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Attention Deficit Hyperactivity Disorder and Environmental Pollution: The Importance of Passive Smoking

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Abstract
Attention deficit hyperactivity disorder (ADHD) is a chronic neurodevelopmental disorder characterized by inattention, impulsivity, and hyperactivity due to altered brain function that begins in preschool age and can persist into adulthood. In addition to genetic factors, environmental exposures have been suggested to play a role in its development, including organic pollutants, some dietary components, and pollutants in general, which can cause neurological, behavioral, and cognitive changes, especially among children, who, due to their immaturity, constitute a higher-risk population group. Among environmental pollutants, passive smoking has gained significant importance due to its association with various diseases that can affect virtually the entire body. This narrative review presents the main clinical characteristics of ADHD in childhood, causal factors, and the importance of passive smoking as a causal factor in this disorder, which is responsible for significant individual and family repercussions.

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Introduction

Attention deficit hyperactivity disorder (ADHD) is a chronic neurodevelopmental disorder of multifactorial, complex, heterogeneous etiology, characterized by inattention, impulsivity, and hyperactivity due to altered brain function [1,2]. It generally begins in preschool age and follows a persistent, trait-like course into adolescence and adulthood [3, 4], with a significant impact on the individual, their family, and society [5], due to repercussions on academic and professional performance, interpersonal relationships, and overall quality of life [1, 6, 7].

ADHD is described in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) and the International Classification of Diseases (ICD) as a condition manifested by inattention, restlessness, and impulsivity that are inappropriate for the developmental stage and cause functional impairment [8]. Since its introduction in the DSM-III (3rd edition, 1980), the central definition of ADHD – based on a minimum number of symptoms of inattention or hyperactivity-impulsivity, or both – has remained essentially unchanged, presenting three subtypes: predominantly inattentive (ADHD-D), predominantly hyperactive/impulsive (ADHD-H), and combined (ADHD-C) [2, 9].

The first known description of this syndrome dates back to Hippocrates in 493 BC, and the first record in medical textbooks, made by German and Scottish physicians, dates from the late 18th century [10]. Throughout history ADHD has received various names such as minimal brain damage, hyperkinetic syndrome and minimal brain dysfunction, changes that occurred as new discoveries about the disorder were published [2]. The nomenclature ADHD emerged in 1994 with the publication of the Diagnostic version. Statistical Manual of Mental Disorder's IV (DSM IV), edited by American Psychiatric Association, being expanded within and outside psychiatric contexts and considered the most common disorder in children and adolescents referred to specialized services [2].

Etiology

Although the etiology of ADHD is not yet fully understood and considering its multifactorial nature, it is known that genetic factors are present and that susceptibility genes interact with environmental risk factors in complex ways [1, 2]. Studies with twins and family members have shown that the heritability of ADHD is approximately 80%, demonstrating that genetic factors strongly contribute to the development of the disorder [10]. Environmental factors must also be considered, given that they play an important role in the etiology of ADHD, although many of them remain unknown [10]. Associations with environmental factors may be due to traumatic brain injury, extreme emotional and/or nutritional deprivation early in life, thyroid gland disorders, heavy metal poisoning (lead), use of anticonvulsants, alcohol, drugs, perinatal stress, low birth weight, prematurity, intrauterine growth restriction and maternal smoking [10-13].

It has also been suggested that specific environmental exposures may be relevant to the ADHD phenotype, including organic pollutants (e.g., pesticides and biphenyls polychlorinated compounds), which are substances capable of damaging cognitive and neural systems [11], some components of the diet such as sugar, artificial food colors, zinc, iron, magnesium and omega-3 fatty acids, but without convincing evidence of their causal role in ADHD [11]. It is important to highlight that ADHD often coexists with other psychiatric disorders such as conduct disorders, depression, anxiety and oppositional defiant disorder [14] which can cause delay in accurate diagnosis, and with some somatic conditions such as dermatitis, obesity, asthma, vision problems, hearing problems and sleep disorders [1, 5, 10].

Prevalence

The estimated global prevalence of children with ADHD is around 7.0%, with some regional variations such as the United States (8.9%). Australia (5.6%), Brazil (5.0%), Europe (4.7%) and some regions of Southeast Asia (3.7%) [1, 2, 4, 5, 9, 12s]. It is well established that the prevalence in males is higher due to the greater likelihood of receiving a diagnosis compared to females. This disparity is partly due to hyperactive behaviors manifested in boys, which are more easily diagnosed. On the other hand, girls often present with more subtle inattention and internalizing behaviors, such as anxiety and low self-esteem, which leads to a delay in identifying the problem or to underdiagnosis [3, 5, 7]. In some individuals, the severity of symptoms decreases during adolescence, but approximately two-thirds of children with ADHD maintain impairments in adulthood [10].

Diagnosis

The diagnosis of ADHD is essentially clinical, as there is no laboratory or imaging test that can be included in the investigation, which must often be carried out by a multidisciplinary team through an approach with various assessments [2, 15]. A thorough clinical interview can identify the main symptoms and associated repercussions that significantly exceed the level of activity, aggressiveness, or dysregulation expected for the age and developmental stage, following the guidelines of the DSM-5 or ICD. In addition to meeting the clinical criteria, other physical, situational, or mental health conditions that may explain the symptoms must be ruled out [10].

To complement specialized medical evaluation, parents, teachers, and caregivers can contribute relevant information through the use of validated questionnaires for screening, assessing severity and frequency of symptoms, and monitoring treatment. Among the most commonly used are the ADHD Rating Scale, the Swanson questionnaire, the Nolan questionnaire and Pelham Questionnaire (SNAP-III and IV) and the Conners questionnaire [10, 16].

The American Psychiatric Association has defined consensus criteria for the diagnosis of ADHD. For children and adolescents under 17 years of age, the presence of 6 or more symptoms of hyperactivity and impulsivity or 6 or more symptoms of inattention is required. For adolescents 17 years of age or older and adults, the presence of 5 or more symptoms of hyperactivity and impulsivity or 5 or more symptoms of inattention is required. Table 1 presents the symptoms of hyperactivity/impulsivity and inattention that should be identified [8, 9, 17].

Table 1: Symptoms of hyperactivity/impulsivity and inattention

Hyperactivity/impulsivity	Inattention
Excessive agitation	Failure to pay close attention to detail; careless mistakes.
Difficulty remaining seated when required.	Difficulty maintaining attention during play, schoolwork, or household activities.
Feeling restless (in adolescents) or running and climbing inappropriately (in younger children)	He seems not to hear, even when spoken to directly.
Difficulty playing quietly	Failure to complete tasks
Difficulty keeping up with the pace, always seeming to be "going a mile a minute "	Difficulty organizing tasks, activities, and belongings.
Talking excessively	Avoid tasks that require constant mental effort.
Difficulty waiting your turn	Loses objects necessary for tasks or activities.
Responding hastily	Easily distracted by irrelevant stimuli.
To interrupt or interfere in the activities of others.	Forgetfulness in routine activities

Modified from APA (8)

It should also be considered that symptoms of hyperactivity/impulsivity or inattention must: occurs frequently, manifest in more than one environment (e.g., school and home), persist for at least six months, be present before the age of 12, impair functioning in academic, social or occupational activities and be excessive for the child's developmental level [12].

Given the diversity of clinical manifestations, the differential diagnosis of ADHD should include psychiatric, neurodevelopmental, and medical conditions that share symptoms of hyperactivity/impulsivity and inattention, such as: anxiety disorders, depressive disorders, bipolar disorder/mania, post-traumatic stress disorder, autism spectrum disorder, oppositional defiant disorder/conduct

disorder, learning and language disorders, adjustment disorder, reactive attachment disorder, disruptive mood dysregulation disorder, psychotic disorders, substance use, personality disorders, intellectual disability, sleep disorders (obstructive sleep apnea, restless legs syndrome), thyroid dysfunction, hearing loss, genetic syndromes (fragile X, neurofibromatosis, 22q11 deletion), fetal alcohol syndrome, previous traumatic brain injury, epilepsy, Tourette syndrome, lead poisoning, anemia, inflammatory bowel disease, vestibulo-visual disorders, and trauma/adverse experiences in childhood [18-21].

Environmental Pollutants and Behavioral Disorders in Childhood

Environmental pollution is known to be responsible for neural, behavioral, and cognitive changes, among others, caused by a large number of harmful components that can come into contact with people through various routes. Especially among children, whose neurodevelopment begins at the embryonic stage, the impacts are significant and often irreversible, since the dysregulation of the neuroendocrine circuit can result in brain alterations during sensitive periods [22]. The disruption of natural barriers (nasal epithelial, intestinal, pulmonary, and blood-brain barriers) that prevent the entry of toxic particles facilitates the passage of atmospheric pollutants into the body, triggering, in addition to oxidative stress and endocrine dysregulation, neuroinflammation which is probably the crucial mechanism for the emergence of cognitive deficits [23, 24].

Exposure to air pollution in childhood is associated with outcomes in child development ranging from alterations in brain structures to subclinical deficits (detected in clinical tests) and developmental disorders, such as ADHD. Among the numerous pollutants that make the environment more risky for human health, smoking is one of the most relevant due to its direct association with high morbidity and mortality rates in all age groups [25, 26].

Passive Smoking and Neurodevelopment

Smoking and its byproducts are among the most dangerous environmental pollutants found worldwide. Cigarette burning produces at least 250 harmful chemical gases (carbon monoxide, hydrogen cyanide, butane, ammonia, benzene, toluene, among others) in addition to particulate matter such as lead, chromium, arsenic, and cadmium, which affect people through inhalation, ingestion, and/or dermal contact, making them passive smokers subject to a large number of alterations in various organs and systems [27, 28]. Passive smoke is considered more harmful than primary smoke because it carries a greater quantity of respirable contaminants dispersed over a longer exposure period, accentuating contact with the organism [1, 29, 30].

Globally, approximately 40% of children and adolescents and 35% of women constitute the most vulnerable exposure groups, mainly in the domestic environment, representing a serious threat to public health and a risk to child development due to neurotoxic effects that compromise both functional and structural aspects. Among the various cognitive and behavioral problems observed in children and related to passive smoking, ADHD emerges as a growing concern due to its potential to persist during adolescence and into adulthood, compromising social and professional functioning, as well as generating higher costs in the areas of health and education [27, 30-32].

Since the mid-1960s, the literature has recorded several articles describing a clinical condition in children called "hyperkinetic syndrome," which presented possible etiologies, clinical characteristics, associated factors, and therapeutic indications. Although initially considered a rare childhood psychosis, the prevalence observed in more than 5% among elementary school children in North America sparked interest in expanding knowledge about this syndrome, which showed evidence of being related to these children's contact with their smoking parents, whose smoking habit contaminated the environment with harmful substances capable of altering the normal activity of the central nervous system [33].

Exposure to secondhand smoke during the prenatal and postnatal periods has been associated with higher rates of behavioral problems in childhood [34-37], most notably ADHD, which has been diagnosed with increasing frequency among preschool children, to the point of stimulating new research aimed at highlighting the importance of early diagnosis and specific measures to avoid, treat or reduce damage for future life.

Over the past twenty years, several articles have been published highlighting the association between passive smoking and ADHD, including 2 case-control studies [38, 39], 4 studies with population samples [40-43], 6 studies with data from national studies [44-49] and 5 systematic reviews [1, 50-53]. All studies demonstrated the relevance of environmental pollution caused by smoking in the symptomatology presented by children, with clear evidence of the participation of the components of cigarette combustion in the origin of ADHD.

Conclusion

ADHD is the most common behavioral disorder in childhood, and its early recognition is essential for improving long-term prognosis due to its significant and chronic impact on emotional, academic, family, and social performance. Treatment results in a significant increase in the use of healthcare services and financial burdens for the family, highlighting the importance of preventive actions with a holistic approach. Therefore, in addition to recognizing and understanding the clinical aspects, it is necessary to identify associated factors that may contribute to the development of the condition, such as passive smoking. One of the most important measures in prevention work is informing parents about the neurotoxic effects of tobacco smoke and its repercussions on the child's physical and emotional health throughout their development. This serious domestic threat is preventable and within the reach of family members, who should receive ongoing counseling for smoking cessation. In this sense, pediatricians and other health professionals play a fundamental role as the first point of reference for offering advice on eliminating smoking and monitoring the child's behavior and development, looking for early signs of emotional changes. Furthermore, given the evidence on the negative effects of secondhand smoke and the increasing prevalence of behavioral problems among children, it is necessary to make public health promotion efforts to raise awareness throughout society that there is no safe level of exposure to secondhand smoke and that the most vulnerable populations, such as children, are more susceptible to diseases that can be prevented in order to improve health conditions and quality of life.

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