

EPIGENETIC MODIFICATIONS: ENVIRONMENTAL INFLUENCES ON CHILD AND ADOLESCENT BEHAVIOR



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ABSTRACT

The article examines epigenetics as an emerging field of biology, considered essential for understanding the modifications that influence gene expression without altering the DNA sequence. Processes such as DNA methylation, histone modifications, and the performance of non-coding RNAs are highlighted, all of which are fundamental in gene regulation and in the maintenance of physical and mental health. Epigenetics is presented as an interdisciplinary discipline that covers areas such as medicine, psychology, neurosciences, and social sciences, especially in the critical phases of childhood and adolescence, periods when human development is particularly susceptible to external influences. The article discusses how early experiences, including environmental stressors and social interaction dynamics, can induce epigenetic changes that shape behaviors and predispositions to mental disorders. In addition, the relevance of early interventions is emphasized, suggesting that a deep understanding of epigenetic mechanisms can provide new perspectives on behavioral plasticity. However, limitations in existing research are recognized, such as the lack of longitudinal studies and the complexity of interactions in the real-life context. The text also raises pertinent ethical issues, especially with regard to interventions in vulnerable populations, such as children and adolescents. It is proposed that future research should focus on the relationships between environmental stressors and epigenetic changes, as well as the effectiveness of early interventions based on epigenetic knowledge. In conclusion, the article asserts that epigenetics is an area of paramount importance for biology and medicine, capable of informing more effective social policies, contributing to the well-being of children and adolescents and promoting the construction of more just and equitable societies.

Keywords: Epigenetics. Behavioral Development. Environmental Factors. Early Interventions. Behavioral Plasticity.

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INTRODUCTION

Epigenetics, an emerging field of biology, more specifically within genetics. (Farsetti & Gaetano, 2023), she investigates modifications that affect gene expression without altering the DNA sequence (Fantappie, 2013), including processes such as DNA methylation, histone modifications, and the action of non-coding RNA. (Costa & Pacheco 2013).

Epigenetics is interdisciplinary, also involving areas such as medicine, psychology, neurosciences, and social sciences, especially when analyzing how environmental factors and life experiences influence human behavior and development.

Epigenetics has been consolidated as an essential area for understanding the mechanisms that regulate gene expression without modifying the DNA sequence. Epigenetic modifications, which encompass processes such as DNA methylation.

DNA methylation is an epigenetic process that involves the addition of methyl groups ($-CH_3$) to certain DNA bases, usually cytosine, which is often followed by a guanine (CG) in regions called CpG islands. This chemical modification does not alter the DNA sequence, but it can influence gene expression. (Concha, Recabarren, & Pérez 2017).

In addition to DNA methylation, there are other processes, as described by Ghosh & Saadat (2023), such as histone modifications, which is defined as chemical changes that occur in proteins called histones, which associate with DNA to form the structure known as chromatin.

These modifications play a crucial role in regulating gene expression and chromatin organization. And finally, the modifications of non-coding RNA (ncRNAs) activities that include:

1. **Control genes:** They help decide which genes are active or inactive.
2. **Organize DNA:** They contribute to the structure of DNA, helping to regulate gene expression.
3. **Influencing proteins:** They can "capture" molecules that regulate proteins, affecting their activity.
4. **Process RNA:** They help prepare messenger RNA, removing unnecessary parts.
5. **Regulate cell growth:** Control the cycle of cell division.
6. **Support the immune system:** They participate in the body's response to infections.
7. **Maintain cellular balance:** They help regulate processes that maintain healthy cellular functions.

These activities show the importance of ncRNAs in the regulation and functioning of cells.

Finally, modifications of DNA methylation processes, histones, and ncRNA activities play a key role in a variety of biological processes. (Costa & Pacheco, 2013, Concha, Recabarren, & Pérez 2017, Ghosh & Saadat, 2023).

These modifications not only influence physical health, but also have significant implications for the behavioral development of children and adolescents, critical periods in which the body is particularly susceptible to interactions between genetic and environmental factors.

Recent research has shown that early experiences—including environmental stressors (Silva & Carvalho, 2023), nutritional quality (Oliver & Mach, 2016), and dynamics of social interactions (Casanello et al, 2016)—can induce epigenetic changes that affect the development of the nervous system and, therefore, shape behavior patterns.

Exposure to adverse environments, for example, can result in epigenetic modifications that predispose individuals to behavioral disorders, such as anxiety and depression, in addition to impacting social and cognitive skills.

In this context, understanding epigenetic mechanisms provides a new perspective on behavioral plasticity, underlining the importance of early interventions.

Furthermore, it is crucial to recognize that epigenetics does not operate in isolation (Vieira, 2017); Its interaction with genetic and environmental factors forms an intricate mosaic that influences human development. The implications of this interaction are vast, covering areas such as education, public health, and social policies. Understanding epigenetic mechanisms can therefore inform intervention strategies that aim to promote healthier and more equitable developmental environments.

This article aims to explore, in a comprehensive way, how epigenetic modifications impact behavioral development in children and adolescents.

The analysis will be based on a narrative review of the existing literature, allowing a detailed understanding of the available scientific evidence on the subject. In particular, reviews and cross-sectional studies that address the relationship between epigenetics and behavior will be examined, providing a critical view of the complex interactions that permeate this field of study.

The sources of information used for this research will include reputable databases, such as Google Scholar, SciELO, and PubMed, ensuring the quality and relevance of the data analyzed.

The intention is to contribute to a deeper understanding of the intersection between biology and behavior, highlighting the need for a multidisciplinary approach in the analysis of human development.

By integrating knowledge from different areas, this study seeks not only to elucidate the epigenetic mechanisms that influence behavior, but also to discuss their implications for social and educational practices.

Thus, it is hoped that the findings presented in this article can collaborate in interventions that promote the well-being of children and adolescents, taking into account the biological nuances that impact their development. Critical reflection on the interactions between biological factors and social contexts is fundamental for the formation of effective strategies that meet the needs of this population.

DEVELOPMENT

EPIGENETICS AND ITS IMPACTS ON HUMAN HEALTH

Epigenetics is a field of study that investigates the chemical changes that regulate gene expression without modifying the DNA sequence. These modifications, which include methylations and histone modifications, play a crucial role in the regulation of genes, influencing fundamental biological processes.

Although some of these changes may occur randomly, similar to what happens in genetic mutations, many are induced by environmental factors, such as diet, exposure to pollutants, and social interactions. Therefore, it is possible to say that epigenetics acts at the intersection between the environment and genetics, reflecting the complex dynamics between internal and external factors that shape human development.

In recent years, epigenetics has been the subject of increasing interest in medicine, especially in research that seeks to reverse pathological epigenetic alterations. Many experts conceive of epigenetics as a potential revolution in the field of medicine, as highlighted by Francis (2015).

This new perspective opens up a range of possibilities for therapeutic interventions, especially in the areas of psychology and psychiatry.

The debate on epigenetics raises a deep reflection on the interrelationship between genetics and environment, especially in relation to cognitive development, personality formation and predisposition to mental disorders. Krueger South, Johnson, and Lacono (2008), as cited by Silva and Freitas (2021), indicate that advances in this field of research offer robust evidence of the epigenetic influence on human behavior.

Recently, Bibó (2025) corroborated this statement, emphasizing that epigenetics has already been sufficiently proven to be an influential factor in behavior.

However, the current focus of research is to determine the depth and intensity of the relationships between epigenetic modifications and specific behaviors or disorders. It is widely recognized that both epigenetics and the environment exert a mutual and significant influence on the physical and psychological development of individuals.

This interaction suggests a pressing need for more integrated learning between psychotherapy and neurosciences, given that genetics and the environment are not isolated fields, but rather interdependent, shaping the brain and, consequently, human behavior (Bibó et al., 2025).

EPIGENETICS AND CHILD DEVELOPMENT

When analyzing children's cognitive development, we are faced with significant complexity, since childhood is a crucial phase in the formation of the individual. During this stage, an intense and accelerated development process is observed that encompasses physical, neurological and psychic aspects. It is in this period that the basis for the human being is established.

The influences that shape this process are largely derived from the child's lived experiences, which are deeply rooted in the family, school, and social interactions. These experiences play a determining role in the way the child perceives the world and develops cognitive and emotional skills (Bibó et al., 2025).

In addition, the child's brain and microbiome are shaped by a complex interaction between genetic and environmental factors. In this context, dietary factors stand out as essential suppliers of nutrients that not only contribute to physical growth, but are also fundamental for sensory and cognitive stimuli that facilitate learning. In addition, proper nutrition is paramount for the overall health and strengthening of the child's immune system (Bibó et al., 2025).

MENTAL HEALTH AND EPIGENETICS

Children's mental health is an area of growing concern, especially in relation to epigenetic changes resulting from exposure to environmental stressors. Silva (2024) points out that these changes may be associated with adverse health conditions, particularly mental disorders.

Epigenetic modifications can interact with the individual's genetic predisposition, influencing neuroendocrine responses that compromise neuroplasticity and, consequently, mental health.

It is crucial to emphasize that children's mental health is extremely sensitive to the influences of their external environment, which includes the family context, school, and social interactions.

The emotional support received, or lack thereof, can have a significant impact on a child's emotional and behavioral development. Thus, child development should be understood as a dynamic and interactive process, dependent on a series of internal and external influences to ensure healthy and balanced growth.

According to Silva (2024), human development, especially in the areas of cognition and mental health, is closely linked to the interaction between biological and environmental factors. A welcoming environment, parental presence and strong family bonds are fundamental for the development of a child's language and behavior, promoting social skills and minimizing the risk of internal disorders, such as depression, and external disorders, such as attention deficit disorder.

Thus, epigenetics and its environmental effects contribute to a better understanding of child and adolescent development.

IMPACT OF STRESS IN CHILDHOOD

Lemos et al. (2023) report that diseases of psychiatric origin account for about 33% of all non-infectious pathologies globally. Exposure to stress during early childhood can increase vulnerability to neuropsychiatric conditions in adulthood. This is due to epigenetic alterations that modify the methylation pattern of DNA genes, which act as markers for psychiatric and behavioral regulation disorders.

The authors categorize the body's responses to stress into three types: positive, tolerable, and toxic, the latter being the most harmful to the individual. Neurobiological changes resulting from stress are often mediated by epigenetic modifications. Research

indicates that individuals who committed suicide had reduced levels of messenger RNA, and many of them reported experiences of abuse in childhood (Lemos et al., 2023).

TRAUMA AND BORDERLINE PERSONALITY DISORDER

Vargas et al. (2024) describe borderline personality disorder (BPD) as characterized by emotional lability, self-image distortions, and a persistent sense of emptiness.

The difficulty in regulating emotional responses and the fear of abandonment often lead to interpersonal conflicts and deficits in various areas of life. Childhood trauma is considered a major factor in the development of BPD, with research indicating that a high percentage of individuals affected by this disorder experienced abuse, neglect, or violence in childhood.

This picture presents a complexity that goes beyond behavior and emotions, involving epigenetic, neurological and morphological changes that manifest themselves throughout development. Thus, we can conclude that BPD is a psychiatric condition of great complexity and multiple etiologies, with clinical, neurological, and epigenetic implications (Vargas et al., 2024).

PRENATAL CARE AND EPIGENETICS

Filho, Flores, and Pedroso (2020) emphasize that new research in the field of neurosciences has provided significant advances in the understanding of epigenetics, allowing for early interventions in prenatal psychology.

This collaboration between psychological and epigenetic knowledge aims to reduce the adverse effects that can arise in early childhood, promoting healthier development.

2.7 OVERWEIGHT, OBESITY AND EPIGENETICS

Borges et al. (2022) cite the World Health Organization (WHO) in stating that obesity is one of the biggest global public health problems, with childhood obesity standing out as a growing concern.

The social perception of the impact of the intrauterine environment on offspring has generated discussions among laypeople, mothers, health professionals, and researchers about the relationship between epigenetics and the environment.

Studies indicate that changes in habits and lifestyle are crucial for the control of childhood obesity, revealing that these factors may have a more significant effect than

genetic inheritance on the predisposition to obesogenic conditions. The environment, therefore, is considered a key determinant that encourages or discourages food consumption and physical activity.

Recent advances in epigenetics have shown that histone modulation, DNA methylation, and expression of non-coding RNA influence predisposition to various diseases.

In addition, maternal overweight during pregnancy can have intergenerational consequences, increasing cardiometabolic risks and obesity in children. However, the practice of physical activity and a balanced diet can improve the pathogenesis of obesity in future generations (Borges et al., 2022).

The authors also highlight the importance of studying the infant gut microbiota and its markers, such as breastfeeding, biological sex, type of delivery, and use of prebiotics and probiotics. These factors can influence the composition of the child's gut microbiota, impacting their development and enhancing weight gain.

CONCLUSION

Epigenetics, as an emerging field of biology, has been consolidated as an essential area for understanding the mechanisms that regulate gene expression without the need for changes in the DNA sequence.

This field of study encompasses processes such as DNA methylation, histone modifications, and the performance of non-coding RNA, all of which play crucial roles in gene regulation and, consequently, in a variety of biological processes (Farsetti & Gaetano, 2023; Costa & Pacheco, 2013).

These epigenetic modifications are particularly significant during critical periods of human development, such as childhood and adolescence, when the organism is especially susceptible to environmental influences.

Recent research has shown that early experiences, including environmental stressors, nutritional quality, and social interaction dynamics, can induce epigenetic changes that impact the development of the nervous system and shape behavior patterns (Silva & Carvalho, 2023; Oliver & Mach, 2016; Casanello et al., 2016).

These findings underscore the importance of a multidisciplinary approach to understanding the intersection between biology and behavior.

However, it is imperative to recognize the limitations that permeate the field of epigenetics. Although updated evidence suggests a strong link between epigenetic modifications and behaviors, the complexity of interactions between epigenetic, genetic, and environmental factors is not yet fully understood.

Much of the available research lacks longitudinal studies that consider individual variability in epigenetic responses to different environmental contexts. This means that the results obtained in a controlled environment may not translate directly to the real world, where interactions are more complex and multifaceted (Vargas et al., 2024).

In addition, the ethical and practical implications of epigenetics-based interventions have yet to be explored in depth. For example, the manipulation of epigenetic factors in a clinical setting raises questions about informed consent, especially when it comes to vulnerable populations such as children and adolescents.

Communication of the risks and benefits associated with epigenetic interventions should be clear and accessible in order to ensure that decisions are made in an ethical and informed manner.

The next steps in epigenetics research should focus in several directions. First, further investigations into the underlying mechanisms that connect environmental stressors and epigenetic changes are needed. This involves not only studying the epigenetic modifications themselves, but also understanding how these modifications interact with the individual's genetic predisposition to influence behaviors and mental health states (Lemos et al., 2023).

In addition, the effectiveness of early interventions based on epigenetic knowledge must be rigorously tested. This includes implementing programs that improve quality of life in high-risk settings where children are exposed to significant stressors. Collaboration between biologists, psychologists, neuroscientists, and public health professionals will be essential to develop and evaluate these interventions.

Critical analysis of social policies is also a crucial aspect. As the understanding of epigenetic mechanisms advances, it is critical that the implications for health, education, and social care policymaking are considered.

A greater understanding of epigenetic influences can inform the creation of healthier and more equitable developmental environments by promoting interventions that not only address the symptoms of mental health problems, but also the underlying causes related to the environment.

In short, epigenetics not only stands out as a vital area of research for biology and medicine, but also represents a key to the formulation of more effective and inclusive social policies. The continued study of epigenetic impacts may open up new possibilities for interventions aimed at the well-being of future generations.

Emerging findings in this field have the potential to contribute significantly to public health, education, and social practices, helping to shape more just and equitable societies where the needs and realities of children and adolescents are adequately and effectively met.

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