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Dietary Alternatives in the Treatment of Attention Deficit Hyperactivity Disorder: Behavioral Symptoms and School Performance

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DIETARY ALTERNATIVES IN THE TREATMENT OF ATTENTION DEFICIT HYPERACTIVITY DISORDER: BEHAVIORAL SYMPTOMS AND SCHOOL PERFORMANCE

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Abstract

Dietary alternatives for the treatment of Attention Deficit Hyperactivity Disorder (ADHD) are less commonly known and discussed, leaving some children untreated and vulnerable to negative consequences. However, numerous studies have examined the behavioral and academic benefits of following diets as alternative treatments for ADHD. This literature review answers the question: Can school performance, negatively impacted by ADHD, be managed in children by following diets that eliminate artificial food coloring (AFC) or by taking iron supplements? The review found that some children with ADHD can benefit from following an AFC exclusion diet or from taking iron supplements. Benefits were more common in children pre-screened for AFC sensitivities and those who had abnormally low iron levels.

Table of Contents

Chapter I: Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common childhood neurodevelopmental disorders where an estimated 6.1 million children have been diagnosed in the United States (Centers for Disease Control and Prevention [CDC], 2020). From 2003 to 2011, the prevalence of children with ADHD has increased by 42% (National Institute of Mental Health [NIH], 2017). The Diagnostic and Statistic Manual of Mental Disorders, fifth edition (DSM-5) defines ADHD as a disorder in which people show a persistent pattern of inattention and/or hyperactivity/impulsivity that interferes with their functioning or development (CDC, 2020). To be diagnosed with ADHD, inattention and/or hyperactivity/impulsivity symptoms must be present before age 12, developmentally inappropriate, present for at least six months, not explained by another mental disorder, and present in at least two different settings (ex: at home, school, work, etc.) (CDC, 2020).

ADHD presents in three ways based on the type of symptoms: combined presentation (inattention and hyperactivity/impulsivity symptoms), predominantly inattentive presentation (mainly inattentive symptoms), and predominantly hyperactive-impulsive presentation (mainly hyperactive/impulsive symptoms) (CDC, 2020). The behaviors of children with ADHD will vary based on their ADHD presentation and what symptoms they present. In a school setting a child with ADHD may have trouble attending to instruction and/or tasks, make careless mistakes or not finish schoolwork, have trouble organizing materials for activities, lose necessary school materials, and are easily distracted. A child may also struggle to stay still and/or seated, have a hard time participating in quiet activities, talk excessively, blurt out answers, interrupt others, and have difficulty waiting their turn (CDC, 2020). No matter the symptom presentation, an ADHD diagnosis makes it more difficult for a child to do well in school.

The Centers for Disease Control and Prevention (2020) notes that behavioral classroom management, organizational training, and special education services or a 504 Plan are school-based strategies used to treat students with ADHD. However, studies show that behavior therapy and medications are the best ways to treat children with ADHD. In 2016, 62% of children took ADHD medication and 47% of children received behavioral therapy; some children received both treatments. Twenty-three percent of children did not receive treatment via medication or behavioral therapy (CDC, 2020).

If ADHD is left untreated, children may experience negative consequences. Children with untreated ADHD experience difficulties forming and keeping friends, have conflicts with parents, and fall behind in school (U.S. Food and Drug Administration [FDA], 2016). Some children are more likely to take dangerous risks, such as drinking and driving, which results in more frequent emergency room visits (FDA, 2016). The percentage of children who do not receive any form of ADHD treatment should be cause for alarm.

The U.S. Food and Drug Administration (FDA) recently approved two types of medications for the treatment of ADHD, stimulants and non-stimulants (FDA, 2016). Various forms of methylphenidate and amphetamine are available stimulant medications for ADHD while three different types of non-stimulant medications are available for children who do not tolerate stimulants well. Some of the common adverse side effects from ADHD medications include: sleep problems, irritability, decreased appetite, tics, delayed growth, headaches, nausea, and irritability when the medication wears off (Boorady, 2020). When a child experiences side effects from ADHD medications, doctors often change the dosage or type of medication (Boorady, 2020). The FDA also recommends behavioral therapy as a form of ADHD treatment. However, neither Boorady, the CDC, or the FDA recommend alternative ADHD treatment options.

While medications are noted as one of the best ways to treat ADHD, parent perceptions of this treatment option vary (CDC, 2020; Coletti et al., 2012). Perceptions that were a barrier to pursuing medications for ADHD treatment included the fear that medications would have negative side effects and could change their child's personality (Coletti et al., 2012). When parents' perceptions of ADHD medications were negative, their child's adherence to medication treatments were low or nonexistent (Coletti et al., 2012). Regardless, if a parent is not comfortable pursuing medication treatment for their child with ADHD, alternative treatment options should be discussed rather than leaving the child untreated and vulnerable to negative consequences.

Alternative treatment options are less commonly discussed because research on alternative therapy does not meet the same experimental standards as medication studies ("Alternative Treatments for ADHD", 2003). However, alternative ADHD treatment options are available and should be noted, especially for children who do not receive ADHD treatment, even if efficacy is variable. Some alternative treatments include fatty acid supplementation, homeopathy, hypnotherapy, vision therapy, oculovestibular treatment, sound training, vitamin/mineral supplementation, and diet change ("Alternative Treatments for ADHD", 2003).

Teachers are commonly the first ones to suspect ADHD in children making it important for educators and school staff to be knowledgeable on the topic (Al-Moghamsi & Aljohani, 2018). Al-Moghamsi and Aljohani (2018) surveyed teachers and found that 41% felt they were knowledgeable about ADHD. Teacher knowledge of treatment was lower at 30.7%. Educators and school staff need to be knowledgeable regarding treatment options, including alternative ADHD treatment options, as they are frequently the first line of contact for developing strategies and disseminating information to improve the academic skills and behaviors of children with ADHD. The FDA recommends that parents contact their children's schools for further information and guidance on treatment strategies for children with ADHD (FDA, 2016).

As an educator, I have personally experienced challenges when working with children who have ADHD. Three students particularly influenced my desire to review alternative treatment options for ADHD. One student was receiving special education intervention and taking ADHD medication but had adverse side effects. Initially, his medication wore off causing more severe symptoms near the end of the school day. When his medication was adjusted, he developed tics. Side effects from medication persisted for a whole school year and further inhibited his academic progress and friendships. The second student received special education intervention but did not take ADHD medication. The student's parents were against medications and solely relied on intervention services. Despite interventions, the student greatly struggled controlling his behaviors and completing academic work in the classroom. Without knowledge of alternative treatment options, this student's special education team and I were at a loss of other strategies to help this student be successful at school. The third student was taking ADHD medication and assessed for special education services because he struggled to attend during classroom instruction. If school staff had been knowledgeable about alternative ADHD treatment options and shared this information with the parents, perhaps alternative treatment could have prevented the student from special education placement. In these cases, and the cases of other students with ADHD, knowledge of alternative treatment options for the treatment of ADHD could have been beneficial.

Diet change and mineral supplementation are the focus of alternative ADHD treatment in this paper since they represent alternative practices that schools could safely implement district wide for all students. The purpose of this literature review is to determine whether ADHD symptoms and school performance in children can be managed by following a diet that eliminates artificial food coloring or by taking iron supplements. Subtopics discuss the typical dietary patterns and mineral levels of children with ADHD; and ways artificial food colorings (AFC) and iron levels affect children's ADHD symptoms related to behavior and school performance.

Understanding the overall dietary patterns and mineral levels of children with ADHD lays the foundation for understanding which specific dietary characteristics have the biggest impact on ADHD symptoms in children, AFC or iron levels. While several studies examined food science and children's diets in general (Batada & Jacobson, Stevens et al., Florence et al., Bateman et al.), fewer studies examined the specific diet qualities of children diagnosed with ADHD (Ptacek et al., Azadbakht & Esmaillzadeh, Wang et al.). The effects of AFC and iron levels on ADHD will also be reviewed to determine their impact on symptom severity and school performance. Studies documented that the foods children consume throughout the day affected academic performance and behaviors (Florence et al., 2008; Park et al., 2012). However, due to limited evidence, doctors rarely discuss alternative ADHD treatment options. Finally, the effects of following either an AFC exclusion diet or an iron supplementation diet for the treatment of ADHD are reviewed. Regardless of the beneficial or unbeneficial findings, this information adds to the ADHD knowledge base for educators and school staff which promotes informed decisions when providing interventions for children with ADHD.

Key Terms and Definitions

- Atopy. The genetic tendency to develop allergic diseases such as allergic rhinitis, asthma and eczema. It is usually associated with increased immune responses to common allergens, especially inhaled allergens and food allergens (Bateman et al., 2004).
- Feingold/K-P Diet: A type of diet developed by Benjamin Feingold which requires individuals to exclude artificial flavors, colors, and natural salicylates (Conners et al., 1976).
- Serum Ferritin: A protein in the blood that contains iron. Serum ferritin levels are commonly measured to determine how much iron a body stores. If serum ferritin levels are low it indicates iron deficiency (Konofal et al., 2004).

Chapter II: Literature Review

Search Parameters

To locate the literature for this thesis, searches of Google Scholar were conducted for publications from 2000-2020. If recent studies were limited, searches were conducted for publications back to 1975. This list was narrowed by only reviewing published empirical studies from peer-reviewed journals that focused on ADHD, dietary treatment alternatives, artificial food colorings, and iron levels to address the guiding questions. The key words used in searches were "attention deficit hyperactivity disorder/ADHD," "dietary patterns," "dietary characteristics," "school performance," "artificial food coloring," "artificial food coloring exclusion diet," "iron deficiency," and "iron supplementation. The structure of this chapter reviewed the literature that considered dietary alternatives for the treatment of attention deficit/hyperactivity disorder in three sections: Typical Dietary Patterns & Mineral Levels in Children with ADHD; Effects of Dietary Patterns and Mineral Levels in Children with ADHD; and Types of Diets to Manage ADHD Symptoms.

Typical Dietary Patterns & Mineral Levels in Children with ADHD

General Dietary Patterns

While the etiology of Attention Deficit Hyperactivity Disorder (ADHD) is unknown, dietary factors have been associated with ADHD and the accompanying behavioral symptoms. Overall, diets are not comprised of single nutrients. Understanding the overall dietary patterns and characteristics of children with ADHD helps identify which specific dietary characteristics may have the biggest impact on ADHD symptoms in children. Ptacek et al., (2014) aimed to identify and explain the patterns of eating behaviors, nutritional quality, and additional factors associated with ADHD symptoms in children. Parents of 100 boys diagnosed with ADHD based on Diagnostic and Statistical Manual of Mental Disorders - fourth edition (DSM-IV) criteria and parents of 100 aged-matched controls without ADHD were included in the study. The boys were six to 10 years old. The researchers examined quantitative characteristics of eating habits such as the number of daily meals and qualitative characteristics such as nutritional quality of food and beverage intake. All of the children's eating habits were assessed using an interview completed by their parents.

The interviewed scores collected by Ptacek et al., (2014) showed significant differences in eating patterns and nutritional quality in ADHD participants compared to controls. Participants with ADHD had more disruptive eating patterns and less adherence to a traditional breakfast, lunch, and dinner schedule which resulted in more frequent eating and consuming items with poorer nutritional quality. The researchers reported that only 13% of participants with ADHD consumed fruits and vegetables about once a week. Ptacek et al., (2014) also found that participants with ADHD consumed more sweetened beverages which accounted for almost half of their daily fluid intake.

Ptacek et al., (2014) noted that one limitation of the study was that it included only boys, due to the low number of girls diagnosed with ADHD in clinical samples. This meant that gender effects could not be statistically controlled and that the study could not generalize to both genders. The researches also noted that parent bias during the interviews could have been a limitation (Ptacek et al., 2014).

One of Ptacek's major findings was that children with ADHD consumed more sweetened and flavored beverages compared to children without ADHD. Azadbakht and Esmaillzadeh (2012) noted similar findings in their study. They further identified typical food items consumed by children with ADHD. Azadbakht and Esmaillzadeh, (2012) examined the relationship between overall dietary patterns and the prevalence of ADHD in children.

Three-hundred-seventy-five, elementary school-age children from all socioeconomic districts of Tehran, Iran participated in the Azadbakht and Esmaillzadeh (2012) study. The presence of ADHD was assessed using the DSM-IV and was identified in 9.7% of the participants. A Food-Frequency Questionnaire (FFQ), consisting of 134 food items that Iranian children commonly consumed, was used to collect dietary recall information. Each child's parents approximated the frequency of food intake on a daily, weekly, and monthly basis over the previous year. The reported frequency for each food item was then converted to daily intake.

Four main dietary patterns were identified: *sweet* (containing ice cream, refined grains, sweet desserts, sugar, and soft drinks), *fast food* (containing processed meat, commercially produced fruit juices, pizza, snacks, sauces, and soft drinks), *Western* (containing processed meat, red meat, butter, eggs, pizza, snacks, animal fat, and hydrogenated fat), and *healthy* (containing fruits, vegetable, vegetable oils, whole grains, legumes, and dairy) (Azadbakht & Esmaillzadeh, 2012). Children who consumed the most items in the sweets or fast food dietary patterns had significantly greater odds (odds ratio 4.05 and 3.21, respectively) of having ADHD compared to children who consumed the least amount of items in these dietary patterns. There were no significant associations between the healthy or Western dietary pattern and ADHD.

Azadbakht and Esmaillzadeh (2012) noted that a major limitation to the study was that the dietary habits of Iranian children did not generalize across different cities or child's age. They theorized that the dietary patterns of children outside Tehran, Iran and preschoolers who may also have ADHD might be different.

Since the sweets and fast food dietary patterns were associated with increased odds of having ADHD, Azadbakht and Esmaillzadeh (2012) noted that the associations could have been due to the specific nutrients in each food pattern. Items in the sweets and fast food dietary patterns contained several additives, minerals, and sugars which may have accounted for the significant association between those patterns and the presence of ADHD. More specifically, the researchers noted that the intake of nutrients such as vitamin B1, B2, zinc, iron, and calcium could be associated with the relationship between dietary patterns and the odds of having ADHD.

Wang et al., (2019) examined nutrients and minerals in dietary patterns of children with ADHD by investigating the relationship between dietary and nutritional components and ADHD. The researchers hypothesized that nutritional imbalance and specific dietary components from an unhealthy diet were related to having ADHD.

Two-hundred-sixteen children with ADHD, diagnosed according to DSM-IV, and 216 age, height, and gender matched controls participated in the study (Wang et al., 2019). The children were recruited from 31 elementary schools in Taiwan. Dietary intake from the previous year was gathered using a Food Frequency Questionnaire (FFQ) completed by each participant's parents. Blood samples were collected to determine the levels of multiple nutrients for each participant.

Congruent to the studies by Ptacek et al., (2014) and Azadbakht and Esmaillzadeh (2012), Wang et al., (2019) found that the children with ADHD presented with an increased intake of high sugar and high fat foods and a reduced intake of fruits, vegetables, and protein compared to children without ADHD. Additionally, they found that the children with ADHD had significantly lower levels of several nutrients in their blood, one of which was ferritin, a protein that indicates how much iron is in the body. Low iron has been associated with inhibiting cognitive ability. Furthermore, the researchers found that an increased intake of fruits, vegetables, meat, and eggs contributed to increased iron stores in the blood (Wang et al., 2019).

Overall, the researchers found an association between poor diets, poor nutrient blood levels and ADHD characteristics. They concluded that managing diet and nutrition in children with ADHD could and should be considered to improve ADHD symptoms. They recommended further research on ways specific nutrients contribute to ADHD symptoms in children (Wang et al., 2019).

Artificial Food Coloring Consumption

Understanding how poor diet and nutrient levels affect ADHD symptoms includes analyzing how much of each nutrient children with ADHD typically consume or naturally have in their body. Children consume artificial food colors (AFC) in a variety of foods and beverages.

Many products specifically marketed to children contain AFC. Batada and Jacobson (2016) assessed what percentage of products marketed to children contain AFC. The researchers wanted to determine if it was easy for children with ADHD to follow Artificial Food Coloring exclusion diets considering the prevalence of food products marketed to children that contain AFC.

The researchers collected food-color information about 810 products from one grocery store in North Carolina. Products were included if they were considered to be marketed to children. To meet this criteria, products displayed a cartoon or child-oriented character on the front, advertised a prize or incentive, included a bright child-oriented design and font, or was a traditional children's item (such as fruit flavored snacks). The researchers collected information about each product's ingredients from the company website or third-party sites (Batada & Jacobson, 2016).

Batada and Jacobson (2016) found that 350 products, or 43.2%, contained AFC. AFC were found in products such as cheese/yogurt/milk items, fruit-flavored snacks, drink mixes, toaster pastries, cakes, candies, and even toothpaste/mouthwash, and vitamins. Candies, fruit-flavored snacks, and drink mixes contained the highest percentage of AFC while produce was the only category found to not have any AFC.

Batada and Jacobson (2016) noted several limitations in this study. First, they noted that data collection was completed over a period of time that included color-focused holidays, such as Valentine's Day and St. Patrick's Day, which may have caused misrepresentation of what was typically available. Second, they noted that items not specifically marketed to children were excluded even if they were popular items, such as soft drinks. Additionally, they noted that data stating the amount of AFC in each product or how much of each product children typically consumed was not collected (Batada & Jacobson, 2016).

The researchers concluded that approximately four in ten food items marketed to children contained AFC making it challenging for children with ADHD to follow an Artificial Food Coloring exclusion diet. They noted that in some of the food categories, almost all of the products contained AFC (Batada & Jacobson, 2016).

Stevens et al., (2014) addressed some of the limitations in the Batada and Jacobson, (2016) study. The study was completed to determine how many AFC were in beverages commonly consumed by children and adolescents in the United States. The researchers purchased 108 beverages or beverage mixes commonly consumed by children that listed AFC as an ingredient. The beverages were purchased from local grocery stores, superstores, pharmacies and convenience stores. The researchers used a spectrophotometer to determine which AFC were present in each beverage and to estimate the total amount of AFC in 8oz of each beverage.

Stevens et al., (2014) found that carbonated beverages contained 0.7 mg to 35 mg AFC per 8oz serving, fruit drinks/punches contained 02. mg to 52.3 mg AFC, sports drinks contained 1.1 mg to 22.1 mg AFC, and energy drinks contained 0.7 mg to 18.8 mg AFC. While the amount of AFC consumed in a beverage varied depending on beverage choice and serving size, a child could consume anywhere from less than a milligram to 90 mg or more AFC in beverages per day. The researcher’s example stated that if a child drank two cans of a bright orange beverage, they could be consuming more than 90 mg of AFC in those two drinks without considering any AFC consumed in the rest of the diet.

Stevens et al., (2014) noted that behavioral studies discovered that more children, especially younger children, reacted to higher doses of AFC (≥50 mg) than to lower amounts (<50 mg) (Stevens et al., 2014). Therefore, Stevens et al., (2015) continued to research how many AFC were contained in foods and sweets commonly consumed by children. Combined with their beverage data, the researchers hypothesized that children consumed far more AFC in food and beverages than previously thought.

Stevens et al., (2015) purchased foods containing AFC from local grocery stores, superstores, pharmacies, movie theaters, ice cream stores, amusement parks, and convenience stores. Types of foods purchased included cereals, popsicles, slushies, ice creams, puddings, yogurts, cakes, cupcakes, and candies. A spectrophotometer determined which AFC were in each item and estimated how many AFC were in one serving size for each item.

The researchers found that cereals contained 9.4 mg to 41.3 mg of AFC per serving, popsicles ranged from 0.3 mg to 13.4 mg, small slushies ranged from 1.6 mg to 22.4 mg, ice creams contained 1.9 mg to 6.0 mg, puddings and yogurts contained 1.4 mg to 5.2 mg, and cakes/cupcakes contained 2.2 mg to 55.3 mg AFC per serving. Additionally cupcake icings ranged from 1.2 mg to 34.7 mg AFC per two tablespoons and candies contained 0.2 mg to 33.3 mg per serving (Stevens et al., 2015).

Considering this data along with the AFC data from beverages, Stevens et al., (2015) concluded that, depending on the child’s diet, the amount of AFC a child consumed could exceed 100 mg. Researchers provided this example: if a child consumed two cans of orange pop, one bowl of all berries Cap'n Crunch cereal, a few handfuls of M&Ms, and a slice of red velvet cake with red icing, the child would have consumed more than 200 mg of AFC. The researchers suggested that one should consider these high AFC intake estimates when analyzing how AFC contributed to behavioral challenges in children with and without ADHD (Stevens et al., 2015).

Iron Levels

Iron is a mineral essential for health. Low iron levels have been known to cause tiredness. More recently researchers have speculated that low iron levels may also cause more severe symptoms in children with ADHD. To test this hypothesis, researchers assessed whether children with ADHD had lower iron levels compared to children without ADHD. Konofal et al., (2004) evaluated iron deficiency in children with ADHD and compared the results to subjects in a healthy control group.

Konofal et al., (2004) recruited children from the same school district who were referred to a pediatrics hospital for school-related problems. The study included 53 children with ADHD and 27 age and gender matched controls, four to 14 years old. The severity of symptoms in the children with ADHD was measured using the Conners' Parent Rating Scale (CPRS). Serum ferritin levels were measured for all children to determine iron levels. All of the participants had been medication free for at least two months before the study.

The researchers found that 84% of the children with ADHD and only 18% of controls had serum ferritin levels lower than 30 ng/mL, a value considered to be abnormally low (Konofal et al., 2004). Additionally, 32% of children with ADHD and only 3% of controls had serum ferritin levels lower than 15 ng/mL, a value considered to be extremely low. They also explored the effects of iron deficiency on ADHD symptoms. They found that serum ferritin levels and ADHD severity were inversely correlated. However, only the cognitive scores on the CPRS correlated significantly with serum ferritin levels indicating that iron deficient children with ADHD were mainly inattentive and distractible.

Konofal et al., (2004) concluded that low iron stores could explain up to 30% of ADHD severity. They suggested further research on whether the use of iron supplementation to increase iron stores decreased ADHD symptoms. Supplementing with iron could decrease the need for psychostimulants.

Berner et al., (2014) found similar results in a study to determine whether an iron deficiency was associated with ADHD. They explored the impact of iron deficiency in children with ADHD. Participants in the study included 1260 children, aged five to 18, who visited various health clinics in Qatar. Of those participants, 630 had ADHD, diagnosed using the DSM-IV and 630 were age and gender matched controls. None of the participants took medications or stimulants.

Berner et al., (2014) collected sociodemographic and clinical data for each participant, including physician diagnosis data for the children with ADHD. Blood samples from all participants provided data related to iron deficiency, serum ferritin levels, serum vitamin D levels, hemoglobin, calcium, magnesium, and phosphorus levels. ADHD symptom severity was measured using the Conners' Parent Rating Scale (CPRS) and Conners' Teacher Rating Scale

(CTRS) filled out by all parents of the participants with ADHD. Berner et al., (2014) noted that a major study limitation was that they did not collect data on dietary iron intake, vitamin D intake, or include data on whether participants were on avoidance/restriction diets.

The data showed statistically significant differences between the children with ADHD compared to controls for levels of vitamin D, serum iron, serum ferritin, hemoglobin, magnesium, serum calcium and phosphorus. Specifically, the children with ADHD averaged serum ferritin levels of 36.26 ng/mL and controls averaged levels of 38.19 ng/mL. However, one-third of participants with ADHD had extremely low serum ferritin levels while all controls had levels considered in the normal range of 15-150 ng/mL. Furthermore, the researchers found that serum vitamin D levels, serum iron, serum ferritin, calcium, physical activity, nervous behavior, consanguinity, BMI, and child birth order were associated with ADHD symptom severity (Berner et al., 2014).

Based on their findings, Berner et al., (2014) concluded that iron deficiency, as indicated by low serum ferritin levels, could lead to more severe ADHD symptoms. They speculated that iron deficiency may be due to genetics, environmental factors, absence of iron supplementation, and/or lack of nutritional foods. However, they noted that iron supplementation could be a first-line of treatment for children with ADHD and iron deficiency.

Millichap et al., (2006) found contradictory results compared to Konofal et al., (2004) and Berner et al., (2014). Millichap et al., compared the serum ferritin levels of children with ADHD with healthy children. They also assessed the correlation between serum ferritin levels and severity of ADHD symptoms. Sixty-eight children, referred to a clinic for ADHD, were included in the study. Fifty-four participants were male and 14 were female, all were five through 16 years old. Twenty-seven control subjects were chosen from the national population data to compare serum ferritin levels while the children with ADHD were compared within the cohort for severity of symptoms. The children with ADHD completed a physical, neurological examination, other laboratory tests and blood analyses, including the measurement of serum ferritin levels. Additionally, questionnaires regarding ADHD symptom severity were completed by the children's parents and teachers.

Millichap et al., (2006) found that the average serum ferritin level of the children with ADHD was 39.9 ng/mL and that of the controls was 44 ng/mL. The serum ferritin levels between the two groups were not significantly different. Seventy-four percent of participants with ADHD had serum ferritin levels less than 50 ng/mL. Of those participants, 44% had serum ferritin levels less than 30 ng/mL, 18% had levels less than 20 ng/mL, and 7% had levels less than 12 ng/mL. To assess differences in ADHD symptom severity, the researchers compared 12 children with the lowest serum ferritin levels to 12 with the highest levels. They found no significant difference in severity of ADHD symptoms, frequency of comorbid disorders, or response to stimulant medications.

The strength of the Millichap et al., (2006) study included using the national population data as the normative control. Researchers explained that it was difficult to obtain valid controls to compare serum ferritin level controls because the levels were dependent on age, gender, race, and socioeconomic factors; and the range of normal levels is wide.

The authors' findings suggested that some children with ADHD may have lower serum ferritin levels but that an association with symptom severity and ferritin levels was not found in this group. The researchers still recommended that iron supplementation be trialed in patients with low serum ferritin levels since it was previously documented as beneficial when prescribed for other neurological disorders (Millichap et al., 2006).

Percinel et al., (2016) found results similar to Millichap et al., using a larger sample size that also considered differences in iron levels between children with ADHD and healthy controls. The study included 200 children with ADHD, who had never taken psychotropic medications, and 100 healthy controls. The children with ADHD were volunteers from a psychiatry clinic and the controls were children of the hospital staff. All participants were between the ages of seven to 15.

Teachers and families of the participants completed forms that indicated the specific disorders and symptom severity. The forms included the Turgay DSM-IV Based Child and Adolescent Behavior Disorders Screening and Rating Scale (T-DSM-IV-S), Conners' Parent Rating Scale (CPRSR:L) and Conners' Teacher Rating Scale-Revised: Long Form (CTRS-R:L). The children also provided fasting blood samples that measured properties of the blood such as iron and ferritin levels (Percinel et al., 2016).

Percinel et al., (2016) found that the average serum ferritin level of children with ADHD was 27.85 ng/mL compared to 30.75 ng/mL in the controls. This resulted in no significant difference in iron levels between children with ADHD and healthy children. The researchers also assessed iron levels and symptom severity of ADHD. Of the three subscales (oppositional, cognitive problems/inattention, and hyperactivity) in the CPRSR:L and CTRS-R:L, only the hyperactivity subscale was negatively correlated with serum ferritin levels.

The researchers noted two limitations to the study. First, they did not formally gather information about the dietary patterns of the participants. Differences in dietary patterns could have influenced overall iron levels. Second, even though serum ferritin was a reliable method to measure iron stores, it was not clear whether serum ferritin levels correlated with brain iron levels. Brain iron levels affect the production of chemicals in the brain which have been found to influence ADHD symptoms (Percinel et al., 2016).

The authors concluded that iron deficiency studies related to ADHD have been inconsistent. They noted that other studies found associations between other psychiatric disorders and iron deficiency. Since ADHD has a high comorbidity rate, they stressed the importance of assessing ADHD without comorbid disorders to truly isolate this association. They recommended further studies with larger sample sizes to remediate this issue (Percinel et al., 2016).

Effects of Dietary Patterns and Mineral Levels in Children with ADHD

General Effects of Dietary Patterns

Dietary patterns and diet quality is known to affect school performance and behavior. Florence et al., (2008) examined the association between overall diet quality and academic performance in children. The researchers recruited 5th grade students from 282 public schools in Nova Scotia, Canada. To be included for analysis, the students completed assessments that considered diet and academic performance. Students were excluded if they reported outlying dietary observations and/or did not complete the dietary or academic assessments. In total, 4589 students who completed both the dietary and academic assessments participated in the study (Florence et al., 2008).

The researchers gathered diet quality index measures for each participant. Scores on the index ranged from zero to 100 with higher scores indicating better diet quality. A modified version of the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ), which gathered information on the participants' intake of food from recommended food groups, energy intake, and nutrient intake, calculated dietary quality index scores. The Elementary Literacy Assessment assessed academic performance. There was a reading and a writing portion to the assessment. The researchers defined good academic performance as passing both portions of the assessment and poor academic performance as failing either or both portions of the assessment. The researchers noted that a major limitation to their study was whether the academic assessment accurately measured academic performance (Florence et al., 2008).

Florence et al., (2008) found diet quality scores that ranged from 26 to 86 with an average of 62.4. Compared to students with the lowest dietary scores, students with middle dietary scores were 26% less likely to fail the literacy assessment and students with highest dietary scores were 41% less likely to fail. Moderation and balance were the components most significantly associated with academic performance. The researchers stated that participants who consumed more fruit and vegetables and fewer fats were significantly less likely to fail the academic assessment. The authors noted that the findings supported improving school nutrition programs which could provide students access to healthy food choices, diet quality, and improve academic performance (Florence et al., 2008).

Park et al., (2012) conducted a study similar to Florence et al., (2008) via assessing individual characteristics of diet quality and relating the characteristics to ADHD symptoms. Park et al., (2012) aimed to investigate the association between dietary characteristics and learning disabilities and ADHD in Korean children. Participants were recruited from five cities in South Korea. The researchers recruited children from 13 schools which best represented the local demographics in each region. Nine-hundred-eighty-six children, ages eight to 11, completed the study. Of these children, 45 met ADHD criteria and 141 met criteria for probable ADHD (Park et al., 2012).

The parents of each participant completed the mini-dietary assessment (MDA) for Koreans which assessed dietary behaviors (Park et al., 2012). The MDA consisted of ten items that assessed the intake levels of salt, fatty meats, dairy products, high-protein foods, vegetables, fried foods, sweetened desserts and whether three daily meals with a balanced diet were consumed. Higher MDA scores indicated healthier dietary behaviors. Learning disabilities were measured by the learning quotient (LQ) derived using the Learning Disability Evaluation Scale (LDES). Higher scores on this assessment indicated better performance. Additionally, ADHD behavioral symptoms were assessed using the parent version of the ADHD Rating Scale (ADHD-RS) and the Child Behavior Checklist (CBCL) (Park et al., 2012).

For all participants, Park et al., (2012) found that dairy product consumption was significantly associated with better reading, math, and writing, and higher LQ scores. Vegetable consumption was significantly, positively correlated with writing. Level of sweetened dessert consumption was significantly associated with lower LDES scores in the areas of listening, thinking, and writing and lower spelling and math scores. Additionally, MDA scores positively correlated with LDES scores (Park et al., 2012). For participants with ADHD, dairy consumption was significantly associated with lower delinquent scores while vegetable consumption was associated with lower inattention scores. The level of sweetened desserts consumption was significantly, positively correlated with hyperactivity, impulsivity, aggressive behaviors, and externalizing problems. Additionally, a balanced diet was associated with lower inattention and ADHD-RS scores and lower aggressive behaviors and externalizing problems on the CBCL. Overall, the results showed that a high intake of desserts, fried food, and salt correlated with more learning, attention, and behavior problems compared to consuming a balanced diet, regular meals, and increased intake of dairy and vegetables which is correlated with fewer learning, attention, and behavior problems (Park et al., 2012). The authors suggested that further research be conducted to consider how diet affects children's behavior to better inform dietary advice and public health policies (Park et al., 2012).

Effects of Artificial Food Coloring Consumption

Studies addressing if artificial food colorings (AFC) consumption and iron levels affect ADHD symptoms could help determine effective treatment options. K.S. Rowe and K.J. Rowe (1994) conducted a study to determine if there was an association between the consumption of AFC and behavioral changes in children being evaluated for hyperactivity. The participants included children referred to a children's hospital for assessment of suspected hyperactivity and whose parents believed they observed differences in their child's behavior as a result of dietary patterns. Two-hundred children participated in stage one of the study and 54 children participated in stage two. Children in stage two consisted of 34 hyperactive children who differed from those in stage one and 20 children without behavioral concerns.

During stage one, the participants consumed a diet free of AFC for six weeks followed by reintroducing AFC foods into their diets. Parents of the children reported behavioral observations during the periods with and without AFC in the child's diet. Consistent parental observations were used to develop a 30-item behavior inventory. The inventory had five groups of related behaviors that included irritability/control, sleep disturbance, restlessness, aggression, and attention span. This inventory was used in stage two of the study (K.S. Rowe & K.L. Rowe, 1994).

Before stage two, the children were on an AFC free diet. The children without behavior concerns consumed the diet for six weeks while the children with behavior concerns were on the diet for at least three months. During the study, participants acted as their own controls. The children who stayed on an AFC free diet and were given a capsule each morning for 21 days. The capsules contained either a placebo or from 1-50mg of an AFC. Parents recorded behavioral ratings every 24 hours using the 30-item behavior scale created in stage one followed by completing a 10-item Conners' inventory (K.S. Rowe & K.L. Rowe, 1994).

Rowe and Rowe (1994) found that 24 of the 54 children reacted to AFC. The children demonstrated behavior variations when they consumed at least five out of six of the AFC doses. For the children who reacted to AFC, behavioral changes were significant after only 2mg of AFC.

Children who did not react to AFC did not have significant behavioral changes. The researchers also found that more severe and longer reactions were noted following ingestion of 10mg of AFC or more. The researchers also noted that the type of behavior differed between age groups. Younger children cried, had tantrums, were irritable, restless, and had sleep disturbances. Older children were irritable, aimlessly active, lacked self-control, and were described as whiney and unhappy.

The authors concluded that some children had behavioral reactions when they consume AFC. The specific behavioral reactions differed by age but all were more severe and prolonged when AFC were consumed in greater amounts (K.S. Rowe & K.L. Rowe, 1994).

Schab and Trinh (2004) conducted a more recent analysis with the same purpose as Rowe and Rowe (1994). Schab and Trinh (2004) wanted to know if AFC contributed to the behavioral symptoms in children with hyperactive disorders. The authors searched for double-blind placebo-controlled studies that evaluated the relationship between AFC consumption and behavioral changes in children (under 18 years old) diagnosed with hyperactive disorders. Hyperactive disorders included minimal brain dysfunction, hyperkinesis, hyperkinetic reaction, hyperactivity, attention deficit disorder, and ADHD. To meet the study inclusion criteria, children either received a placebo or were placed on diets with or without AFC. Schab and Trinh (2004) grouped the studies into two categories. The first category included studies that specifically tested the AFC effects for children diagnosed with a hyperactivity disorder. The second category included studies that fit the inclusion criteria but included primarily children without hyperactive disorders or a heterogeneous group.

The authors analyzed 15 trials in the first group of studies which included 219 subjects (Schab & Trinh, 2004). In this group the authors found the significant effect size of 0.283 meaning that when the children were exposed to AFC, the severity of their symptoms increased by more than one quarter of a standard deviation. In the second trial group the authors analyzed eight studies which included 132 subjects. The overall size of effect was non-significant for this population. However, when the authors isolated studies that pre-screened participants for responsiveness to AFC, they found a significant effect size (0.316) for this population as well.

Schab and Trinh (2004) concluded that AFC contributed to symptom severity in children with hyperactivity disorders. The effect size was about one third to one half the effect for trials that measured methylphenidate as a treatment for ADHD. This meant that behavioral changes observed due to AFC may cause one third to one half of the children's behaviors when not taking psychostimulants. The authors recommended additional research before suggesting an artificial food colorings exclusion diet. While some parents may want non-pharmacological treatment for their children, Schab and Trinh (2004) noted that the AFC diets can be very restrictive and further inhibit psychosocial outcomes for children with ADHD. They suggested identifying which subjects were AFC-responsive before recommending this type of diet (Schab & Trinh, 2004).

Bateman et al., (2004) used methods similar to Rowe and Rowe (1994) but with children in the general population. They wanted to determine if AFC and a preservative in the diet of three-year-old children in the general population affected hyperactive behavior. The researchers hypothesized that food additives would affect children's behavior regardless of other characteristics noted for the child (Bateman et al., 2004).

The study included three-year-old children who were residents on the Isle of Wight, UK and registered with general practitioners. Two hundred seventy seven children completed all four weeks of the study. Before the trial began, the children were assessed for hyperactivity using parent rating scales and a clinical test that measured degree of inattention, overactivity, fidgetiness, and impulsivity. The children were also assessed for other behavior problems and completed an atopy test (a test for allergic diseases) (Bateman et al., 2004).

During the trial, the children consumed a diet that eliminated AFC and benzoate preservatives for four weeks. During weeks two through four the children were challenged with drinks that contained 20 mg of AFC and 45 mg of benzoate or a placebo. Eighty-one percent of children drank all or almost all of the active and placebo drinks, 5% of children drank less than two thirds of the active and placebo drinks. The children's behavior was assessed daily by their parents and weekly via clinical testing. Dietary "mistakes" (any food or beverage consumed during the trial period that contained AFC or benzoate preservative) were also reported by parents (Bateman et al., 2004).

Bateman et al., (2004) found that parents' hyperactivity ratings significantly decreased when children were on an AFC free diet and significantly increased when they consumed the active drink versus the placebo. No significant differences in parental ratings for impulsivity, activity, and inattention during the AFC free diet or when consuming the active drink were noted. There were also no significant behavioral differences in clinical testing with children on the AFC free diet or when they consumed the active drink. The results were consistent regardless of whether the child was identified as hyperactive or atopic (Bateman et al., 2004).

Overall, the authors found that the AFC and benzoate preservatives negatively impacted three-year-olds in the general population regardless of hyperactivity levels. Compared to other studies, the authors found that the estimated size effect of an AFC exclusion diet (0.51) was less than that of taking methylphenidate (0.82) but similar to taking clonidine (0.58) for treatment in children with ADHD. The authors recommended that similar studies be conducted in the general population targeting older children (Bateman et al., 2004).

Effects of Iron Levels

P. Oner and O. Oner (2007) investigated the relationship between hematological variables related to iron deficiency, such as ferritin and hemoglobin, and behavioral symptoms in children with pure ADHD and ADHD with comorbid disorders. The researchers hypothesized that behavioral symptoms in children with ADHD were related to ferritin levels and that this relationship may be more notable in children with comorbid disorders.

Children, aged five to 16, were recruited from an outpatient clinic of a general hospital to participate in the study. One-hundred-fifty-one children with ADHD participated in the study which included 45 children with comorbid disorders such as: conduct disorder, depression, elimination disorders, tic disorder, anxiety disorder, intellectual disability, and learning disorders. All participants were diagnosed with ADHD for the first time and had never taken medication. ADHD symptom severity was assessed using the Conners Parent (CPRS) and Teacher Rating Scales (CTRS). Ferritin, hemoglobin, mean corpuscular volume (MCV), and red cell distribution width (RDW) levels were measured for each participant. Low ferritin or MCV values and high RDW values are an indication of iron deficiency (P. Oner & O. Oner, 2007).

The results revealed a significant, negative correlation between CPRS and CTRS scores and ferritin levels in children with ADHD as a whole. The data indicated that behavior problems increased as iron stores decreased. CTRS scores remained significantly negatively correlated in the group with ADHD and comorbid disorders meaning that only teachers reported behavioral differences. For the purely ADHD children, CPRS and CTRS scores negatively correlated with ferritin levels but not significantly. The authors speculated that the presence of comorbid conditions may increase the effect of lower iron levels on behavioral symptoms in ADHD. They suggested that ferritin levels be assessed in subjects with ADHD especially for those with comorbid conditions (P. Oner & O. Oner, 2007).

P. Oner and O. Oner expanded on their previous study by investigating if ferritin levels affected ADHD symptoms and cognitive performance. The study by O. Oner et al., (2008) investigated the relationship between hematological variables related to iron deficiency and behavioral symptoms and cognitive performance in children with ADHD. Participants were recruited from an outpatient clinic at a general hospital that included 52 children, ages seven to 13. All children had been diagnosed with ADHD for the first time and had never taken medication and 19 children had comorbid conditions (O. Oner et al., 2008).

The CPRS and CTRS assessed the severity of ADHD symptoms. Cognitive measures were assessed using a battery of neuropsychological tests which included Wisconsin Card-Sorting Test (WCST), Stroop Color-Word Test, Continuous Performance Test (CPT), subtests from the

Wechsler Intelligence Scale for Children Revised (WISC-R), and Trail Making Test A-B. Together these tests assessed abstraction/flexibility, sustained attention, mental tracking, complex attention, and interference control. Hematological variables including ferritin, hemoglobin, MCV, and RDW were also measured for each participant (O. Oner et al., 2008).

The researchers found that CPRS hyperactivity scores were significantly related to ferritin levels in children with ADHD (O. Oner et al., 2008). Children with lower ferritin levels had higher CPRS scores which indicated more severe behavioral problems. Contrary to their previous study, they found that CTRS hyperactivity scores were not related to ferritin levels in this population of children. The researchers also did not find significant correlations between any of the neuropsychological test scores and ferritin, hemoglobin, MCV, or RDW. These findings led the authors to hypothesize that iron supplementation may have varying impacts on hyperactivity, inattentiveness, and cognitive variables in children with ADHD. They recommended further studies with larger sample sizes to investigate this topic (O. Oner et al., 2008).

Juneja et al., (2010) also studied the effects of iron levels on ADHD symptoms in children. The researchers conducted a case control study which aimed to determine the body iron levels of children with ADHD and determine the correlation between iron levels and ADHD symptoms. Participants were selected from a child development and early intervention clinic in New Delhi, India. All participants in the treatment group were newly diagnosed with ADHD based on DSM IV criteria and included 50 children, six to 14 years, 25 children with ADHD, and 25 age and sex matched controls (Juneja et al., 2010).

The researchers conducted intelligence testing by administering an adapted version of the Wechsler Intelligence Scale for children (WISC) while parents and teachers completed the CPRS and CTRS including the hyperactivity, cognitive, and oppositional subscales to measure ADHD symptom severity. The researchers also collected fasting blood samples that measured serum ferritin and hemoglobin levels. Following initial data collection, the ADHD children started behavior modification therapy. The subjects who did not respond to the therapy were offered methylphenidate therapy. All children with iron deficiency were given iron supplements (Juneja et al., 2010).

Data from the study indicated that children with ADHD had significantly lower serum ferritin levels compared to controls. Juneja et al., (2010) found that CPRS and CTRS oppositional scores significantly correlated with serum ferritin levels in the children with ADHD; as ferritin levels went down, CPRS and CTRS scores increased, indicating more severe behaviors. CPRS and CTRS scores for inattention and hyperactivity for the ADHD group were negatively correlated but not significantly. There was no correlation between ferritin levels in any of the CPRS and CTRS subscales for controls (Juneja et al., 2010).

The authors noted several limitations in the study. First, the sample size was small. Second, researchers noted that only children with severe cases of ADHD sought medical advice for behavioral and/or school related problems. Parents of children with mild and moderate cases usually did not seek medical advice, thus the data may have represented only severe cases of ADHD. Third, 44% of the participants with ADHD had an ODD comorbidity which meant that the study results may have been skewed due to the correlation between ferritin levels and ODD not just ADHD (Juneja et al., 2010).

The findings by Juneja et al., (2010) suggested that iron deficiency, as indicated by low serum ferritin levels, may heighten some ADHD symptoms. The authors noted that iron deficiency was common in low income countries. They recommended further studies using larger sample sizes to address ADHD in other populations (Juneja et al., 2010).

Donfrancesco et al., (2013) explored this topic with a sample size similar to that of Oner and Oner (2007) but with the addition of a control group. Donfrancesco et al., (2013) had two goals: to compare serum ferritin levels in stimulant-naive children with ADHD and matched controls and to determine any association of serum ferritin levels to ADHD symptom severity, ADHD subtypes, and/or IQ (Donfrancesco et al., 2013).

The study participants included 194 children, ages six to 14 years (Donfrancesco et al., 2013). One-hundred-one of the children were newly diagnosed with ADHD and recruited from an outpatient clinic in Rome, Italy. Age and gender matched controls (93) were recruited from family pediatricians in the same area. The participants with ADHD were diagnosed using the DSM-IV criteria. ADHD was ruled out in the control participants through clinical interviews with pediatricians specifically trained to diagnose ADHD. ADHD symptom severity was measured by having the parents and teachers of the children in the ADHD group complete an adapted version of the ADHD-Rating Scale (ADHD-RS). IQ was measured using the WISC-III-Italian version. Finally, serum ferritin levels were gathered through participants' blood samples (Donfrancesco et al., 2013).

Donfrancesco et al., (2013) found no significant differences in serum ferritin levels between children with ADHD and controls or among ADHD subtypes. The children with ADHD tended to have lower serum ferritin levels but not significantly. No correlation was found between serum ferritin levels and ADHD symptom severity or IQ. The authors considered that a possible reason for the mixed results across studies was that psychostimulants could affect appetite which, in turn, could alter children's serum ferritin levels (Donfrancesco et al., 2013). Therefore significant differences in findings may have been due to studies that included children who took psychostimulants or who had not been medication free long enough.

The authors suggested that iron levels in children with ADHD should be assessed in more depth than serum ferritin levels. They noted that brain iron levels were thought to affect neuronal functions which could affect ADHD symptoms. However, it was unclear the extent to which serum ferritin levels correlated with brain iron levels. They further noted that lower serum ferritin did not always reflect brain iron levels and recommended that additional studies investigate the relationship between brain iron levels and ADHD (Donfrancesco et al., 2013).

Types of Diets to Manage ADHD Symptoms

Artificial Food Coloring Exclusion

Studies that examined the effects of artificial food coloring exclusion diets tended to also evaluate the effects of artificial food coloring on behavior. Therefore, the design of many studies was to challenge participants with doses of AFC. Pollock and Warner (1990) followed this design to assess the effects of artificial food colors on childhood behavior. Pollock and Warner (1990) recruited children from a pediatric allergy clinic and via a survey of food additive intolerance. Children were included in the study if their parents believed that AFC negatively affected behaviors and their children improved on diets that eliminated food additives. Nineteen of 39 children completed all parts of the seven-week study (Pollock & Warner, 1990).

Participants remained on a diet that eliminated food additives, including AFC (Pollock & Warner, 1990). During the trial, researchers conducted double-blind, placebo controlled challenges where the participants were given capsules that contained AFC or a placebo. The AFC capsules contained food colors known to be associated with negative reactions to food additives (tartrazine, sunset yellow, carmoisine, and amaranth) at a dosage estimated to greatly exceed the current estimated daily intake. Participants swallowed one capsule during breakfast for seven weeks. Two separate weeks, participants consumed the AFC capsule and the remaining weeks they consumed the placebo. During the seven weeks, parents of the participants recorded daily behavior using the Conners hyperactivity index (Pollock & Warner, 1990).

Pollock and Warner (1990) found that average behavior scores were significantly higher when the children consumed the AFC capsule compared to placebo. However, they noted that even though behavior scores were statistically significant, they may not have been detectable by parents. AFC capsule behavior scores remained the same on day one and day seven. This indicated that consuming more AFC throughout the week did not lead to more severe behavior ratings. The researchers concluded that a daily intake of 125mg of AFC can have a significant, negative (although small) effect on the behavior of general population children. To avoid nutritional inadequacy Pollock and Warner (1990) recommended that professional guidance be attained if parents want to manipulate their children's diet. However, they suggested alternative interventions for behavior over dietary modifications (Pollock & Warner, 1990).

McCann et al., (2007) conducted a similar, more recent study with a larger sample size. McCann et al., (2007) recruited 137, 3-year-old and 130, 8/9-year-old children registered in nurseries, preschools, and elementary schools in Southampton, UK to consider whether the intake of artificial food colors and additives (AFCA) affected childhood behavior.

The participants consumed an AFC free diet for the duration of the study with challenge drinks given over the six weeks. The researchers created two active drink mixes per age group (containing AFC and sodium benzoate preservative) and one placebo mix. The first drink mix (mix A) was similar to the Bateman et al., (2004) study. The second drink mix (mix B) contained the current average daily consumption of food additives by age group of children in the UK. For 3-year-old children, mix A and B contained approximately the same amount of AFC as in two 56 gram bags of sweets. For 8/9 year old children, mix A contained a dose approximate to two bags of sweets and mix B about four bags of sweets. Several behavior measures calculated the global hyperactivity aggregate (GHA) for each participant. The GHA measured individual differences in hyperactivity using different sources such as teachers, parents, direct observations, and computerized tests. The GHA also addressed the components of hyperactivity: overactivity, impulsivity, and inattention (McCann et al., 2007).

McCann et al., (2007) found that mix A induced a significant adverse effect on behavior ratings compared with placebo for all 3-year-old children; however, mix B did not have the same effects. For 8/9-year-old children, mix A and mix B caused significant adverse effects on behavior ratings when children consumed at least 85% of the drink. Additionally, when children were on the AFCA-free diet, their behavior improved by an average effect size of 0.18 (McCann et al., 2007). These results indicated that AFC and/or sodium benzoate preservative in the diet of children increased hyperactivity compared to a diet free of these additives, but that substantial differences in individual child responses were present. The authors noted that the study used a general population sample and not specifically on children with ADHD (McCann et al., 2007).

Conners et al., (1976) studied specifically children with hyperkinetic impulse disorder (now known as ADHD). The researchers aimed to determine if a diet eliminating artificial flavors, colors, and natural salicylates (the Feingold/K-P diet) was associated with hyperkinetic symptoms in children. Children, age six to 12 years, were recruited to participate. A child psychiatrist examined the children to confirm the hyperkinetic impulse diagnosis. Fifteen children completed the entire study (Conners et al., 1976).

Prior to treatment, the subjects' parents and teachers completed semi-weekly behavior questionnaires for four weeks regarding their child's current behavior (Conners et al., 1976). All medication was discontinued after the first two weeks while parents continued to fill out the behavior questionnaires. This established baseline behavior data. During treatment, children were randomly assigned to the control or the K-P diet (Conners et al., 1976). The K-P diet excluded artificial flavors, colors, and natural salicylates. None of the items on the K-P diet were included in the control diet and vice versa. The parents of the children met with nutritionists who explained the diet and provided a list of food items to include and exclude. The children were on the diet for four weeks and parents completed weekly symptom ratings. This procedure was repeated having all of the participants consume the alternate diet (Conners et al., 1976).

Overall, Conners et al., (1976) found that significantly more children who consumed the K-P diet were rated with improved behavior compared to children on the control diet. The K-P diet was significantly more effective than the control diet based on teacher ratings but not by parent ratings. However, both teacher and parent ratings indicated that child behavior was significantly better, approximately 15%, on the K-P diet compared to baseline behaviors. The control diet did not show a significant effect with only approximately a 3% behavior improvement. The authors noted that one reason parents may not have noticed behavior difference between the K-P diet and the control diet is that children may have responded better in a more structured setting such as the classroom (Conners et al., 1976). A classroom setting where more attention and goal-oriented behaviors were provided may have made the behavior improvements due to diet more evident to teachers and not parents (Conners et al., 1976).

Based on this study, the authors concluded that there was a strong association between a diet free of natural salicylates, artificial flavors, and artificial colors and reduced hyperactivity in some children with hyperkinetic impulse disorder (Conners et al., 1976). However they cautioned these results based on the fact that any dietary change in a family is likely to produce behavioral effects. The authors also noted that the K-P diet reduced the nutrient intake of the participants. Thus they recommended that parents consider dietary counselling if attempting this type of diet (Conners et al., 1976).

More recent meta-analyses have compiled information on this topic. Nigg et al., (2012. completed a meta-analysis to determine the role diet and food colors played in ADHD or its symptoms. The researchers identified studies in a literature search that used four different databases. To be included in the analysis studies used a random assignment or crossover design, were conducted with children, and used restriction diets that removed food colors or food colors were manipulated with measurable effect sizes. The study included 24 publications regarding synthetic food colors and 10 additional studies that analyzed dietary restrictions (Nigg et al., 2012).

Nigg et al., (2012) analyzed six studies with a total of 195 children regarding restriction diets for improvement in hyperactive symptoms. Dietary restrictions produced a potentially, clinically meaningful benefit in children with ADHD. Restriction diets had an effect size of 0.29, about one-third the effect size of medication at 0.9. Researchers stated that approximately 33% of children with ADHD may positively respond to a dietary intervention. To address food colorings effect, the researchers analyzed 20 studies, where 794 parents of participants reported behavior and 323 teachers/observers completed reports. Data analysis indicated that only parent-reported studies produced a reliable association between AFC and ADHD symptoms. However, a reliable effect size was not established when analysis was restricted to studies with only FDA-approved food colors. This meant that the effect size from parent-reported studies was likely due to studies completed outside the United States which may have included additional AFC. Generally, the researchers stated that up to 8% of children with ADHD may have symptoms related to AFC (Nigg et al., 2012).

Nigg et al., (2012) discussed several caveats. One major caveat was that no studies restricted to FDA-approved food colors had been completed in the past 20 years; thus making most of the findings out of date for current use. Additionally, most of the studies examined combinations of colors with little consistency between studies making it impossible for the researchers to compare effect sizes for individual compounds. Overall, Nigg et al., (2012) concluded that the evidence was too weak to recommend treatment options but too substantial to ignore. Researchers recommended a renewed investigation to evaluate how diet, food additives, and AFC affect ADHD (Nigg et al., 2012).

Sonuga-Barke et al., (2013) completed a meta-analysis on the effectiveness of non-pharmacological interventions as an ADHD treatment. The researchers analyzed dietary interventions, including restricted elimination diets, artificial food color exclusions, and free fatty acid supplementation. To be included in the analysis, studies were randomized controlled trials that included children three to 18 years diagnosed with ADHD. The studies also compared a category of non-pharmacological interventions with a control. Fifty-four trails were included in the meta-analysis of which eight trials regarded artificial food color exclusion diets (Sonuga-Barke et al., 2013).

The authors measured post-treatment changes in ADHD symptom severity from baseline by gathering data from ADHD-specific symptom scales including the DSM IV, CPRS, CTRS, or ADHD related questionnaires (Sonuga-Barke et al., 2013). They conducted two analyses: the first using outcome data gathered from parents or teachers regardless of if they were blinded to treatment and the second using data only from trials where the rater was probably blinded to treatment (Sonuga-Barke et al., 2013).

Sonuga-Barke et al., (2013) found all dietary interventions were significantly more effective than controls in the first analysis. However, when restricted to blinded trials, only artificial food color exclusion diets and free fatty acid supplementation resulted in statistically significant improvement in ADHD symptom severity compared to controls. When the analysis was restricted to trials that included children with no/low medication, the effect size was not statistically significant (Sonuga-Barke et al., 2013).

From the meta-analysis results the authors concluded that dietary interventions, including artificial food color exclusion diets, had a small but statistically significant effect on ADHD symptom severity (Sonuga-Barke et al., 2013). They noted that the effects of AFC exclusion diets may have been limited to children with ADHD who also had food sensitivities. The authors recommended further studies to better understand non-pharmacological interventions and ways to incorporate the interventions with pharmacology (Sonuga-Barke et al., 2013).

Iron Supplementation

Iron supplementation was studied as a potential dietary intervention for children with ADHD. Konofal et al., (2005) conducted the first study that specifically addressed the effectiveness of iron supplementation in children with ADHD who were iron-deficient. The researchers recruited one, three-year-old participant for the case study. The child selected had hyperactivity, attention deficit, impulsivity, and sleep problems and was diagnosed with ADHD based on DSM IV criteria (Konofal et al., 2005).

Before the trial, researchers ruled out possible behavior causes such as family functioning, borderline intellectual functioning, pervasive developmental disorders, speech/language disorders, anxiety, depression, and other acute or chronic illnesses. The participant was unmedicated. Blood samples were collected to evaluate iron deficiency. ADHD symptom severity was assessed at baseline and throughout the trial using the CPRS and CTRS. During the trial, the child was given 80 mg of ferrous sulfate (iron supplementation) daily (Konofal et al., 2005).

Baseline screening revealed low serum ferritin levels (13 ng/mL), indicating iron deficiency without anemia (Konofal et al., 2005). Normal ferritin levels for a preschool-aged child was 15 to 80 ng/mL. Baseline raw total scores from the CPRS and CTRS were 30 and 32, respectively. After four months on iron supplements, the child's serum ferritin levels increased to 97 ng/mL. Parents and teachers reported moderate behavioral improvements. After eight months, the child's serum ferritin levels increased to 102 ng/mL and parents and teachers reported considerable improvements in behavior. CPRS and CTRS raw total scores decreased to 19 and 13, respectively. However, the authors noted limitations that decreased behavioral symptom severity could have been partly due to better sleep quality that was reported while the participant took iron supplements (Konofal et al., 2005).

Konofal et al., (2005) recommended screening serum ferritin levels in children with ADHD. If ferritin levels are low, researchers suggested iron supplementation. Overall, the researchers noted that research findings supported larger, double-blind placebo-controlled studies to consider iron supplementation in children with ADHD (Konofal et al., 2005).

Based on their previous results Konofal et al., (2008) conducted a double-blind placebo-controlled study of iron supplementation effects in children with ADHD without anemia. The researchers recruited 23 participants from an outpatient clinic, 18 boys and 5 girls, diagnosed with ADHD based on DSM IV criteria and aged five to eight. The participants also had serum ferritin levels less than 30 ng/mL which indicated iron deficiency. Children were excluded from the study if they had an IQ less than 80, relevant psychiatric comorbidities, chronic medical conditions, on iron supplements within the last three months, or had treatment with other medications (Konofal et al., 2008).

The researchers used the CPRS as the primary measure for ADHD symptom severity (Konofal et al., 2008). Secondary measures included the ADHD Rating Scale (ADHD RS), CTRS, and Clinical Global Impression-Severity (CGI-S). Participants were randomized to either the iron supplements or placebo group with a 3:1 ratio. The iron supplement was an 80mg ferrous sulfate tablet. Either the iron supplement or placebo tablet was taken every day in the morning for 12 weeks. ADHD symptom severity, serum ferritin levels, and adverse events reported by parents were also measured at baseline and throughout the trial (Konofal et al., 2008).

Konofal et al., (2008) found that serum ferritin levels increased in the treatment group compared to the placebo group. CPRS and CTRS also improved in the treatment group compared to the control group, although not significantly. However, ADHD RS severity significantly decreased, especially the inattention subscore, after treatment was completed in the treatment group. Additionally, 23.5% of participants in the treatment group were rated as very much improved on the CGI-S and 29.4% were rated as minimally improved (Konofal et al., 2008). The authors stated that a major limitation to their study was the small sample size, especially in the placebo group. The choice of using the CPRS short form as the primary outcome measure was also stated as a limitation because the authors believed the non-ADHD items diluted the results (Konofal et al., 2008).

The authors concluded that iron supplementation appeared to improve ADHD symptom severity, in children with low serum ferritin levels, at a level comparable to stimulants (Konofal et al., 2008). They stated that iron supplementation was well tolerated with mild to moderate side effects including constipation, nausea, and abdominal pains in some participants. They suggested future trials on this topic be completed with larger sample sizes and more controls (Konofal et al., 2008).

Several studies have excluded children on psychostimulants when assessing serum ferritin levels, ADHD behavioral symptoms, and iron supplementation. Calarge et al., (2010) explored the association between serum ferritin levels and response to psychostimulants. The researchers investigated whether serum ferritin levels were associated with ADHD symptom severity and with response to psychostimulants. They recruited children with ADHD from a child psychiatry clinic via advertisements, flyers, letters to professionals, a Website, and a waiting list of families interested in participating in ADHD treatment studies. Forty-nine participants, aged six to 14, completed all phases of the study (Calarge et al., 2010).

Before the trial, all participants discontinued their current medications for one week (Calarge et al., 2010). During the trial, the participants were put on a weight-based dose of amphetamine for two weeks followed by three weeks of amphetamine-dose-adjustment to improve clinical response. The parents of the participants completed ratings of their child's inattention, impulsivity, and hyperactivity using the Swanson, Nolan, and Pelham Version IV (SNAP-IV) and the CPRS-Revised. These ratings were completed at baseline and throughout the trial. Serum ferritin concentration, to assess iron levels, was also measured in each participant (Calarge et al., 2010).

Results from the Calarge et al., (2010) study showed that all participants exhibited moderately severe ADHD symptoms and had an average serum ferritin level of 18.4 ng/mL. The researchers found that, at baseline, serum ferritin levels were inversely correlated with inattention, hyperactivity/impulsivity, and total ADHD symptom scores. They also found that serum ferritin levels were associated with the weight-adjusted dose of amphetamine used. This meant that the lower the participant's ferritin levels, the higher dose of amphetamine they needed for an optimized clinical response. The researchers noted a limitation to these findings was that some associations between serum ferritin concentration and symptom severity were moderated if participants were previously medicated before starting the study (Calarge et al., 2010).

The authors stated that the significant association between serum ferritin levels and sensitivity to psychostimulants was an important discovery (Calarge et al., 2010). They noted that iron supplementation decreased ADHD symptoms in children but wondered if it allowed lower doses of psychostimulants. They suggested further research in this area especially in light of the increased use of psychostimulants and potential side effects (Calarge et al., 2010).

In 2017, Panahandeh et al., investigated whether adding an iron supplement with psychostimulants decreased ADHD symptoms in a study of 42 children with ADHD. The children recruited from a child psychiatry clinic in southwest Iran, were between the ages of five to 15, had serum ferritin levels under 30 ng/mL, were non-anemic, and did not have other psychiatric disorders or acute medical problems (Panahandeh et al., 2017).

The participants were randomly assigned to either the treatment or control group. The treatment group received ferrous sulfate as an iron supplement and methylphenidate once a day for eight weeks. The control group only received methylphenidate once a day for eight weeks. Serum ferritin levels collected for each participant estimated iron levels at baseline and at the end of treatment. Symptom severity was measured at baseline and the end of treatment using the Child Symptom Inventory-4 (CSI-4) completed by participants' parents (Panahandeh et al., 2017).

Panahandeh et al., (2017) noted no significant differences in CSI-4 scores between the treatment and control groups at baseline. After two months, CSI-4 scores significantly decreased for both groups but more so in the treatment group. CSI-4 scores regarding inattention and hyperactivity/impulsivity, and total CSI-4 scores were significantly lower in the treatment group compared to the control group at the end of the trial. The authors noted few limitations in the study that included a small sample size, iron levels estimated by only serum ferritin, and using a fixed dose of ferrous sulfate/kg body weight (Panahandeh et al., 2017). The conclusive results showed that adding ferrous sulfate as an iron supplement to methylphenidate significantly increased serum ferritin levels and decreased ADHD symptom severity in children with ADHD who had low ferritin levels (Panahandeh et al., 2017).

Improving iron levels through iron supplementation could also improve school performance. Soemantri et al., (1985) investigated how iron supplementation affected measures of school performance. The researchers recruited children from three primary schools in Kalibawang, Indonesia. The children were above the 80th percentile in weight and height and had no hematological-related diseases, severe illnesses, nutrition deficiency, physical handicaps, or neurological abnormalities (Soemantri et al., 1985). This likely excluded some children with ADHD although the authors did not specifically say. In total, 119 children participated and completed the study; 78 were iron-deficient anemic and 41 were non-anemic (Soemantri et al., 1985).

Before iron supplementation, blood samples were collected from participants to check for anemia (Soemantri et al., 1985). An IQ test, educational achievement and concentration tests, and behavioral measures were conducted with each participant prior to the trial. Participants were randomly assigned to an iron supplement or placebo group. The iron supplement group received 10 mg/kg per day of ferrous sulfate for three months while the control group received a placebo tablet. After the three months, the participants again completed blood tests, an educational achievement test, a concentration test and behavioral measurements (Soemantri et al., 1985).

The researchers found no significant differences in IQ measurements between the participants with and without anemia (Soemantri et al., 1985). They also found that, after treatment, participants with anemia in the iron supplement group demonstrated blood measurement increases that indicated increased iron levels. Regarding academic achievement, participants in the treatment group had significantly higher increases in test scores compared to the control group regardless of anemia status. Additionally, children with anemia in the treatment group had larger increases in test scores compared to the children without anemia who were also in the treatment group. However, children without anemia demonstrated significantly higher achievement scores compared to the children with anemia after treatment was completed regardless of study group (Soemantri et al., 1985).

Soemantri et al., (1985) concluded that even though iron supplementation improved academic performance in anemic children, the three month period was not enough time to make up for the learning deficits the children already experienced (Soemantri et al., 1985). They also stated that the association between iron deficiency and poor school performance should be recognized regardless of cause, especially since the association could be easily prevented (Soemantri et al., 1985).

Chapter III: Discussion and Conclusion

Summary of Literature

Numerous studies examined the benefits of following specific diets as alternative treatments to improve school performance in children with ADHD. Understanding the overall dietary characteristics of children with ADHD and the effects of artificial food colors (AFC) and iron levels helps narrow down which diet has the largest positive effect on ADHD symptoms and school performance. Studies found that children with ADHD showed significant differences in eating patterns and nutritional quality compared to children without ADHD (Ptacek et al., 2014; Azadbakht & Esmaillzadeh, 2012; Wang et al., 2019). Children with ADHD had lower adherence to a traditional breakfast, lunch, and dinner schedule which resulted in more frequent eating and consuming foods with poorer nutrition quality (Ptacek et al., 2014). Subjects had increased high sugar and high fat food intake and fewer consumed fruits, vegetables, and proteins compared to children without ADHD (Ptacek et al., 2014; Azadbakht & Esmaillzadeh, 2012; Wang et al., 2019). More specifically, children with ADHD tended to follow sweet and fast food dietary patterns which contained ice cream, refined grains, sweet desserts, sugar, soft drinks, processed meat, commercially produced fruit juices, pizza, snacks, sauces, and soft drinks (Azadbakht & Esmaillzadeh, 2012).

Certain dietary qualities and patterns were found to affect school performance and behavior. Researchers discovered that children who had poorer overall diets were more likely to fail academic assessments compared to children with better overall diets (Florence et al., 2008; Park et al., 2012). Additionally, the sweets and fast food dietary patterns in children with

ADHD highlighted many components that were associated with poorer academic performance. Specifically, researchers found that children who consumed fewer fruit and vegetables and more fats were significantly more likely to fail academic assessments (Florence et al., 2008). Results for children with ADHD specifically, found that a high intake of desserts, fried food, and salt correlated with increased learning, attention, and behavior problems compared to subjects who reported a balanced diet, regular meals, and increased intake of dairy and vegetables (Park et al., 2012). Artificial food colors (AFC) are one of the common additives in dietary patterns associated with poor school performance.

How many AFC are consumed by children? AFC in many different foods and beverages are commonly consumed by children. Batada and Jacobson (2016) found that 43.2% of food products marketed to children contained AFC. In just two cans of an orange beverage, children consumed 90 mg of AFC without considering the AFC in the rest of their diet (Stevens et al., 2014). Additionally, researchers noted that the amount of AFC consumed could vary by children's overall diet (Stevens et al., 2014; Stevens et al., 2015). For example, if a child consumed two cans of orange pop, one bowl of all berries Cap'n Crunch cereal, a few handfuls of M&Ms, and a slice of red velvet cake with red icing, the child would have consumed more than 200 mg of AFC (Stevens et al., 2015). Therefore it could be hypothesized that children with ADHD consume a greater daily amount of AFC since they more commonly follow dietary patterns high in additives and AFC.

Knowing how AFC affect children with ADHD plays a role in determining if a dietary alternative to treatment should be considered. Studies found that some children demonstrated significantly worse behavioral symptoms when consuming AFC (K.S. Rowe & K.L. Rowe, 1994; Schab & Trinh, 2004; Bateman et al., 2004). It was calculated that behavioral changes observed due to AFC could represent one-third to one-half of the children's behavior incidents when unmedicated (Schab & Trinh, 2004). Additionally, behaviors presented differently in different age groups (K.S. Rowe & K.L. Rowe, 1994). However, researchers noted that AFC diets were restrictive and suggested identifying children who are AFC-responsive before recommending this type of diet, especially since not all children negatively reacted to AFC (Schab & Trinh, 2004).

Further studies examined any positive effects of AFC diets on behaviors of children with ADHD. The authors found that AFC free diets had small but significant effects on behaviors of some children with ADHD (McCann et al., 2007; Pollock & Warner, 1990; Conners et al., 1976; Nigg et al., 2012; Sonuga-Barke et al., 2013). They also found substantial differences between children's' responses to AFC and an AFC free diet were present especially in children with food sensitivities (McCann et al., 2007; Sonuga-Barke et al., 2013). However, one meta-analysis noted that a reliable effect size was not established when analysis was restricted to studies with only FDA-approved food colors, meaning that these results were most likely due to studies outside the United States which may have included additional AFC (Nigg et al., 2012). Additionally, authors noted that restriction diets, such as an AFC free diet, could reduce the nutrient intake of children and recommended that dietary counselling be considered before attempting this type of diet (Conners et al., 1976; Pollock & Warner, 1990).

Iron levels were another dietary consideration with the potential to affect symptom severity and school performance in children with ADHD. Children with ADHD have demonstrated poor nutrient blood levels compared to children without ADHD (Wang et al., 2019). Iron, measured by nutrient blood serum ferritin levels, was significantly lower in some children with ADHD compared to children without ADHD (Konofal et al., 2004; Berner et al., 2014; Juneja et al., 2010). Researchers found that approximately one-third of children with ADHD had extremely low serum ferritin levels (Konofal et al., 2004; Berner et al., 2014). However, results were inconsistent. Other studies found no significant differences in serum ferritin levels of children with ADHD compared to children without (Millichap et al., 2006; Percinel et al., 2016). These contrasting studies found that children with ADHD had serum ferritin levels in the normal range and only 7% had extremely low serum ferritin levels (Millichap et al., 2006; Percinel et al., 2016). Additionally, Millichap et al., (2006) noted that all serum ferritin studies were limited because serum ferritin levels were largely dependent on age, gender, race, and socioeconomic factors, and the large range of normal levels. This also makes it difficult to directly compare studies. Despite contrasting results, most researchers concluded that the association between iron levels and ADHD symptom severity should continue to be researched along with iron supplementation as alternative ADHD treatment options (Konofal et al., 2004; Berner et al., 2014; Millichap et al., 2006).

The way iron levels affect children with ADHD determines whether iron supplementation should be considered as an alternative treatment. The effects of increased iron levels in children with ADHD showed inconsistent results. Some studies found that serum ferritin levels were inversely correlated with ADHD symptom severity (Konofal et al., 2004; Berner et al., 2014; P. Oner & O. Oner, 2007; O. Oner et al., 2008; Juneja et al., 2010). In some children, low iron levels explained up to 30% of ADHD symptom severity (Konofal et al., 2004). However, low iron levels had varied and inconsistent effects for oppositional, inattentive, and hyperactivity symptoms among studies (Percinel et al., 2016; P. Oner & O. Oner, 2007; O. Oner et al., 2008; Juneja et al., 2010). Researchers also speculated that the presence of a comorbid condition may have increased the behavioral effects from low iron levels, thus the significant associations may have been due to the comorbid disorder and not the ADHD (P. Oner & O. Oner, 2007; Juneja et al., 2010). Additionally, other researchers found no significant association between iron levels and ADHD symptom severity or IQ among children with ADHD and controls or among ADHD subtypes (Millichap et al., 2006; Donfrancesco et al., 2013). Overall, the findings led authors to hypothesize that iron supplementation may have varied or no effect on symptom severity in children with ADHD.

Low serum ferritin levels were associated with increased dosage of amphetamine to manage ADHD symptoms in children (Calarge et al., 2010). However, it was hypothesized that iron supplementation may decrease ADHD symptoms and allow for a lower dosage of psychostimulants (Calarge et al., 2010). Many authors found that iron supplementation decreased symptom severity and increased academic performance in children with ADHD (Konofal et al., 2005; Konofal et al., 2008; Panahandeh et al., 2017; Soemantri et al., 1985). Konofal concluded that iron supplementation improved ADHD symptom severity at a level comparable to that of stimulants (Konofal et al., 2008). In children with low serum ferritin levels who take psychostimulants, iron supplementation could increase serum ferritin levels and decrease ADHD symptom severity (Panahandeh et al., 2017). Additionally, iron supplementation was well tolerated with mild side effects making it a dietary alternative (or additive) that could be considered for ADHD treatment in children with low serum ferritin levels (Konofal et al., 2008).

Professional Applications

Understanding the effects of artificial food colors (AFC) and iron levels on children with ADHD and the potential benefits of AFC exclusion diets and iron supplementation could be applicable on national, state wide, and individual levels in regards to education. Nationally, findings on this topic could aid in reforming school-provided breakfast, lunch, and snack options. AFC and iron levels not only affected the behaviors and academic results in some children with ADHD but also affected typically developing children. AFC exclusion diets and iron supplementation improved the behaviors and academic achievement in children with and without ADHD. National reform on school nutrition programs should exclude foods with high levels of AFC and substitute more iron rich food options. This may reduce the achievement gap for special education students with ADHD and for low income students who may have poor nutrition.

On a state-wide or district level, the research on AFC and iron levels could be used to develop and guide education about nutrition habits for children and parents, especially for those identified with ADHD. The benefits of increased iron levels and the impact of AFC consumption could be included as a main component in nutritional teachings as it is easy to monitor without consulting a doctor. Regarding AFC, the amount present in food products has increased drastically over the years. Europe now requires warning labels on foods that contain AFC. While the United States does not yet require this, individual states or school districts could require teaching this information to help children and parents make informed food intake decisions; thus potentially improving children's' academics and behavior.

The research results are also applicable for parents, teachers, and educational staff. For parents, as previously mentioned, information on the effects and benefits of AFC exclusion diets and iron supplementation could help them make informed decisions about their child's diet. This information could also aid parents, teachers, and educational staff in understanding the potential causes of symptom severity in ADHD. Additionally, if the association between ADHD symptom severity and AFC and/or iron levels was established for individual students, parents, teachers, and educational staff could address the causes of the child's symptoms (poor academics and disruptive behaviors) instead of targeting symptom management.

For teachers and educational staff, the study results could inform decisions on choosing the best snack options for students. Special education departments could make informed decisions about which food items to provide as incentives. Additionally, teachers and educational staff are frequently chosen first by parents for behavior and academic solutions regardless of ADHD diagnosis or if the child is medicated. Educators and staff who are well informed of treatment options to address ADHD can share the information with parents who could consult with physicians to consider options for their child. This knowledge could be especially important for parents who may be against prescribed medication for their child.

Limitations of the Research

This paper was limited by search parameters and limitations within the pool of research. During my search, I excluded most studies over 20 years old. With the increased prevalence and levels of AFC in food products, I wanted research to reflect current AFC consumption data. Additionally, the association between iron levels and ADHD symptoms is a relatively new hypothesis with most studies published in the past 15 years. I also excluded studies that excluded children with ADHD from the participant pool. Since the main focus of this paper was on children with ADHD, it was crucial that research studies generalized to that population. Additionally, studies were excluded if the focus diet was a restriction or elimination diet. These diets also eliminated AFC from children's diets but eliminated several additional additives, which would have made it difficult to determine if the association was directly correlated with AFC. Finally, I excluded studies whose main participants were infants, adults, or university students. The diets and ADHD symptoms for these individuals differs from school-age children thus creating a potential topic for another paper.

My research was also limited by research available in the pool of research. In regards to AFC studies, very little new research was conducted in this area. This forced me to review some studies over 20 years old, which potentially limited generalizing the results to current times. Research could also not be limited to studies within the United States. Not enough studies were conducted in the United States to gain an accurate understanding of the effects of AFC, iron levels, and the associated diets for children with ADHD. Finally, not enough studies were available targeting purely ADHD participants to gain an accurate understanding of this topic.

Thus reviewed studies were broadened to include children with ADHD and comorbid disorders and general population samples that did not specifically exclude children with ADHD.

Implications for Future Research

The findings from this review highlight several areas for continued and potential research. To start, the effects of AFC and AFC exclusion diets on ADHD should be revisited. Levels of AFC found in food products have steadily increased yet few recent studies on this topic have been conducted in the United States (US) in the last 20 years. Additionally, research should be done regarding the effects of AFC approved by the Food and Drug Administrative (FDA); this would provide valuable information on the effects of AFC specifically in the US.

The effects of iron levels and iron supplementation on ADHD should also continue to be researched. Studies on this topic are relatively new with inconclusive results. More studies should be done to better determine if an association is present and whether iron supplementation could be a beneficial treatment option for some children with ADHD. Furthermore, studies should be conducted using larger sample sizes and differing populations. This would help determine if children with ADHD have lower iron levels than non-disabled children or if this association was mainly due to other geographical factors.

Finally, research on the effects of AFC, iron levels, and the associating diets should be conducted with varying populations such as those in different disability categories, age groups, genders, etc. Results from such research could give information on which associations are present in other populations or to compare the associations among populations.

Conclusion

In conclusion, some children with ADHD can benefit from following an AFC exclusion diet or from taking iron supplements. Beneficial results include decreased ADHD symptom severity and improved academic performance. However, the effect sizes of these dietary alternatives on children with ADHD were typically lower than the effect size of children who take psychostimulants. Additionally, many children who benefitted from following the dietary alternatives were either pre-screened for sensitivities to AFC or had abnormally low iron levels. There was not enough data to support that the diets would be beneficial for all children with ADHD. The benefits to following an AFC exclusion diet or taking iron supplements for the treatment of ADHD in children would currently be based on case-by-case trials.

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