The Impact of Early Life Stress on Neural Circuits of Anxiety and Depression in Adolescents

Boyi Liu

Wuxi United International School, Wuxi, China

Kaylasummer@163.com

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Abstract: This study explores how stress factors in early life shape adolescent mental health. Early stress experiences may lead to changes in brain structure and function, which in turn affect emotion regulation and coping mechanisms. These changes are mainly reflected in neural circuits related to emotion, such as the prefrontal cortex, hippocampus, and amygdala, in terms of their activity levels and connectivity. Through a comprehensive analysis of adolescent anxiety and depression symptoms, it was found that early life stress may promote anxiety and depression at the neurobiological level by altering neurotransmitter expression and neural plasticity. Individual differences in coping strategies and social support systems also affect mental health when adolescents face life stress. Understanding the impact of early life stress on neural circuits can help develop corresponding interventions and improve adolescent mental health.

1. Introduction

1.1. Research Background

Adolescence is a key stage for psychological and physiological development. Early life stress is particularly significant during this period. In recent years, with rapid social and economic development, young people face increasing environmental pressures. These pressures include academic burden, interpersonal problems, and changes in family structure. Early life stress can affect adolescent mental health. It can cause neurobiological changes, which then influence emotion regulation and coping abilities. Many adolescents develop anxiety and depression symptoms due to excessive psychological stress. Over time, these problems may lead to more serious mental illnesses. To understand how early life stress affects adolescent anxiety and depression through neural circuits, it is necessary to identify potential risk factors. Only then can effective interventions be provided to promote adolescent mental health. Research in this field needs to analyze both psychological and biological mechanisms. A multidimensional approach can enhance the theoretical value and practical significance of the research. This can better help adolescents cope with stress and achieve better development.

1.2. Research Significance

Studying the impact of early life stress on neural circuits of adolescent anxiety and depression has important theoretical and practical significance. Theoretically, this research can help better understand adolescent mental health problems. It can explore how early stress experiences affect emotion regulation and behavior through biological mechanisms. By interpreting relevant neural circuits, it can reveal the biological basis of psychological problems and fill gaps in the intersection of psychology and neuroscience. Practically, the results can provide a reliable basis for developing mental health interventions. They can guide educators, counselors, and social workers to identify high-risk groups and adopt targeted prevention and intervention strategies. This can promote the mental health of adolescent groups. The research can also increase family and social awareness of the importance of early psychological intervention. It can support the implementation of relevant policies and practices and help build a social environment that better supports adolescent development. Ultimately, the goal is to reduce anxiety and depression symptoms.

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2. Overview of Early Life Stress, Adolescent Anxiety and Depression, and Neural Circuits

2.1. Concept and Classification of Early Life Stress

Early life stress refers to various psychological and emotional pressures that individuals are experiencing in childhood. These pressures mainly come from a variety of factors such as family environment, social interaction or academic challenges. In order to better understand these pressures, they must be divided into three categories according to the source: family pressure, social pressure and academic pressure[1]. For those from the family, usually including parental separation, family economic difficulties, parent-child relationship tension, etc., these factors will directly affect the individual's emotional security and sense of belonging. Social pressure mainly refers to external environmental threats such as peer influence, social relationship alienation or school violence. These threats will make individuals feel lonely and helpless. For those pressure from academics, they are reflected in the increase in classroom learning requirements and fierce competition for further education. These situations will cause academic burden and conflicts of self-expectations. Only by studying teenagers who have been exposed to stress for a long time can we find that they are more prone to anxiety, depression and other negative emotions, and even have a profound impact on brain development. It is necessary to analyze the concept and classification of early life stress, so as to identify vulnerable groups and provide a theoretical basis for psychological intervention and support.

2.2. Characteristics and Manifestations of Adolescent Anxiety and Depression

Anxiety and depression are common mental health problems in adolescents. Their manifestations are diverse. Anxiety usually causes adolescents to feel constantly tense and uneasy. They may worry excessively. In learning, social interaction, or daily life, it is difficult for them to relax. They may also have physical symptoms such as palpitations, sweating, and nausea. Mood swings are common. They often have negative expectations for the future. This reduces their ability to cope with stress and affects daily functioning and interpersonal relationships. Depression is characterized by low mood, loss of interest, and lack of energy. Adolescents may lose enthusiasm for activities they previously enjoyed. They may feel helpless and have low self-worth. Behaviorally, depressed adolescents often avoid social interaction, fall behind academically, isolate themselves, and may even have thoughts of self-harm or suicide. Sometimes anxiety and depression co-occur, forming a complex psychological state that affects overall mental health. To detect adolescent anxiety and depression in time and provide effective intervention, careful observation is key. Only then can adolescents grow better.

2.3. Basic Concept of Neural Circuits and Related Brain Areas

Neural circuits are networks formed by interconnected neurons in the brain. These networks transmit and process information through electrical and chemical signals [2]. Understanding this concept requires recognizing the importance of interactions between different brain regions for psychological and physiological functions. In the study of adolescent anxiety and depression, several key brain areas are closely connected. The prefrontal cortex is responsible for higher cognitive functions. It helps with decision-making, emotion regulation, and behavior control. Dysfunction here is closely related to anxiety and depression symptoms. The amygdala plays an important role in processing emotions and fear responses. Changes in its activity can trigger anxiety responses. Brain areas like the hippocampus are closely related to memory and emotion integration. Excessive early life stress can change hippocampal structure, affecting emotion regulation and coping strategies. Analyzing the functional characteristics of these brain areas helps understand how early life stress affects the development of adolescent anxiety and depression through neural circuits. Research can provide a more precise theoretical basis for mental health interventions.

3. Neural Circuit Mechanisms of Early Life Stress Affecting Anxiety and Depression

3.1. Abnormal Activation of the Stress Response System

The stress response system is mainly composed of the hypothalamic-pituitary-adrenal (HPA) axis [3]. Its function is to regulate hormone release in the body when facing stress. For individuals who

experienced early stress, the HPA axis may be overactivated. This causes stress hormones like cortisol to remain at high levels. This process has deep effects on both the body and mind. Long-term high cortisol levels are associated with reduced emotion regulation. They can also cause structural and functional changes in neurons. These changes are especially obvious in the prefrontal cortex, which regulates emotion and decision-making, and in the amygdala, which is involved in emotional responses. Abnormal HPA activation can make adolescents show stronger anxiety and fear reactions when facing future challenges. This reduces their coping ability and worsens depressive symptoms. Understanding the mechanism of abnormal stress response system activation can provide scientific evidence for psychological support interventions for adolescents.

3.2. Dysfunction of the Reward System

The reward system mainly works through dopamine pathways. Key brain regions include the ventral tegmental area and the striatum. This system is responsible for feeling reward, motivating behavior, and regulating emotion. Adolescents who experienced early stress often show abnormalities in dopamine signaling and brain region function. This leads to a weaker response to reward stimuli. They may lose interest in things they used to like and have lower reward sensitivity. Early life stress can cause neural changes that reduce motivation to act positively under challenges or pressure. This also increases the risk of depression and anxiety. Dysfunction of the reward system can affect adolescents' social skills and sense of self-efficacy. It can also block the development of positive social connections and coping strategies. Studying the reward system is important for understanding adolescent mental health and for providing theoretical support for intervention strategies.

3.3. Neural Plasticity and Synaptic Remodeling

Neural plasticity refers to the ability of the nervous system to adapt to experiences. This includes important functions such as learning, memory, and emotion regulation. Adolescents who experienced early stress show changes in neuron structure and function [4]. This leads to synaptic remodeling. Long-term stress may reduce the formation of synapses and lower the expression of growth factors. This impairs the function of key areas like the prefrontal cortex and hippocampus. Defects in synaptic remodeling weaken emotion regulation and increase anxiety and depression tendencies. They also change the ability to respond to positive stimuli. Synaptic changes affect learning and memory, making adolescents less able to adapt to challenges during development. To provide scientific evidence for interventions, research on neural plasticity and synaptic remodeling mechanisms is necessary. This helps identify the potential impact of early life stress on adolescent mental health.

4. Pathways Linking Early Life Stress and Psychopathology

4.1. Biological Mediating Factors

4.1.1. Gene-Environment Interaction

Genetic background can make adolescents more sensitive to environmental factors. Certain genes can increase the likelihood of developing anxiety and depression when facing early stress. Specific genes related to emotion regulation and stress response, such as 5-HTTLPR and BDNF, are significantly associated with stress response. Carriers of the short allele of 5-HTTLPR show higher anxiety and depression risk after early life stress [5]. This indicates a complex interaction between genetic susceptibility and environmental influence. Early life stress can also affect gene expression regulation, causing long-term mental health problems. Studying gene-environment interactions helps explain the complexity of adolescent psychological disorders. It provides a theoretical basis for personalized interventions. Effective mental health interventions must consider individual genetic traits and environmental background. This can make interventions more precise.

4.1.2. Epigenetic Regulation

Epigenetics studies how environmental factors affect mental health by altering gene expression. Adolescents who experienced early life stress often show epigenetic modifications, such as DNA

methylation and histone modifications [6]. These changes can reduce the expression of certain genes and affect neurotransmitter systems and stress response functions. Individuals with early stress show abnormal methylation patterns in genes related to anxiety and depression. This affects emotion regulation and reduces stress adaptability. Epigenetic regulation also explains why individuals show different psychological responses to similar environmental stress. Understanding epigenetic mechanisms is important in studying adolescent psychological disorders. It helps clarify the interaction between genes and environment. Research in this field provides important biological evidence for early intervention strategies. This helps identify high-risk groups and supports precise interventions.

4.2. Psychosocial Mediating Factors

4.2.1. Changes in Cognitive Patterns

When experiencing stress, teenagers will form negative cognitive habits, such as always thinking about bad things or worrying excessively, which leads to their views on daily things to become pessimistic. When they encounter setbacks, they will think that they are not capable and ignore the influence of external factors. This kind of self-denying idea will aggravate anxiety and depression. The pressure of early experience will make individuals feel afraid and uneasy about the future. In the face of challenges, they lack of confidence and motivation. Long-term negative thinking will form a self-fulfilling prediction, making anxiety and depression more serious. Only by adjusting the cognitive mode and through cognitive behavioral therapy and other interventions can help teenagers re-establish a positive way of thinking and improve their ability to cope with difficulties. It is necessary to analyze the changes in cognitive patterns, that can better identify and intervene in the psychological problems of adolescents, which is of great significance in both practice and theory.

4.2.2. Impaired Emotion Regulation

Adolescents who experienced early stress often lack skills to identify and manage emotions effectively. They struggle to adapt and cope with life challenges. They cannot adjust themselves during high emotional states and are more likely to fall into negative moods when sad or anxious. Impaired emotion regulation is often accompanied by abnormal physiological activation, such as excessive anxiety responses and mood swings. Adolescents lacking effective emotion regulation strategies tend to avoid or suppress emotions. Negative emotion handling can worsen psychological problems, forming a vicious cycle. Social support is affected when adolescents face difficulties. Their social skills and relationship quality decline, reducing access to emotional support. Improving emotion regulation can promote mental health recovery and development.

4.3. Environmental Reinforcement Pathways

4.3.1. Family Dysfunction

In families with constant conflict or poor communication, adolescents often do not receive enough emotional support and security. This increases the risk of psychological problems. In dysfunctional families, parents may face difficulties such as emotional distress or financial problems. These issues affect parents' emotions and make them ignore children's emotional needs. Adolescents living in these families usually show severe anxiety and depression. They struggle to resist both external and internal stress. Family violence, poor parent-child relationships, overcontrol, or coldness can make adolescents feel worthless and worsen mental health problems. Dysfunctional families also affect adolescents' ability to make friends, making it hard to form healthy social relationships. To improve adolescent mental health, family function needs attention and improvement.

4.3.2. Lack of Peer Relationships and Social Support

Adolescents experiencing early life stress may show social anxiety, preference for being alone, and difficulty interacting with others. This affects their ability to maintain good relationships with peers. Adolescents without stable peer relationships lack emotional support when facing stress or challenges. Loneliness can increase anxiety and depression. In healthy social circles, peers provide

understanding and empathy to relieve emotional distress. Unstable relationships increase psychological burden. Early life stress reduces adolescents' trust in others and their willingness to seek social support. This can create a cycle of social avoidance. Lack of social support is closely related to the occurrence of anxiety and depression. Attention should be paid to how adolescents build and maintain peer relationships and cultivate a positive social support network. This can promote mental health and improve coping ability.

5. Intervention Strategies and Future Research Directions

5.1. Biomedical Interventions

5.1.1. Neural Modulation Techniques

Neural modulation techniques mainly include transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) [7]. These methods directly affect brain activity in a non-invasive way. TMS uses magnetic pulses to stimulate specific brain regions. It can regulate neural circuit function. Studies have shown that stimulating the prefrontal cortex helps improve emotion regulation and reduce anxiety and depression symptoms. tDCS applies a weak electrical current to change neuron excitability. This can enhance neural plasticity and promote recovery of emotional and cognitive functions. Neural modulation techniques are highly safe and tolerable. They can also be combined with psychological therapy to achieve better intervention effects. Future research should evaluate different techniques using biomarkers for personalized treatment. This can optimize neural modulation interventions for adolescents. It can improve treatment targeting and effectiveness and promote better mental health outcomes.

5.1.2. Drug Development

Current new drug development mainly focuses on adjusting neurotransmitter balance to improve neural circuit function. Traditional antidepressants, such as selective serotonin reuptake inhibitors (SSRIs), are widely used to treat adolescent mood disorders [8]. However, many adolescents using SSRIs experience delayed effects or side effects. Researchers are developing new drugs targeting dopamine, norepinephrine, and other neurotransmitter pathways. These drugs can relieve symptoms more effectively and improve tolerance. Research on personalized drug therapy based on biomarkers is gradually advancing. Interventions must consider individual genetic and biological characteristics to develop precise treatment plans. Effective new drugs can meet adolescent treatment needs and improve their quality of life. Future research should focus on combining multiple mechanisms to create effective treatment strategies.

5.2. Psychosocial Interventions

5.2.1. Cognitive Behavioral Therapy (CBT)

The core idea of CBT is to improve emotions and behavior by identifying and changing negative thinking patterns. For adolescents who experienced early life stress, CBT helps them recognize unreasonable thinking, such as excessive worry and self-devaluation [9]. It provides effective alternative cognitive strategies. Therapy emphasizes practical skill training, including emotion regulation, problem-solving, and stress coping skills. This helps adolescents face challenges with more confidence and flexibility. CBT also includes exposure therapy. Adolescents gradually confront situations that trigger anxiety. This helps them overcome fear and improve adaptability. Adolescents who receive CBT intervention generally show significant improvements in anxiety and depression symptoms. Integrating CBT into adolescent mental health interventions can improve life quality and psychological resilience.

5.2.2. Mindfulness Training and Exercise Interventions

Mindfulness training helps adolescents improve self-awareness by focusing on present experiences. It can reduce negative emotions and develop acceptance of emotional stress. Mindfulness meditation can lower anxiety, improve emotion regulation, and enhance psychological resilience. Exercise also

plays an important role in improving mental state. Scientific exercise releases endorphins and other neurotransmitters, enhancing mood and reducing anxiety and depression symptoms. Exercise can improve physical fitness, provide social support, and increase self-confidence and sense of belonging. Combining mindfulness training and exercise interventions can enhance both emotional management skills and physical fitness. This strengthens adolescents' ability to cope with psychological difficulties. Current research should analyze the combined effects of mindfulness and exercise interventions. This can inform comprehensive mental health promotion strategies and provide innovative solutions for adolescent mental health problems.

5.3. Policy and Educational Recommendations

5.3.1. School Mental Health Screening

Through regular mental health screening, schools can timely discover students' problems in emotional regulation, social ability and learning performance, and take intervention measures quickly. In the process, a variety of methods such as questionnaires, interviews and observations should be used to assess the current psychological state of adolescents and their ability to cope with stress. Only by combining screening results with individualized intervention strategies can we provide professional psychological counseling and support for students in need. For those who pay attention to students' mental health. Schools must establish a linkage mechanism, and also encourage teachers to cooperate with mental health professionals to pay attention to students' mental health. By carrying out mental health education and workshops, students' emotional management and social adaptability can be enhanced [10]. Only by achieving a healthy supportive campus environment can we promote the mental health development of adolescents, enhance their ability to cope with future challenges, and reduce the negative impact of early life pressure. Through continuous mental health screening, the school should provide timely help for students, so as to improve the attention and attention and attention of whole school teachers and students to mental health issues.

5.3.2. Family Support Programs

To strengthen family cohesion and function, education, training, and resources should be provided. This helps family members understand and respond to adolescents' mental health issues. Specific measures include regular training in family communication skills. This enhances emotional interaction and trust between parents and children. Family support programs should also include mental health knowledge dissemination. This helps parents recognize emotional problems and apply coping strategies in daily life. Organizing family activities, such as shared reading or outdoor exercises, improves interaction and connection among family members. A positive and healthy family atmosphere provides adolescents with emotional support and security, reducing anxiety and depression risk. Family support programs promote the growth and development of both families and adolescents.

6. Conclusion

The impact of early life stress on anxiety and depression in adolescents is a complex and multifaceted issue, which involves multiple levels such as biology, psychology and social environment. Early stress will lead to changes in neural circuits, which in turn affects emotional regulation ability and cognitive patterns, thus increasing the risk of anxiety and depressive symptoms in adolescents. To understand these mechanisms, targeted interventions must be formulated. Intervention strategies include biomedical intervention, psychosocial intervention, policy support and educational advocacy, etc., which can effectively alleviate the negative impact of early stress. For teenagers who are experiencing these problems, schools and families should play a positive role in providing necessary emotional support and resources through mental health screening and family support programs. Future research needs to explore the impact of early life stress in different cultural contexts, and strengthen attention to specific groups of people, so as to promote the formulation of personalized intervention strategies.

References

[1] Kemp K, Reddy R, Johnston B, et al. Early Life Stress, Parental Emotion Socialization, and Cardiovascular Health in Young Adulthood [J]. Physiology, 2025, 40(Sup1). DOI:10.1152/physiol.2025.40.S1.2053.

[2] Li Na, Zhang Hongbin. An Exploration of Neural Network Technology [J]. Youth Science: Teacher Edition, 2013, 34(6).

[3] Gunnar M R, Sebanc A M, Tout K, et al. Peer rejection, temperament, and cortisol activity in preschoolers [J]. Developmental Psychobiology, 2003. DOI:10.1002/dev.10144.

[4] Garlick, Dennis. Understanding the nature of the general factor of intelligence: the role of individual differences in neural plasticity as an explanatory mechanism [J]. Psychological Review, 2002, 109(1):116–136. DOI:10.1037//0033-295X.109.1.116.

[5] Kaufman J, Yang B Z, Douglas-Palumberi H, et al. Brain-derived neurotrophic factor–5-HTTLPR gene interactions and environmental modifiers of depression in children [J]. Biological Psychiatry, 2006, 59(8):673–680. DOI:10.1016/j.biopsych.2005.10.026.

[6] Zhang Mengke. An Introduction to Epigenetics [J]. Biology Teaching, 2013.

[7] Cui Huiru, Li Wei, Wang Jijun, et al. Current Status of Repetitive Transcranial Magnetic Stimulation and Transcranial Direct Current Stimulation in the Treatment of Anxiety Spectrum Disorders [J]. International Journal of Psychiatry, 2018, 45(6):4. DOI:CNKI:SUN:GWYJ.0.2018-06-008.

[8] Wang Chenyang. Research Progress on the Use of Selective Serotonin Reuptake Inhibitors in Child and Adolescent Mood Disorders [J]. Chinese Journal of Psychiatry, 2006, 39(1):3. DOI:10.3760/j:issn:1006-7884.2006.01.019.

[9] Cohen, Judith A; Mannarino, Anthony P; Deblinger, Esther. Treating Trauma and Traumatic Grief in Children and Adolescents: Cognitive-Behavioral Therapy [M]. East China Normal University Press, 2009.

[10] Xian Huiying. Optimizing Cognition to Improve Junior Middle School Students' Emotion Regulation Ability [J]. Mental Health Education in Primary and Secondary Schools, 2010(14):2. DOI:10.3969/j.issn.1671-2684.2010.14.013.