ISSN-E: 18735347-02779536

Artificial Food Coloring and Its Impact on Behavioral Outcomes in Children with ADHD: A Comprehensive Study

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ISSN-E: 18735347-02779536

1- INTRODUCTION

1-1- Research Background

Attention-Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by persistent patterns of inattention, hyperactivity, and impulsivity that interfere with functioning or development [1]. The prevalence of ADHD has increased dramatically in recent years, prompting researchers and healthcare professionals to explore various environmental factors that may contribute to its symptoms [2-5]. Among these factors, dietary components, particularly artificial food colorings, have garnered significant attention [6-8].

The link between diet and behavior was notably highlighted by Dr. Benjamin Feingold in the 1970s. His observations suggested that certain food additives, including artificial colorings and salicylates, could exacerbate hyperactive behaviors in children. Feingold's work led to the development of the Feingold Diet, which restricts foods high in these additives. His initial findings indicated that about 50% of hyperactive children showed marked improvement when placed on this diet. Despite ongoing debates regarding the efficacy of the Feingold Diet, many parents have reported positive behavioral changes in their children, fueling further research into the diet-behavior connection [9].

Research indicates that artificial food colorings may affect children's behavior through several mechanisms. Some studies suggest that these additives can provoke allergic reactions or sensitivities, leading to behavioral disturbances. Additionally, the consumption of synthetic colorings may influence neurotransmitter levels, particularly dopamine, which plays a crucial role in attention and behavior regulation. The potential impact of these additives on the central nervous system (CNS) warrants further investigation, especially considering the rising incidence of ADHD diagnoses [10].

Numerous studies have explored the relationship between artificial food colorings and behavioral issues in children. For instance, a randomized controlled trial by McCann et al. [11] demonstrated that children consuming drinks containing artificial colorings exhibited significantly higher hyperactivity scores compared to those given placebo drinks. Similarly, studies by Arnold et al. [12] and Miller et al. [13] found associations between synthetic food colorings and increased irritability, restlessness, and sleep disturbances in children. These findings support the hypothesis that dietary factors, particularly artificial additives, may contribute to ADHD symptoms.

The growing body of evidence has prompted regulatory bodies to reconsider the safety of artificial food colorings. In 2008, the UK Food Standards Agency recommended phasing out specific colorings linked to hyperactivity, citing substantial evidence of their adverse effects on children's behavior. This recommendation reflects a broader shift toward prioritizing children's health and safety in food production and marketing [14].

1-2- Research Problem

Despite the accumulating evidence linking artificial food colorings to behavioral issues in children, particularly those diagnosed with ADHD, there remains a significant gap in understanding the extent and mechanisms of this relationship. The variability in individual responses to dietary interventions complicates the issue, as not all children with ADHD exhibit sensitivity to food colorings. This inconsistency raises critical questions regarding the role of genetics, environmental factors, and individual dietary habits in moderating the effects of artificial additives on behavior.

Key Issues to Address

1. Not all children with ADHD react similarly to artificial food colorings, suggesting that genetic predispositions or other environmental factors may play a role in moderating these effects.
2. Most studies have focused on short-term dietary interventions. There is a lack of longitudinal research examining the long-term behavioral outcomes of eliminating artificial colorings from the diet of children with ADHD.
3. While some studies suggest that artificial colorings may influence neurotransmitter levels, the precise biological mechanisms underlying these effects remain poorly understood. Further research is needed to elucidate how these additives interact with the CNS and influence behavior.
4. The dietary context in which artificial colorings are consumed may also be significant. For instance, the overall nutritional quality of a child's diet could influence their sensitivity to food additives.
5. There is a need for increased public awareness regarding the potential effects of artificial food colorings on behavior. Many parents may not be aware of the implications of these additives or how to manage their children’s diets effectively.

1-3- Aim and Objectives

This paper aims to investigate the effects of artificial food coloring on the behavior of children diagnosed with ADHD, focusing on identifying specific behavioral changes associated with dietary modifications.

Objectives

- To assess the behavioral changes in children with ADHD when dietary interventions are applied, specifically focusing on the elimination of artificial food colorings.
- To identify demographic or genetic factors that may contribute to varying sensitivities among children with ADHD regarding artificial food colorings.
- To explore the potential biological mechanisms by which artificial food colorings impact behavior, including effects on neurotransmitter levels and inflammatory responses.

- To evaluate the overall dietary patterns of children with ADHD to understand how these patterns may mediate the effects of artificial colorings on behavior.
- To disseminate findings through community outreach and educational programs aimed at parents and educators, highlighting the potential impact of diet on ADHD symptoms and the importance of monitoring food additives.

1-4- Research Significance

Understanding the relationship between artificial food colorings and behavior in children with ADHD is of considerable significance for several reasons. As ADHD continues to be one of the most commonly diagnosed neurodevelopmental disorders in childhood, identifying environmental factors such as diet that may exacerbate symptoms is essential for developing effective management strategies. Given the rising prevalence of ADHD globally, insights gained from this research could inform public health policies regarding food safety and nutrition. If artificial food colorings are demonstrated to significantly impact behavior, regulatory bodies may reconsider the use of these additives in children's food products, thereby improving public health outcomes.

Findings from this study could provide healthcare providers and parents with evidence-based dietary intervention strategies. By understanding which foods and additives may provoke hyperactive behaviors, families can make informed dietary choices that potentially mitigate ADHD symptoms, improving the quality of life for affected children and their families.

This research will contribute to the growing body of literature on the diet-behavior connection, adding depth to the understanding of ADHD’s multifaceted nature. By exploring diet, particularly the role of artificial additives, this study highlights a crucial but often overlooked aspect of managing ADHD. The study may pave the way for individualized dietary plans tailored for children with ADHD, acknowledging that some may be more sensitive to artificial additives than others. Such personalized interventions could enhance the efficacy of existing treatment strategies.

Emphasizing the importance of eliminating or reducing artificial food colorings can encourage both manufacturers and consumers to prioritize healthier food alternatives. This shift could stimulate demand for cleaner, more natural ingredients in children’s foods, fostering a broader trend toward improved nutrition.

The dissemination of research findings will raise awareness among parents, educators, and healthcare professionals regarding the potential impact of diet on child behavior and ADHD. This knowledge can empower parents to advocate for their children’s health by monitoring food additives in their diets. In summary, this research aims to illuminate the significant connection between artificial food coloring and ADHD symptoms in children. By exploring this relationship, we aim to provide a clearer understanding of the dietary influences on behavior, which could lead to better health outcomes for children facing the challenges of ADHD. Ultimately, this study aspires to contribute to a larger dialogue on how dietary modifications can play a vital role in managing behavioral issues in childhood, fostering a healthier future for children affected by ADHD.

2- LITERATURE REVIEW

Attention-Deficit/Hyperactivity Disorder (ADHD) is a complex neurobehavioral developmental disorder that affects a significant portion of the child population worldwide [15]. It is characterized by persistent patterns of impulsivity, inattention, and, in some cases, hyperactivity. The prevalence of ADHD is estimated to be between 3% and 5% globally, with symptoms often beginning before the age of seven [16].

2-1- Definition of ADHD

ADHD is defined as a neurobehavioral developmental disorder characterized by a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. The disorder is associated with differences in brain activity and structure, particularly in the frontal cortex, basal ganglia, and cerebellum—regions essential for behavior inhibition, attention maintenance, and mood regulation [2].

The clinical definition of ADHD has evolved since its inception in the mid-20th century. Initially referred to by various terms, including "minimal brain damage," "minimal brain dysfunction," and "hyperactivity," the terminology surrounding ADHD has undergone significant changes as understanding of the disorder has advanced. For instance, the term "minimal brain damage" became less appropriate as it was recognized that many children without brain damage exhibited ADHD symptoms [17]. Today, the terms ADHD, Attention Deficit Disorder (ADD), and Adult Attention Deficit Disorder (AADD) are used, particularly among older adolescents and adults who may not exhibit hyperactivity but still experience inattention [18].

2-2- ADHD Types

According to the **Diagnostic and Statistical Manual of Mental Disorders** (DSM-IV), ADHD symptoms are categorized into three subtypes [19]:

1. **Inattentive Type**: Characterized primarily by inattention.
2. **Hyperactive/Impulsive Type**: Characterized primarily by hyperactivity and impulsivity.
3. **Combined Type**: A combination of inattentive and hyperactive-impulsive symptoms.

Approximately 50% to 75% of individuals with ADHD fall into the combined type, while 20% to 30% exhibit the inattentive type, and over 15% are classified as hyperactive/impulsive [20].

ADHD is generally a chronic disorder, with 30% to 50% of individuals diagnosed in childhood continuing to experience symptoms into adulthood. As they mature, many adolescents and adults develop coping mechanisms to manage their impairment [21]. In 1978, ADHD was formally recognized as affecting adults, often referred to as AADD, with symptoms of hyperactivity generally being less pronounced. Diagnosis can provide adults with insights into their behaviors and help them seek appropriate coping and treatment strategies. Studies indicate that adult ADHD can be effectively treated with a combination of medication and behavioral therapy [22].

2-3- Historical Context of ADHD

The historical context of ADHD can be traced back to the 19th century. Dr. Heinrich Hoffman, a physician and author, provided one of the earliest descriptions of ADHD-like behavior in his poem "The Story of Fidgety Philip," published in 1845. This poem captures the essence of a child with ADHD, illustrating behaviors such as fidgeting and impulsivity [23].

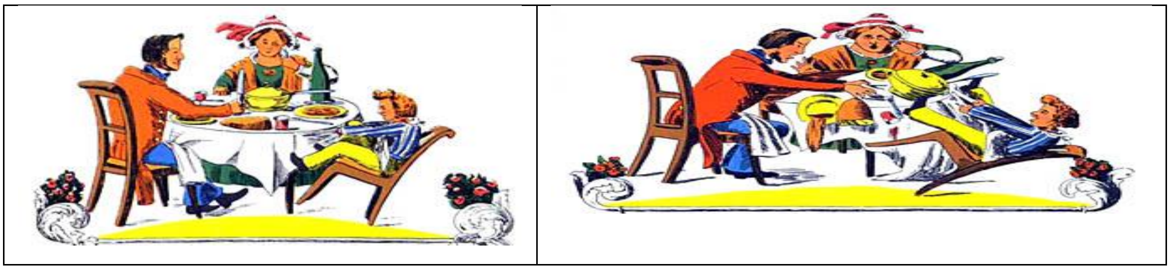


Figure 1: “The Story of Fidgety Philip”

In 1902, Sir George Still delivered a series of lectures to the Royal College of Physicians in England, examining a group of impulsive children. He suggested that these behaviors were not the result of poor parenting but rather a genetic dysfunction (Still, 1902). This marked the first clinical description of ADHD, initially labeled as "Morbid Defect of Moral Control."

Over the years, ADHD has been referred to by various names:

- **1902**: "Morbid Defect of Moral Control"
- **1922**: "Post-encephalitic Behavior Disorders"
- **1930s**: Introduction of amphetamines for treating hyperactivity.
- **1956**: Ritalin introduced as a treatment for hyperactivity.
- **1960**: Renamed "Minimal Brain Dysfunction."
- **1968**: "Hyperkinetic Reaction of Childhood," despite many children diagnosed exhibiting attention deficits without hyperactivity.

In the 1980s, ADHD became more formally recognized with the National Institute of Mental Health identifying a set of characteristics associated with Attention Deficit Disorder, both with and without hyperactivity. The 1994 edition of the **Diagnostic and Statistical Manual of Mental Disorders** (DSM-IV) established three subtypes for ADHD, reflecting a growing understanding of the disorder that would be crucial for diagnosis and treatment.

2-4- Epidemiology of ADHD

The global prevalence of ADHD is estimated at approximately 3% to 5% in individuals under the age of 19, although significant geographical variation exists. For instance, rates of ADHD diagnoses are noted to be higher in North America compared to regions like Africa and the Middle East (Polanczyk et al., 2007). Research has indicated that ADHD diagnosis rates can range from as low as 2% to as high as 14% among school-aged children, which mirrors differences in diagnostic practices and healthcare access (LONI, 2008).

In the United States, the diagnosis and treatment of ADHD have increased notably since the 1970s. For example, in the 1970s, approximately 12 per 1,000 children were diagnosed with ADHD, while this figure rose to 34 per 1,000 by the late 1990s (National Collaborating Centre for Mental Health, 2008). A gender disparity in ADHD diagnosis is also evident, with estimates from the UK in 2003 indicating prevalence rates of 3.6% for males compared to less than 1% for females (NICE, 2008). In Saudi Arabia, ADHD is reported at a ratio of approximately 4:1, with boys being diagnosed more frequently than girls (Fig 2). Variations in prevalence by country can be influenced by factors such as diagnostic criteria, age and gender demographics of the population, and socio-economic factors.

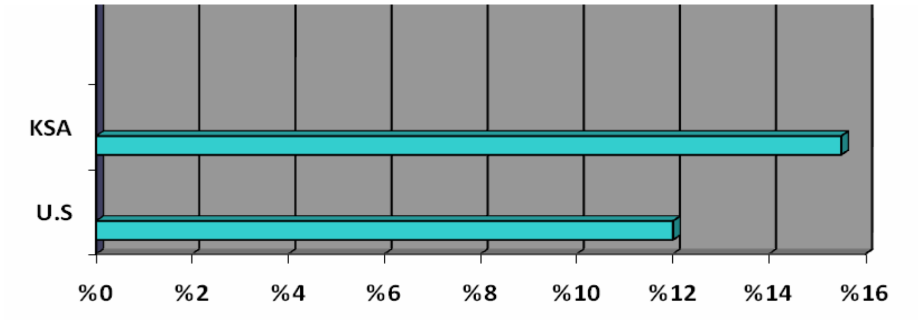


Figure 2: The percent of ADHD children in United State and in Saudi Arabia.

2-5- Etiology of ADHD

The specific etiology of ADHD remains elusive, with several factors identified that may contribute to the disorder. Research suggests a multifactorial origin, including:

1. **Genetic Factors**: There is significant evidence pointing to hereditary components of ADHD as numerous studies highlight high rates of ADHD among first-degree relatives of affected individuals (Bailly, 2000).

2. **Neurobiological Factors**: Changes in brain structure and function have been implicated in the disorder. Neuroimaging studies have established that individuals with ADHD often present variations in the neuroanatomy and neurochemistry of key brain regions associated with attention and behavior, particularly in dopamine pathways critical for attention regulation [2].

3. **Environmental Influences**: Various external factors, including prenatal exposure to toxins (such as tobacco or alcohol), psychosocial stressors, and low socioeconomic status, may exacerbate the risk of developing ADHD symptoms.

Researchers have observed that altered brain pathways, particularly those involving dopamine neurotransmission, can lead to difficulties with attention, planning, and impulse control—core characteristics of ADHD [2].

2-6- Pathophysiology of ADHD

The pathophysiology of ADHD is complex and not fully understood. A leading premise is that ADHD is related to dysfunction in catecholamine (including dopamine) transmission, which affects attention and behavior regulation. Neuroimaging studies have indicated various structural and functional anomalies in individuals with ADHD. Research suggests that certain brain structures, particularly in the frontal cortex, may develop three years later in children with ADHD compared to their peers (Oshi, 2002). The frontal lobe plays a crucial role in cognitive functions such as planning, decision-making, and impulse control. Delays in its maturation could account for the behavioral symptoms observed in ADHD.

Studies using single-photon emission computed tomography (SPECT) and positron emission tomography (PET) imaging have shown that individuals with ADHD may display reduced blood flow and glucose metabolism in brain areas responsible for attention and impulse control (Zametkin et al., 1990). Interestingly, the degree of neural activity inversely correlates with the severity of concentration difficulties in individuals diagnosed with ADHD.

Several studies have reported abnormalities in the dopamine transport system in individuals with ADHD, including heightened concentrations of dopamine transporters in the striatum, which is associated with impaired planning and reward processing (Dougherty et al., 1999). Medications like methylphenidate improve function by modulating dopamine levels, thus enhancing attention and reducing impulsivity. An intriguing hypothesis within ADHD research is that some individuals may experience sensory overstimulation as a form of sensory processing dysfunction, which could stem from abnormalities in ion channel regulation within the peripheral nervous system (Lou et al., 1998).

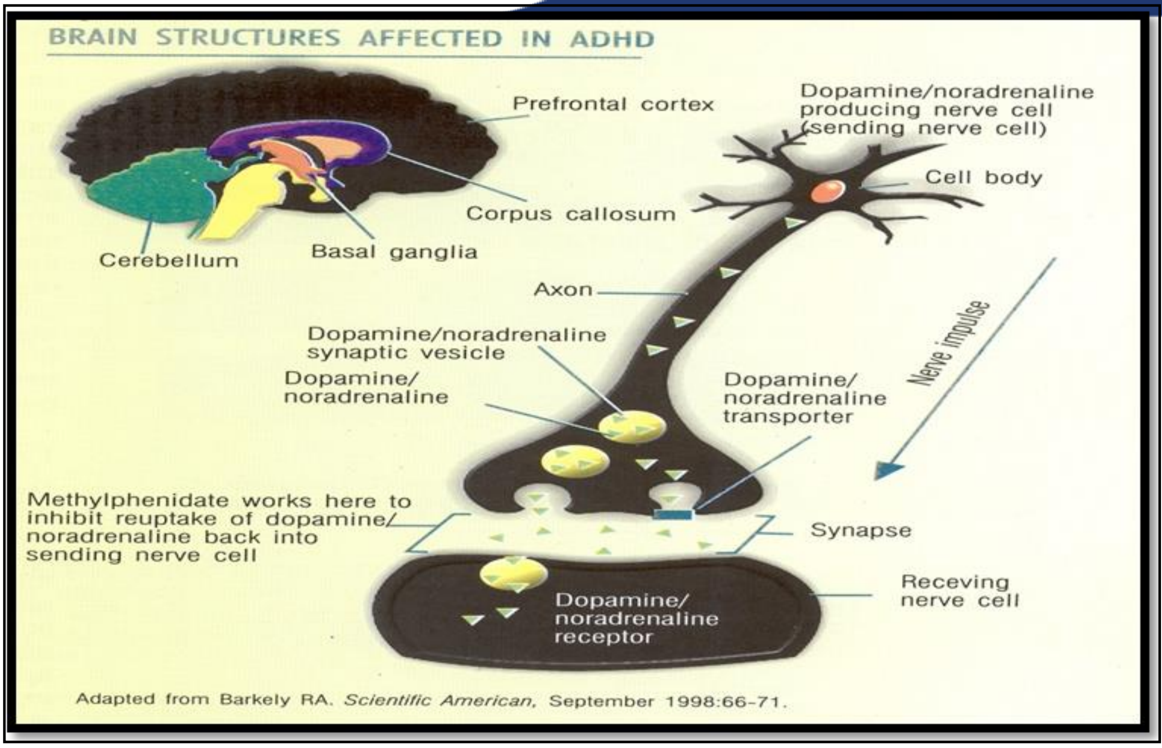


Figure 3: The dopamine with ADHD

2-7- Treatment Approaches

Treatment for ADHD typically encompasses a multimodal approach that may include pharmacological intervention, behavioral therapies, and educational supports.

The primary treatment for ADHD is stimulant medication, including methylphenidate (often known as Ritalin) and amphetamines. These medications are effective in reducing core symptoms of ADHD, including inattention, impulsivity, and hyperactivity, by increasing dopamine and norepinephrine levels in the brain to improve attention and behavior regulation (Kessler et al., 2006).

For individuals who may not respond well to stimulants or exhibit undesirable side effects, non-stimulant options such as atomoxetine (Strattera) can be considered. Atomoxetine works as a selective norepinephrine reuptake inhibitor and is associated with a lower risk of abuse (Kessler et al., 2006).

Behavioral therapies, including cognitive-behavioral therapy (CBT), parent training, and skills training, are beneficial in supplementing medication treatment. These therapies aim to modify maladaptive behaviors, improve social skills, and establish adequate coping strategies.

Education about ADHD for both patients and their families is essential for managing the disorder effectively. Providing information on symptom management, coping strategies, and ways to create supportive environments can significantly enhance treatment outcomes.

2-8- Nutritional Management of ADHD

Research suggests that nutrition plays a critical role in the management of ADHD symptoms. Several studies have indicated that dietary factors, including food allergies, sensitivities, and nutritional deficiencies, may contribute to the severity of ADHD symptoms [21]. While there is no universally accepted diet for ADHD, a balanced diet rich in essential nutrients are essential for optimal brain function and behavior regulation. Dietary interventions typically focus on eliminating specific foods that may trigger or exacerbate ADHD symptoms. One of the most well-known elimination diets is the **Feingold Diet**, which posits that certain artificial additives, colors, and salicylates found in foods can negatively affect behavior in sensitive children [9]. Although some parents report improvements in behavior when following this diet, scientific evidence supporting its efficacy remains mixed [2].

The Feingold Diet emphasizes the removal of artificial colors, flavors, and preservatives from the diet, as well as certain natural substances like salicylates. Proponents of this diet claim that many children with ADHD experience reduced hyperactivity and improved focus when these substances are eliminated. However, systematic reviews of the diet's efficacy have produced inconclusive results, with some studies showing minimal improvement in ADHD symptoms [9].

While specific elimination diets may not be universally effective, general dietary recommendations emphasize the importance of a balanced diet. A diet rich in whole foods, including fruits, vegetables, whole grains, lean proteins, and healthy fats, is essential for supporting cognitive function and emotional well-being [22]. Additionally, avoiding excessive sugar and processed foods may help mitigate hyperactive behaviors in some children [24].

In contrast to dietary interventions that focus on elimination, nutritional supplementation seeks to address potential deficiencies that may contribute to ADHD symptoms. Several nutrients have been studied for their potential impact on ADHD, including essential fatty acids, vitamins, and minerals [25].

Research has indicated that children with ADHD may have lower levels of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [26]. These fatty acids are crucial for brain health and function, and deficiencies may contribute to cognitive deficits and behavioral issues. A study conducted by Martin et al. [27] found that supplementation with omega-3 fatty acids resulted in significant reductions in hyperactivity and impulsivity among children with ADHD. The findings suggest that omega-3 supplementation may be an effective adjunctive treatment for managing ADHD symptoms, especially in children who do not respond adequately to traditional pharmacotherapy.Several vitamins and minerals have been associated with ADHD symptoms, including magnesium, zinc, iron, and B vitamins. Deficiencies in magnesium have been linked to increased hyperactivity and behavioral problems in children [28]. Supplementation with magnesium has shown promise in reducing hyperactive behaviors in children with ADHD. Zinc deficiency has been implicated in various neuropsychiatric disorders, including ADHD. Research has shown that children with ADHD may have lower zinc levels, and supplementation has been associated with improvements in attention and behavior [29]. In addition, Iron deficiency has been correlated with more severe ADHD symptoms and cognitive deficits. Studies have indicated that improving iron levels can lead to better behavioral outcomes in children with ADHD [30].

Adequate levels of B vitamins, particularly B6, are essential for the synthesis of neurotransmitters, including serotonin, which plays a role in mood regulation. Supplementation with B vitamins, particularly B6, has been suggested as a potential strategy for managing ADHD symptoms [31]. Some studies have shown that a B-complex supplementation regimen can positively impact ADHD symptoms, although more comprehensive research in larger populations is needed to establish clear guidelines [32-36].

Research indicates that some children with ADHD exhibit difficulties in glucose metabolism, leading to fluctuations in blood sugar levels that may exacerbate hyperactivity. When these children consume high-sugar or high-carbohydrate foods, they may experience rapid blood sugar spikes followed by significant drops, which can result in lethargy, irritability, and increased hyperactive behaviors [37].

One proposed approach to mitigate these effects involves reducing the intake of simple sugars and high-glycemic index carbohydrates, which can lead to more stable blood sugar levels and improved behavior. Some studies have suggested that children with better-controlled diets, particularly those low in refined sugars and processed foods, show improved concentration and decreased hyperactivity [38].

The neurotransmitter serotonin has been implicated in ADHD, particularly regarding mood regulation. Children with ADHD often display lower serotonin levels, which may contribute to impulsivity and emotional dysregulation [39]. Since vitamin B6 is crucial for serotonin synthesis, ensuring adequate intake of this vitamin may offer some benefits in managing ADHD symptoms.Oxidative stress may play a role in the pathophysiology of ADHD. Increased oxidative stress can damage brain cells, potentially exacerbating symptoms. Antioxidants such as vitamins E and C, along with minerals like selenium, help combat oxidative damage and target free radicals that could contribute to neuronal injury [40,41]. Incorporating antioxidant-rich foods, such as colorful fruits and vegetables, may provide protective benefits for children with ADHD.There is a noteworthy correlation between the dietary patterns in early childhood and behavioral outcomes later in life. A comprehensive study conducted over several decades found that children diagnosed with ADHD had higher rates of substance use disorders, depression, and low self-esteem in adulthood compared to their non-ADHD counterparts [42]. These findings underscore the importance of early nutritional interventions to address potential deficiencies and sensitivities, aiming to improve immediate symptoms while promoting long-term well-being. Considering the complexity of ADHD, a multimodal approach to treatment that includes nutritional management, behavioral therapies, and, when necessary, pharmacological interventions is critical. Medication, such as Ritalin and Dexedrine, provides symptomatic relief but does not cure ADHD or address underlying causes. Given that some studies have shown comparable effects of dietary interventions and pharmacological treatments, incorporating nutrition as a foundational element of ADHD management may enhance overall outcomes [2].

3- MATERIAL & METHOD

3-1- Study Design

Our study was therapeutic experimental study based on the concept of elimination, that foods which contain coloring agents are eliminated from children's diet. This study began in January 2024. Questionnaires were distributed to the parents (mothers) and teacher in the school or in the behavioral centers, to assess the children's behaviors. The questionnaires applied two times, one before the dietary intervention and one after the intervention. Handouts of the disallowed food items and pictures of the disallowed food items were given to children's mothers. The nutritional intervention procedure was divided into two phases:

Phase one:

The children's parents were asked to continue their children's normal daily diet, and take daily food records for a week to have an idea on what they are actually eating and their preferences. At the end of that week, we collected the food records and distribute a questionnaire for the parents and teachers to assess the children behavior at that week.

Phase two (elimination period)

The children were put on partly free food additives (food coloring E102, E104, E110, E122, E124 and E129) for a period of six weeks. Handouts of the disallowed food items were given to the parents which included confectionery, cotton candy, soft drinks, energy drinks, flavored chips (Doritos, Nachos, etc.), cereals (corn flakes), cake mixes, custard powder, soups (particularly "cube" soups), sauces(ketchup), ice cream, ice pops, candy, chewing gum, , jam, jelly, mustard, flavored yogurt , noodles, pickles and other pickled products, certain brands of fruit squash, fruit cordial, many convenience foods together with lemon and honey products, smoked meat, hot dog, colored fruit and cupcake .

3-2- Study sample:

Seven subjects were recruited for the study was diagnosed with the attention deficit hyperactivity disorder (ADHD). Inclusion criteria included boys aged between 5 and 11 years old, with ADHD, where the children were not on a special diet. Children who were >11 and <5, girls, not diagnosed with ADHD, or who followed a special diet were excluded from the study. **(Fig.3, Table 1)**

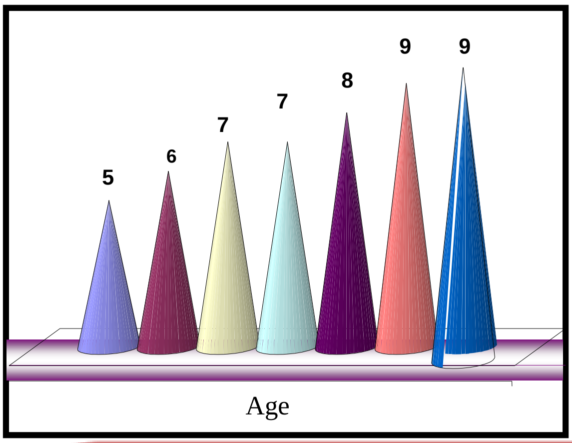


Figure 3: Age of study sample

Table 1: Study sample

No.	Date of birth	Age	Gender	Who completed a questionnaire
1	02/09/2000	9	Boy	Mother
2	24/07/2002	7	Boy	Mother
3	01/01/2004	5	Boy	Mother
4	2002/08/03	7	Boy	Mother
5	2004/02/02	6	Boy	Mother
6	04/11/2001	8	Boy	Mother
7	01/01/2000	9	Boy	Mother

3-3- Study tools

Study tools included questionnaires to collect and analyze data and information related to the study, in order to achieve the objectives of the study, and answer research's question.

There are two types of questionnaires:

- A special questioner to identify the symptoms of (ADHD) from parent's point of view**.**
- Another questioner to identify symptoms of (ADHD) from children's teacher's point of view**.**

3-4- Measure study variables:

Trio-quaternion standard was used for terms responses of study participants as follows:

[never, sometimes, often, a lot] so that the response "a lot" takes 3 grades, "often" 2 grades," sometimes" 1 grade, and "never" zero. For the practical analysis and interpretation of the study data to achieve the objectives, questions and test hypothesis, in order to derive the most prominent results, the study data entered in a software Statistical Package for Social Science (SPSS) program, and after the data has been analyzed, the statistical tables derived and then display and interpret the results.

The data analysis scenario was being within the following conception:

- Compare the sample trends toward the most important symptoms of ADHD with children before and after the dietary intervention from parent's point of view.
- Compare the sample trends toward the most important symptoms of ADHD with children before and after the dietary intervention from teacher's point of view.

4- RESULTS

There is a difference between the arithmetic mean before and after treatment and this decrease has been negatively signed. This means that the results of the responses after treatment shows that there is an effect of the treatment led to a lack of symptoms in this study, we find that the questions (40, 28) achieved the highest difference in the study, (- 1.15 and - 1) respectively, followed by symptoms (1, 2, 4, 11, 13, 21) which have a difference (-8.6).

We find symptoms (7, 22, 33, 35, 36, 42, 44) achieved the least difference (- 0.14), and we find that all these symptoms indicate the behavior of non-acceptable or desirable behaviors. With the symptoms (15, 38), there has been no change in the average and there is no evidence on the impact of the treatment, while symptoms (27, 32, 37) gives a positive difference talking about Symptoms are not acceptable, this means that the result is positive.

From these results we have achieved, it was very clear that there is positive impact of the nutritional intervention on the ADHD children from the parent' point of view. Figure (4) compare the results of the symptoms for children before and after treatment from the parent's point of view.

There is a difference between the arithmetic mean before and after treatment and this decrease has been negatively signed. These result shows that there is an effect of the treatment led to a lack of symptoms which indicate behaviors affect the academic achievement of children and clearly shows the improvement in children behavior and school or school activities from the teacher's point of view (figure 5).

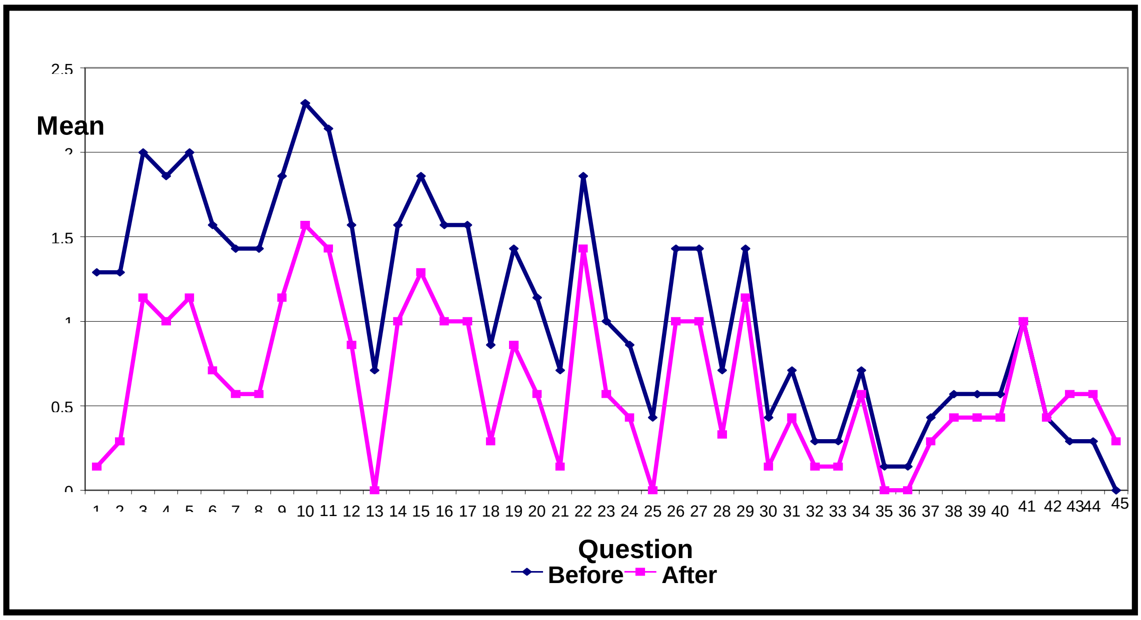
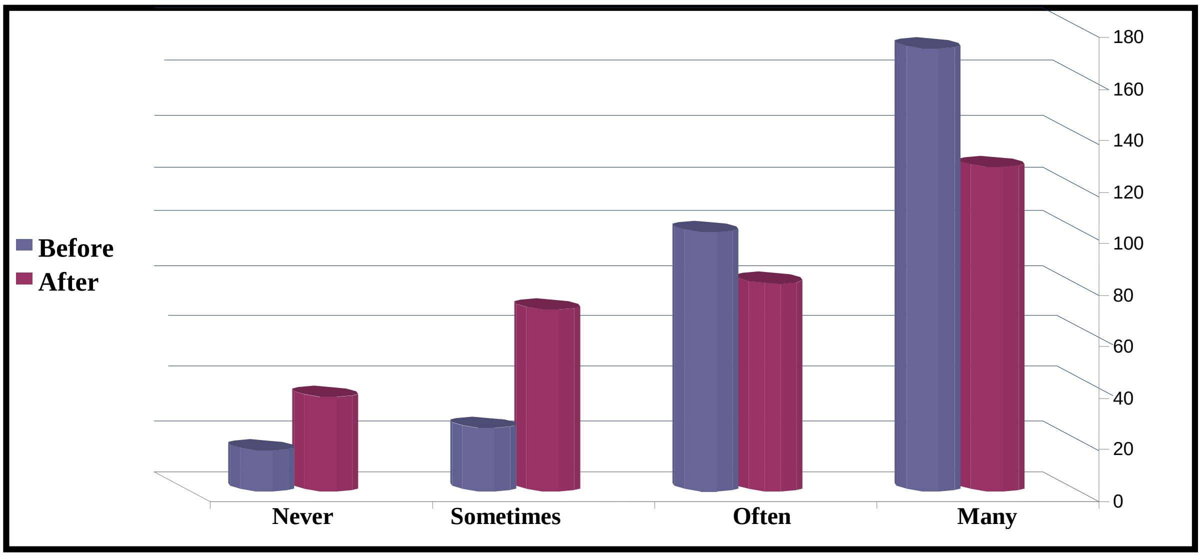


Figure 4: Comparison of symptoms' results for children before and after treatment from the ***parent's*** point of view



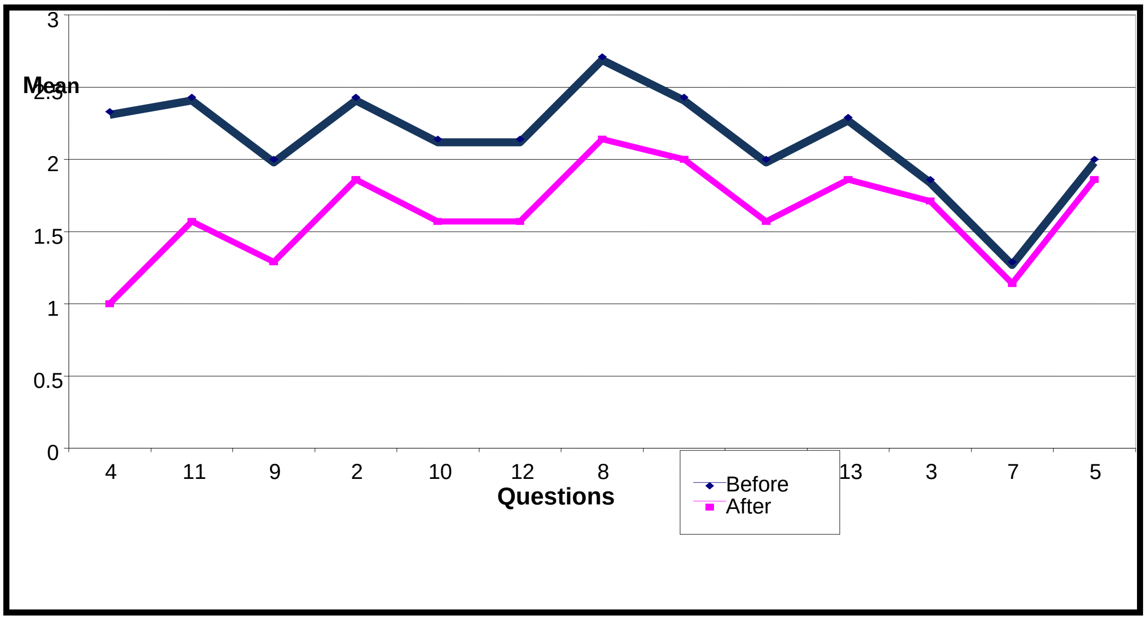


Figure 5: Comparison of symptoms' results for children before and after treatment from the ***teacher*'s** point of view

There is a decrease in the number of frequencies of the answers (many and often) which indicate increase in the symptoms related to ADHD and increase in the number of frequencies of the answers (sometimes and never) which indicate decrease in symptoms related to ADHD from the parent's point of view, and through this we can deduce that there is improvement and change in ADHD symptoms (figure 6).

Table 2: Comparison of number of frequencies of the study sample before and after treatment from the of the ***parents'*** point of view

Child status	(Always)	(Often)	(sometimes)	(never)	Total
Before	**172**	**101**	**25**	**16**	**314**
After	**126**	**81**	**71**	**37**	**315**

Figure 6: Comparison of number of frequencies of the study sample before and after treatment from the of the

parent's point of view

There is a decrease in the number of frequencies of the answers (many and often) which indicate increase in the symptoms related to ADHD and increase in the number of frequencies of the answers (sometimes and never) which indicate decrease in symptoms related to ADHD from the teachers' point of view, and through this we can deduce that there is improvement and change in ADHD symptoms (fig. 7).

Table 3: Comparison of number of frequencies of the study sample before and after treatment from the ***teachers'*** point of view

Child status	(Always)	(Often)	(sometimes)	(never)	Total
Before	**42**	**25**	**18**	**5**	**90**
After	**21**	**24**	**33**	**11**	**89**

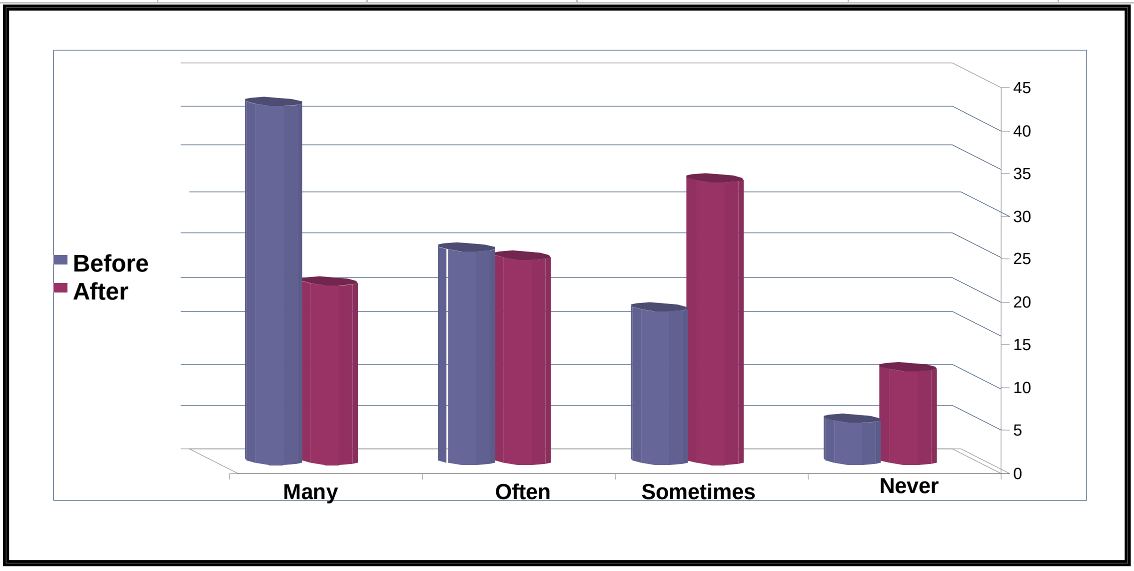


Figure 7: Comparison of number of frequencies of the study sample before and after treatment from the ***teachers'*** point of view

Distribution of the sample according to the symptoms from the parent' point of view

The sample was distributed according to the symptoms from the ***parent's*** point of view before treatment as follows, never: 16 repetition and recurrence 5%, **sometimes:** 25 repetition the rate of recurrence is 8%, **often** a repetition of 101 the rate of recurrence 32%, **many** 172 repetition and recurrence rate of 55% (fig. 8).

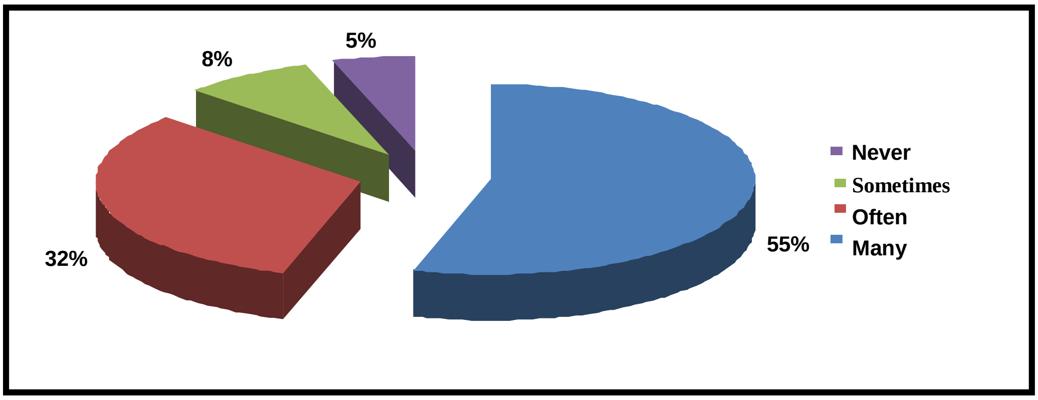


Figure 8: Shows the degree of symptoms on the study sample from the parent' point of view before the treatment

The sample was distributed according to the symptoms from the ***parent's*** point of view after treatment as follows, **never**: 37repetition and recurrence 12%, **sometimes:** 71 repetition the rate of recurrence is 23%, **often** a repetition of 81 the rate of recurrence 26%, **many** 126 repetition and recurrence rate of 39% (fig. 9).

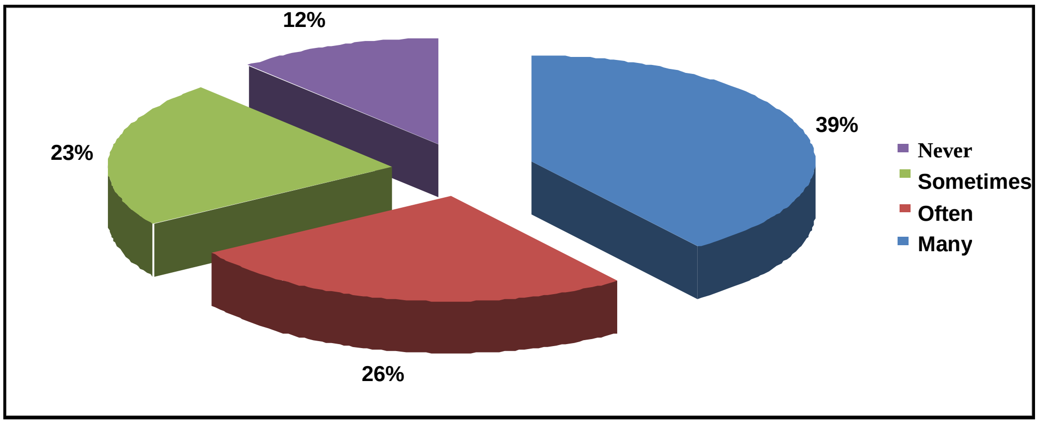


Figure 9: Shows the degree of symptoms on the study sample from the parent' point of view after the treatment

Distribution of the sample according to the symptoms from the teachers' point of view

The sample was distributed according to the symptoms from the ***teacher's*** point of view before treatment as follows, **never**: 5 repetition and recurrence 5%, **sometimes:** 18 repetition the rate of recurrence is 20%, **often** a repetition of 25 the rate of recurrence 28%, **many** 42 repetition and recurrence rate of 47% (fig. 10).

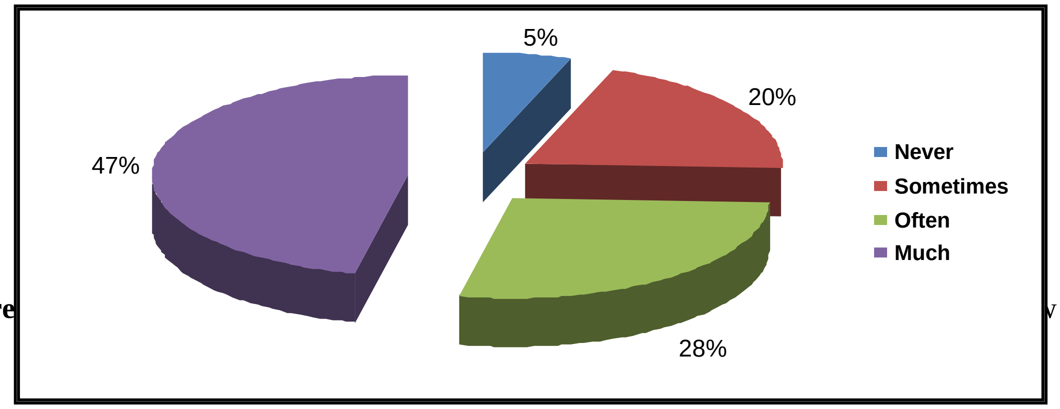


Figure before the

The sample was distributed according to the symptoms from the ***teacher's*** point of view after treatment as follows, **never**: 11 repetitions and the recurrence rate of 12%. **Sometimes:** 33 repetition the rate of recurrence of 37%, **often** a repetition of 24, rate of recurrence 27%, **many** 21-repetition recurrence rate of 24% (fig. 11).

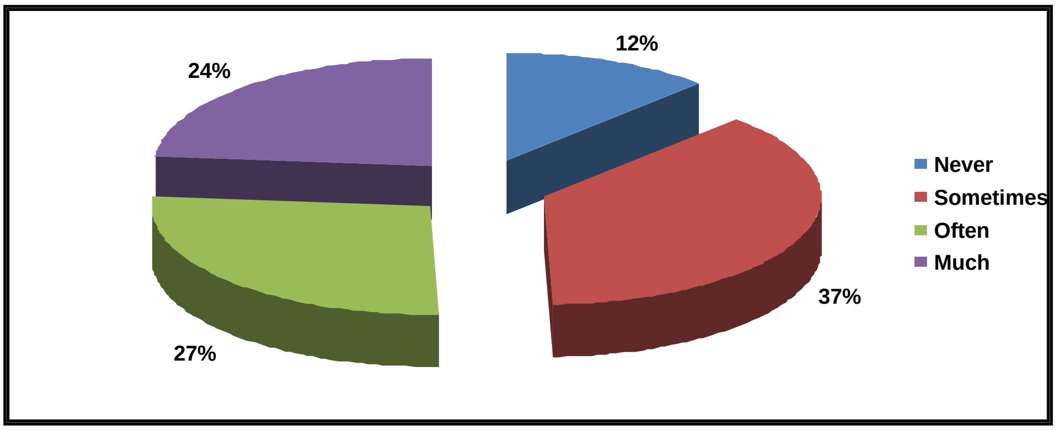


Figure 11: Shows the degree of symptoms on the study sample from the teachers' point of view after the treatment

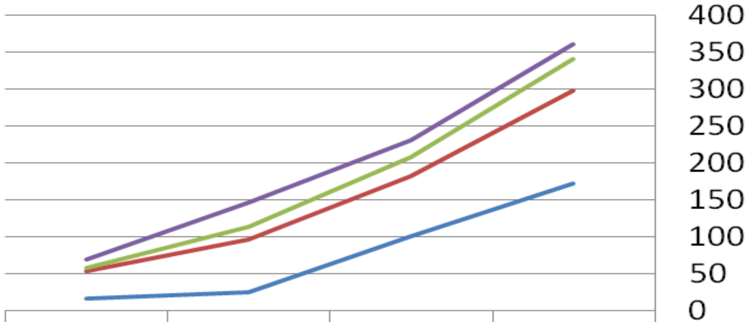
A T Test-Paired sample was done on the results of a study (before treatment and after treatment) from the parents' point of view and found that the value of the test function equal to t = (0.012159 -) means that the (P-value equal to nearly zero), and this indicates that there is substantial improvement (statistically significant) in the value of the symptoms of (ADHD) after treatment, and therefore the positive effect of treatment (fig. 12).

A T Test-Paired sample (before treatment and after treatment) from the of teachers' point of view and found that the value of the test function equal to t = (0.01216 -) means that the (P-value equal to nearly zero), indicating that There is substantial improvement (statistically significant) in the value of the symptoms of (ADHD) after treatment, and therefore the positive effect of treatment.

Table 8: Comparison of number of frequencies of the study sample before and after treatment from the ***parents and teachers'*** point of view

	Many	Often	Some times	Never	Total	Mean	S. D	T
Before (parents)	**172**	**101**	**25**	**16**	**314**	**78.5**	**73.07**	**(0.012159-)**
After (parents)	**126**	**81**	**71**	**37**	**315**	**78.75**	**36.70**	
Before (teachers)	**42**	**25**	**18**	**5**	**90**	**22.5**	**15.42**	**(0.01216 -)**
After (teachers)	**21**	**24**	**33**	**11**	**89**	**22.25**	**9.07**	

(P-value for both parents and teachers equal to nearly zero), and this indicates that there is substantial improvement (statistically significant)



	Never	SomeTimes	Often	Many
After (teachers)	11	33	24	21
Before (teachers)	5	18	25	42
After (parents)	37	71	81	126
Before (parents)	16	25	101	172

Figure 12: Comparison of number of frequencies of the study sample before and after treatment from the ***parents and teachers'*** point of view

5- DISCUSSION & CONCLUSION

5-1- Discussion

Recent advancements in research have highlighted the significant interplay among psychology, neurochemistry, and nutrition, leading to the emergence of the multidisciplinary field known as psychoneuro-nutritional medicine. This model has successfully addressed various mental health issues, ranging from behavioral disorders in children to cognitive and emotional challenges in adults, paving the way for new, low-tech, cost-effective strategies to enhance functional neurobiochemistry.

Nutritional interventions based on this model aim to reduce exposure to neurotoxic substances, such as artificial food colorings, while simultaneously increasing the intake of nutrients that support the normalization of neurochemical activity. Specific dietary adjustments have shown promise in improving cognitive and emotional functioning.

The association between food additives and behavioral changes, particularly in children with ADHD, was first posited by Feingold in the mid-1970s. A consensus conference by the National Institute of Health (NIH) in 1982 corroborated this notion, concluding that certain dyes and dietary components could contribute to ADHD symptoms in a subset of children. More recently, the Food Standards Agency (FSA) in the UK recommended phasing out six artificial colors linked to increased hyperactivity, based on a study by a research team from the University of Southampton.

In our study, which included a sample of seven boys diagnosed with ADHD, we conducted a two-phase intervention. The first phase lasted two weeks, during which the children maintained their regular diet,

ISSN-E: 18735347-02779536

including food coloring agents. The second phase extended for six weeks and involved the elimination of most artificial colorings from their diet. Results indicated that all seven boys exhibited significant improvements in hyperactivity and inattention after transitioning to a diet free from artificial colorings.

Statistical analysis using a paired sample t-test revealed a significant reduction in ADHD symptoms from both parents' and teachers' perspectives, with a p-value close to zero (t = -0.012159). This finding suggests a substantial improvement in symptoms post-intervention. Notably, parents reported more pronounced changes in behavior than teachers, likely due to their extended exposure to their children's behavior across various settings and circumstances.

5-2- Limitations of Study Design

The design of our study has several limitations that may have affected our ability to detect the effects of dietary changes on behavior in children with ADHD. The small sample size of only seven boys limits the generalizability of our findings. Additionally, the study faced challenges with participant retention during the challenge phase, as families encountered difficulties modifying their children's diets over the six-week period.

Another limitation is the complexity of food composition, making it challenging to isolate and assess the specific effects of individual components, including artificial food colorings. Many staple food products contain these additives, complicating efforts to eliminate them entirely from the children's diets. As the adage goes, “if a child is limping because he has five nails in his shoe, removing one nail won’t help him much.”

Moreover, we could not ensure compliance with the artificial food coloring-free regimen among parents, which required considerable commitment and control. Lastly, we aimed to extend our research by contacting the ADHD Support Group in Saudi Arabia, but unfortunately, we were unable to establish communication.

5-3- Conclusion

Attention-deficit hyperactivity disorder (ADHD) is a multifaceted condition that requires a comprehensive treatment approach. Nutritional management, an aspect often overlooked in ADHD treatment, has shown potential in addressing symptoms linked to food additives. Increasing evidence suggests that many children with behavioral issues may be sensitive to specific food components that adversely affect their behavior. Dietary modifications, therefore, should be considered a vital component of ADHD management.

Our findings indicate that significant improvements in hyperactive behaviors can result from the removal of artificial colorings and sodium benzoate from children's diets. Future studies should involve a larger participant pool, including families willing to engage in double-blind food challenge phases. The potential long-term public health benefits of such dietary changes are underscored by follow-up studies indicating that young hyperactive children are at risk for ongoing behavioral difficulties, including the development of conduct disorders and educational challenges.

We advocate for the removal of artificial food colors and benzoate preservatives from children's diets, as the evidence supporting this change is compelling. These findings warrant further investigation in diverse population samples to examine whether similar benefits can be observed in older children and adolescents. High-quality research is urgently needed to better understand how dietary changes and nutritional supplements can effectively contribute to the treatment of ADHD, ultimately enhancing the quality of life for affected children and their families.

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