± 42.10 ng/mL for the Combined type, 26.45 ± 21.67 ng/mL for the Hyperactive type, and 34.12 ± 30.50 ng/mL for the Inattentive type, with no important difference observed (P=0.683).

Table 5: Serum Ferritin and Vitamin D mean values in ADHD subtypes				
	Combined type (n=12)	**Hyperactive type (n=11)**	**Inattentive type (n=12)**	**P-value**
S. Vitamin D (nmol/L)	40.15 ± 16.75	38.89 ± 14.23	36.23 ± 17.98	0.812
S. Ferritin (ng/ml)	38.60 ± 42.10	26.45 ± 21.67	34.12 ± 30.50	0.683

Discussion

The demographic features of the children in the study indicate a diverse age distribution across the control and case groups. In the 13–15 age range, the controls were 2 men (5.71%) and no females, whereas the cases included 1 female (2.86%) and 3 males (8.57%). In the 10–12 age range, the controls included 3 females (8.57%) and 6 men (17.14%), while the cases consisted of 5 females (14.29%) and 6 males (17.14%). The 6–9 age cohort exhibited the highest representation of both girls and males, with 4 females (11.43%) and 20 males (57.14%) in the control group, alongside 8 females (22.86%) and 12 males (34.29%) in the case group. Bener et al. [11] and Hassan et al. [12] reported that the prevalence of ADHD is higher in school-aged children aged six to nine years compared to youth. Ramtekkar et al. [13] also determined the mean age of ADHD to be between 7 and 12 years.

The ADHD outcomes assessed using the INCLEN tool showed that among the 35 cases, 12 children (34.29%) were diagnosed with the inattentive subtype, 11 (31.43%) with the hyperactive subtype, and another 12 (34.29%) with the combined subtype. This reflects a balanced distribution between the inattention and combined subtypes, with hyperactivity being slightly lower.

In this Result, Significant variations in serum ferritin levels were observed among the control and case groups. In the control group, 22 children (62.86%) exhibited normal ferritin levels, whereas 19 children (54.29%) in the case group did. Notably, a greater proportion of children in the case group (16, or 45.71%) exhibited low ferritin levels compared to the control group (8 children, or 22.86%). None of the patients exhibited elevated ferritin levels, although 5 children (14.29%) in the control group did. A p-value of 0.037 signifies a statistically significant disparity in serum ferritin levels between the two groups. Serum ferritin levels serve as an early warning sign of iron shortage and are a good indicator of the amount of iron stored in bodily tissues. One essential mechanism for the transport of iron throughout brain tissue is the interaction between foreign ferritin and cell receptors. Iron insufficiency is clearly shown by decreased ferritin levels [14].

A higher proportion of the case and control groups had low serum vitamin D levels (71.43% of cases and 65.71% of controls, respectively). The difference between the groups was not statistically significant, according to the p-value of 0.573. Low vitamin D levels in both cases and controls may be due to the high incidence of vitamin D shortage in otherwise healthy Indian youngsters, as demonstrated in the study of Angurana et al. [15].

The mean values of serum ferritin and vitamin D across various ADHD subtypes exhibit minor differences without statistical significance. The average serum vitamin D levels were 40.15 nmol/L for the mixed type, 38.89 nmol/L for the hyperactive type, and 36.23 nmol/L for the inattentive type, with a p-value of 0.812. The mean serum ferritin values were 38.60 ng/ml for the mixed type, 26.45 ng/ml for the hyperactive type, and 34.12 ng/ml for the inattentive type, with a p-value of 0.683. The results indicate no substantial difference in ferritin and vitamin D levels among ADHD subtypes. Goksugar et al. [16] found that the mean serum vitamin D level in the ADHD group (20.9±19.4 ng/ml) was lower than that in the control groups (34.9±15.4 ng/ml), showing a significant difference between the two groups. Similarly, according to Kamal et al. [17], children with ADHD have much lower vitamin D levels than controls (7.6% vs. 4.6%).

Conclusion

The findings of the research show a significant association between children's ADHD symptoms and nutritional deficiencies, particularly low blood ferritin levels. The distribution of ADHD subtypes was largely consistent among participants; however, the results indicate that children with ADHD exhibited a higher prevalence of low serum ferritin than the control group, suggesting that iron deficiency may exacerbate ADHD symptoms. Conversely, vitamin D levels showed no statistically significant difference between patients and controls, indicating that its impact on ADHD may be less substantial. The results underscore the substantial impact of nutritional status on ADHD, emphasizing the need for further research to explore these associations and to incorporate dietary treatments into a comprehensive treatment plan for affected children.

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