

Research Note



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Correspondence to

Joo Won Shin

Department of Secondary Special Education,
Daegu Haany University, 1 Hanuidae-ro,
Gyeongsan 38610, Korea.
Email: aaron1123@dhu.ac.kr

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ORCID iDs

Jung Min Cho

<https://orcid.org/0000-0002-6172-7583>

Joo Won Shin

<https://orcid.org/0009-0007-5614-4600>

Conflict of Interest

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Nutrigenomics for Autism Spectrum Disorder: A Multidisciplinary Framework for Personalized Nutrition in Special Education

Jung Min Cho ¹, **Joo Won Shin** ²

¹Functional Food Research Institute, Industry-Academic Cooperation Foundation, Daegu Haany University, Gyeongsan 38610, Korea

²Department of Secondary Special Education, Daegu Haany University, Gyeongsan 38610, Korea

ABSTRACT

Autism spectrum disorder (ASD) is a multifactorial neurodevelopmental condition often accompanied by metabolic and nutritional imbalances. Conventional dietary interventions, such as the gluten-free, casein-free diet, typically fail to consider individual genetic variations. Nutrigenomics, the study of gene-nutrient interactions, offers a promising framework for exploring personalized dietary interventions that may help address the metabolic and neurological complexities associated with ASD, although current evidence remains preliminary. This research note offers recommendations for integrating nutrigenomics into special education through a multidisciplinary approach that combines clinical nutrition, genetics, and educational practice via a 3-phase agenda. Stage 1 focuses on identifying behavioral subgroups within special education settings and using validated tools such as the Child Behavior Checklist Scale to analyze nutritional intake. Stage 2 involves the development and pilot-testing of behavior-specific nutrition protocols that are tailored to these subgroups, incorporating input from practice experts in nutrigenomics. Lastly, in Stage 3, a personalized nutrition model that incorporates genetic screening and metabolic profiling is constructed in collaboration with dietitians, educators, and caregivers. By bridging clinical and educational domains, this study seeks to establish nutrigenomics-based nutrition therapy as a viable and equitable intervention for improving health and developmental outcomes among students with ASD.

Keywords: Nutrigenomics; Autism spectrum disorder; Diet therapy; Comprehensive health care

INTRODUCTION

Autism spectrum disorder (ASD) is a complex neurodevelopmental condition influenced by genetic, metabolic, and environmental factors. Conventional management strategies typically emphasize behavioral therapies and generalized dietary interventions, but emerging research has suggested the importance of more individualized approaches [1]. Nutrigenomics, the study of gene-nutrient interactions, offers a promising avenue for tailoring dietary interventions to an individual's genetic profile, which can optimize health outcomes for those with ASD.

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Emerging evidence suggests that genetic polymorphisms can influence nutrient metabolism, impacting neurological function, inflammation, and oxidative stress, which are key factors implicated in ASD. While certain dietary interventions such as the gluten-free, casein-free (GFCF) diet have gained popularity, these do not incorporate individual genetic predispositions that may necessitate more precise nutritional modifications. The gut–brain axis has recently been highlighted as a key biological pathway that bridges diet, microbiome composition, and neurodevelopmental outcomes in ASD [2]. Alterations in intestinal microbiota may influence neurotransmitter synthesis, immune signaling, and nutrient absorption, in turn affecting genetic and metabolic factors described in nutrigenomics frameworks.

A multidisciplinary approach that integrates nutrigenomics, clinical nutrition, neurobiology, and special education is needed to address the multifaceted nature of ASD. A collaborative framework between nutritionists, geneticists, clinicians, and educators can facilitate the development of targeted nutritional strategies that address the physiological and cognitive aspects of ASD. This study explores the potential of nutrigenomics in unlocking personalized nutrition therapy for ASD and discusses the challenges and broader implications of its implementation. Despite growing evidence regarding metabolic differences in ASD, nutrition remains underrepresented in educational planning. Thus, bridging clinical nutrition and special education can facilitate more holistic and equitable interventions.

THE SCIENTIFIC BASIS FOR NUTRIGENOMICS IN ASD

Nutrigenomics examines the influence of genetic variations on an individual's response to dietary components [3], offering insight into the biochemical mechanisms underlying ASD. Several genetic polymorphisms have been explored for their potential association with metabolic dysfunctions in ASD. For instance, variations in the methylenetetrahydrofolate reductase (MTHFR) gene may influence folate metabolism, which plays a role in DNA methylation and neurodevelopment [4]. Similarly, polymorphisms in the catechol-O-methyltransferase (COMT) and monoamine oxidase A genes influence neurotransmitter metabolism [5], potentially impacting the levels of dopamine and serotonin, which are critical for behavior regulation. Deficiencies in the fatty acid desaturase (FADS) gene, which regulates omega-3 fatty acid metabolism, can result in a decrease in essential fatty acids and exacerbate neuroinflammation, which is commonly observed in ASD [6]. Although these polymorphisms may modulate neurologically-relevant metabolic processes, their specific contribution to ASD remains unclear.

In addition to these gene–nutrient relationships, recent studies have also emphasized the role of the gut–brain axis in linking nutrition, metabolism, and neural signaling in ASD. For instance, dysbiosis in ASD affects microbial metabolites such as short-chain fatty acids and tryptophan derivatives [7], which regulate neuronal signaling and epigenetic modulation [8]. Certain genetic variants (e.g., MTHFR, COMT) also alter the host response to microbiota-derived metabolites, suggesting the importance of a nutrigenomic–microbiomic interface in dietary personalization. Therefore, both genetic and microbial factors are crucial in shaping individual nutritional needs and neurobehavioral outcomes.

Considering these genetic variations, a one-size-fits-all dietary approach is not optimal for managing ASD. Instead, precise nutritional strategies tailored to an individual's genetic profile

could enhance nutrient metabolism and improve neurodevelopmental outcomes. By leveraging genetic information, clinicians and researchers can formulate targeted dietary interventions that can support optimal brain function and overall health in individuals with ASD.

PERSONALIZED NUTRITION STRATEGIES FOR ASD

Personalized nutrition strategies based on nutrigenomic findings may be better in managing ASD compared to conventional dietary interventions. For example, the methylation pathways of individuals with MTHFR mutations can be supported through supplementation with active forms of folate (i.e., 5-methyltetrahydrofolate) and vitamin B₁₂ (i.e., methylcobalamin) [9]. Enhancing these pathways may help regulate neurotransmitter synthesis and cognitive function. Meanwhile, individuals with FADS gene variants may benefit from targeted omega-3 fatty acid supplementation that ensures adequate levels of essential fatty acids needed for brain health and inflammation control.

Mitigating oxidative stress is another critical component of personalized nutrition in ASD [10]. Elevated oxidative stress levels, which are seen in many individuals with ASD, can negatively impact brain function. Accordingly, antioxidant-rich diets that incorporate nutrients such as polyphenols, vitamin E, and glutathione precursors may help counteract oxidative damage. Thus, genetically-tailored dietary recommendations can enhance an individual's antioxidant defenses, potentially improving neurological and behavioral outcomes.

Generalized dietary approaches, such as the GFCF diet, lack individualized metabolic considerations. In contrast, nutrigenomics-based dietary therapy offers a scientifically grounded strategy for optimizing nutrition in ASD. This personalized approach facilitates more precise dietary modifications that align with the unique metabolic needs of individuals with ASD, potentially improving health and developmental outcomes.

BROADER CONSIDERATIONS: NUTRIGENOMICS IN THE CONTEXT OF ASD EDUCATION AND TREATMENT

While nutrigenomics presents significant promise in the management of ASD, it should not be viewed in isolation, but rather as part of a broader, integrative treatment approach. These nutrigenomics-based dietary strategies are best implemented alongside behavioral, medical, and educational interventions. Thus, collaborative efforts between dietitians, geneticists, neuroscientists, and special education professionals are needed to holistically address the multifaceted health challenges in ASD [11]. This multidisciplinary approach enables a more comprehensive evaluation of the metabolic, neurological, and behavioral factors influencing symptoms in ASD.

In this context, developing evidence-based intervention protocols that integrate genetic insights with practical dietary modifications is crucial. Personalized nutrition programs should complement existing ASD therapies, ensuring that the dietary interventions align with behavioral and cognitive support strategies. Additionally, caregivers and educators, who play a vital role in implementing dietary changes in real-world settings, must be given the necessary guidance and support to facilitate adherence to personalized nutrition plans.

Integrating nutrigenomics into the treatment of ASD requires structural support within both educational and healthcare systems. Despite growing evidence, nutrition unfortunately remains largely absent from individualized education plans (IEPs) and special education policies. Thus, systemic advocacy is needed to formally recognize clinical nutrition as a vital component of special education services. Establishing school-based multidisciplinary teams that include registered dietitians can help in the execution of personalized nutrition plans and facilitate communication between caregivers, educators, and healthcare providers. Ultimately, the sustainable integration of nutrigenomics-informed dietary interventions into ASD care requires both policy innovation and cross-sector collaboration that prioritizes equity, personalization, and real-world applicability.

CHALLENGES AND FUTURE DIRECTIONS

Several challenges must be addressed before nutrigenomics can be fully integrated into the management of ASD. One primary limitation is the need for more extensive clinical research. Preliminary studies have suggested promising outcomes, but large-scale, longitudinal research remains essential to establish the efficacy of nutrigenomics-driven dietary interventions among ASD populations. Cost and accessibility are also significant barriers. Genetic testing and personalized nutrition programs are relatively expensive and not yet widely available. To address these issues, policy initiatives and funding support are needed to expand the availability of genetic testing and personalized dietary counseling. Lastly, ethical considerations must be carefully addressed, since the use of genetic data for dietary planning raises concerns about privacy and data security. Strict ethical guidelines and regulatory oversight are necessary to protect individuals' genetic information while ensuring the responsible application of nutrigenomics-based interventions.

A collaborative effort between researchers, healthcare providers, policymakers, and educators is needed to overcome these challenges. Interdisciplinary collaboration and supporting evidence-based research in the field of nutrigenomics can facilitate its application as a practical and widely implemented tool in the dietary management of ASD.

OUR RESEARCH AGENDA: A STEPWISE APPROACH TO DEVELOPING MULTIDISCIPLINARY NUTRITION INTERVENTIONS FOR STUDENTS WITH ASD

As a research team composed of a registered dietitian and a special education teacher, we are committed to building a scientifically grounded and educationally viable model of nutrition intervention for students with ASD (**Table 1**). Our long-term research agenda aims to integrate clinical nutrition and educational practice through a stepwise approach that bridges foundational evidence with individualized strategies, ultimately building a nutrigenomics-based model of care. This agenda includes 3 stages undertaken in progression: foundational (Stage 1), developmental and translational (Stage 2), and integrative (Stage 3). Together, these stages form the blueprint of our multidisciplinary research collaboration.

Table 1. Multiphase research agenda for bridging clinical nutrition and special education in ASD students

Stage	Subject	Core activities	Key outcomes
Stage 1	Foundational research: nutrient intake and behavioral profiles	- Nutritional assessment of macro- and micronutrient intake patterns among students with ASD in special education settings. - Identification and classification of behavioral subgroups via standardized behavioral assessment tools (e.g., CBCL, ADHD Rating Scale). - Cross-analysis of dietary intake and behavioral profiles to identify nutrition-behavior linkages.	- Behavioral phenotype-nutrition pattern linkage - Target subgroups for intervention - Evidence base for IEP nutritional inclusion
Stage 2	Translational research: development and pilot of tailored interventions	- Development of behavior-specific nutrition intervention protocols with multidisciplinary collaboration. - Pilot implementation of nutrition interventions within school environments. - Evaluation of feasibility, acceptability, and stakeholder perceptions regarding nutrigenomics-based dietary guidance.	- Feasible, subgroup-specific dietary interventions - Key participant feedback on nutrigenomic guidance - Foundation for personalized protocols
Stage 3	Integrative research: toward a nutrigenomics-based nutrition model	- Genetic screening for polymorphisms influencing nutrient metabolism (e.g., MTHFR, FADS). - Mapping identified genetic variants to individualized nutritional requirements. - Construction of a coordinated, multidisciplinary care model involving dietitians, educators, and caregivers.	- Personalized diet plans based on genetics - School-based multidisciplinary model - Prototype for policy-level integration

ASD, autism spectrum disorder; CBCL, Child Behavior Checklist; ADHD, Attention-Deficit/Hyperactivity Disorder; IEP, individualized education plan; MTHFR, methylenetetrahydrofolate reductase; FADS, fatty acid desaturase.

Stage 1. Foundational research: nutrient intake and behavioral profiles in special education ASD populations

Stage 1 involves an initial study that aims to identify the nutritional status of children and adolescents in special education settings, specifically by analyzing dietary intake across subgroups with distinct behavioral characteristics.

This foundational research will examine patterns in macro- and micronutrient intake based on observable behavioral issues (e.g., attention deficit, hyperactivity, irritability, and emotional dysregulation) by cross-referencing dietary records with standard behavior rating scales in special education (e.g., Child Behavior Checklist and Attention-Deficit/Hyperactivity Disorder Rating Scale) [12]. The detailed dietary assessment and reliability procedures are described as follows:

- Dietary assessment toolkit: (a) Three-day weighed food record (2 weekdays, 1 weekend day) with caregiver assistance; (b) Two non-consecutive 24-hour recalls using a caregiver-proxy multiple-pass method and portion-size photo book; (c) A brief, validated food frequency questionnaire to capture usual patterns (e.g., fatty acids, folate-rich foods) [13]. School meals will be directly observed and weighed when feasible, while packed lunch items will be photographed and weighed at home/school.
- Reliability and feasibility measures for ASD: Multi-informant triangulation (caregiver + teacher aide logs), photo-assisted entries, standardized utensil/plate guides in classrooms, training sessions for caregivers/teachers, reference portion booklets. This will involve test-retest recalls in a 10% subsample, inter-rater checks on coding, and calibration sessions for weighing. Sensory/selective eating and food neophobia will be recorded via brief checklists and used as covariates [14]. Missing or ambiguous entries will be resolved through follow-up calls and packaging bar-code capture.

Establishing an evidence base that links behavioral phenotypes to dietary patterns can help inform more targeted hypotheses for intervention. This stage also lays the groundwork for identifying specific subgroups that would derive the greatest benefit from nutritional modification. Importantly, this foundational stage aims to quantify nutritional gaps and highlight the urgency of incorporating nutrition into IEPs for students with developmental challenges.

Stage 2. Translational research: developing and testing behavior-specific nutrition interventions

Building on the foundational data from Stage 1, Stage 2 involves developing tailored nutrition intervention protocols for specific ASD behavioral profiles. These protocols will be designed through multidisciplinary collaboration across nutritionists, special educators, behavioral therapists, and caregivers. For example, students exhibiting inattention and impulsivity may receive a protocol emphasizing omega-3 fatty acid intake, iron-rich foods, and scheduled nutrient timing to stabilize cognitive performance. Meanwhile, another subgroup with mood instability and aggression may be recommended diets rich in magnesium and tryptophan to support neurotransmitter balance.

These nutrition protocols will prioritize whole-food–based modifications and complemented by targeted supplementation only when dietary intake is insufficient or clinically indicated. For example, students exhibiting mood instability or irritability may be offered a protocol with magnesium-rich foods (e.g., legumes, green leafy vegetables, nuts, and whole grains) and if necessary, a supplemental dose of 100–200 mg elemental magnesium (magnesium citrate or glycinate) administered once daily with meals, consistent with the tolerable upper intake levels for children and adolescents. Meanwhile, subgroups with inattention or impulsivity may be recommended omega-3 fatty acid intake corresponding to the upper physiological range of approximately 0.75–2 g combined eicosapentaenoic acid + docosahexaenoic acid per day through oily fish (e.g., salmon, mackerel, sardine) or equivalent capsule supplements (300–500 mg per unit) if dietary intake is insufficient, as per previous clinical nutrition guidelines [15].

This stage involves small-scale pilot studies within special education settings to assess the feasibility, acceptability, and short-term impact of these behavior-linked nutrition interventions. Pilot data will include behavioral observations, dietary adherence, and caregiver/teacher feedback. Pilot interventions will also be integrated into existing classroom routines and IEPs, which can allow educators to observe any behavioral and cognitive changes within authentic learning contexts. This can help determine the practical feasibility of nutrition-based strategies in school settings. These studies will be critical in refining intervention design and establishing the early evidence of effectiveness before proceeding to more intensive and individualized approaches.

Behavior-specific nutrition protocols will be developed in the context of known ASD-related genetic variants (e.g., MTHFR, FADS). Pilot interventions will focus on optimizing nutrient metabolism and neurobehavioral outcomes through gene-informed dietary strategies. Direct microbiome modulation is not the primary target, but rather, these interventions aim to indirectly support gut–brain communication through improvements in metabolic balance and dietary quality.

Lastly, this stage will include a research arm that explores the perception and acceptability of genetics-based dietary guidance among caregivers and educators. Since Stage 3 will incorporate genomic insights, it is essential to understand the perspectives of key stakeholders regarding the ethical, logistical, and cultural implications of nutrigenomics for its successful future implementation.

Stage 3. Integrative research: toward a nutrigenomics-based, multidisciplinary model of nutrition therapy

Stage 3 centers on the integration of nutrigenomics into clinical nutrition interventions for

students with developmental disabilities, particularly those with ASD. This phase will build upon the translational findings by utilizing nutrigenomic screening to identify key genetic polymorphisms relevant to nutrient metabolism (e.g., MTHFR C677T, COMT Val158Met, and FADS1/2 variants), using these as the basis for individualized dietary recommendations. Ultimately, we aim to construct a multidisciplinary nutrition care model that incorporates genetic screening, clinical nutrition planning, and special education support within a coordinated framework.

- **Methodology:** Participants will undergo targeted saliva-based genotyping for nutritionally relevant variants. Genotype data will be analyzed alongside metabolic and dietary intake profiles to develop personalized nutrition plans. These individualized recommendations will be regularly refined and reviewed in monthly multidisciplinary case conferences involving dietitians, special educators, and caregivers, ensuring that the dietary strategies align with behavioral and learning objectives in the classroom. Educational professionals will play a central role in translating nutrition plans into daily routines and in supporting consistent implementation in both school and home environments. Behavioral, metabolic, and dietary adherence outcomes will be tracked over an intervention period of 12–16 weeks with interim data safety and quality checks, as well as nutritional assessments of dietary intake and relevant biochemical indicators (e.g., folate, plasma fatty acids). Family-centered educational materials will be provided to improve adherence and facilitate communication between caregivers and educators.
- **Ethical considerations:** All genetic testing and data management will comply with international standards for research ethics, privacy, and data protection, including de-identification, secure data storage, and limited-access consent. Participation will be fully voluntary, and participants may withdraw their data at any stage. Families will be given feedback regarding the educational interpretation of gene–nutrient relationships, while avoiding diagnostic or deterministic framing.
- **Expected outcomes:** This integrative stage aims to produce a prototype for a school-based, nutrigenomics-informed nutrition care model that involves practical coordination among dietitians, genetic counselors, educators, and families. The expected outcomes include improved behavioral regulation, enhanced nutritional adequacy, and strengthened home–school collaboration in implementing personalized dietary strategies. Ultimately, this model aims to serve as a validated framework for the policy-level integration of clinical nutrition into special education systems, thereby advancing both equity and personalization in ASD care.

IMPLICATIONS

The integration of nutrigenomics into the management of ASD holds significant potential for advancing personalized healthcare. Incorporating additional insights from the gut–brain axis into these nutrigenomics-based nutrition models may offer a broader biological context for the dietary management of ASD. This approach leverages known genetic variations in ASD to design nutritional strategies that indirectly support gut–brain communication and overall neurodevelopmental function, rather than directly targeting the microbiome. By aligning nutrigenomic insights with IEPs, this framework promotes continuity between clinical and educational domains. By addressing individual metabolic and genetic needs, this approach can improve dietary interventions while lessening the trial-and-error nature of current ASD dietary strategies.

Due to the growing role of genetic testing in nutrigenomics-based interventions, ethical and psychosocial implications must be carefully considered. Since families may experience emotional stress, anxiety, or altered perceptions of responsibility when provided with genetic information related to ASD, accessible counseling and transparent communication are needed throughout the testing and intervention process. Additionally, the potential misuse of genetic data, such as in educational decision-making, insurance coverage, or social labeling, poses a risk of genetic stigma and discrimination. Strict data protection policies, ethical oversight, and public education are therefore essential to ensure the responsible and equitable implementation of these personalized nutrition strategies.

From a practical perspective, several institutional, organizational, and practical barriers hinder the integrating nutrition into IEPs, thereby limiting the inclusion of nutritional considerations in educational planning for students with ASD. At the institutional level, one major barrier is the absence of standardized frameworks or policy recognition that validate nutrition as a legitimate component of special education. Because nutrition-related interventions are typically classified under medical or clinical services, these typically fall outside the scope of IEP documentation. To address this, we propose the development of standardized guidelines for incorporating nutrigenomics-based clinical nutrition data into the IEP objectives. These guidelines would establish clear criteria for the importance of nutritional factors (e.g., genetic variants that affect nutrient metabolism) in informing individualized educational planning.

At the organizational level, the lack of structured collaboration between healthcare and educational systems often precludes the effective implementation of interventions. Most schools do not employ registered dietitians, and communication between clinical nutritionists, teachers, and caregivers remains fragmented. In response to these issues, our model promotes the establishment of multidisciplinary systems wherein dietitians, special educators, and caregivers collaboratively design, implement, and evaluate nutrition-related interventions. This structure facilitates feedback loops, shared decision-making, and coordinated goal-setting, thereby ensuring the alignment of nutritional interventions with educational objectives and continuous monitoring of progress across home, school, and clinical contexts.

At the practical level, even when nutritional recommendations exist, educators and families often lack the tools or contextual understanding to meaningfully apply these in daily routines. To overcome this, our model directly links these gene-informed nutritional strategies to concrete educational goals (e.g., enhancing attention, reducing hyperactivity, or stabilizing emotional regulation). By framing nutrition as a modifiable factor that influences learning outcomes, rather than an isolated health issue, this model has practical utility in both the classroom and home environments. To further support its real-world implementation, teachers and caregivers can be provided with accessible educational materials and training modules, which ensure that nutrigenomics-guided interventions are both actionable and sustainable within the IEP framework. Through these mechanisms, the proposed model can reframe nutrition from a peripheral health consideration into a scientifically grounded, policy-aligned, and educationally relevant component of individualized programming for students with ASD.

By addressing underlying metabolic and nutritional imbalances, these personalized nutrition plans could improve overall health outcomes and quality of life for individuals with ASD. Interdisciplinary collaboration among healthcare professionals and educators is essential to

implement these holistic dietary interventions, ultimately supporting the cognitive, ethical, and physiological well-being of individuals with ASD.

CONCLUSION

Nutrigenomics offers a promising basis for the development of personalized nutrition therapy for individuals with ASD. By accounting for genetic variations that influence nutrient metabolism, this approach offers a more precise and effective dietary management strategy. Despite challenges such as research limitations, accessibility issues, and ethical concerns, concerted multidisciplinary efforts spanning genetics, nutrition, and special education can help realize future advancements in ASD care. The integration of nutrigenomics into the management of ASD can potentially redefine dietary interventions, thereby unlocking new opportunities for optimizing health, education, and well-being in this population.

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