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The Connection between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder, Therapeutic Approaches

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Abstract

A Traumatic Brain Injury (TBI) is an injury to the brain caused by an external force (vehicle, accidents, violence, sports injuries, industrial accidents, falls). Brain trauma can occur either from an object penetrating the skull or from rapid acceleration (speeding up), or deceleration (slowing down or stopping suddenly) of the brain. Traumatic Brain Injury (TBI) is a major cause of mortality and disability, especially in children and young adults. Based on the Glasgow Coma Scale (GCS), the neurological scale used to measure a person's level of consciousness after a brain injury, traumatic brain injury is classified as: mild (GCS 13 - 15), moderate (GCS 9 - 12), severe (GCS 8 or less), and evaluates the following functions: Eye Opening (E), Motor Response (M), and Verbal Response (V), to determine a patient's overall GCS, add together the scores from eye opening, motor response and verbal response. Scores range from 3 to 15. A score of 8 or less signifies coma. Symptoms can vary depending on the severity of the head injury. An individual with a mild traumatic brain injury can remain conscious, or may experience a loss of consciousness for a few seconds or minutes. Other symptoms may include headache, confusion, dizziness, vision changes, ringing in the ears or changes in hearing, fatigue or lethargy, a change in sleep patterns, behavioral or mood changes, and cognitive and/or executive functioning problems. People with a moderate or severe traumatic brain injury may show the same symptoms, but may also have a headache that gets worse, repeated vomiting or nausea, convulsions or seizures, an inability to awaken from sleep, dilation of one or both pupils of the eyes, slurred speech, weakness or numbness in the extremities, loss of coordination, and increased confusion, restlessness, or agitation. Attention-Deficit/Hyperactivity Disorder secondary

to Traumatic Brain Injury (TBI) is one of the most common neurobehavioral consequences of Traumatic Brain Injury (TBI), occurring in 20% to 50% of individual's post-injury (Irastorza, 2011). Some of the most persistent problems include impairment in memory, attention and concentration, language, executive skills, social judgment, social behavior, and impulsiveness. Previous studies have shown that Traumatic Brain Injury (TBI) is a major cause of mental health problems and increases the risk of Attention-Deficit/Hyperactivity Disorder (Schachar et al., 2015). According to studies (Ilie et al., 2015), physical brain injury contributes to the development of Attention-Deficit/Hyperactivity Disorder. Because the risk of Attention-Deficit/Hyperactivity Disorder development after Traumatic Brain Injury (TBI) remains high over an extended period, and some of the most persistent problems include impairment in memory, attention and concentration, language, executive skills, social judgment, social behavior, and impulsiveness; this master thesis shows the importance of an early prompt intervention after brain injury, and the need to establish a therapeutic plan in order to treat the Attention-Deficit/Hyperactivity Disorder development and evolution. The purpose of the present study is to investigate the association between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder, and also to show the importance of prompt intervention and preventive therapy in order to stop the Attention-Deficit/Hyperactivity Disorder development and evolution.

Keywords

Traumatic Brain Injury (TBI), Attention-Deficit/Hyperactivity Disorder, Brain Injury, Head Injury, Attention, Hyperactivity, Cognitive Behavioral Therapy, Therapy, Meditation, Diet

1. Introduction

Traumatic Brain Injury (TBI) results from an impact on the head that ruins normal brain function affecting a person's cognitive abilities, including learning and thinking skills.

Based on GCS, Traumatic Brain Injury (TBI) is classified as mild, moderate or severe.

Moderate to severe Traumatic Brain Injury (TBI) can result in changes in a person's state of consciousness (coma, vegetative states, minimally conscious state and brain death), awareness or responsiveness. Some people with Traumatic Brain Injury (TBI) will develop seizures, fluid buildup in the brain (hydrocephalus), infections, blood vessels in the brain, frequent headaches, or vertigo (a condition characterized by dizziness).

Also, Traumatic Brain Injury (TBI) can result in cognitive problems (memory, learning, reasoning, judgment, attention or concentration could be affected), executive functioning problems (difficulties in planning, problem solving, mul-

titasking, decision making, beginning and completing tasks), communication problems (cognitive and social problems), behavioral (difficulty in social situations, difficulty with self-control, lack of awareness of abilities) and emotional changes (anxiety, depression, anger, insomnia, irritability), sensory problems (loss of hearing, taste, smell, sight).

Severe Traumatic Brain Injuries (TBI) might increase the risk of degenerative brain diseases, such as Alzheimer's disease, Parkinson's disease.

Rehabilitation is an important step in the treatment of the injured brain to maximize the recovery and to help the patient to adjust to any difficulties or disabilities they may have. Cognitive therapy and behavioral therapy are the most important therapies that must start after Traumatic Brain Injury (TBI) (Little et al., 2021; Barman et al., 2016) to improve memory, attention, perception, learning, planning, and judgment, learn coping skills, work on interpersonal relationships, and improve general emotional well-being, learn or relearn how to perform daily tasks, such as getting dressed, cooking, and bathing.

The recovery course depends on several factors, such as, the area of the brain affected and the extent of injury; the complications that may occur after brain injury; the quality of rehabilitation received; the person's ability to adapt to changes in circumstances that may occur after brain injury; and finally, the state of mind of the patient.

Traumatic Brain Injury (TBI) contributes to worldwide death and disability more than any other traumatic insult, in Europe 2.5 million people suffer a Traumatic Brain Injury (TBI) each year, being the leading cause of death and disability in young adults (CENTER-TBI, 2020).

Traumatic Brain Injury (TBI) is also associated with developing mental conditions, including Attention-Deficit/Hyperactivity Disorder and is frequently followed by mental illness especially Attention-Deficit/Hyperactivity Disorder (Schachar et al., 2015).

Research has shown that Attention-Deficit/Hyperactivity Disorder secondary to Traumatic Brain Injury (TBI) is one of the most common neurobehavioral consequences of brain injury (Li et al., 2018). Impairment in memory, attention and concentration, language, executive skills, social judgment, social behavior, inhibitory control difficulties and impulsiveness are some of the consequences of Attention-Deficit/Hyperactivity Disorder after Traumatic Brain Injury (TBI).

"Attention-Deficit/Hyperactivity Disorder is the most common learning and behavior problem in children. But the issue doesn't end there: It is also one of the most common problems in adults" (Amen, 2013: p. 33.).

Attention-Deficit/Hyperactivity Disorder is a mental condition characterized by symptoms of inattention, hyperactivity and impulsivity; and can have a significant social impact on people's lives affecting their education, working and home life, relationships. As a developmental disorder, Attention-Deficit/Hyperactivity Disorder is evident early in childhood and, with maturation, shows changing symptom manifestations (Zillmer et al., 2008). Pre-school and school-aged children can face with behavioral problems, such as high activity levels,

poor inhibitory control, and short attention span. They often suffer from other comorbid conditions: oppositional defiant disorder (ODD), communication disorders, and anxiety disorders, and those with comorbidities are more impaired than those with ADHD alone. School aged children with ADHD tend to be impaired in terms of academic achievement, family interactions and peer relationships. Adults have poor outcomes in terms of academic achievement and attainment, occupational rank and job performance, risky sexual practices and early unwanted pregnancies, relationship and marital problems, traffic violations and car accidents, and psychiatric comorbidities (Cherkasova et al., 2013). People with Attention-Deficit/Hyperactivity Disorder can present low self-confidence and higher levels of low self-esteem. The severity of Attention Deficit/Hyperactivity Disorder can be designate as mild (few symptoms beyond the required number for diagnosis are present, symptoms result in minor impairment in social, school or work settings), moderate (symptoms or functional impairment between mild and severe are present) or severe (many symptoms are present beyond the number needed to make a diagnosis; several symptoms are particularly severe; symptoms result in marked impairment in social, school or work settings) under the criteria in the DSM V (2013).

According to Centers for Disease Control and Prevention (CDC, 2020), the Service Organization that protects the public's health, the causes and risk factors for Attention-Deficit/Hyperactivity Disorder are unknown, but current research shows that genetics plays an important role (Thapar & Stergiakouli, 2010). In addition to genetics; brain injury, exposure to environmental during pregnancy or at a young age, alcohol and tobacco use during pregnancy, premature delivery, low birth weight are also other possible causes and risk factors. In some cases, the diagnosis of Attention-Deficit/Hyperactivity Disorder may reflect a dysfunctional family, a disadvantaged socioeconomic background (Russell et al., 2015; Pires et al., 2013).

Typical behaviors of Attention-Deficit/Hyperactivity Disorder occur more commonly in children who have experienced violence and emotional abuse. The social construct theory of ADHD suggests that because the boundaries between "normal" and "abnormal" behavior are socially constructed (i.e. jointly created and validated by all members of society, and in particular by physicians, parents, teachers, and others), it then follows that subjective valuations and judgements determine which diagnostic criteria are used and, thus, the number of people affected.

Neuropsychologists consider ADHD a neurobiological based developmental disorder that responds to specific types of environmental and pharmacologic interventions. However, the etiology of ADHD is currently unknown (Zillmer et al., 2008).

According to DSM V (2013), three presentations of Attention-Deficit/Hy- peractivity Disorder are listed:

- ADHD predominantly inattentive presentation.
- ADHD predominantly hyperactive-impulsive presentation.

- ADHD combined presentation.

While in DSM V, 2013 are listed three form of ADHD, Dr. Daniel Amen discovered, thanks to SPECT technology (single photon emission computed tomography which assesses blood flow and activity in the brain), that there are seven types of Attention-Deficit/Hyperactivity Disorder:

1) Classic ADHD: decreased activity in the underside of the prefrontal cortex, cerebellum and basal ganglia during concentration, normal activity at rest.

2) Inattentive ADHD: decreased activity in the underside of the prefrontal cortex, cerebellum and basal ganglia during, normal activity at rest.

3) Overfocussed ADHD: increased activity at rest and during concentration in the anterior cingulate gyrus, as well as decreased activity in the underside of the prefrontal cortex, cerebellum and basal ganglia.

4) Temporal Lobe ADHD: decreased activity (and occasionally increased) activity in the temporal lobes at rest and during concentration, as well as decreased activity in the underside of the prefrontal cortex, cerebellum and basal ganglia during concentration.

5) Limbic ADHD: increased deep limbic activity at rest and during concentration, decreased activity in the prefrontal cortex, cerebellum and basal ganglia during concentration.

6) Ring of Fire ADHD: increased activity in many areas of the brain.

7) Anxious ADHD: increased activity in the basal ganglia at rest and during concentration, decreased activity in the prefrontal cortex and cerebellum during concentration (Amen, 2013).

Attention-Deficit/Hyperactivity Disorder is associated with functional impairments in some of the brain's neurotransmitter systems, particularly those involving dopamine and norepinephrine. The dopamine and norepinephrine pathways project to the prefrontal cortex and striatum, and are directly responsible for modulating executive function (cognitive control of behavior), motivation, reward perception, and motor function. These pathways govern a variety of cognitive processes.

- Frontal cortex: The seat of high-level functioning in the brain, this region helps people with working memory, flexible thinking, and self-control. The prefrontal cerebral cortex covers the front of the frontal lobe. A deficiency of norepinephrine within this brain region may be responsible for inattention and problems with higher-order thinking.
- Limbic system: This region, located deep in the brain, regulates our emotions. Symptoms may include restlessness, inattention, or emotional volatility.
- Basal ganglia: These neural circuits regulate communication within the brain. Information from all regions of the brain enters the basal ganglia and is relayed to other areas of the brain. Deficits in the basal ganglia can cause the information to "short-circuit," causing inattention or impulsivity.
- Reticular activating system: This is the most important relay system of the many pathways in the brain's information superhighway. A block in the RAS

can lead to inattention, impulsivity, or hyperactivity.

Significant brain structure modifications appear in Attention-Deficit/Hyperactivity Disorder reduction of volume in certain brain structures, with a proportionally greater decrease in the volume in the left-sided prefrontal cortex, the posterior parietal cortex also shows thinning, brain structures in the prefrontal-striatal-cerebellar and prefrontal-striatal-thalamic circuits have also been found to differ between people with and without ADHD, Magnetic resonance imaging reveals that subcortical volumes of the accumbens, amygdala, caudate, hippocampus, and putamen appear smaller in individuals with ADHD, inter-hemispheric asymmetries in white matter tracts.

Attention-Deficit/Hyperactivity Disorder treatment typically involves therapy or medications either alone or in combination. Therapies for Attention-Deficit/Hyperactivity Disorder may involve behavioral, psychological, social, educational and lifestyle interventions.

Behavioral therapies in Attention-Deficit/Hyperactivity Disorder have had good results so they are the recommended first line treatment in those who have mild symptoms or are preschool-aged (Mahone, 2017). Psychological therapies used include: classroom-led behavioral therapies, behavior therapy, cognitive behavioral therapy (CBT), interpersonal psychotherapy, parent-led behavioral therapy, family therapy, school-based interventions, social skills training, behavioral peer intervention, organization training, parent management training, and neurofeedback.

CBT refers to a type of mental health treatment that focuses on the thoughts and behaviors, and is a program that helps people with Attention-Deficit/Hyperactivity Disorder to develop concrete strategies and skills for coping with the ADHD symptoms (inattention, hyperactivity, impulsivity). CBT helps ADHD individuals to develop programs in time management, organization, and planning.

Neurofeedback involves computer-based exercises, which provide feedback regarding attention levels to enable behavioral training and aims to decrease EEG theta and increase EEG beta and SMR activity, and to teach the patient to increase and decrease brain activity.

Regular physical exercise may be beneficial for individuals with Attention-Deficit/Hyperactivity Disorder. The long-term effects of regular exercise in Attention-Deficit/Hyperactivity Disorder individuals include better behavior and motor abilities, improved executive functions (including attention, inhibitory control, and planning, among other cognitive domains), faster information processing speed, and better memory (Gawrilow et al., 2016). Physical activity may reduce Attention-Deficit/Hyperactivity Disorder symptoms, increase self-esteem, reduce levels of anxiety and depression and improve social behavior (Zang, 2019).

Among the medication used we can find Stimulants (Methylphenidate, Amphetamine) and Non-stimulants (Atomoxetine, Guanfacine). Non-stimulants were approved for the treatment of Attention-Deficit/Hyperactivity Disorder in 2003 but they do not work as quickly as stimulants.

Current recommendations advocate the importance of a balanced diet, good nutrition and supplement for ADHD people.

Reduced Symptoms of Inattention after Dietary Omega-3 Fatty Acid Supplementation in Boys with and without Attention-Deficit/Hyperactivity Disorder Study (Bos et al., 2015), shows that dietary supplementation with omega-3 fatty acids reduces symptoms of Attention-Deficit/Hyperactivity Disorder, both for individuals with ADHD and typically developing children.

The Effect of Vitamin D3 Supplementation on Serum BDNF, Dopamine, and Serotonin in Children with Attention-Deficit/Hyperactivity Disorder Study (Seyedi et al., 2019), indicate that Vitamin D3 supplementation in children with Attention-Deficit/Hyperactivity Disorder can increase serum dopamine levels.

Diet matters for treatment and prevention and also, supplements may improve symptoms of Attention-Deficit/Hyperactivity Disorder. "Joseph Egger reported in the British medical journal The Lancet that 116 of 185 hyperactive children had a positive response to a low-allergen diet (higher in protein and lower in simple carbohydrates) supplemented by calcium, zinc, magnesium, and vitamins" (Amen, 2013: p. 238.).

Traumatic Brain Injury (TBI) is a leading cause of death and disability in Worldwide and is associated with developing mental conditions, including Attention-Deficit/Hyperactivity Disorder. To investigate the link between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder, a literature review of studies that examined this relationship was conducted. Numerous specialized medical pages were searched for original studies that specifically evaluated the relationship between TBI and ADHD.

An improved understanding of the association between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder has an important clinical, scientific and public health relevance. If brain injury is found to be a risk in development of Attention-Deficit/Hyperactivity Disorder, that could lead to the development of early intervention strategies aimed to prevent the ADHD development.

2. Objectives

The aim of this study is to investigate the association between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder, and also to show the importance of prompt intervention and preventive therapy in order to stop the Attention-Deficit/Hyperactivity Disorder development and evolution.

The research questions are as follows:

- Does Traumatic Brain Injury (TBI) lead to Attention-Deficit/Hyperactivity Disorder?
- Is there a link between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder?
- Does psychological therapy prevent the Attention-Deficit/Hyperactivity Disorder development after Traumatic Brain Injury (TBI)?

The objective of the present study is to investigate the association between brain injury and Attention-Deficit/Hyperactivity Disorder, if Traumatic Brain Injury (TBI) can develop Attention-Deficit/Hyperactivity Disorder in some point of people lives.

If there is a link between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder, a strategies plan in order to decrease the number of traumatic brain injury is required. Knowing the connection between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder we could have large clinical, scientific, and public health implications and Attention-Deficit/Hyperactivity Disorder prevention will be more approachable.

It is known that Traumatic Brain Injury (TBI) symptoms include behavioral or mood changes, confusion, and trouble with memory, concentration, attention, or thinking. After brain injury, cognitive and behavioral therapy must start in order to improve patient independent functioning both at home and in society.

Considering that Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder show common symptoms, the uninterrupted unlimited psychological therapy for the management of cognitive problems, executive functioning problems, communication problems, behavioral and emotional changes problems decrease risk of Attention-Deficit/Hyperactivity Disorder can prevent Attention-Deficit/Hyperactivity Disorder development?

3. Material and Methods

To investigate the link between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder, a literature review of studies that examined this relationship was conducted.

PubMed, Science Direct, PsycINFO, Medline were searched for relevant studies that specifically evaluated the relationship between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder. Titles were examined first and eliminated based on lack of relevancy to attention and hyperactivity problems after Traumatic Brain Injury (TBI), abstracts were excluded if the outcomes clearly did not relate to the association between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder.

The search returned a total of 250 articles published between August 2010 and March 2019, 186 were examined by title, and 64 were examined based on abstract. The full text was examined for 43 of the articles and 31 of these were excluded for the following reasons: not specifically assessing traumatic brain injury and attention deficit/hyperactivity disorder or couldn't access the article. Following exclusion of irrelevant articles based on title and abstract, 12 studies fit a priori inclusion criteria and the analysis found a significant association between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder.

The following keywords were used to generate the search: Traumatic Brain Injury, Attention-Deficit/Hyperactivity Disorder, Brain Injury, Head Injury, Attention, Hyperactivity, Therapy, Meditation, Diet.

4. Results

During the research, associations between lifetime Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder development following were observed.

Numerous studies suggested that there is a link between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder (See **Table 1**).

Daniel Amen noted that one of the most common causes of ADHD-like symptoms outside of genetics is head trauma, especially to the prefrontal cortex, when the prefrontal cortex is injured, people have more ADHD-like symptoms. Neuroimaging plays a major role in establishing ADHD symptoms after TBI. Using SPECT brain imaging, he showed that changes in brain structure and function after TBI are directly related to Attention-deficit/hyperactivity disorder development. All SPECT brain imaging case studies showed clear decreased activity in the prefrontal cortex. In his book, Healing ADD, he described some of the ADHD cases after TBI, cases that come to show the connection between Traumatic Brain Injury (TBI) and Attention-deficit/hyperactivity disorder. ADHD patients who had suffered a Traumatic Brain Injury (TBI), were reported with old lesions and decreased activity in prefrontal cortex, in temporal lobes or both prefrontal cortex and temporal lobes, and also in cingulate gyrus (Amen, 2013).

The survey (Max et al., 2005) showed that ADHD in the first 6 months after injury occurred in 18 of 115 (16%) of returning participants. All subtypes of ADHD occurred. Children without preinjury ADHD 5 - 14 years old with TBI were observed prospectively for 6 months with semistructured psychiatric interviews. Injury severity, lesion characteristics, and preinjury variables including psychiatric disorder, family psychiatric history, family psychiatric history of ADHD, family function, socioeconomic status, psychosocial adversity, and adaptive function were assessed with standardized instruments. Socioeconomic status and orbitofrontal gyrus lesions independently significantly predicted ADHD.

Secondary Attention-Deficit/Hyperactivity Disorder in Children and Adolescents 5 to 10 Years After Traumatic Brain Injury Study (Narad et al., 2018), and Parent-Reported Mild Head Injury History in Children: Long-Term Effects on Attention-Deficit Hyperactivity Disorder Study (Li et al., 2018), showed that Children with a history of Traumatic Brain Injury (TBI) have an increased risk for the development of Attention-Deficit/Hyperactivity Disorder even many years after injury. Therefore, childhood head injuries are a significant public health concern and associated ADHD development later in life.

Longitudinal Study of Postconcussion Syndrome: Not Everyone Recovers followed 285 patients who sustained TBIs. Only 27% fully recovered from their symptoms and of those who did, 67% did so within the first year (Hiploylee et al., 2017). This suggested that symptoms following a brain injury are common and that the longer they last, the more likely the symptoms are to be permanent.

Table 1. Association between TBI and ADHD.

References	Design	Conclusion
Max et al., 2005	*n* = 143 5 - 14 years old TBI followed in five trauma center using semistructured psychiatric interviews, no preinjury ADHD	SADHD in the first 6 months after injury occurred in 18 of 115 (16%) of returning participants. All subtypes of ADHD occurred
Narad et al., 2018	*n* = 187 children with no preinjury ADHD TBI DSM-Oriented Attention-Deficit/Hyperactivity Problems Scale of the parent-reported Child Behavior Checklist	Of the 187 children, 48 (25.7%) met the definition of SADHD. Severe TBI was associated with SADHD compared with the control group (81 in the TBI group and 106 in the control group)
Li et al., 2018	*n* = 418 children TBI longitudinal study Child Behavior Checklist was used to measure child iDSM-IV-oriented ADHD at ages 6 (Wave I) and 12 years (Wave II)	57 children (13.6%) had a single injury and 42 (10.0%) had multiple injuries before the age of 6 years. The long-term effect of multiple mild injury on ADHD at age 12 years was significant (R2 = 0.103, $P < 0.05$), even after controlling for ADHD at age 6 years
Ilie et al., 2015	*n* = 3993 cross-sectional sample TBI surveyed by Computer Assisted Telephone Interviewing (CATI)	Among adults with a history of TBI, 6.6% screened ADHD positive, and 5.9% reported having been diagnosed with ADHD in their lifetime. Adults with lifetime TBI had significantly greater odds of scoring positive on the ADHD/ASRS screen, and of reporting a history of diagnosed ADHD than without TBI, when holding values of sex, age, and education constant.
Stojanovski et al., 2019	TBI *n* = 418, no TBI *n* = 3193 The relationship of TBI was examined by assessing: 1) ADHD polygenic score (discovery sample ADHD n = 19,099, control sample n = 34,194), 2) basal ganglia volumes, and 3) fractional anisotropy in the corpus callosum and corona radiata.	Youths with TBI reported ADHD symptom severity compared with those without TBI. genetic predisposition to ADHD does not increase the risk for ADHD symptoms associated with TBI ADHD symptoms associated with TBI may be a result of a mechanical insult rather than neurodevelopmental factors.

The association between Traumatic Brain Injury (TBI) and ADHD in a Canadian adult sample.

study (Ilie et al., 2015), who followed 3993 Ontario adults aged 18 or older with a history of TBI, observed significant associations between lifetime brain injury and Attention-Deficit/Hyperactivity Disorder development. This associa-

tion appeared robust, occurring roughly similarly among all categories of sex and education and occurs for adults as well as adolescents.

According to Polygenic Risk and Neural Substrates of Attention-Deficit/Hyperactivity Disorder Symptoms in Youths With a History of Mild Traumatic Brain Injury (Stojanovski et al., 2019), study who followed 3611 youth, 418 of whom who had sustained a Traumatic Brain Injury (TBI), physical brain injury in children contributes to the development of Attention-Deficit/Hyperactivity disorder, distinct from genetic risk for the disorder. Thus, this study suggested that there are at least two forms of Attention-Deficit/Hyperactivity Disorder: one form that is an expression of a genetic risk and the other which develops after Traumatic Brain Injury (TBI). Also, the results above show that when Attention-Deficit/Hyperactivity disorder symptoms occur in conjunction with Traumatic Brain Injury (TBI), established genetic risk for Attention-Deficit/Hyperactivity disorder may not be an important risk factor. Therefore, this suggests that Attention-Deficit/Hyperactivity disorder following Traumatic Brain Injury (TBI) develops differently, not due to genetic risk, genetic predisposition to ADHD does not increase the risk for ADHD symptoms associated with TBI. ADHD symptoms associated with TBI may be a result of a mechanical insult rather than neurodevelopmental factors (Stojanovski et al., 2019).

We can conclude that Traumatic Brain Injury (TBI) can develop later in people life, regardless of age, gender and education, a distinct form of Attention-Deficit/Hyperactivity Disorder, other than genetic form. Studies above suggested a clear relationship between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder developing (See Table 2). Taking this into account, strategies plan in order to decrease the number of TBI and interventions that can prevent ADHD are required.

Because the risk of late Attention-Deficit/Hyperactivity Disorder development after Traumatic Brain Injury (TBI) remains high over an unknown period, preventive therapeutic approaches should begin early and continue for an unlimited and uninterrupted period of time.

Studies above come to show the benefits of cognitive and behavioral therapies for the management of post-head injury symptoms and Attention-Deficit/Hyperactivity Disorder symptoms also.

Table 2. Percentage and frequency of ADHD after TBI.

Head Injury History		ADHD frequency n (%)
Children		
aged (n)	5 to 14 (143)	18 (16)
	5 to 10 (187)	48 (25.7)
Adult		
aged (n)	18 or older (3993)	(5.9)
total %		18.06

When it comes about the therapy of patients suffering after TBI, the Study, Interventions for attention problems after pediatric traumatic brain injury: what is the evidence? (Backeljauw & Kurowski, 2014), showed us that cognitive training appears to be beneficial when targeting attention or attention and memory specifically rather than mixing with other behavioral or cognitive interventions after Traumatic Brain Injury (TBI).

Cognitive Behavioral Therapy vs relaxation with educational support for medication-treated adults with ADHD and persistent symptoms: a randomized controlled trial (Safren et al., 2010), randomized controlled trial assessing the efficacy of Cognitive Behavioral Therapy for 86 symptomatic adults with Attention-Deficit/Hyperactivity Disorder who were already being treated with medication, showed that among adults with persistent ADHD symptoms treated with medication, the use of Cognitive Behavioral Therapy support resulted in improved ADHD symptoms. Cognitive Behavioral Therapy is a promising approach regarding the treatment of depression and anxiety in adults with ADHD (Auclair et al., 2016).

According to this study, Mindfulness Meditation Training for Attention-Deficit/Hyperactivity Disorder in Adulthood: Current Empirical Support, Treatment Overview, and Future Directions (Mitchell et al., 2015), Mindfulness Meditation Training for ADHD in Adulthood seems to be a feasible and well-accepted intervention in ADHD samples.

Early interventions in Attention-Deficit/Hyperactivity Disorder have showed persisting efficacy, according to the study Preventive Interventions for ADHD: A Neurodevelopmental Perspective (Halperin et al., 2012). It may result in the diminution of later impairment. Therefore, we can conclude that early interventions: cognitive, behavioral therapy and meditation can provide support in order to help people to manage post-head injury symptoms as well as those with Attention-Deficit/Hyperactivity Disorder.

Along with Cognitive Behavioral Therapy, meditation, diet, and regular physical exercises, Neurofeedback seems to be a viable treatment alternative. Recent Study (Enriquez-Geppert et al., 2019) showed the efficacy of neurofeedback in regulating the brain functions in ADHD (See **Table 3**).

5. Discussion

Traumatic Brain Injury (TBI) is a major global health problem and remains the single largest cause of trauma morbidity and accounts for nearly one-third of all trauma deaths. Patients with Traumatic Brain Injury (TBI) often experience enduring emotional and cognitive sequelae. Increased Traumatic Brain Injury (TBI) severity also increases the incidence of ADHD from 7% - 46% going from mild to severe TBI respectively. Thus, children with TBI, less than 2 years old, have double the risk for the development of ADHD as compared to the general population (Morse & Garner, 2018).

Studies mentioned above suggested a clear relationship between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder. Taking this

Table 3. Therapeutic plan.

Therapeutic plan	Objection
Cognitive Behavioral Therapy	developing concrete strategies and skills for coping with the ADHD symptoms (inattention, hyperactivity, impulsivity); developing programs in time management, organization, and planning; improving daily life struggles: procrastination, time management, distractibility, disorganization
Neurofeedback	improving focus reducing inattentive and hyperactive/impulsive ADHD symptoms
Meditation	diminishing and combating temper problems, anxiety, impulsivity, restlessness, insomnia, lack of focus
Diet	increasing serum dopamine levels
Regular physical exercises	improving executive functions; increasing self-esteem; reducing levels of anxiety and depression; improving social behavior

into account, strategies plan in order to decrease the number of Traumatic Brain Injury (TBI) and interventions that can prevent Attention-Deficit/Hyperactivity Disorder are required.

According to the Centers for Disease Control and Prevention (CDC, 2020), the best treatment for Traumatic Brain Injury (TBI) is prevention and following tips bellow we can reduce the risk of brain injury:

- Wear a seat belt every time you drive, or ride, in a motor vehicle.
- Never drive while under the influence of alcohol or drugs.
- Wear a helmet, or appropriate headgear, when you or your children: ride a bike, motorcycle, snowmobile, scooter, or use an all-terrain vehicle; play a contact sport, such as football, ice hockey, or boxing; use in-line skates or ride a skateboard; bat and run bases in baseball or softball; ride a horse; or ski or snowboard.
- Prevent Older Adult Falls: talk to the doctor to evaluate the risk for falling; make the home safer.
- Make living and play areas safer for children.

Brain injury prevention can save people from a Traumatic Brain Injury (TBI) decreasing the risk of mental health problems development.

Thus, first step in prevention of Attention-Deficit/Hyperactivity Disorder development is Traumatic Brain Injury (TBI) prevention.

Considering the fact that there is a link between Traumatic Brain Injury (TBI) and late Attention-Deficit/Hyperactivity Disorder development, we can conclude that there is a need for preventive approaches in order to prevent the Attention-Deficit/Hyperactivity Disorder development.

Because the risk of late Attention-Deficit/Hyperactivity disorder development after Traumatic Brain Injury (TBI) remains high over an unknown period, preventive approaches should begin early and continue uninterrupted for an unlimited period of time.

Taking into account the symptoms of Attention-Deficit/Hyperactivity Dis-

order, the approaches must target stopping the appearance of impairment in memory, attention and concentration, language, executive skills, social judgment, social behavior, and impulsiveness.

As the studies have already shown, early interventions like psychotherapy, psychosocial interventions, meditation can provide support in order to help people to manage post-head injury symptoms and to prevent the Attention-Deficit/Hyperactivity Disorder risk.

Cognitive rehabilitation therapy aims to help people regain their normal brain function and also learn them compensatory strategies for coping with persistent deficiencies involving memory, problem solving, and the thinking skills to get things done. Knowing that the magnitude of executive dysfunction and attention problems would be moderated by family and parenting factors (Kurowski et al., 2011), family therapy can help family members to find better ways to handle disruptive behaviors and to encourage behavior changes, and improve interactions with the patient. Parenting training teaches parents the skills they need to encourage and reward positive behaviors in their children.

Mindfulness meditation could help people decrease the impact of negative cognitions. This type of metacognitive awareness that mindfulness purportedly elicits may also be expanded beyond cognition to observing one's own body, emotional reactions, overt behavior, and environmental feedback with greater awareness, which can lead to improved overall self-monitoring and self-regulation. Meditation is a simple technique that can help in prevention of Attention-Deficit/Hyperactivity Disorder development by controlling stress, decreasing anxiety, improving cardiovascular health, and achieving a greater capacity for relaxation. Mindfulness meditation practices can be conceptualized as a set of attention-based, regulatory, and self-inquiry training regimes cultivated for various ends, including wellbeing and psychological health (Lutz et al., 2015).

Regular Physical exercise must have an important place in the preventive plan of decreasing the risk of Attention-Deficit/Hyperactivity Disorder, the long-term effects of regular exercise individuals include better behavior and motor abilities, improved executive functions, faster information processing speed, and better memory. Physical activity may prevent Attention-Deficit/Hyperactivity Disorder symptoms, increase self-esteem, reduce levels of anxiety and depression and improve social behavior.

Also, a healthful diet can prevent and reduce symptoms of Attention-Deficit/Hyperactivity Disorder by reducing exposure to artificial colors and additives and improving intake of omega-3 fats and micronutrients.

When it comes to Neurofeedback technique, used alone or in combination with pharmacological treatment, it gained increasing interest in the treatment of Attention-Deficit/Hyperactivity Disorder being a viable treatment improving some of the behavioral concomitants of ADHD (Pakdaman et al., 2018). Attention-Deficit/Hyperactivity Disorder differs in terms of the type of presentation (inattentive, impulsive/hyperactive, or combined). Training in neurofeedback has proven its effectiveness when it comes about impulsive/hyperactive ADHD

children and combined ADHD children presentation reducing the symptomatology associated with attention deficit with hyperactivity disorder (Cueli et al., 2019). In terms of efficacy in adults, study (Schönenberg et al., 2017) examined the efficacy (compared with sham neurofeedback) and efficiency (compared with meta-cognitive therapy) of a standard EEG neurofeedback protocol in adults with ADHD. All three treatments were equivalently effective in reducing ADHD symptoms.

Thereby, a feasibility plan of action in treating Attention-Deficit/Hy- peractivity Disorder after a Traumatic Brain Injury (TBI) in order to stop the appearance of impairment in memory, attention and concentration, language, executive skills, social judgment, social behavior, and impulsiveness must contain the steps bellow:

- Creating a therapeutic plan focused on Cognitive Behavioral Therapy to improve daily life struggles: procrastination, time management, distractibility, disorganization, poor internal supervision, short attention span;
- Creating a Regular Physical exercise plan: physical exercises have positive effects on health and well-being, improve mood and quality of life and reduce stress, decrease impulsivity and hyperactivity, improve attention, and performance;
- Creating a Mindfulness Meditation program: it helps to diminish and combat temper problems, anxiety, impulsivity, restlessness, insomnia and lack of focus;
- Focusing on the diet: diet can have a positive effect on cognition, feelings, and behavior being an important tool in prevention and control of ADHD symptoms;
- Ensuring a stable and friendly living environment;
- Creating a neurofeedback program: in order to achieve healthier, more focused state, and reduce inattentive and hyperactive/impulsive ADHD symptoms;
- Boosting the brain's reserve (extra brain function) to cope with stress factors.

The brain is a plastic organ that changes, reacts and adapts to its environment. Thanks to neuroplasticity, the brain that changes itself (Doidge, 2010), this plan can have significant implications for healthy development, learning, memory, recovery from brain damage making possible prevention for Attention-Deficit/ Hyperactivity Disorder development.

Harnessing neuroplasticity may not only offer an arm in the vast arsenal of approaches being taken to tackle neurological disorders, such as neurodegenerative diseases, but from ample evidence, it also has major implications in neuropsychological disorders (Sasmita et al., 2018). Recent studies have shown that CBT has the impact of physically changing the brain, highlighting the role of neuroplasticity in successful recovery from these psychological disorders. Every sustained activity ever mapped, including physical activities, sensory activities, learning, thinking, and imagining, changes the brain as well as the mind (Doidge, 2010).

Cognitive Behavioral Therapy along with regular exercise, diet, meditation and Neurofeedback have shown that it is the perfect approach in order to prevent the ADHD development following a brain injury.

6. Conclusion

The results of the current literature review suggest that there is connection between lifetime Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder development and we can conclude that Traumatic Brain Injury (TBI) can develop later in people life, regardless of age, gender and education, a distinct form of Attention-Deficit/Hyperactivity Disorder, other than genetic form.

To facilitate reducing the risk of Attention-Deficit/Hyperactivity Disorder among people with Traumatic Brain Injury (TBI), uninterrupted therapeutic intervention must start early for an unlimited period of time and clinicians should monitor for signs of ADHD onset in the years after TBI. Mental health professionals play a critical and important role in the prevention and treatment of both Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder.

Cognitive Behavioral Therapy, Mindfulness meditation, Regular Physical exercise and healthy diet should be part of early intervention increasing the chances for a patient better life.

Additional studies are required in the future for exploring the mechanisms underlying the relationship between Traumatic Brain Injury (TBI) and Attention-Deficit/Hyperactivity Disorder and developing specific diagnostic markers for identifying Attention-Deficit/Hyperactivity Disorder in people with brain injury.

Considering the limitations and the strengths of this current study, continued research is necessary to better understand the association and outcomes of Traumatic Brain Injury (TBI), and develop effective programs and treatments in order to decrease the risk of Attention-Deficit/hyperactivity disorder development.

All the findings of the present study showed that Cognitive Behavioral Therapy, regular physical exercises, diet, meditation and Neurofeedback are the perfect approach in order to prevent the ADHD development following a brain injury.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Amen, D. G. (2013). *Healing ADD*. Penguin Random House LLC.

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Auclair, V., Harvey, P. O., & Lepage, M. (2016). La thérapie cognitive-comportementale

dans le traitement du TDAH chez l'adulte [Cognitive Behavioral Therapy and the Treatment of ADHD in Adults]. *Sante Mentale au Quebec, 41,* 291-311. https://pubmed.ncbi.nlm.nih.gov/27570962 https://doi.org/10.7202/1036976ar

Backeljauw, B., & Kurowski, B. G. (2014). Interventions for Attention Problems after Pediatric Traumatic Brain Injury: What Is the Evidence? *PM & R: The Journal of Injury, Function, and Rehabilitation, 6,* 814-824. https://doi.org/10.1016/j.pmrj.2014.04.004

Barman, A., Chatterjee, A., & Bhide, R. (2016). Cognitive Impairment and Rehabilitation Strategies after Traumatic Brain Injury. *Indian Journal of Psychological Medicine, 38,* 172-181. https://doi.org/10.4103/0253-7176.183086

Bos, D. J., Oranje, B., Veerhoek, E. S., Van Diepen, R. M., Weusten, J. M., Demmelmair, H., Koletzko, B., de Sain-van der Velden, M. G., Eilander, A., Hoeksma, M., & Durston, S. (2015). Reduced Symptoms of Inattention after Dietary Omega-3 Fatty Acid Supplementation in Boys with and without Attention Deficit/Hyperactivity Disorder. *Neuropsychopharmacology, 40,* 2298-306. https://doi.org/10.1038/npp.2015.73

Centers for Disease Control and Prevention (2020). *Attention-Deficit/Hyperactivity Disorder (ADHD).* https://www.cdc.gov

Center-TBI (2020). *10 Facts about TBI.* https://www.center-tbi.eu

Cherkasova, M., Sulla, E. M., Dalena, K. L., Pondé, M. P., & Hechtman, L. (2013). Developmental Course of Attention Deficit Hyperactivity Disorder and Its Predictors. *Journal of Canadian Academy of Child and Adolescent Psychiatry, 22,* 47-54. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3565715/#b20-ccap22_1p0047

Cueli, M., Rodríguez, C., Cabaleiro, P., García, T., & González-Castro, P. (2019). Differential Efficacy of Neurofeedback in Children with ADHD Presentations. *Journal of Clinical Medicine, 8,* 204. https://doi.org/10.3390/jcm8020204

Doidge, N. (2010). *The Brain That Changes Itself. Stories of Personal Triumph from the Frontiers of Brain Science*. Penguin Books.

Enriquez-Geppert, S., Smit, D., Pimenta, M. G., & Arns, M. (2019). Neurofeedback as a Treatment Intervention in ADHD: Current Evidence and Practice. *Current Psychiatry Reports, 21,* 46. https://doi.org/10.1007/s11920-019-1021-4

Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2016). Physical Activity, Affect, and Cognition in Children with Symptoms of ADHD. *Journal of Attention Disorder, 20,* 51-62. https://doi.org/10.1177/1087054713493318

Halperin, J. M., Bédard, A. C., & Curchack-Lichtin, J. T. (2012). Preventive Interventions for ADHD: A Neurodevelopmental Perspective. *Neurotherapeutics, 9,* 531-541. https://doi.org/10.1007/s13311-012-0123-z

Hiploylee, C., Dufort, P. A., Davis, H. S., Wennberg, R. A., Tartaglia, M. C., Mikulis, D., Hazrati, L. N., & Tator, C. H. (2017). Longitudinal Study of Postconcussion Syndrome: Not Everyone Recovers. *Journal of Neurotrauma, 34,* 1511-1523. https://doi.org/10.1089/neu.2016.4677

Ilie, G., Vingilis, E. R., Mann, R. E., Hamilton, H., Toplak, M., Adlaf, E. M., Kolla, N., Ialomiteanu, A., van der Mass, M., Asbridge, M., Vingilis-Jaremko, L., Rehm, J., & Cusimano, M. D. (2015). The Association between Traumatic Brain Injury and ADHD in a Canadian Adult Sample. *Journal of Psychiatric Research, 69,* 174-179. https://doi.org/10.1016/j.jpsychires.2015.08.004

Irastorza, L. (2011). Treatment of ADHD Secondary to Traumatic Brain Injury. *European Psychiatry, 26,* 1246-1246. https://doi.org/10.1016/S0924-9338(11)72951-0

Kurowski, B. G., Taylor, H. G., Yeates, K. O., Walz, N. C., Stancin, T., & Wade, S. L.

(2011). Caregiver Ratings of Long-Term Executive Dysfunction and Attention Problems after Early Childhood Traumatic Brain Injury: Family Functioning Is Important. *PM & R: The Journal of Injury, Function and Rehabilitation, 3,* 836-845. https://doi.org/10.1016/j.pmrj.2011.05.016

Li, L., Li, Y., McDonald, C., & Liu, J. (2018). Parent-Reported Mild Head Injury History in Children: Long-Term Effects on Attention-Deficit Hyperactivity Disorder. *Global Pediatric Health, 5,* 2333794X18756465. https://doi.org/10.1177/2333794X18756465

Little, A., Byrne, C., & Coetzer, R. (2021). The Effectiveness of Cognitive Behaviour Therapy for Reducing Anxiety Symptoms Following Traumatic Brain Injury: A Meta-Analysis and Systematic Review. *NeuroRehabilitation, 48,* 67-82. https://doi.org/10.3233/NRE-201544

Lutz, A., Jha, A. P., Dunne, J. D., & Saron, C. D. (2015). Investigating the Phenomenological Matrix of Mindfulness-Related Practices from a Neurocognitive Perspective. *The American Psychologist, 70,* 632-658. https://doi.org/10.1037/a0039585

Mahone, E. M., & Denckla, M. B. (2017). Attention-Deficit/Hyperactivity Disorder: A Historical Neuropsychological Perspective. *Journal of the International Neuropsychological Society, 23,* 916-929. https://doi.org/10.1017/S1355617717000807

Max, J. E., Schachar, R. J., Levin, H. S., Ewing-Cobbs, L., Chapman, S. B., Dennis, M., Saunders, A., & Landis, J. (2005). Predictors of Attention-Deficit/Hyperactivity Disorder within 6 Months after Pediatric Traumatic Brain Injury. *Journal of the American Academy Child and Adolescent, 44,* 1032-1040. https://doi.org/10.1097/01.chi.0000173293.05817.b1

Mitchell, J. T., Zylowska, L., & Kollins, S. H. (2015). Mindfulness Meditation Training for Attention-Deficit/Hyperactivity Disorder in Adulthood: Current Empirical Support, Treatment Overview, and Future Directions. *Cognitive and Behavioral Practice, 22,* 172-191. https://doi.org/10.1016/j.cbpra.2014.10.002

Morse, A. M., & Garner, D. R. (2018). Traumatic Brain Injury, Sleep Disorders, and Psychiatric Disorders: An Underrecognized Relationship. *Medical Sciences, 6,* 15. https://doi.org/10.3390/medsci6010015

Narad, M. E., Kennelly, M., Zhang, N., Wade, S. L., Yeates, K. O., Taylor, H. G., Epstein, J. N., & Kurowski, B. G. (2018). Secondary Attention-Deficit/Hyperactivity Disorder in Children and Adolescents 5 to 10 Years after Traumatic Brain Injury. *JAMA Pediatrics, 172,* 437-443. https://doi.org/10.1001/jamapediatrics.2017.5746

Pakdaman, F., Irani, F., Tajikzadeh, F., & Jabalkandi, S. A. (2018). The Efficacy of Ritalin in ADHD Children under Neurofeedback Training. *Neurological Sciences, 39,* 2071-2078. https://doi.org/10.1007/s10072-018-3539-3

Pires, T. de O., da Silva, C. M., & de Assis, S. G. (2013). Association between Family Environment and Attention Deficit Hyperactivity Disorder in Children-Mothers' and Teachers' Views. *BMC Psychiatry, 13,* 215. https://doi.org/10.1186/1471-244X-13-215

Russell, A. E., Ford, T., & Russell, G. (2015). Socioeconomic Associations with ADHD: Findings from a Mediation Analysis. *PLoS ONE, 10,* e0128248. https://doi.org/10.1371/journal.pone.0128248

Safren, S. A., Sprich, S., Mimiaga, M. J., Surman, C., Knouse, L., Groves, M., & Otto, M. W. (2010). Cognitive Behavioral Therapy vs Relaxation with Educational Support for Medication-Treated Adults with ADHD and Persistent Symptoms: A Randomized Controlled Trial. *JAMA, 304,* 875-880. https://doi.org/10.1001/jama.2010.1192

Sasmita, A. O., Kuruvilla, J., & Ling, A. P. K. (2018). Harnessing Neuroplasticity: Modern Approaches and Clinical Future. *International Journal of Neuroscience, 128,* 1061-1077. https://doi.org/10.1080/00207454.2018.1466781

Schachar, R. J., Park, L. S., & Dennis, M. (2015). Mental Health Implications of Traumatic Brain Injury (TBI) in Children and Youth. *Journal of the Canadian Academy of Child and Adolescent Psychiatry, 24,* 100-108. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4558980

Schönenberg, M., Wiedemann, E., Schneidt, A., Scheeff, J., Logemann, A., Keune, P. M., & Hautzinger, M. (2017). Neurofeedback, Sham Neurofeedback, and Cognitive-Behavioural Group Therapy in Adults with Attention-Deficit Hyperactivity Disorder: A Triple-Blind, Randomised, Controlled Trial. *The Lancet Psychiatry, 4,* 673-684. https://doi.org/10.1016/S2215-0366(17)30291-2

Seyedi, M., Gholami, F., Samadi, M., Djalali, M., Effatpanah, M., Yekaninejad, M. S., Hashemi, R., Abdolahi, M., Chamari, M., & Honarvar, N. M. (2019). The Effect of Vitamin D3 Supplementation on Serum BDNF, Dopamine, and Serotonin in Children with Attention-Deficit/Hyperactivity Disorder. *CNS & Neurological Disorders Drug Targets, 18,* 496-501. https://doi.org/10.2174/1871527318666190703103709

Stojanovski, S., Felsky, D., Viviano, J. D., Shahab, S., Bangali, R., Burton, C. L. et al. (2019). Polygenic Risk and Neural Substrates of Attention-Deficit/Hyperactivity Disorder Symptoms in Youths with a History of Mild Traumatic Brain Injury. *Biological Psychiatry, 85,* 408-416. https://doi.org/10.1016/j.biopsych.2018.06.024

Thapar, A., & Stergiakouli, E. (2010). An Overview on the Genetics of ADHD. *Acta Psychologica Sinica, 40,* 1088-1098. https://doi.org/10.3724/SP.J.1041.2008.01088

Yang, L. Y., Huang, C. C., Chiu, W. T. et al. (2016). Association of Traumatic Brain Injury in Childhood and Attention-Deficit/Hyperactivity Disorder: A Population-Based Study. *Pediatric Research, 80,* 356-362. https://doi.org/10.1038/pr.2016.85

Zang, Y. (2019). Impact of Physical Exercise on Children with Attention Deficit Hyperactivity Disorders. *Medicine, 98,* e17980. https://doi.org/10.1097/MD.0000000000017980

Zillmer, E., Spiers, M., & Culbertsone, W. (2008). *Principles of Neuropsychology* (2nd ed.). Thomson Wadsworth.