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Impact of Monosodium Glutamate and Aspartame on Adolescent Health

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Abstract

Adolescents with type 2 diabetes mellitus face unique health challenges exacerbated by the widespread consumption of monosodium glutamate (MSG) and aspartame. This review investigated the potential risks and benefits of these additives to inform dietary guidelines and interventions. This paper undertook a comprehensive investigation into the impact of monosodium glutamate consumption and aspartame use on cognitive function, behavior, and weight management outcomes among adolescents diagnosed with type 2 diabetes. By synthesizing a wide range of literature and conducting a critical analysis of seminal studies, The objective of this article is to offer insights into the potential advantages and drawbacks linked to the ingestion of these food additives within this demographic. This article explored the complex interplay between dietary choices, metabolic health, and overall well-being in adolescents grappling with type 2 diabetes mellitus (T2DM), thereby contributing to a deeper understanding of dietary interventions in this vulnerable population. Sedentary lifestyles, unhealthy diets, and genetic predispositions contribute to this trend. Sedentary behavior, fueled by technology and digital devices, reduces physical activity levels.

Keywords: *Monosodium glutamate (MSG), Aspartame, Type 2 diabetes mellitus (T2DM), Cognitive function, Metabolic disorders, Neurobiological effects, Weight management.*

1. Introduction

Unhealthy dietary habits, characterized by processed foods and sugary beverages, increase obesity risk. Genetic factors also play a role, amplifying susceptibility to the disease(Wilk et al., 2022). This paper undertook an analysis of the prevalence and implications of type 2 diabetes mellitus in adolescents, with a focus on dietary factors, including monosodium glutamate and aspartame. Type 2 diabetes mellitus has become increasingly prevalent among adolescents, posing significant challenges to their health and well-being. This rise in adolescent type 2 diabetes mellitus is closely linked to the obesity epidemic and dietary habits characterized by excessive consumption of processed foods high in sugars and unhealthy fats. The impact of dietary factors on the health outcomes of adolescents with type 2 diabetes mellitus cannot be overstated, as diet plays a central role in the management and progression of the disease(Valaiyapathi et al., 2020).

Type 2 diabetes mellitus (T2DM) is a metabolic disorder characterized by insulin resistance and relative insulin deficiency. It differs from type 1 diabetes mellitus (T1DM) in that T2DM typically develops later in life and is often associated with lifestyle factors such as obesity, physical inactivity, and poor dietary habits(Valaiyapathi et al., 2020). In T2DM, the body becomes resistant to the effects of insulin or does not produce enough insulin to maintain normal blood glucose levels, leading to hyperglycemia and various metabolic disturbances.

From an observational study, the prevalence of type 2 diabetes mellitus in this demographic group has been steadily increasing, mirroring the rise in childhood obesity rates(Valaiyapathi et al., 2020). The need to explore these dietary patterns is especially critical, as understanding the pathophysiology of type 2 diabetes mellitus in adolescents can inform more effective intervention strategies. A better understanding of the pathophysiology of type 2 diabetes

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mellitus in adolescents is crucial for effective management and intervention strategies, such as encouraging regular physical activity, adopting a balanced diet with reduced sugar and saturated fats, and promoting healthy weight management through behavior change programs(Valaiyapathi et al., 2020). This study explores the impact of MSG and aspartame on adolescents with T2DM, a critical area of research given the rising prevalence of both obesity and diabetes in this population.

In light of this context, this research aims to investigate the impact of regular consumption of foods containing monosodium glutamate and the use of aspartame as a sugar substitute on cognitive function, behavior, and weight management outcomes in adolescents with type 2 diabetes mellitus. Both monosodium glutamate and aspartame are commonly used food additives with potential implications for health, particularly in vulnerable populations such as adolescents with type 2 diabetes mellitus.

Monosodium glutamate is known for its ability to enhance the taste of food but has also been associated with adverse health effects, including headaches, nausea, and potential cognitive impacts(Kouzuki et al., 2019). Similarly, aspartame, a widely used artificial sweetener found in various diet products, has garnered attention for its role in sugar-free alternatives and its potential effects on health, which was proved by the experiment (Collison et al., 2012). Despite being approved by regulatory agencies, concerns persist regarding its safety and potential effects on health, including cognitive function and weight management outcomes. Monosodium glutamate belongs to the class of amino acids. It is derived from glutamic acid, an amino acid naturally found in various foods such as meat, fish, and vegetables. Monosodium glutamate acts as a neurotransmitter in the body and is primarily known for enhancing the umami taste of food. Monosodium glutamate receptors are found in taste buds on the tongue, specifically on the umami taste receptors. Through the experiment, when monosodium glutamate binds to these receptors, it enhances food's savory or meaty flavor, making it more palatable(Zanfirescu et al., 2019). Aspartame, on the other hand, has chemical subunits of phenylalanine, aspartic acid, and methanol. It is commonly used in sugar-free and diet products as a low-calorie alternative to sugar. The receptors for aspartame are not well defined, but they are known to interact with taste receptors on the tongue that detect sweetness. This interaction leads to a perception of sweetness without the added calories of sugar. Both monosodium glutamate and aspartame are not naturally occurring chemicals in the body. While glutamic acid (the precursor of MSG) is naturally present in foods, the concentrated form of monosodium glutamate used as a food additive is not naturally produced by the body. Similarly, phenylalanine and aspartic acid (components of aspartame) are amino acids found in protein-containing foods, but the concentrated form of aspartame is not naturally produced in the body.

This review aims to comprehensively evaluate the physiological, biochemical, and psychological impacts of monosodium glutamate (MSG) and aspartame, particularly in adolescents with type 2 diabetes mellitus (T2DM). By synthesizing existing research, this study seeks to identify the potential risks and benefits of these additives, providing insights into their role in cognitive function, behavior, and weight management. Investigating these impacts is essential, given the pervasive use of MSG and aspartame in processed foods and the increasing prevalence of T2DM among adolescents. A deeper understanding of these relationships can inform public health strategies, dietary guidelines, and future research efforts to address this pressing issue.

2. Methodology

To ensure a comprehensive and systematic review of existing literature on the effects of monosodium glutamate and aspartame on adolescents with type 2 diabetes mellitus, I used the following research methodology:

2.1 Search Engines and Databases

I conducted an extensive literature search using Google Scholar as our primary database. Additional verification of sources was performed using PubMed and Scopus to ensure credibility and relevance.

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2.2 Search Keywords and Filters

The literature search was performed using specific keywords to identify relevant studies. The primary search terms included: "monosodium glutamate health effects," "aspartame and cognitive function," "MSG and metabolic disorders," "artificial sweeteners and diabetes," and "T2DM and neurobiological impact." Filters were applied to select peer-reviewed articles published in English, focusing on studies from the past 15 years to ensure contemporary relevance.

2.3 Inclusion and Exclusion Criteria Studies were selected based on the following criteria:

Inclusion Criteria: Research articles, systematic reviews, and meta-analyses examined the physiological, biochemical, and neurobiological impacts of MSG and aspartame on adolescents, particularly those diagnosed with T2DM. Studies involving human and relevant animal models were included.

Exclusion Criteria: Studies that primarily focused on adult populations, lacked empirical data, or were not peer-reviewed were excluded. Additionally, articles that solely discussed MSG or aspartame without reference to metabolic or cognitive effects were omitted.

2.4 Study Categorization

To organize the findings, selected studies were categorized into three primary areas of impact:

1. Physiological Effects: Research examining MSG and aspartame's role in metabolic disorders, insulin resistance, and weight regulation.
2. Biochemical Effects: Studies analyzing the biochemical pathways influenced by these compounds, including alterations in glucose metabolism and neurotransmitter activity.
3. Neurobiological Effects: Literature exploring cognitive and behavioral changes, including effects on memory, spatial cognition, and anxiety.

By employing this structured methodology, I ensured a rigorous and objective approach to evaluating the effects of MSG and aspartame on adolescents with T2DM, providing a well-founded basis for our analysis and discussion.

3. Literature Review

The impact of monosodium glutamate and aspartame on health outcomes has garnered significant attention in recent years, particularly in relation to their potential effects on cognitive function, behavior, and weight management, especially in adolescents with type 2 diabetes mellitus(Collison et al., 2012). Monosodium glutamate, commonly used as a flavor enhancer, and aspartame, an artificial sweetener, are ubiquitous in processed foods and beverages, making their consumption prevalent among adolescents(Wilk et al., 2022). Understanding the physiological, biochemical, and psychological impacts of these additives is crucial for evaluating their safety and efficacy in managing type 2 diabetes mellitus and promoting overall health.

3.1 Physiological Effects

Type 2 Diabetes Mellitus is a serious condition that affects people's health and quality of life, often leading to cognitive problems like difficulty thinking and remembering. Type 2 Diabetes Mellitus has physiological effects itself. Studies using brain imaging have found that people with T2DM and cognitive issues (T2DM-CI) show unusual brain activity and structural changes (Dai et al., 2024). Research combining data from 19 studies found that these patients had higher activity in the left anterior cingulate cortex (ACC.L) and lower activity in the left lingual gyrus (Dai et al., 2024). Additionally, the amount of gray matter (GM), which is important for brain function, was lower in the right superior temporal gyrus (STG.R) and the left inferior occipital gyrus(Dai et al., 2024). These changes were linked to problems like vision issues and longer durations of diabetes.

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Physiologically, monosodium glutamate and aspartame have been implicated in various health concerns. For instance, studies have suggested that monosodium glutamate consumption may lead to headaches, particularly in susceptible individuals(Zanfirescu et al., 2019). This phenomenon, known as "Chinese Restaurant Syndrome," has raised concerns about the potential neurophysiological effects of monosodium glutamate. Similarly, aspartame has been linked to adverse reactions such as migraines, irritable moods, and anxiety in some individuals. Alterations in neurotransmitter levels, including serotonin and dopamine, can result in mood disorders such as depression and anxiety, along with changes in motivation and pleasure responses (Czarnecka et al., 2021).

Additionally, aspartame has been linked to an increased risk of cardiovascular diseases, hormone-related cancers, and early menarche in young girls and the link between type 2 diabetes mellitus and aspartame is unclear. However, genotoxicity studies have yielded mixed results, with some indicating potential risks of formaldehyde production and genotoxic activity, especially when combined with other substances like acesulfame-K, which can be found in most sweet products (Wilk et al., 2022). These physiological responsess underscore the need for comprehensive investigations into the mechanisms through which monosodium glutamate and aspartame influence health outcomes, especially in vulnerable populations like adolescents with type 2 diabetes mellitus (Czarnecka et al., 2021).

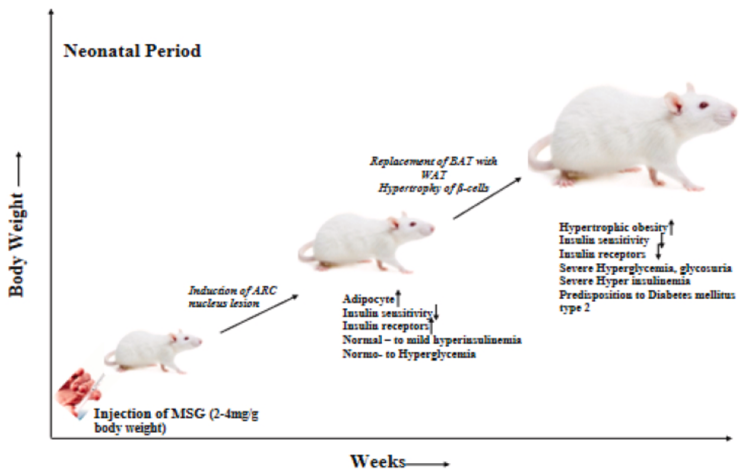

Figure 1. Pathway of MSG in Diabetes mellitus (Kayode et al., 2023)

Studies suggest that even at low doses, monosodium glutamate consumption may have toxic effects, particularly affecting metabolic processes and energy balance, both of which contribute to obesity (Niaz et al., 2018). Animal studies have shown that neonatal exposure to monosodium glutamate can predispose to obesity later in life, possibly through mechanisms involving disrupted energy balance, increased food palatability, and alterations in hormonal signaling like leptin (Niaz et al., 2018). Moreover, MSG-induced obesity has been associated with inflammatory responses, altered glucose tolerance, and hepatic damage, indicating a complex interplay of physiological changes that can contribute to weight gain. Additionally, while the term "Chinese restaurant syndrome" refers to immediate symptoms like burning sensations, weakness, and palpitations, the long-term effects of monosodium glutamate consumption on weight regulation, adipose tissue physiology, and metabolic health are also of concern.

However, further research is needed to fully understand the extent of monosodium glutamate's impact on weight and related health outcomes in human models(Niaz et al., 2018). Multiple investigations, involving both humans and animals, have linked the utilization of monosodium glutamate as a taste enhancer to the development of obesity and metabolic syndrome, and these documented impacts are commonly ascribed to monosodium glutamate's direct interactions within the brain, influencing food consumption, body mass, and lipid processing(María Catalina et al., 2018). The surge in global obesity rates has prompted a closer examination of dietary factors, notably the impact of artificial sweeteners like aspartame on weight management. Despite being marketed as a healthier substitute for sugar, the effects of aspartame on energy intake, appetite control, and weight gain remain complex and inconclusive. Studies suggest that replacing sugar with artificial sweeteners may not lead to reduced overall energy intake and could potentially result in increased consumption over time. Moreover, both sugar-sweetened and artificially sweetened beverages have been associated with heightened subjective hunger, potentially contributing to higher calorie intake and subsequent weight gain.(Czarnecka et al., 2021) The result is mentioned in Table 1. However, one nevertheless cannot attribute the rise in obesity solely to aspartame or other artificial sweeteners due to the multifaceted nature of dietary behaviors, and lifestyle factors influencing weight.

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3.2 Biochemical Effects

In addition to physiological effects, monosodium glutamate and aspartame may exert biochemical influences that warrant exploration. Both substances have been associated with oxidative stress, characterized by an imbalance between reactive oxygen species (ROS) production and antioxidant defenses. Oxidative stress plays a pivotal role in the pathogenesis of various metabolic disorders, including type 2 diabetes mellitus. Furthermore, inflammation, another hallmark of metabolic dysfunction, has been linked to the consumption of artificial sweeteners like aspartame. Aspartame metabolism releases methanol, aspartic acid, and phenylalanine, which are absorbed in the gastrointestinal tract. Methanol is then oxidized in the liver, leading to the production of formaldehyde and formic acid, which can damage liver cells. These metabolic processes also generate superoxide anions and hydrogen peroxide, causing protein denaturation and enzymatic changes.

Additionally, aspartame metabolites like phenylalanine can be toxic to the brain and may contribute to physiological changes, especially in individuals with phenylketonuria who cannot metabolize phenylalanine effectively(Czarnecka et al., 2021). Therefore, aspartame consumption should be carefully monitored, particularly for those with phenylketonuria, as indicated by FDA labeling requirements.

3.3 Psychological Effects

Psychological factors also play a significant role in the impact of MSG and aspartame on health outcomes. Research suggests that these additives may influence mood, behavior, and cognitive function, albeit the mechanisms are not fully understood. For example, studies have reported associations between aspartame consumption and alterations in neurotransmitter levels, including dopamine, norepinephrine, and serotonin(Niaz et al., 2018). These neurotransmitters play essential roles in regulating neurophysiological activity, and disruptions in their synthesis or release may contribute to behavioral and cognitive changes observed with MSG and aspartame intake. Further research is needed to elucidate the neurobiological responses to these additives and their implications for adolescents with T2DM.

The link between monosodium glutamate and aspartame consumption and type 2 diabetes mellitus and weight management outcomes is a topic of significant interest and debate. While some studies have suggested potential associations between artificial sweeteners and metabolic dysregulation, including insulin resistance and weight gain, the evidence remains inconclusive(Wilk et al., 2022). In adolescents with type 2 diabetes mellitus, the impact of monosodium glutamate and aspartame on glucose metabolism, insulin sensitivity, and body weight requires careful examination(Valaiyapathi et al., 2020). Longitudinal studies assessing dietary patterns, glycemic control, and body composition in adolescents consuming foods containing these additives are essential for elucidating their role in T2DM management and weight-related outcomes.

3.4 Behavioral Effect

Changes in eating behavior, food preferences, and overall dietary patterns associated with regular consumption of foods containing monosodium glutamate and aspartame can influence glycemic control and metabolic health outcomes(Valaiyapathi et al., 2020). The impact of aspartame on autism remains a subject of research and discussion. While there is a correlation between the rise in autism rates and increased consumption of aspartame, particularly in carbonated beverages like diet soda, the exact causal relationship is not definitively established. Aspartame's metabolism in the body leads to the production of methanol, which is known to be neurologically toxic. However, debates persist about whether aspartame itself directly triggers autism or if other factors, such as oxidative stress from methanol, play a more significant role. Studies have noted higher dietary methanol intake among mothers of children with autism, indicating a potential association.

A study examines how aspartame impacts anxiety-like behavior, neurotransmitter activity, and gene expression in the amygdala, a brain region crucial for managing anxiety and fear. C57BL/6 mice were given water containing either 0.015% or 0.03% aspartame—amounts equal to 8–15% of the FDA's recommended maximum daily human intake—or plain water (Jones et al., 2022). Both male and female mice that consumed aspartame exhibited pronounced

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anxiety-like behaviors, as measured through the open field test and the elevated zero maze. Therefore, aspartame consumption can lead to increased anxiety-like behavior in mice, likely due to its effects on brain activity and gene expression in the amygdala.

Nevertheless, conclusive evidence linking aspartame to autism is lacking, and further research is needed to determine the exact effects and potential risks associated with its consumption, especially in vulnerable populations like children and pregnant women. Studies indicate that aspartame and its metabolites pose risks for neurodegenerative diseases like Alzheimer's and Parkinsonism. Methanol, a metabolite, generates free radicals causing cell damage, while aspartame activates harmful calcium channels in neurons. Long-term use leads to nerve degeneration and memory issues, affecting learning skills and behavior. Additionally, aspartame disrupts neurotransmitter levels, hormone function, and cellular activities, potentially contributing to mood disorders and cognitive impairments in teenagers.(Czarnecka et al., 2021) Aspartame can impact adolescents' hormonal balance and mood disorders in various ways. Its influence on insulin and glucose regulation may lead to fluctuations in blood sugar levels, contributing to mood swings and fatigue. Aspartame's effects on hormones like leptin and ghrelin may disrupt appetite regulation and contribute to weight management issues and related mood disturbances. Furthermore, its impact on cortisol, adrenaline, and neurotransmitter balance can lead to chronic stress, potentially exacerbating mood disorders and behavioral changes in adolescents. These findings underscore the importance of considering the potential health effects of aspartame, particularly in vulnerable populations, to promote overall well-being and mental health.(Czarnecka et al., 2021)

Table 1 Summary of MSG and Aspartame impact

	MSG	Aspartame
Impact on Weight Management	High	Unclear
Metabolic	High	High
Impact on Behavior	High	High

In summary, the impact of monosodium glutamate and aspartame on cognitive function, behavior, and weight management outcomes in adolescents with type 2 diabetes mellitus is a complex and multifaceted area of research. Physiological, biochemical, and psychological factors all contribute to the overall effects of these additives on health outcomes. Research investigating the mechanisms of action, long-term effects, and potential interactions with type 2 diabetes mellitus management strategies is essential for informing clinical practice and promoting optimal health in this vulnerable population.

4. Limitations of Current Research

While this review synthesizes findings on the impacts of MSG and aspartame, several limitations in the cited studies should be noted. Many studies rely on animal models, which may not directly translate to human health outcomes. Additionally, the small sample sizes and short durations of some studies reduce their generalizability. Funding sources for certain studies, such as those sponsored by industry stakeholders, may also introduce biases. These limitations highlight the need for more comprehensive, long-term human studies to validate the current findings. In the discussion of Collison et al. (2012), the study's reliance on animal models limits its direct applicability to human populations, particularly adolescents. For Wilk et al. (2022), the lack of long-term data restricts conclusions about the chronic impacts of aspartame consumption. In the context of Niaz et al. (2018), industry funding may introduce a conflict of interest, potentially skewing interpretations in favor of monosodium glutamate safety.

5. Conclusion

The literature reviewed sheds light on the specific impacts of monosodium glutamate consumption and aspartame use on adolescents diagnosed with type 2 diabetes mellitus. These food additives, commonly found in processed foods and beverages, have been studied extensively for their potential effects on cognitive function, behavior, and weight management outcomes in this vulnerable population.

Monosodium glutamate and aspartame have been associated physiologically with oxidative stress markers, inflammation indicators, and metabolic disturbances. These physiological changes can exacerbate insulin resistance,

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impair glucose metabolism, and contribute to weight gain, all of which are significant concerns in the management of type 2 diabetes mellitus among adolescents.

Biochemically, both monosodium glutamate and aspartame have been implicated in disrupting insulin sensitivity, altering lipid metabolism, and influencing satiety levels. These biochemical alterations can lead to erratic blood glucose levels, poor glycemic control, and challenges in weight management, further complicating the management of type 2 diabetes mellitus in this demographic.

Neurobiologically, monosodium glutamate and aspartame have been shown to affect neurotransmitter levels, particularly dopamine, norepinephrine, and serotonin, which play crucial roles in mood regulation, cognitive function, and behavioral patterns. The neurochemical impacts of these additives may contribute to mood fluctuations, cognitive impairments, and changes in eating behaviors observed in adolescents with type 2 diabetes mellitus.

Overall, the cumulative impact of monosodium glutamate consumption and aspartame use on adolescents with type 2 diabetes mellitus encompasses a range of physiological, biochemical, and neurobiological effects that can significantly impact their health outcomes. These effects include exacerbation of insulin resistance, disruption of glucose metabolism, challenges in weight management, mood fluctuations, cognitive impairments, and altered eating behaviors.

In light of these findings, it is imperative to consider the potential risks associated with MSG and aspartame consumption in adolescents with type 2 diabetes mellitus when designing dietary interventions and management strategies. Future research should focus on elucidating the underlying mechanisms of action, long-term consequences, and personalized approaches to mitigating the adverse effects of these food additives in this vulnerable population. By addressing these concerns, healthcare professionals can optimize the management of type 2 diabetes mellitus and improve the overall well-being of adolescents affected by this metabolic disorder.

Although the studies by Czarnecka et al. (2021) and Niaz et al. (2018) provide valuable insights, their limited sample sizes and lack of longitudinal data restrict the generalizability of their findings. Additionally, industry-funded research on aspartame raises potential conflicts of interest, necessitating cautious interpretation of results.

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