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Обзор литературы / Review article

Unraveling the intricacies of the gut-brain axis: from physiology to psychology and obesity

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Abstract

The human body, a marvel of complexity, operates through a network of interconnected systems that extend beyond the conventional confines of organs and tissues. Among the most intriguing and dynamic of these networks is the gut-brain axis (GBA), it was considered only for digestion, but in recent years GBA has evolved dramatically, uncovering its profound implications for both physical and mental well-being. Background: As scientific research continues to delve into the intricacies of this bidirectional pathway, a deeper understanding emerges of how the GBA impacts not only digestion and metabolism but also mental health and obesity. **Material and methods.** This article conducts a systematic review of current scientific literature to explore the intricate mechanisms and profound implications of the GBA on mental health and obesity**. Results.** Components of the GBA, including the enteric nervous system, vagus nerve, neurotransmitters, gut hormones, and gut microbiota, collectively orchestrate digestion, metabolism, mood, cognition, and behavior. Recent research elucidates the role of the GBA in neurotransmitter production, microbiota composition, immune function, stress response, and vagus nerve communication, highlighting its significance in mental well-being. Moreover, disruptions in the GBA contribute to alterations in appetite regulation, metabolism, and gut microbiota composition, linking it to the development and exacerbation of obesity. **Conclusions.** Understanding the intricate connections within the GBA provides a foundation for developing targeted interventions to promote holistic health and well-being. By recognizing the multifaceted nature of the GBA, individuals and healthcare professionals can explore innovative approaches to address mental health disorders, life style modification and obesity effectively.

Key words: gut-brain axis, obesity, gut-brain cross talk.

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Ось «кишечник – мозг»: от физиологии к психологии и ожирению

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Резюме

Организм человека работает через сеть взаимосвязанных систем, которые выходят за пределы обычных границ органов и тканей. Ось «кишечник–мозг» (ОКМ) – термин, используемый для описания взаимодействия между мозгом и микробиотой кишечника. Раньше этот термин рассматривали только при описании вопросов пищеварения, но в последние годы он претерпел значительную эволюцию и используется для описания последствий физического и психического состояния организма. Возникает более глубокое понимание того, как ОКМ влияет не только на пищеварение и метаболизм, но и на психическое здоровье и ожирение. **Материал и методы.** В данной статье приводится обзор современной научной литературы с целью изучения сложных механизмов и глубоких последствий влияния ОКМ на психическое здоровье и ожирение. **Результаты.** Компоненты ОКМ, включая энтеральную нервную систему, блуждающий нерв, нейротрансмиттеры, гормоны кишечника и микробиоту кишечника, в совокупности управляют пищеварением, метаболизмом, настроением и поведением. Последние исследования проясняют роль ОКМ в выработке нейротрансмиттеров, составе микробиоты, иммунитете, реакции на стресс и передаче по блуждающему нерву, подчеркивая его значение для психического состояния. Более того, нарушения в работе ОКМ способствуют изменениям в регуляции аппетита, метаболизма и состава микробиоты кишечника, связывая их с развитием и усугублением ожирения. **Заключение.** Понимание сложных связей внутри ОКМ создает основу для разработки целенаправленных мероприятий, способствующих целостному здоровью организма. Признавая многогранный характер ОКМ, можно искать инновационные подходы для эффективного решения проблем психических расстройств, модификации образа жизни и ожирения.

Ключевые слова: ось «кишечник – мозг», ожирение.

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Introduction

Understanding the GBA

The GBA encompasses a myriad of components, each contributing to the intricate dialogue between the gut and the brain. The vagus nerve, a major player in this communication system, facilitates the transmission of signals between the gut and the brain, influencing various physiological functions such as digestion, nutrient absorption, and immune responses [1]. Neurotransmitters, including serotonin and dopamine, act as messengers, relaying information between neurons in the enteric nervous system and the central nervous system [2]. Gut hormones such as ghrelin and leptin play a crucial role in regulating appetite and energy balance by signaling hunger and satiety [3]. The gut microbiota, a diverse community of microorganisms residing in the gastrointestinal tract, adds another layer of complexity, influencing both the gut and the brain through the production of bioactive compounds and metabolites [4].

Physiological foundations of the GBA

The physiological impact of the GBA extends beyond basic digestive functions. The gastrointestinal tract, often referred to as the "second brain," houses an extensive network of neurons and glial cells that operate independently of the CNS but remain in constant communication with it. The ENS, comprising over 100 million neurons, orchestrates various digestive functions, including peristalsis, secretion, and nutrient absorption, in a coordinated manner. Ghrelin, often referred to as the "hunger hormone," stimulates appetite, promoting food intake and influencing energy expenditure [5]. Leptin, on the other hand, signals satiety and plays a crucial role in regulating body weight and fat storage [6]. The gut microbiota contributes to energy homeostasis by fermenting indigestible fibers and producing short-chain fatty acids (SCFAs), which can modulate metabolism and influence adipose tissue function [7].

Recent studies have shed light on the role of gut hormones and their impact on metabolism. For example, glucagon-like peptide-1 (GLP-1) and peptide YY (PYY), released from the gut in response to food intake, contribute to feelings of fullness and satiety [8]. Additionally, the gut microbiota has been implicated in the regulation of glucose metabolism and insulin sensitivity, with alterations in its composition linked to insulin resistance and obesity [9].

Key Components of the GBA

The enteric nervous system (ENS), also termed the "second brain," comprises a network of neurons within the gastrointestinal tract, autonomously controlling gut functions and communicating with the central nervous system through the *vagus nerve*. Acting as the primary conduit for gut-brain communication, the vagus nerve transmits sensory information from the gut to the brain and modulates motor signals from the brain to the gut, regulating various physiological

processes including digestion and appetite. Serotonin, dopamine, gamma-aminobutyric acid, and glutamate are among the *neurotransmitters* and neuropeptides that mediate gut-brain communication, influencing mood, appetite, and gastrointestinal motility. *The gut microbiota*, a diverse ecosystem of microorganisms residing in the gut, produce metabolites such as short-chain fatty acids and neurotransmitters that modulate neural activity and immune function. *Immune system*: the gut-associated lymphoid tissue and immune cells within the gut play a crucial role in maintaining immune homeostasis and responding to microbial challenges, thereby influencing neural function and overall health.

Impact on Psychology

The intricate web of the GBA extends its profound influence into the realm of psychology, affecting mood, cognition, and behavior. This bidirectional communication pathway between the gastrointestinal tract and the central nervous system allows for intricate interactions that influence mental well-being. Here are some ways in which the GBA impacts psychological factors.

Neurotransmitter production

The gut is often referred to as the "second brain" due to its significant production of neurotransmitters, including serotonin, dopamine, and gamma-aminobutyric acid. Serotonin, a neurotransmitter primarily associated with mood regulation, is produced in significant quantities in the gut. Alterations in gut microbiota composition can influence serotonin levels, potentially contributing to mood disorders such as depression and anxiety. Serotonin plays a crucial role in regulating mood, anxiety, and depression. Approximately 90% of serotonin in the body is produced in the gut [10]. Dysregulation of serotonin levels in the gut has been linked to mood disorders, including depression and anxiety. Moreover, the gut-brain connection allows stress and emotions to impact gut function, leading to symptoms such as abdominal discomfort and changes in bowel habits [11].

Microbiota composition

The gut microbiota, comprising trillions of microorganisms, has a symbiotic relationship with the host and influences various aspects of brain function and behavior. The emerging field of psychobiotics explores the potential of certain probiotics to positively impact mental health by modulating the gut microbiota. These beneficial microorganisms may produce compounds that interact with the GBA, influencing neurotransmitter production and neuroinflammation, with potential implications for mental well-being [12]. The composition and diversity of the gut microbiota can impact neurotransmitter production, neuroinflammation, and neural signaling pathways [2]. Alterations in the gut microbiota, known as dysbiosis, have been associated with mood disorders and cognitive impairments.

Immune function

The gut microbiota plays a crucial role in regulating immune function and inflammation. Dysregulated immune responses and chronic inflammation have been implicated in the pathogenesis of psychiatric disorders, including depression and schizophrenia. Communication between the gut microbiota and the immune system can modulate neuroinflammation and neuroimmune responses, influencing psychological well-being [13].

Stress response

The GBA is intricately involved in the stress response system, including the hypothalamic-pituitary-adrenal axis. Chronic stress can disrupt the balance of the GBA, leading to alterations in gut microbiota composition, increased intestinal permeability, and dysregulation of neurotransmitter systems [14]. These changes may contribute to the development or exacerbation of mood disorders and anxiety.

Vagus nerve communication

The vagus nerve, a major component of the GBA, serves as a crucial conduit for communication between the gut and the brain. Vagal signaling influences emotional regulation, memory, and social behavior. Stimulation of the vagus nerve has been explored as a potential therapeutic intervention for mood disorders and anxiety [15]. The GBA represents a complex and dynamic system that influences psychological factors through multiple pathways. Understanding the intricate interplay between the gut, the brain, and the microbiota is essential for elucidating the mechanisms underlying psychiatric disorders and developing novel therapeutic strategies. By recognizing the impact of the GBA on psychological factors, researchers and clinicians can explore innovative approaches to promote mental health and well-being.

Link to Obesity

Obesity is an important aspect to consider in the context of the GBA. The link between the GBA and obesity is multifaceted and characterized by excessive accumulation of body fat, involving disruptions in appetite regulation, altered metabolism, and changes in the gut microbiota. Dysregulation of ghrelin and leptin signaling can lead to increased appetite and reduced satiety, contributing to overeating and weight gain [16]. Gut dysbiosis, characterized by an imbalance in microbial communities, has been associated with obesity, inflammation, and metabolic dysfunction [17]. The microbiome's role in appetite

and influencing adipose tissue function further contributes to the obesity puzzle [8] and also links the production of satiety hormones and neurotransmitters. Dysregulation of gut-brain communication may lead to impaired appetite regulation, predisposing individuals to overeating and weight gain [18].

Psychological factors, such as chronic stress, emotional eating, and the impact of mood disorders, also play a significant role in the development and exacerbation of obesity. Stress-induced changes in the hypothalamic-pituitary-adrenal axis can lead to increased cortisol levels, promoting abdominal fat deposition and influencing food preference [19]. Addressing obesity requires a comprehensive approach that targets both physiological and psychological factors. Strategies aimed at restoring gut microbiota balance, promoting healthy dietary habits, and addressing underlying emotional and behavioral patterns are essential for the prevention and management of obesity [20].

Moreover, obesity is often accompanied by comorbidities such as insulin resistance, type 2 diabetes, and cardiovascular disease, further underscoring the complex interplay between gut health, metabolism, and psychological well-being.

Recommendations for supporting gut-brain health

Through a comprehensive exploration of the GBA, we can gain valuable insights into the intricate connections between physiology, psychology, and obesity, ultimately paving the way for more effective interventions and treatments in these areas. By implementing lifestyle modifications that support gut-brain health, individuals can optimize their vitality and resilience across the lifespan.

Dietary modifications: consumption of a balanced diet rich in fiber, prebiotics, and probiotics can promote a healthy gut microbiota and support gut-brain communication [21]. *Stress management*: chronic stress can disrupt the balance of the GBA, leading to gastrointestinal symptoms and mental health disorders; practicing stress-reduction techniques such as meditation and yoga can mitigate these effects [22]. *Regular exercise*: physical activity positively influences gut microbiota composition and promotes neuroplasticity in the brain, engaging in regular exercise enhances mood, cognition, and gut motility [23]. *Sleep hygiene*: adequate sleep is essential for maintaining the integrity of the GBA, implementing good sleep hygiene practices can optimize sleep quality and support gut health [24]. *Mindful eating*: practicing mindful eating involves paying attention to hunger cues and savoring food, which can regulate appetite, improve digestion, and enhance the mind-body connection [25].

Conclusions

The GBA emerges as a central player in the intricate dance of physiology, psychology, and obesity. Understanding the multifaceted connections within this axis provides a foundation for developing targeted interventions in the realms of mental health and weight management. obesity represents a significant public health challenge with multifaceted origins rooted in the intricate interplay between the GBA, metabolism, and psychological factors. By understanding the complex mechanisms underlying obesity, we can develop targeted interventions that promote holistic health and well-being. As research continues to unravel the complexities of the GBA, the potential for personalized approaches to address obesity and mental health disorders becomes increasingly promising.

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