THE QUALITY OF NUTRITIONAL INTAKES IN CHILDREN WITH AUTISM: A PROSPECTIVE STUDY

A Thesis

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ABSTRACT

BACKGROUND: Autism is a neurodevelopmental disorder that affects 1 in every 91 US children. The nutritional status of children with autism may be compromised by common behaviors, such as aberrant mealtime behaviors, food aversions or selectivity, and gastrointestinal pathology.

METHODS: This prospective study investigated the dietary intakes of children with autism aged 3-9 years (n=24). Three-day food records were analyzed to determine 1) macro and micronutrient intakes before and after self-supplementation of vitamins and minerals (SSVM) and 2) trends in the MyPyramid's food group selection. Descriptive statistics were used to derive mean nutrient intakes and the proportion with intakes ≥ 80% of Dietary Reference Intake (DRI).

RESULTS: Nutrients commonly inadequate were those that are important for bone health (vitamins A, D, and K, with 58.3%, 58.3%, and 91.7% consuming intakes <80% DRI, respectively), digestion and metabolic pathways (pantothenic acid and biotin, with 54.2% and 54.2% consuming intakes <80% DRI), and brain health (choline and vitamin D with 95.8% and 58.3% consuming intakes <80% DRI). Vegetables and dairy were most frequently absent, with only 5 of 24 participants meeting recommended intakes for either group. Nutrient-contributing dietary supplements were reported as used daily by 45.8% of the sample (n=11). However, SSVM showed only marginal benefits in improving the proportion meeting reference intake levels.

CONCLUSION: Great variation and areas of concern in nutrient intakes and food selection patterns were documented in this sample. Individualized nutrition assessment and counseling, especially regarding the use of appropriate supplementation, may be useful for children with Autism.

DEDICATION

Dedicated to my parents, Debra and Dennis, my big brother Jason, and my fiancé Adam.

Your love and support guide me everyday.

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CHAPTER 1

INTRODUCTION

BACKGROUND

In a 1943 case report of eleven developmentally challenged children, Dr. Leo Kanner first defined a cluster of behavioral symptoms as "inborn autistic disorder." Kanner described the comparable behavioral dysfunctions in these eleven children as abnormal relation and interaction with people and objects, limited spontaneity and obsessive activities, and speech development delay or failure (1). Today, autism is classified into a class of neurodevelopmental disorders known as Autism Spectrum Disorders (ASDs).

Autism Spectrum Disorders are characterized by three core features: impaired social interaction; impaired language, communication, and imaginative play; and a limited range of interests and activities (2). According to the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV), Asperger's syndrome and Pervasive Development Disorder-Not Otherwise Specified (PDD-NOS) also fall on the spectrum (3). Though the diagnosis and treatment of autism has come a long way since Dr.

Kanner's initial diagnoses in 1943, a definitive etiology and curative intervention remain unknown, leaving an urgent need for further research of evidence-based interventions for children presenting with this disorder.

A recent survey of over 78,000 parents or caregivers of children aged 3-17, found the incidence of autism in children has again jumped, from a previously estimated 1 in every 150 children in 2003 (4), to a current estimate of 1 in every 91 children, based on 2007 data from the National Survey of Children's Health (5). Based on this new data, researchers estimate that 1.1% of the total population of children aged 3 to 17 years in the U.S., now present on the autism spectrum (5). This is a dramatic increase within the past 20 years, with estimates of autism prevalence in the 1980s once estimated at 1 in every 2500 children (4).

Some researchers allege that this surge in prevalence is secondary to an improved screening and diagnostic protocol rather than a true increase in prevalence of the disorder. Even with improved diagnostic criteria, diagnosis remains difficult due to the variable cognitive manifestations of ASD, which can range from a nonverbal, severely debilitated, and self-injuring child, to a high-functioning child with an above average IQ, despite inadequate social skills (2). Consequently, even with improved diagnostic measures and public awareness, autism may go undiagnosed in the underserved population. Currently, autism must be diagnosed by a trained clinician based on the following criteria, as specified in the DSM-IV:

- Qualitative impairments in social interaction, as manifested by two of the following: marked impairment in the use of multiple nonverbal behaviors (such as eye-to-eye gaze, facial expression, body postures, and gestures), failure to develop appropriate peer relationships, lack of spontaneous activity and enjoyment in people or objects, and lack of social or emotional reciprocity.

- Qualitative impairments in communication as manifested by at least one of the following: delay or failure to develop spoken language or, in those with adequate speech, inability to initiate or sustain conversation, stereotyped and repetitive use of language, and lack of spontaneous and social play.

- Restricted, repetitive, and stereotyped behavior, interests, and activities, as manifested by at least one of the following: preoccupation and abnormal intensity or focus on interests, inflexible adherence to specific routines or rituals, stereotyped and repetitive motor functions, and preoccupation with parts of objects vs. the whole (3).

Retrospective studies indicate that the majority of parents of children later diagnosed with ASD first notice abnormal behaviors at the age of two, with three years of age being the current average age for clinical diagnosis (6). Despite improved early diagnosis and treatment, most children with ASD are not independent as adults and will continue to experience significant and life-altering impairments for the remainder of their lives (7). Diagnosis is often a devastating moment for both the child and family.

In addition to behavioral symptoms, children with ASD often present with co-morbid conditions, including seizures, immune dysfunction, gastrointestinal symptoms, and aberrant eating behaviors (8). Upon diagnosis, families often seek the cause of their child's disorder and the most efficacious treatments in practice. Sadly, the cause of autism is complex, with genetic and non-genetic factors. Unknown etiologies have resulted in an abundance of interventions in the public eye, some with proven efficacy to improve behavior, others with little-to-no scientific backing. Regardless, treatments may be intensive for the child and expensive for the family, with a plethora of treatments

available, such as speech and language therapy, psychological and behavioral intervention, occupational and physical therapies, pharmacological intervention, dietary intervention, or complementary and alternative medicine (CAM) (9).

PATHOPHYSIOLOGY

As noted above, a definitive etiology for autism is unknown. Genetic, environmental, immune, and gastrointestinal etiologic theories have been postulated. A small percentage of ASD cases (~10%) have been definitively linked to genetic diseases (such as tuberous sclerosis complex, fragile X syndrome, etc.). While this is a small percentage, many researchers believe genetics continue to play at least a partial role in most cases (10). In addition, multiple studies have reported an increased risk for autism of 4-10% in siblings of children diagnosed with an ASD; an increased risk of 30% in fraternal twins; and a staggering 36-96% increased risk of identical twins sharing the disorder (7). Current thought is that an interaction between multiple and variable susceptibility genes, epigenetic effects, and environmental factors may be the co-mechanisms of the core features of autism (7).

Still, other theories exist. Recently in the media, there has been a surge in belief that prenatal exposure to some medications such as Depakote or Thalidomide; exposure to heavy metals such as lead and mercury; or the much-debated exposure to Thimerosal-containing vaccines, such as the Measles-Mumps-Rubella vaccine, cause regression in behavioral development (7). Though some parents still advocate against vaccination, there is no established causative link between these vaccines and an ASD diagnosis, nor is there definitive evidence of any other environmental toxin as a contributing causal factor of autism.

The high prevalence of GI symptoms found in the ASD population prompted an additional hypothesis that the GI pathology may be related to the etiology of ASD. One theory proposes that abnormal breakdown of the proteins gluten and casein, found in wheat and dairy products, results in peptides crossing the intestinal barrier into the bloodstream. These peptides act as endogenous opioids and result in behavioral regression characteristic of ASD (11). Based on this theory, the Gluten-free Casein-free Diet (GFCF) eliminates the proteins gluten and casein, with hopes that removal of these proteins from the diet will prevent increased intestinal permeability, and thus behavioral impairments. While results are conflicting, improvements reported in some autistic children on the GFCF diet has led some researchers to speculate about a more prominent role of immunology and food allergies in children with ASD (12).

Another hypothesis is that of intestinal disparities in autistic children that may result in a link to the disorder. Finegold et al (9) investigated the difference in intestinal microflora of autistic children compared to neurotypical children via stool samples. This study revealed a significantly increased presence of *Clostridia* in the stools of autistic children as well as an autism-specific species of *Clostridia*, gram-positive bacterium (*Clostridium boltaeae),* which was not present in neurotypical children. These findings suggest a possible connection between altered microflora, intestinal permeability, and faltered immunology with autism. More research on the etiology of autism is needed and presently continues in the field of genetics, immunology, neuroanatomy, and neurochemistry (10).

SIGNIFICANCE OF THE PROBLEM

Anecdotally, it is clear that children with ASD frequently suffer from concurrent gastrointestinal symptoms. The most documented GI symptoms include chronic diarrhea, excessive gas, abdominal discomfort and distension, constipation, gastroesophageal reflux, and food intolerances (8). Because of these symptoms, dietary supplements or other treatments targeting the GI tract are often trialed by parents of children with autism in hopes of alleviating GI symptoms, supplementing the diet, and/or improving behavior. It is estimated that 50-75% of children with autism receive some form of supplement or complementary and alternative medicine (CAM). The most common treatments are biologically based, a category that includes dietary supplements (13). At this time research has been unable to distinguish whether these problem mealtime behaviors result in, or are caused by, GI symptoms. Regardless, GI symptoms and problem mealtime behaviors are of concern as they may inhibit the ability of the child to consume an appropriate diet, thus compromising the nutritional status of this population (14).

Problem eating behaviors may include unwillingness to try new foods, mouthing objects, rituals surrounding eating, smelling and throwing food, and eating non-edibles (10). Several factors have been implicated in the frequency of problem eating behaviors, including core features of the disorder itself, family preferences, and sensory hypersensitivities (15). Repetitive behavior and restricted interests, one of the core features of autism, is believed to play a significant role in food selectivity, though Schreck and Williams found that the family's food preferences were the most significant indicator of the child's eating behaviors, not the severity of autistic symptoms (15).

Abnormal communication skills make it especially difficult for children with autism to communicate needs such as hunger, fullness, food likes and dislikes, or GI discomfort, making meal times a struggle for both the child and family (16). In addition, children with ASD often have sensory hypersensitivities, which may result in further restriction or refusal of foods based on an aversion to the texture, color, packaging, or temperature of the food (16, 17). For whatever reason, when variety is restricted in the diet, the nutritional status of the child may be compromised (14) and macro or micronutrient needs may not be met on a daily basis through diet alone.

Despite the evident concern for the ability of children with autism to meet daily nutritional needs, there are few studies that fully investigate whether macronutrient and micronutrient needs are being met through the diet alone. Of those that do exist, outcome measures and reports are conflicting. Several studies document significantly inadequate intake of several nutrients and/or food groups (18, 19), while others found no significant differences between nutritional intakes in children with autism as compared to their neurotypical peers (14, 20). However, the studies available are difficult to interpret because nutrient standards and interpretations of the "adequate" versus "inadequate" intake vary from study to study. Upon review of the literature, there are two areas of need that appear to be lacking in these studies: 1) many of the current studies fail to examine the entire macronutrient and micronutrient profile, with most "nutrient analyses" being completed for a limited range of food groups, macronutrients, and sometimes select micronutrients 2) of the studies that do inquire about nutrient-contributing supplements (such as multivitamins and minerals), no studies can be found at this time that go on to

complete a nutrition analysis with and without the nutrient-contributing supplement to examine the impact of supplement on the true quality of nutritional intake. Such research is needed, as the nutrient profile of children with autism remains largely un-characterized.

RESEARCH OBJECTIVES

This research was a part of a larger pilot study that was the first to systematically examine problem eating behaviors in children with autism to determine the relationships between these behaviors and other autism-associated factors, including: nutritional quality of dietary intake, nutrition-specific genetic differences, sensory processing characteristics, and intestinal microfloral abnormalities. The purpose of this correlational research was to define the phenotypic presentations of mealtime behaviors in children with autism and enable more accurate determination of the most appropriate and effective intervention for this multi-faceted disorder.

This sub-set of the pilot study was designed to meet the gaps in the available literature by determining the nutritional quality of dietary intake in children with autism by examining food selections from major food groups and a full range of macro and micronutrients, while accounting for nutrient-contributing supplements. Nutrient-contributing supplements, for the purpose of this study, were defined as only those supplements that implicitly deliver macronutrients or micronutrients, such as multivitamin/mineral supplements, fish oil, etc. A separate analysis was conducted with inclusion of nutrient-contributing supplements to determine the contribution of these supplements in meeting the participants' nutrient needs. The objectives of this research are as follows:

1. To investigate the quality of dietary intakes, and any trends that may be present, in children with autism by examining
    a. food selections from each food group, expressing the intakes as a percentage of MyPyramid recommended daily servings for the appropriate age category.
    b. macronutrient and micronutrient intakes by analyzing 3-day food records, expressing these intakes as a percentage of the Dietary Reference Intakes (DRI) for the appropriate age group, with ≥80% of the DRI for each nutrient defined for this study as meeting daily need.
2. To analyze 3-day diet records with the addition of nutrient-contributing dietary supplements in order to identify the contribution of supplementation in attaining Dietary Reference Intakes for both macronutrients and micronutrients in children with autism.

RESEARCH APPROACH

Clinicians of a Midwestern University Center for Excellence in Developmental Disabilities recruited 30 children, aged 3 to 9, diagnosed with an autism spectrum disorder (ASD) for the pilot study described above. Recruitment was completed through professional client contacts and also through established autism networks and supports. Twenty-four of these 30 participants submitted a completed 3-day diet record and were used as participants for this subset of the pilot study (n=20 with an autism diagnosis, n=4 with a diagnosis of PDD-NOS). Informed consent was obtained from each participant's caregiver. The Institutional Review Board (IRB) at the university through which this research was conducted approved the informed consent procedures. The IRB as well as

the university's Office of Responsible Research approved all study methods. Study participants and a consenting parent or caregiver were asked to attend one data collection session. The data collection visit was either a home visit or a session at University Center for Excellence in Developmental Disability, per the caregiver's preference.

A research assistant explained and distributed the 3-day diet record at this single data collection session, along with a self-addressed envelope for easy return. Caregivers were asked to complete this record for the enrolled participant by recording a typical weekend day and two typical weekdays. The research assistant also inquired about supplement use and any dietary restrictions or modified diet regimens during this visit. With regards to supplement use, the research assistant asked for the following information from the caregiver: 1) dietary supplement currently being taking by the child; 2) brand name of the supplement (if known); 3) typical dose consumed; and 4) the frequency of dosage (number of times per day).

The 3-day diet record was analyzed using ESHA Food Processor SQL® Nutrition and Fitness Software 10.5 (21). This software allows for analysis of 160+ nutrients from a database of over 35,000 foods (21). The purpose of this analysis was to evaluate the quality of dietary intakes in regards to both food group selections and macro and micronutrient levels of foods consumed in this sample of children with autism. The analysis tabulated nutrients in terms of Dietary Reference Intakes, or DRIs. The Institute of Medicine established the Dietary Reference Intake, which is an umbrella term that includes four types of nutrient intake reference standards, including: the Recommended Dietary Allowance (RDAs), the Estimated Average Requirements (EARs), the Adequate Intake Levels (AIs), and the Tolerable Upper Intake Levels (ULs). The DRIs, composed

of these four nutrient standards, represent our best knowledge of recommended intake for all essential nutrients (22). An average DRI of the three days reported in the diet record will be used for each nutrient analyzed. Refer to Table 3.1, page 37 for a list of all nutrients analyzed, their measure, and what standard of DRI was used. Food group selections were compared to MyPyramid recommended daily servings for a child of relevant age, and nutrient intakes were compared to Dietary Reference Intakes (DRIs) for children of relevant age. An intake of ≥80% of the DRI was defined as meeting daily needs, based on standards set in a recent clinical trial by Lindsay et al (23).

A secondary analysis was computed with the addition of nutrient-contributing supplements to examine the contribution of these dietary supplements in achieving DRIs for macro and micronutrients. A nutrient-contributing supplement is defined, for the purposes of this research, as any supplement that specifically delivers macro and/or micronutrients, intended to supplement, or enhance, food intake alone for the respective nutrients (i.e., multivitamin and mineral supplement). If applicable, it will be documented that a child is following a modified diet, which is defined, for the purposes of this research, as an on-going and purposeful avoidance or limiting of specific foods, food groups, or nutrients (for example, a Gluten-Free, Casein-Free Diet).

Descriptive statistics were used to summarize data from the nutrition analysis and to determine nutrition consumption characteristics of the sample. This analysis allowed for identification of trends in food selection from each food group, quantities of macro and micronutrients consumed both with and without nutrient-contributing supplements, and any existing inadequacies in the diet of this sample of children with autism.

GLOSSARY OF TERMS

Autism Spectrum Disorders (ASD): Autism Spectrum Disorders are a group of developmental disabilities that cause significant social, communication, and behavioral challenges. ASDs are "spectrum disorders," meaning that ASDs affect each person in different ways, and can range from mild to severe (4).

DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, published by the American Psychiatric Association (3).

Asperger's Syndrome: is on the continuum of ASD and is equivalent to high-functioning autism. A diagnosis of Asperger's Syndrome usually occurs when symptoms of autism are present without significant language or cognitive delay (4).

Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS): People who meet some of the criteria for autistic disorder or Asperger's syndrome, but not all, may be diagnosed as PDD-NOS; Symptoms may include only social and communication challenges (4).

Complementary and Alternative Medicine (CAM): CAM practices endorse promotion of health and involvement of the patient in a process of healing that addresses the underlying cause of illness, as interpreted by the practitioner. CAM therapies include mind-body medicine, biologically based practices, manipulative and body-based practices, and energy medicine (13).

Gluten: the protein found in oats, barley, and rye (11).

Casein: a milk protein, also found in milk-based dairy products (11).

Gluten-Free, Casein-Free Diet (GFCF): a diet requiring the elimination of the proteins gluten and casein, which are believed to cause or aggravate symptoms of ASD (13).

Intestinal Permeability: dysfunction of the intestinal epithelial barrier which permits entry of macromolecules such as milk protein, causing sensitization of the immune system and subsequent food allergies; it has also been postulated, though not proven, that these macromolecules enter the blood stream cause opioid-like effects (12).

Microflora: a vast layer of bacterial and fungal species inhabiting the gastrointestinal tract, which provides a layer of defense against invading pathogenic microbes (12).

Sensory Hypersensitivities: dysfunction in one's ability to modulate sensory input, resulting in atypical responses such as sensory seeking or sensory avoidance behavior (24).

Nutritional Supplements: Levy and Hyman, 2005, defined nutritional supplements as any vitamin, mineral, or other substance considered "natural" and available without prescription. The proposed basis for using nutrition supplements is the enhancement of neurotransmitter function by increasing availability of substrate and cofactors and/or to compensate for presumed biochemical deficits (25). Under this definition, nutritional supplements may include probiotics, digestive enzymes, or other substances intended to affect the gastrointestinal tract or metabolic pathways.

Nutrient-Contributing Supplement: For the purpose of this study only, nutrient-contributing supplements are those nutritional supplements that implicitly deliver macronutrients or

micronutrients for the purpose of supplementing, or enhancing, food intake alone. This definition, in itself, would exclude supplements that lack macronutrient or micronutrient ingredients, such as probiotics and digestive enzymes.

Modified Diet or Restricted Diet Regimen: For the purpose of this study only, a "special diet" can be defined as any diet regimen that includes an on-going and purposeful avoidance or limiting of specific foods, food groups, or nutrients.

CHAPTER 2

REVIEW OF LITERATURE

OVERVIEW

Problem eating behaviors are so often present in children with autism spectrum disorders that these behaviors were once listed among diagnostic criteria (26). Clinical trials have reported frequencies of these problem-eating behaviors as high as 72% to 77% (18; 24). The most common problem mealtime behavior in autistic children is excessive food selectivity, characterized by a limited range of foods or textures (26). Other problem behaviors may include mouthing objects, rituals surrounding eating, and avoidance of new foods (10). Although more rare than other eating behaviors, pica and total food refusal have been noted as more severe problem eating behaviors in children with autism (18).

PROBLEM MEALTIME BEHAVIORS AND NUTRITIONAL RISK

Several studies to date have investigated the range and prevalence of various problem mealtime behaviors in children that fall on the ASD spectrum. Matson et al (27) investigated the frequency of nine distinct problem eating behaviors in children diagnosed with autism or pervasive developmental disorder-not otherwise specified (PDD-NOS) versus atypically and typically developing children with similar

demographics. The nine investigated behaviors included: prefers food of a certain texture or smell, eats too much, will only eat certain foods, weight gain, has poor appetite, eats too little, weight loss, eats things not meant to be eaten, and eats too quickly. The study included 112 children with autism or PDD-NOS, 53 atypically developing children matched for age and gender, and 114 neurotypical children also matched for age and gender. The most problematic behaviors found in this study included 1) *prefers food of a certain texture or smell*, occurring in 82% of children with autism and in 65% of children with PDD-NOS but in only 11% of neurotypical children 2) *will only eat certain foods*, occurring in 83% of children with autism and 70% of children with PDD-NOS but in only 7% of neurotypical children 3) *eats things that are not meant to be eaten,* occurring in 39% of children with autism and 30% of children with PDD-NOS but in only 1% of neurotypical children 4) *eats too quickly,* occurring in 36% of children with autism and in 40% of children with PDD-NOS but in only 9% of neurotypical children and 5) *eats too much*, occurring in 33% of children with autism and in 38% of children with PDD-NOS but in only 11% of neurotypical children.

As expected, problem eating behaviors occur significantly more in children with an ASD than in typically developing children. However, the investigators also found that most children suffered a combination of several problem mealtime behaviors, resulting in a consistent interference in eating patterns (27). Not only is every mealtime a continuous battle for both the parents and the child, but also this interference in mealtime may put the child at risk for nutritional insufficiencies.

Dominick et al (26) conducted a study to investigate a broader spectrum of atypical behaviors present in children with autism versus children with a history of

language impairment (HLI). Sixty-seven children diagnosed with ASD and 39 children with a HLI participated in a study investigating atypical eating behaviors, abnormal sleep patterns, self-injurious behaviors, aggression, and temper tantrums. Investigators discovered that all of these behaviors were significantly more prevalent in children with autism compared to children with a history of language impairment. Atypical eating behaviors were present in 76.4% of participants and in only 15.4% of children with hearing learning impairments ($p<0.001$). Similar to findings by Matson et al (27), the most common eating behavior was food selectivity, with preference for one particular food present in 58% and an on-going limited range of foods observed in 63% of the children with autism. In addition, 30% of ASD participants showed an aversion to foods of a certain texture and 14% showed an aversion to foods of a certain color (26). The researchers also sought relationships among these abnormal behavior sets and found that atypical eating behaviors were significantly correlated with temper tantrums. Again, this brings to light the struggle parents often face at mealtimes when their child is on the spectrum, as well as the frequent parental concern when only a limited range of foods are contributing to their child's nutritional status.

It has long been postulated that children with ASD lack the communication necessary to express food preferences or even discomforts at mealtimes, thus resulting in frustration and temper tantrums. In Dominick's study, the age of onset for the abnormal behavior sets ranged from as early as the first year of life to up to five years of age, but abnormal eating behaviors tended to be one of the earliest developments, with most onsets occurring within just one year of birth (26).

These studies have shown the evident concern and hardship caused by problem eating behaviors in families of children with autism. Problem eating behaviors are posited to have a multi-faceted etiology. Several factors have been deemed possible contributors to the high frequency of these behaviors in children with an ASD, including sensory processing difficulties, gastrointestinal symptoms, or the core features of the disorder itself. Whatever their nature, nutritional quality must be assessed when these behaviors are present to ensure adequate nourishment and appropriate growth and development.

SPECIAL DIETS AND NUTRITIONAL SUPPLEMENTS

Gastrointestinal Symptoms have been posited as an etiological theory for autism spectrum disorders and/or as a possible contributor to abnormal mealtime behaviors in this same population (8). However, GI symptoms are present in many, but not all children with ASD, and it remains unclear whether these symptoms exist as a secondary result of the disorder, or whether they are actually a root cause for abnormal mealtime behaviors and aggression. GI studies in children with ASD unveiled several GI abnormalities including intestinal permeability, chronic reflux and inflammation, metabolic enzyme deficiencies, and dysbiosis (9; 11; 12; 28).

The high rates of gastrointestinal symptoms and problem eating behaviors in children on the spectrum have sparked a trend for special diet use and nutritional supplements as alternative treatments for children on the spectrum. Because special diet use and use of some nutritional supplements will affect overall nutritional quality, these therapies are important to consider when evaluating nutritional intake in this population of children.

These treatments fall under the scope of Complementary and Alternative Medicine, or CAM. CAM is one of the most widely used "natural" methods of intervention trialed by parents of children with autism, with as many as 50-75% of children with autism estimated to be treated with CAM therapies (13). Hanson et al (29) confirmed this estimate when they reported that 74% of 112 families with children on the spectrum reported use of a CAM therapy. Because CAM therapies are perceived as "natural," they are also viewed as lower intensity treatments with fewer side effects than conventional medicine (13). While a wide range of CAM therapies exist, the most frequently practiced are biologically-based. Biologically based therapies can be defined as an alternative treatment, which "seeks to alter physiology or change the underlying processes that result in the symptoms of autism," (25). Hanson's study found that 54% of those families utilizing CAM chose a biologically based therapy, including modified diets, vitamin and/or mineral supplements, or food or herbal remedies (29).

GLUTEN-FREE, CASEIN-FREE DIET

One of the most widely used special diets in children with autism is the Gluten-Free, Casein-Free Diet (GFCF diet). This diet is predicated on the hypothesis that children with autism suffer from intestinal permeability, or the leaking of macromolecules across the intestinal membrane and into the bloodstream. The culprits for intestinal permeability are believed to be gluten, a wheat protein, and casein, a milk protein. Once in the bloodstream these peptides are believed to exert an "opioid-like" effect on the central nervous system (11). Avoidance of these proteins altogether is expected to alleviate behavioral out-lash resulting from the opioid-effect.

Levy and Hyman rated the GFCF Diet a "Grade B," because some studies have shown improvements in language and behavior after the implementation of the diet but these results are not evident in *all subjects* with autism. Additionally, they are quick to note that few trials meet recommended randomized controlled methods, and also that it's difficult to pinpoint whether improvements are from removal of lactose in children who were actually lactose intolerant or whether improvements stem from an alteration in dietary protein sources, or both (25). This diet can be very restrictive to a child's diet, which presents a concern for meeting nutrient needs if the child is already expressing food selectivity at meals. This diet may especially hinder calcium and Vitamin D intake (25) due to the avoidance of dairy products as well as the B Vitamins and Folic Acid typically found in fortified wheat products. Caregivers should consult with a dietitian before trialing this diet to ensure the child is receiving adequate nutrition.

The Cochrane Database of Systematic Reviews completed a search of all randomized controlled trials (RCT) involving gluten and casein elimination diets, in attempts of conducting a meta-analysis on this diet intervention for autism. Only two small-scale, randomized controlled trials were identified (30; 31). Thirty-three studies were excluded due to inability to meet RCT criteria. The first, a trial by Knivsberg and colleagues, included only ten autistic participants and ten controls, while the second, a trial by Elder and colleagues, included only fifteen total participants (32). Homogeneity of intervention outcomes was not sufficient to conduct a meta-analysis between the two RCTs so results were reported separately.

In the Knivsberg study, four outcome measures were investigated after 12 months of diet implementation: number of autistic traits, linguistic age in months, non-verbal

cognitive level, and presence of motor problems. Only one outcome, the *number of present autistic traits,* was a true positive effect noted in the gluten-free, casein-free diet group (GFCF diet). The intervention group showed a 6.90 mean reduction in the number of autistic traits present after completion of the GFCF diet, while the control group of neurotypical peers showed a 0.30 mean reduction in the number of autistic traits (31). It is, however, important to keep in mind that this was a very small scale randomized controlled trial, and so outcome effects may not be accurate in proportion to the true population.

Contrary to Knivsberg's study, Elder et al (32) reported no significant differences between the intervention group and the control group for presence of autistic traits after implementation of the elimination diet. Elder et al was also a small-scale study, though its methods were well designed in that it was double blinded and elimination diets were modified to the individual needs of the participants. The reviewers identified Elder's methods and designs as the blueprint for a well-designed trial in this area of need, though a washout period before the diet is implemented is requested for future use. However, four years after this initial review, the authors completed a follow-up search for additional randomized control trials of the GFCF diet, and only two additional articles were identified—one new trial and one on-going trial. The authors deem this finding as "disappointing, bearing in mind the extent to which these diets are being used by parents of children with autism," (32). A small survey-based study recently conducted at large Midwestern university indicated that 48% of 20 families with an autistic child had considered the use of special or restricted diet, and 28% of families had actually

implemented the GFCF diet at some point in time (35). Though a small study as well, these findings indicate the impact special diet use can have on nutritional quality in this population of children.

From the Cochrane review, it is evident that results from the GFCF diet are conflicting, and currently, not enough evidence exists to support its claims and prevalence of use. Furthermore, its use requires abstinence from dairy and wheat containing products, which puts the child at risk for nutritional deficiencies. Before beginning such a restricted diet regimen, it is important for caregivers to know the research and have the ability to weigh the advantages and disadvantages. With a plethora of information available online, it is becoming more difficult for caregivers to filter out the evidence-based interventions.

VITAMIN B6 AND MAGNESIUM SUPPLEMENTATION

Vitamin and mineral supplements are intended to enhance neurotransmitter function by increasing availability of substrate or cofactors and/or to compensate for presumed deficiencies (25). Vitamin B6 and Magnesium is one of the most commonly used supplements in autism (25). Hanson et al (29) reported that 30% of 112 families with children on the spectrum were providing the child with a vitamin and mineral supplement, with the most frequently reported being Vitamin B6 and Magnesium. Vitamin B6/Magnesium was given a "Grade B" by Levy and Hyman because of a lack of research and outcomes showing efficacy (13).

A Cochrane Review searched for clinical trials using Vitamin B6-Magnesium supplementation in children with autism and located three studies completed between 1993 and 2002 with a total sample size of 33 children. The objective of this search was

to determine the efficacy of Vitamin B6 and Magnesium for treating social, communication, and behavioral responses of children and adults with autism (33). However, a meta-analysis was not possible due to methodological deficits, varied supplementation dosage, and differences in outcome measures.

The most recent in this study, Kuriyama 2002, focused on treatment of pyroxidine-dependent epilepsy in children with PDD. The study had a sample of only 8 children, to whom they provided 100-200 mg/day of Vitamin B6, but not magnesium. The outcome measures included only IQ and social quotient, with IQ showing a significant improvement in the children taking Vitamin B6 (33). The two other studies were both crossover designs. Tolbert 1993, utilized 200mg/70 kg of Vitamin B6 and 100mg/70 kg of Magnesium as the interventional treatment; however, no significant effects in outcome were noted (33). The final study in this review, Findling 1997, also yielded no significant differences in improvement of autism behaviors after supplementation with 30mg/kg of Vitamin B6 and 10mg/kg of Magnesium, with maximum supplementation dosages capped at 1000 mg Vitamin B6 and 350 mg Magnesium (33). None of these studies addressed Vitamin B6 and Magnesium intake through food sources before supplementation was initiated, nor did these studies address changes in nutritional status or effects on overall nutritional quality after supplementation.

One additional study has been published since the Cochrane Review. In this study, Vitamin B6 was trialed at 0.6 mg/kg/day and Magnesium was trialed at 6 mg/kg/day in 33 children on the spectrum along with 36 neurotypical controls. Unlike past clinical trials, these researchers reported that 60% of the intervention group (n=20)

showed improvement in social interaction, communication, and stereotyped behavior. Interestingly, symptoms returned when treatment was discontinued (34). Of concern in all of these studies is that excess pyridoxine, or B6, results in peripheral neuropathy, and no tolerable upper limit has been established for children (25). In addition, high dosages of magnesium can reduce heart rate and cause weakened reflexes (35). Dietary intake should be evaluated to determine whether supplementation of these nutrients is necessary and safe.

OMEGA-3 FATTY ACID SUPPLEMENTATION

Omega-3 fatty acids, a kind of polyunsaturated fatty acid, are crucial for brain development and cannot be produced in the body. Recent investigations have shown that deficiencies of omega-3 fatty acids may be related to several neurodevelopmental disorders, including autism spectrum disorders (36). The survey conducted by Hanson et al (29) indicated that 23% of 112 families reported use of food supplements, which included Omega-3 fatty acids, fish oil, and digestive enzymes.

Amminger et al (36) conducted a double blind, randomized controlled trial of omega-3 fatty acid supplementation of 1.5g/day in 13 children presenting with severe autism. The intervention group (n=7) showed significant improvements in hyperactivity and stereotypy as compared to the placebo control group (n=6) after taking omega-3 supplementation for 6 weeks. A more recent open label study supplemented nine children with autism with 500 mg of omega-3 fatty acids twice daily for 12 weeks. Eight of the nine children showed a 33% improvement in autism symptoms based on the Autism Treatment Evaluation Checklist. One child showed no changes, and none of the children worsened (37). However, like other nutrition supplementation methods, caution

is needed. Fish oil, the most widely available omega-3 supplement, is an anti-coagulant and excessive amounts may cause bruising. Neither of these studies investigated the adequacy of omega-3 fatty acid consumption through food intake. It is important to determine whether supplementation is necessary, and ensure that caregivers are aware of appropriate doses for the child.

FOLIC ACID AND VITAMIN B12 SUPPLEMENTATION

Recent studies have suggested that children with autism have abnormal methylation cycles, a decrease in antioxidant/detoxification capacity, and an increase in oxidative stress that are suspected to result from deficient levels of folic acid and vitamin B12 (38). In an open-label trial, 40 children with autism were treated with 75 mcg/kg of methylcobalamin (B12) two times/week and 400 mcg of folinic acid, an active form of folate, two times/day for 3 months (38). The primary outcome measure of this study was the metabolic profile compared to baseline. At baseline, the children with autism had metabolic profiles that were, on average, significantly different from the control children ($p<0.005$). After vitamin B12 and folinic acid supplementation, the children experienced significant increases in cysteine, cysteinylglycine, and glutathione concentrations, all of which function in metabolic pathways. Also, remnants of oxidative stress were also significantly reduced (38). After three months of intervention, metabolic profiles were nearly normalized. Despite these powerful results, no reference to actual intake before supplementation was noted, giving us no interpretation of the true intakes of these nutrients in the participants' diets. Further studies are needed to confirm these findings.

Still other nutritional therapies exist that contribute little to nutritional quality but "claim" to exert beneficial effects on symptoms of autism spectrum disorders and

gastrointestinal abnormalities. Some have documented research studies to test for safety and efficacy, including melatonin supplementation used to improve sleep patterns in children with ASD (35) or probiotics, taken to enhance healthy bacterial growth in the microflora and improve digestion. Others have little-to-no research to document safety and efficacy of use, including dimethylglycine (DMG) believed to enhance methylation pathways in metabolism and anti-fungal medications believed to function as a bowel detoxification system needed to correct dysbiosis, or a greater presence of harmful bacterium in the gut (35). Because these supplements do not fit this study's definition of nutrient-contributing supplements, in that they do not directly deliver macronutrients or micronutrients with the purpose of enhancing food intake of these substances, they will not be extensively reviewed here. However, it is important to document such available treatments, as they are expected and often reported in the ASD population.

At this point in time, none of these supplements are currently supported by randomized control trials for the purposes of improving symptoms of autism. Because of the high frequency of use of dietary supplements in children with an ASD, research investigating nutritional adequacy in the ASD population is needed to determine a need, if any, of micronutrient nutritional supplementation in children with autism.

NUTRIENT INTAKES

The purpose of this proposed research is to investigate the quality of nutritional intake. Use of special diets and nutritional supplementation will impact nutritional status, and thus are important in analyzing nutritional intake. Few studies to date have investigated the nutritional quality in children diagnosed with an autism spectrum disorder. Of those that have, results are conflicting, with some studies reporting

nutritional adequacy while others pinpoint inadequacies in major food groups. All studies to date have several debilitating limitations in methodology. Investigators request a further investigation into nutritional adequacy of children with ASD:

> "It is not enough to describe those behaviors that may interfere with eating [in children with autism]. Rather, it is critical to determine the impact those behaviors have on the dietary status of the child by actually assessing the adequacy of the consumed diet," (20).

No studies to date have been designed to analyze and compare nutritional intake before and after the inclusion of nutrient-contributing supplements.

Schreck et al (18) reported significantly fewer food choices ($p \leq 0.01$) from all food groups—dairy, fruits, vegetables, protein, and starch—in 138 children with ASD compared to 298 neurotypical children. Food choices and problem eating behaviors were tallied from the Food Preference Inventory as well as the Children's Eating Behavior Inventory. The autism group consumed the most foods from the starch group (mean 15.82 selections), followed by fruits (8.09), proteins (7.82), and minimal choices from dairy (4.32) and vegetable (4.00). The control group's food choices were nearly double in all food groups as compared to the autism group. Interestingly, these restricted food choices did not extend to the families of children with an ASD, with comparable eating patterns in both sets of families (18). This study, however, failed to acquire dietary intake records, inhibiting the ability to analyze the nutritional adequacy of the diet based on macro and micronutrients.

Raiten and Massaro published a study in which caregivers of 40 subjects with ASD and 34 typical subjects were asked to complete a 7-day diet record in order to analyze nutritional adequacy. Nutrients analyzed included: fat, carbohydrate, protein,

and vitamin A, thiamin, riboflavin, niacin, vitamin C, calcium, phosphorus, and iron. Nutrient analysis of the diet records revealed that the children with ASD had a significantly greater intake of *all nutrients* as compared to the controls ($p<0.02$) except for fat, vitamin A, and vitamin C, which did not differ between groups (20). However, the ASD group was comprised of children with a higher mean age (10.6±4.3 years) than the controls (8.8±4.8 years), as well as a greater proportion of males, 70% versus only 56% of the controls, which may have caused a skewed increase in nutrient intake in the ASD group. Also noted was that 38% of ASD subjects and 30% of the control subjects were regularly taking a vitamin and mineral supplement, which would contribute to nutrient intake, though these supplements were not included in analyses. The investigators concluded that overall adequacy of dietary intakes were similar for both groups (20). However, intakes were not actually compared to any established recommended intakes but solely to the control group, making this a brash conclusion.

A study by Ho and Eaves (19) investigated quality and quantity of nutrient intakes as well as the presence of obesity in an autistic population of 54 Canadian children. Three-day diet records were analyzed for energy, fat, protein, carbohydrate, vitamin, and mineral content and compared to Canadian nutrition guidelines. Contrary to Raiten's findings of over-consumption, only 4 children in this study met the recommended servings from each food group (19). However, all subjects had adequate protein consumption and on average, consumed more carbohydrate than the typical Canadian child's diet, indicating that these children's diet may be very lopsided—high in meats and carbohydrates, but low in fruits and vegetables. Though the mean intake of calcium met Canadian recommendations, calcium intake varied greatly among the children's diets,

with some children consuming far below recommended levels. Interestingly, 61% of participants had mismatched supplement regimens, meaning they took supplements for vitamins or minerals they over-consumed or did not take supplements for those nutrient needs not being met through diet alone (19). The investigators concluded that children with autism consume diets containing recommended amounts, except for calcium and iron, which varied greatly among individuals. (19)

Ho and Eaves also found that 42.6% of subjects presented with obesity, defined as 120% of ideal body weight, which was far greater than expected by the Canadian incidence of obesity in children, typically recorded as 15-25%. This prevalence of obesity was significantly correlated with severity of behaviors in these children (19). The authors concluded that children with autism might be at a higher risk for obesity compared to neurotypical peers (19), though no control group was utilized in this study for comparison.

More recent studies investigating the nutrient intake of children with autism have also reported conflicting results. Herndon and colleagues analyzed 3-day diet records for 46 children with an ASD and 31 children of neurotypical development for macro and micronutrients. Data were not analyzed for type or amount of any vitamin or mineral supplement in this study. Analysis revealed that children with an ASD consumed significantly less calcium and more vitamin B6 and vitamin E compared to their neurotypical peers. Also children with an ASD chose less dairy foods and consumed more non-dairy proteins than typical children. Adjustments for age and sex did not affect significance of findings except for intake of B6, which was no longer significant after adjustment (17). Both the children with ASD and neurotypical children met

recommendations for other macro and micronutrients similarly, though both groups failed to meet recommended intakes for a large proportion of nutrients, including fiber, calcium, iron, vitamin E, and vitamin D based on Dietary Reference Intakes (17). Overall, the investigators found few differences in average intake of nutrients between the ASD population and their neurotypical peers, though variety of intake was more variable from day-to-day among the ASD population (17), which may speak to mealtime behaviors and food selectivity.

Lockner et al (14) compared 3-day food records of preschool age children, 20 children with autism and 20 neurotypical peers. Food records were analyzed and compared to Estimated Average Requirements (EAR). EARs are not established for all nutrients, including calcium and fiber, so determining adequacy of nutritional intake in this study was limited. Regardless, these investigators reported similar findings for most nutrients between the autism group and the controls. Although some nutrients were consumed less than the recommended amount, these nutrients were similarly low in both control subjects and ASD subjects. Vitamins E and A were most likely to be consumed in low amounts by both groups (14), which contradicts Herndon's finding that children with an ASD consumed higher amounts of vitamin E (17). Nutritional supplements were not included in the nutrition analysis, despite the investigators finding that 60% of ASD subjects and only 25% of control subjects were consuming a vitamin/mineral supplement (14). The difference in supplementation among the participants in this study is great, and would impact micronutrient intake.

Levy et al (8) investigated the relationship between dietary intake and the presence of gastrointestinal symptoms in 52 children with autism. Reported frequency of

GI symptoms was high, with 54% of the participants reporting abdominal pain, constipation, stool abnormalities, or a combination of these disturbances. The investigators compared stool consistency by groups—bulky, loose or mushy, and solid—to dietary intake for possible relationships. 44% of the subjects had abnormal stool patterns. Food records were evaluated for energy, protein, carbohydrate, and fat, as a % of Recommended Dietary Allowances (RDAs). Adequate intake was defined as >77% of the RDA. No micronutrients were analyzed in this study. Dietary intakes remained within 95-101% of recommended ranges for calories, carbohydrates, and fats. The only exception was protein, with intakes averaging 211% of the RDA for this age group, but ranging from 67-436% among participants. Though protein was consumed in adequate amounts in earlier studies, no study noted such a high over-consumption. Investigators found the relationship between macronutrient intake and stool consistency was positive for all groups, though all were low positives (8).

Schmitt et al (39) investigated nutrition risk in 20 boys with autism compared to 18 typically developing boys. For this study, controls were matched by age, height, weight, and BMI percentile. A questionnaire that was developed and piloted by the investigators evaluated eating behaviors, food preferences, and supplement use. Caregivers were asked to complete this questionnaire in addition to a 3-day diet record. The investigators considered consumption of at least 67% of the daily reference values to be adequate for both macronutrients and micronutrients. This study's "established" standard of nutritional adequacy at 67% falls 10% lower than Levy's expectations in the previously noted study. This discrepancy in nutritional standards creates difficulty in interpreting the nutritional quality of the diets consumed by children in these studies.

In Schmitt's (39) study, both groups consumed adequate amounts of calories, protein, carbohydrates, and fat. However, both groups consumed below 67% of the daily reference value for fiber. While no significant differences existed in vitamin or mineral intake between boys with autism and neurotypical boys, the intake in the boys with autism was highly variable from participant-to-participant and from day-to-day. And though not significantly different from peers, the boys with autism consumed below 67% of the reference values for vitamins E and K. In general, intake was adequate in the autism population in this study, though this does not mean these children are exempt from nutritional risk. This study found that the autism subjects and the typical subjects consumed only an average of 8 and 10 different foods each day, leaving them to rely on vitamin and mineral supplements to meet nutrient needs, with 45% of the boys with autism and 50% of the typical boys on a vitamin/mineral supplement.

A final study by Johnson et al (40), defined an intake of <80% of RDAs to be inadequate in the analysis of food frequency inventories and 24 hour dietary recall interviews. This differs from Levy and Schmitt, who claimed >77% or >67% of recommended guidelines was considered "adequate," respectively (41; 17; 40). "Adequate" intake was defined as 100% and "inadequate" intake was defined as <80% of DRIs or RDAs. Few significant differences in dietary intake between the autism group and the control group were found in this study. Significant differences were found in vegetable choices, vitamin K intake, and magnesium intake, with the autism group consuming significantly less foods from the vegetable group (mean of 0.47 vs. 1.17 in the controls, $p=0.001$) and lower amounts of vitamin K (mean of 49.98 mcg vs. 58.68 mcg in the controls, $p=0.048$), but significantly higher amounts of magnesium (67% of children

with autism consuming >100% of needs and only 40% of controls consuming >100% of needs, p=0.015).

After reviewing these studies, it becomes obvious that not only is the expected standard of intake variable in these studies, but so is the reference. While some studies compare the intake of children with ASD solely to typically developing children, other studies use DRIs, or simply EARs or RDAs. Until standards for comparison are established, it remains difficult to interpret such variable outcomes.

Despite these limitations, these studies clearly expose the variability in nutritional intake among children with an autism spectrum disorder, as well as a high frequency of supplement use. See Table 2.1 for a general summary of findings from this literature review of the quality of nutritional intake in children with autism. It is important to note that none of these studies conducted nutrition analyses with and without inclusion of supplements to identify true nutrient profiles for this population of children. In addition, few of these studies investigated a macro and micronutrient profile as well as food selection from each food group. Further research in this area is warranted.

Study	*ASD (n)*	*Control (n)*	*Dietary Tool*	*Significant Findings*
Raiten & Massaro, 1986	40	34	7-day Diet Record	• ASD group had significantly greater intake of protein, carbohydrates, niacin, thiamin, riboflavin, calcium, phosphorus, and iron ($p<0.02$) • No significant difference in vitamin A, C, or fat.
Ho & Eaves, 1997	54	N/A	3-day Diet Record	• Only 4 subjects with ASD (7.4%) met recommended servings from all food groups. • All subjects had adequate protein intake, but had lower fat intake and higher carbohydrate intake than recommended nutrient intake for Canadians (RNI). • 42.6% of subjects were obese.
Herndon et al, 2009	46	31	3-day Diet Record	• ASD children consumed significantly less calcium but consumed increasingly more Vitamin B6 and E than controls. • ASD children consumed significantly more non-dairy proteins and fewer dairy items. • Both groups did not meet RDI for fiber, calcium, iron, vitamin D, and vitamin E
Lockner et al, 2008	20	20	3-day Diet Record	• Vitamin E and A were the least likely to be met by EAR for both groups • ASD subjects consumed less calcium and fiber, but with no established EAR, significance was not determined
Levy et al, 2007	52	N/A	3-day Diet Record	• The ASD subjects met 95-101% of RDA guidelines for calories, carbohydrates, and fat • ASD subjects over-consumed protein at 211% of RDA with a range of 67-436% RDA among subjects • This study used 77% of RDA consumption as adequate diet • No micronutrients assessed
Schmitt et al, 2008	20	18	3-day Diet Record	• This study defined adequate consumption as >67% of Dietary Reference Intake • Both groups consumed <67% for fiber • ASD group consumed <67% for vitamins E and K
Johnson et al, 2008	19	15	24-hr Recall	• This study considered <80% of RDAs or DRIs as inadequate • ASD group consumed significantly less vitamin K and significantly less food choices from the vegetable group
Lindsay et al, 2006	20	N/A	FFQ	• This study considered <80% of RDAs or DRIs as inadequate • 45% consumed <80% Calcium, 30% consumed <80% pantothenic acid, 25% consumed <80% Vitamin D, 40% consumed <80% Vitamin K

TABLE 2.1 Studies Investigating Nutritional Quality in Children with ASD

CHAPTER 3

METHODOLOGY

INTRODUCTION

This investigation was part of a larger pilot study that was the first to systematically examine problem eating behaviors in children with autism to determine the relationships between these behaviors and other autism-associated factors, including: nutritional quality of dietary intake, nutrition-specific genetic differences, sensory processing characteristics, and intestinal microfloral abnormalities. The purpose of the pilot study was to describe the clinical and biologic phenotypic presentations of mealtime behaviors in children with autism. This sub-set of the investigation examined and described the nutritional quality of dietary intake in children with autism with regards to food selections from each food group and for a broad range of macro and micronutrients, while accounting for and analyzing nutritional impact of any nutrient-contributing supplements in children with autism.

RESEARCH AIMS

There is limited research on nutritional quality of dietary intake in children with autism. Of the available literature, there is great variability among nutritional standards used, outcome measures, and findings. Interestingly, many studies fail to assess nutrient-

contributing supplement use in nutritional analysis. The literature has noted variable nutritional intakes, though some have shown inadequate consumption of calcium, fiber, vitamins A, D, E, and K as well as limited intake of foods from the vegetable group. The aim of this study was to fill the gap in the available literature by examining food selection from each food group to determine trends in food aversions as well as to examine macro and micronutrient intakes with and without the addition of any nutrient-contributing supplements to determine if nutritional adequacy is achieved in this population of children with autism either through diet alone or through supplementation.

RESEARCH OBJECTIVES

1. To investigate the quality of dietary intakes, and any trends that may be present, in children with autism by examining
    a. food selections from each food group, expressing the intakes as a percentage of MyPyramid recommended daily servings for the appropriate age category.
    b. macronutrient and micronutrient intakes by analyzing 3-day food records, expressing these intakes as a percentage of the Dietary Reference Intakes (DRI) for the appropriate age group, with ≥80% of the DRI for each nutrient defined for this study as meeting daily need.
2. To analyze 3-day diet records with the addition of nutrient-contributing dietary supplements in order to identify the contribution of supplementation in attaining Dietary Reference Intakes for both macronutrients and micronutrients in children with autism.

RESEARCH DESIGN

Clinicians of a Midwestern University Center for Excellence in Developmental Disability recruited participants for this study. Both present clients and past clients were recruited. Past clients were mailed a letter detailing the study and present clients were provided both written and oral information regarding the study. Eligibility criteria were: 1) child must be ages 3-9 years old, male or female 2) child must have a medical diagnosis of autism spectrum disorder (would accept PDD-NOS, Asperger's Syndrome, or autism). Participants were excluded only if they did not meet these two criteria or if they did not provide consent.

The Institutional Review Board at and the Office of Responsible Research at the university through which this study was conducted had approved all research protocols and consent procedures for the pilot study and this sub-set study. Caregivers were asked to provide informed consent for all participants because age inhibits the participants from providing consent. Caregivers of participants were asked to attend one data collection session, and had the option of setting up a home visit or attending a clinic at a Midwestern University Center for Excellence in Developmental Disability, per the caregiver's preference.

During the data collection session, parents were given a 3-day food record for this sub-set of the study. The caregiver was instructed to complete the food record using one typical weekend day and two typical weekdays for the child. The caregiver was instructed to include all foods and beverages, as well as cooking methods and portion sizes. If eating away from home, the restaurant name was asked to be included. During this instruction, the Research Assistant prompted the caregiver to disclose the following

information: 1) any dietary supplement being taken by the child during the days of "typical intake" 2) if known, to provide a brand name of the supplement 3) to provide the typical dose consumed and 4) the frequency of dosage (number of times per day). Finally, the Research Assistant asked the caregiver to disclose any modified or restricted diet the child was following at the time of food recording. A pre-addressed and stamped envelope was provided for easy return of the food record to investigators. Follow-up calls were made as needed to encourage return rates.

Using the 3-day food records, nutrition analysis was completed using ESHA Food Processor SQL Nutrition and Fitness Software ® 10.5. This software allows for analysis of 160+ nutrients from a database of over 35,000 foods (21). Two analyses were completed. The first analysis included foods and beverages only, and investigated food selections from each food group and a broad range of macro and micronutrient intakes from the diet. The secondary analysis included any nutrient-contributing supplements to Nutrient-contributing supplements were defined as any supplement that contributes macro or micronutrients and thus enhances food intake.

Both analyses tabulated food selections as a percentage of the MyPyramid recommended servings for each food group for a child of relevant age. The analyses also tabulated macro and micronutrients as a percentage of Dietary Reference Intakes (DRIs) for a child of relevant age. Dietary Reference Intakes represent our current best knowledge for recommended intakes of all essential nutrients. The DRI were developed by the Institute of Medicine and serve as an umbrella term that includes four types of nutrient intake references standards, including: the Recommended Dietary Allowance, (RDAs), which describe the intakes thought to be needed to meet the requirement of

nearly all healthy people (97%) in a particular physiological state and age; the Estimated Average Requirements (EARs), which describes the amount of the nutrient needed to meet requirements for 50% of the healthy population; the Adequate Intake Levels (AIs), which is used to describe an intake that appears to support adequate nutritional status when scientific evidence is insufficient to establish an RDA or EAR; Estimated Energy Requirements for kcal (EER), used to estimate the energy needed to maintain energy balance in a healthy person of a given sex, age, weight, height, and physical activity; and the Tolerable Upper Intake Levels (ULs), used to describe the highest level of chronic intake of a nutrient thought not to be detrimental (22). For all nutrients and food group selections, an average of the three days recorded was used. For the purposes of this study, $\geq$ 80% of the DRI for each macronutrient and micronutrient was defined as meeting a daily need. This standard was adapted from a trial by Lindsay and colleagues that investigated the impact of Risperidone on nutritional status in children with autism (23). See Table 3.1 for a complete list of macro and micronutrients analyzed, their measure, and the substandard of DRI investigated.

SAMPLE SELECTIONS

For the pilot study, 30 children with an autism spectrum disorder were recruited through a Midwestern University Center for Excellence in Developmental Disability and through autism networks and support groups. Clinic coordinators helped in identifying potential participants; past clients of the clinic that matched eligibility criteria were mailed an invitation letter detailing the study, and new clients of the clinic were provided study information by clinicians. Participants completed dietary survey information as part of the protocol. Of the 30 participants, 24 returned the 3-day diet records and thus

Macronutrients	*Measure*	*DRI substandard*
Carbohydrate	Grams (g)	RDA
Protein	Grams (g)	RDA
Fat	Grams (g)	AI
Saturated Fat	Grams (g)	
Trans Fatty Acids	Grams (g)	
Monounsaturated Fat	Grams (g)	
Polyunsaturated Fat	Grams (g)	
Essential Fatty Acids		
Omega-3 Fatty Acids	Grams (g)	
Omega-6 Fatty Acids	Grams (g)	
Linolenic Acid	Grams (g)	
Linoleic Acid	Grams (g)	
Micronutrients	*Measure*	*DRI substandard*
Vitamin A	Retinol Activity Equivalents (RAE)	RDA defined in mcg
Vitamin B1, Thiamin	Milligrams (mg)	RDA
Vitamin B2, Riboflavin	Milligrams (mg)	RDA
Vitamin B3, Niacin	Milligrams (mg)	RDA
Vitamin B6, Pyridoxine	Milligrams (mg)	RDA
Vitamin B12, Cobalamin	Micrograms (mcg)	RDA
Vitamin C	Milligrams (mg)	RDA
Vitamin D	Micrograms (mcg)	AI
Vitamin E	Milligrams (mg)	RDA
Folate	Micrograms (mcg)	RDA
Vitamin K	Micrograms (mcg)	AI
Pantothenic Acid	Milligrams (mg)	AI
Calcium	Milligrams (mg)	AI
Chromium	Micrograms (mcg)	AI
Copper	Milligrams (mg)	RDA defined in mcg
Iodine	Micrograms (mcg)	RDA
Iron	Milligrams (mg)	RDA
Magnesium	Milligram (mg)	RDA
Manganese	Milligram (mg)	AI
Molybdenum	Micrograms (mcg)	RDA
Phosphorus	Milligram (mg)	RDA
Potassium	Milligram (mg)	AI
Selenium	Microgram (mcg)	RDA
Sodium	Milligram (mg)	AI
Zinc	Milligram (mg)	RDA
Choline	Milligram (mg)	AI
Other Dietary Components	Measure	
Energy	Calories (kcal)	EER
Cholesterol	Milligrams (mg)	No DRI established, based on Dietary Guidelines
Caffeine	Milligram (mg)	No DRI established
Dietary Fiber	Grams (g)	AI
Fluoride	Milligram (mg)	AI

Table 3.1 Macro and Micronutrients Analyzed from 3-day Diet Record.

constituted the sample selection for this study. Of these 24 participants, 20 were diagnosed with autism (83%) and 4 were diagnosed with PDD-NOS (17%), 20 were male (83%), and 4 were female (17%). Though the pilot study recruited a control sample of neurotypical children, these participants did not complete the 3-day diet record, and so no control sample was used in this study.

DATA ANALYSIS/INSTRUMENTATION

A 3-day diet record was used to collect a typical dietary intake over one weekend day and two weekdays to account for variability of dietary intake during weekends. The 3-day food record is considered a valid and reliable method of dietary intake assessment (40). For each food group selection and nutrient, the average intake of the three days was analyzed using ESHA Food Processor SQL® Nutrition and Fitness Software 10.5 (21) to determine dietary intakes for food group servings and macro and micronutrients listed in Table 3.1 above. For food group selections, values were interpreted as a percentage of the MyPyramid daily recommended servings for each food group for a child of relevant age. For the nutrients, values were interpreted as a percentage of Dietary Reference Intakes (DRIs) for children of the appropriate age using the following equation:

$$\frac{\text{Mean Food group or Nutrient intakes (for 3 days)}}{\text{Recommended intake levels}} \times 100$$

As defined above, an intake of 80% or greater of the DRI was defined as meeting the daily need and a value <80% was categorized as failing to meet daily need for both food group selections and individual nutrient intakes. For those children taking a nutrient-contributing supplement, the supplement was selected from a list in Food Processor Software® if found in the database. If not found, the supplement's ingredients were

manually entered. These intake levels were expressed as a % of DRI, similarly, in order to determine the contribution of nutrient supplementation in meeting nutrient needs.

STATISTICAL PROCEDURES

Descriptive statistics were used to summarize data from standardized nutrition measures. This information was used to identify trends in macro and micronutrients consumed as well as trends in food selections (or aversions) from each food group (Objective 1). The dietary analysis was then re-computed with the addition of any nutrient-contributing supplements to determine the contribution of these supplements in achieving nutrient needs (Objective 2).

CHAPTER 4

THE QUALITY OF NUTRITIONAL INTAKES IN CHILDREN WITH AUTISM

ABSTRACT

BACKGROUND: Autism is a neurodevelopmental disorder that affects 1 in every 91 US children. The nutritional status of children with autism may be compromised by common behaviors, such as aberrant mealtime behaviors, food aversions or selectivity, and gastrointestinal pathology. **METHODS:** This prospective study investigated the dietary intakes of children with autism aged 3-9 years (n=24). Three-day food records were analyzed to determine 1) macro and micronutrient intakes before and after self-supplementation of vitamins and minerals (SSVM) and 2) trends in the MyPyramid's food group selection. Descriptive statistics were used to derive mean nutrient intakes and the proportion with intakes ≥ 80% of Dietary Reference Intake (DRI). **RESULTS:** Nutrients commonly inadequate were those that are important for bone health (vitamins A, D, and K, with 58.3%, 58.3%, and 91.7% consuming intakes <80% DRI, respectively), digestion and metabolic pathways (pantothenic acid and biotin, with 54.2% and 54.2% consuming intakes <80% DRI), and brain health (choline and vitamin D with 95.8% and 58.3% consuming intakes <80% DRI). Vegetables and dairy were most frequently absent, with only 5 of 24 participants meeting recommended intakes for either

group. Nutrient-contributing dietary supplements were reported as used daily by 45.8% of the sample (n=11). However, SSVM showed only marginal benefits in improving the proportion meeting reference intake levels. **CONCLUSION:** Great variation and areas of concern in nutrient intakes and food selection patterns were documented in this sample. Individualized nutrition assessment and counseling, especially regarding the use of appropriate supplementation, may be useful for children with Autism.

INTRODUCTION AND STATEMENT OF PURPOSE

A recent nation-wide survey revealed that the prevalence of autism spectrum disorders is again on the rise, from 1 in every 150 US Children aged 3-17 in 2003, to a current estimate of 1 in every 91 children (5). According to the Diagnostic and Statistical Manual 4th edition (DSM-IV), Autism Spectrum Disorder (ASD) is a classification of neurodevelopmental disabilities that includes the diagnoses of Autism, Asperger's Syndrome, and Pervasive-Developmental Disorder-Not Otherwise Specified (PDD-NOS) (3). Three core features that characterize ASD are: impaired social interaction; impaired language, communication, and imaginative play; and a limited range of interests or activities (2). While a definitive etiology for ASD remains unknown, many researchers in this field believe that a combination of susceptibility genes, epigenetic effects, and environmental factors may contribute to a multi-faceted etiology (7).

One of the core features of autism—repetitive interests and stereotypic behaviors—is believed to play a role in the presentation of problem mealtime behaviors that are so commonly witnessed in children with autism (10,15,26,27). Other symptoms of autism, including gastrointestinal dysfunction and discomfort (8), sensory hypersensitivities (16, 24), or food intolerances and allergies (12) are also believed to

contribute to a limited range of foods, textures, or color in the diet. Clinical trials have documented the frequency of problem-eating behaviors as high as 72%-77% of children with ASD (18, 24). These behaviors may inhibit the quality of nutrient intakes, and thus compromise nutritional status and optimal growth in children with autism.

Several studies to date have examined the nutrient profiles of children with autism. The findings of the available literature are inconclusive. Several studies noted an unexpected increase in consumption of select nutrients in children with ASD, especially protein (8, 20), carbohydrate (19, 20), niacin (20), thiamin (20), riboflavin (20), calcium (20), phosphorus (20), vitamin B6 (17), vitamin E (17), and iron (20). Other studies found that children with ASD did not meet needs for fat (19), fiber (14, 17, 39) calcium (14, 17), vitamin A (14), vitamin D (17), vitamin E (14, 17, 39), vitamin K (39, 40), and iron (17). See Table 4.1 for a summary of the available literature. However, it is difficult to interpret and synthesize the findings of these studies into an accurate characterization of dietary intake in children with autism because of varying methods and design, use of different nutrient standards, small sample sizes, and varying interpretations of "adequate" versus "inadequate" intakes.

The growing ASD epidemic has led to a concurrent rise in use of Complementary and Alternative Medicines (CAM), with an estimated 50-75% of children with ASD utilizing such treatments (13, 29). While a plethora of CAM therapies exist, the most frequently trialed are biologically-based, including a modified diet, such as the Gluten-Free Casein-Free Diet, vitamin and/or mineral supplement, or herbal remedy (29). No

known studies to date have included nutrient-contributing dietary supplements in the nutrient analysis, failing to acknowledge the contribution these supplements have in meeting nutrient needs.

The purpose of this study was to address the gaps in the available literature by examining the full nutritional profile of children with autism. The objectives of this study were to analyze 3-day diet records from children with autism, aged 3-9, to determine trends in 1) macro and micronutrient intakes before and after use of any self-supplemented nutrient-contributing dietary supplements and 2) MyPyramid's food group selections and/or aversions to certain food groups.

METHODS

This prospective study was part of a autism pilot study at a Midwestern University Center for Excellence in Developmental Disabilities (UCEDD) that was the first to systematically examine problem eating behaviors in children with autism and determine correlations with other autism-associated factors, including: nutritional quality of dietary intake, sensory processing characteristics, and intestinal microfloral abnormalities. The Institutional Review Board and the Office of Responsible Research at the university through which this research was conducted approved the research protocol. Informed consent was obtained from the caregiver of each study participant.

Sample. Clinicians of a Midwestern University Center for Excellence in Developmental Disability identified clients as potential participants. New clients of this center were verbally provided with an invitation and past clients were mailed an invitation letter detailing the study. The pilot study aimed to enroll 30 children with an

ASD, ages 3-9, at time of enrollment. Participants eligible for this sub-set of the pilot study had a confirmed diagnosis of ASD, were ages 3-9, had a parent or caregiver that provided informed consent, and returned a 3-day diet record.

Data Collection. During a single data collection session, consenting parents/caregivers were instructed to complete a 3-day diet record for the participant. The 3-day diet record is considered a valid and reliable method of dietary intake assessment (41). The caregiver was instructed to complete the diet records using one typical weekend day and two typical weekdays for the child, a protocol that ensures typical intake without a bias for weekday or weekend food choices. The caregiver was instructed to include all foods and beverages, as well as cooking methods and portion sizes. If eating away from home, the restaurant name was also requested. During this instruction, the Research Assistant prompted the caregiver to disclose the following information: 1) any dietary supplement being taken by the child during the days of "typical intake" 2) if known, to provide a brand name of the supplement 3) to provide the typical dose consumed and 4) the frequency of dosage (number of times per day). Finally, the Research Assistant asked the caregiver to disclose any modified or restricted diet the child was following at the time of food recording.

Data Analysis and Statistics. Analysis of 3-day diet records was completed using ESHA Food Processor SQL® Nutrition and Fitness Software 10.5 (21). Two analyses were completed. The first analysis reported MyPyramid food group selections (grains, vegetables, fruits, milk and dairy, and meat and beans) and macro and micronutrient intakes from food and beverage sources alone. The secondary analysis included the use of any self-supplemented nutrient-contributing dietary supplements. For

the purposes of this study, nutrient-contributing supplements were defined as any supplement that contributes macro or micronutrients. Dietary supplements that do no contribute to macro or micronutrient intake, such as probiotics, digestive enzymes, or melatonin, would not change a nutrient analyses and so were noted, but excluded from nutrient analysis. When available, the supplement was chosen from ESHA's established food database. If not found within this database, ingredients of the supplement were entered in appropriate proportions to the best ability of the researchers.

An average of the three days was used to express each nutrient intake as well as food group selections. All nutrients were expressed as a percentage of Dietary Reference Intakes (DRIs) for a child of relevant age. The Institute of Medicine established the Dietary Reference Intake as an umbrella term that incorporates four different standards: the Estimated Average Requirements (EARs), the Recommended Dietary Allowances (RDAs), the Adequate Intake Levels (AIs), and the Tolerable Upper Intake Levels (ULs). The DRIs represent our current best knowledge of recommended intake for all essential nutrients (22). An intake of ≥80% of DRI was defined as meeting a daily need, a standard that was adapted from a recent autism study by Lindsay et al (23). Similarly, food group selections were expressed as a percentage of the MyPyramid recommended servings for a child of relevant age. An intake of ≥80% of the MyPyramid recommended servings was defined as meeting a daily need.

Descriptive statistics were used to derive mean intakes, standard deviations, and standard errors of the means from the 3-day diet records. These statistics summarize and identify trends in 1) the quality of nutritional intake before and after use of any nutrient-

contributing supplementation and 2) trends in MyPyramid food group selections and/or food group aversions. Standard deviations (SD) and standard error of the means (SEM) depict variation between the mean and extreme outliers affecting the sample mean.

RESULTS

Thirty children with ASD, aged 3-9, were enrolled in the autism pilot study (See Figure 4.1 for participant flow chart). Twenty-four of the 30 participants (80%) returned a 3-day diet record and so were included in this study. Of the 24 participants, 83% were male (n=20) and 17% were female (n=4). All 24 participants had a medical diagnosis of ASD, 83% with an autism diagnosis (n=20) and 17% with a diagnosis of PDD-NOS (n=4). In addition, 29% of participants had secondary or multiple diagnoses, including Fetal Alcohol Effect (n=1), Oppositional Defiant Disorder (n=1), Down's Syndrome (n=1), Obsessive Compulsive Disorder (n=1), Attention Deficit Hyperactivity Disorder (n=1), Celiac Disease/Gastric Ulcers (n=1), and Fragile X Syndrome (n=1). Ages, heights, weights, and body mass indexes (BMIs) were obtained for each participant. Table 4.2 describes these anthropometric characteristics of the participants at baseline.

Macro and Micronutrient Intakes. A complete nutrient analysis of dietary intake is offered in the Appendix Table number A1. A discussion of all nutrients is beyond the scope of this study; from herein, only the nutrients most under-consumed in this sample will be discussed. Of the 41 nutrients analyzed, 19 can be identified as nutrients of concern (Table 4.3). These nutrients were identified because at least 30% of the sample failed to meet the established daily need, or 80% of the Dietary Reference Intake (DRI). These 19 nutrients included: dietary fiber, monounsaturated fatty acids (MUFA), linolenic acid, linoleic acid, vitamin A, biotin, vitamin D, vitamin E, vitamin K,

pantothenic acid, calcium, chromium, iodine, magnesium, manganese, molybdenum, potassium, selenium,and choline. The analysis indicated that none of the participants met 80% of the DRI for fluoride. However, fluoride intakes may be underreported in this nutrient analysis due to undisclosed drinking water sources and unknown frequency of fluoridated toothpaste use. For this reason, fluoride intakes were not listed as a nutrient deficit in this sample. For most of these 19 nutrients, a majority deficit was discovered. At least 50% of the sample failed to consume 80% of the DRI for 16 of the nutrients, and 80% of the sample failed to consume 80% of the DRI for 9 of the nutrients (Table 4.3). The nutrients identified as most under-consumed in this population are important for bone health (calcium and vitamins A, D, and K, with 41.7%, 58.3%, 58.3%, and 91.7% consuming intakes <80% DRI, respectively), digestion and metabolic pathways (pantothenic acid and biotin, with 54.2% and 54.2% consuming intakes <80% DRI), and brain health (choline, vitamin D, and the essential fatty acids, linolenic acid and linoeleic acid, with 95.8%, 58.3%, 83.3%, and 85.% consuming intakes <80% DRI, respectively).

Despite a trend in low intakes of these nutrients, it is evident that consumption varies greatly among participants. Vitamin A intakes ranged from 68.0 to 3261.1 retinol equivalents; calcium intakes ranged from 196.3 to 2294.8 mg; and potassium intakes ranged from 907.9 to 5689.4 mg. Some variation was even more evident due to outliers who failed to consume any of a specific nutrient. The minimum intakes for biotin, vitamin D, fluoride, iodine, and molybdenum, were noted as 0, or failure to consume anyfoods containing the specified nutrient over the three days of recorded intake, which greatly skews mean intake. For this reason, standard deviations and standard errors of the means are reported in Table 4.3 to depict variable intakes and outlier effects. Of all the

nutrients analyzed, protein intakes were the only intakes that were overconsumed by all participants. Every participant consumed at least 130% of the DRI for protein, with a range that exceeded 500% of the DRI. High protein consumption has been reported in other nutrient studies for children with autism (8, 20).

Regardless, it's important to portray the scarcity of consumption of several of these nutrients and the physiological impact such inadequate intake may have on these children with ASD with regards to bone health, adequate digestion and metabolism for growth, and brain health. TABLE 4.4 presents the physiologic functions and common food sources for the 19 nutrients of concern. In addition to trends in under-consumption of nutrients associated with bone health, digestion/metabolism, and brain health, other slightly less prevalent trends are also noted. These trends include under-consumption of nutrients associated with cardiovascular health, antioxidant function, synthesis of metabolic factors (including thyroid hormones and glucose), and cell differentiation. Deficiency of these nutrients could result in devastating effects on growth and development in this age group of children, especially in children with ASD who already exhibit problem mealtime behaviors that diminish the ability to meet nutritional needs.

Food Group Selections. Each participant's food record was analyzed for 3-day average mean servings from each of the MyPyramid food groups: grains, vegetables, fruits, milk and dairy, and meats beans. Mean intakes were expressed as a percentage of MyPyramid recommended servings for a child of the relevant age (Figure 4.2). Foods were *least* selected from the vegetable group among this sample, with a mean food selection of only 42.6% of MyPyramid recommended daily servings. The mean number of food selections from the milk group was nearly as low, with a mean food selection of

61.25% of recommended daily servings. The sample's mean food selections for the meats, grains, and fruit groups surpassed the established standard of ≥ 80% of recommended servings, with mean food selections of 85.7%, 110.5%, and 120.8% of recommended daily servings respectively. Figure 4.1 also displays the average 3-day minimums and maximums of foods selected from each food group. These ranges depict the true variation in food selectivity, with intakes from the fruit group ranging from a selection of 0% to 625% of the recommended servings. Servings from the meat and beans group ranged from consuming 2% to 481% of daily recommended servings.

A closer analysis (Appendix Table A2) of each participant revealed that only 5 of the 24 (20.8%) participants consumed, on average, ≥ 80% of the MyPyramid recommended servings for vegetables and milk. Only 8 participants (33.3%) consumed ≥ 80% of the daily recommended servings for meats and beans. Fruits and grains were the most widely accepted food groups, with 13 and 17 of the 24 participants consuming at least 80% of the recommended daily servings, respectively (54.2% and 70.8% respectively).

Supplement Use. Of the 24 participants who completed a 3-day diet record for analysis, only 3 of the participants' caregivers (12.5%) reported a modified diet. One caregiver reported a "gluten avoidance" due to a secondary diagnosis of Celiac Disease. Casein foods were not omitted from this child's diet. The other two caregivers reported a full Gluten-free, Casein-free (GFCF) diet, indicating that all foods containing gluten and casein (wheat and dairy proteins) were omitted on a daily basis. Length of diet use was not disclosed. The GFCF diet lack enriched grains and dairy, causing concern for potentially low intakes of the B vitamins, folate, calcium, and vitamin D. However, low

intakes in these nutrients were not consistently seen among these three participants. These three participants averaged adequate intakes of the B vitamins, except one child on the GFCF diet who was low in biotin, pantothenic acid, and folate, meeting only 21.6%, 31.0%, and 68.3% of the DRI, respectively. Calcium and vitamin D intakes were low in the other participant on the GFCF diet, with intakes meeting only 42.8% and 24.8% of the DRI, respectively. The relatively sufficient intakes in these nutrients, despite following a GFCF or gluten-free diet, may be attributed to use of dietary supplements. The participant on the gluten-free diet did not regularly use a nutrient-contributing supplement but did report regular intakes of a fortified nutritional beverage, Pediasure®. The two particiants following a GFCF diet did report supplement use. One participant reported a gummy multivitamin/mineral without iron, a children's calcium supplement (250 mg/day), a fish oil supplement (800 mg/day) and Primadolphus® probiotic. The other participant reported regular use of 25 different dietary supplements, 7 of which were nutrient-contributing. In this list was a chewable multivitamin/mineral with iron, which may compensate for a lack of nutrients through avoidance of wheat and dairy foods. Dietary supplements, among all participants, were reported at a much higher rate than use of a modified diet.

Of the 24 participants, 13 were taking some form of dietary supplement (54.2%). Eleven of these participants (45.8%) used a nutrient-contributing supplement, which included: a gummy multivitamin/mineral without iron (n=6), a chewable multivitamin/mineral with iron (n=2), a liquid multivitamin/mineral with iron (n=1), fish oil or other omega-3 source (n=5), calcium citrate (n=2), vitamin K (n=2), zinc (n=1), vitamin B12 lollipop (n=1), an amino acid blend (n=1), biotin (n=1), and folinic acid

(n=1). Supplements reported by this sample, but not included in analysis (non-nutrient contributing) were: probiotic/prebiotic (n=7), cucumin (n=4), melatonin (n=3), digestive enzymes (n=3), glutathione cream (n=2), chelation agent (n=1), pycnogenol (n=1), and inositol (n=1). Pharmacological agents included antidepressants (n=2), vitamin b-12 shot (n=1), antifungal (n=1), and an anti-reflux (n=1). In addition, several participants reported fortified beverage consumption (Pediasure® (n=2), milk powder (n=1), and fortified rice milk products (n=2). However, these were not evaluated as supplements but rather as foods because they were used daily in lieu of milk products.

Despite the high use of nutrient-contributing dietary supplements (45.8% of participants), only marginal improvements in nutrient quality were seen evident (Figure 4.3). With regards to the 19 nutrients of concern, no improvements were noted in 6 of these nutrients, including: dietary fiber, fluoride, manganese, molybdenum, potassium, and selenium. The greatest improvements were seen in iodine and pantothenic acid intake, with 6 and 5 participants meeting recommended iodine and pantothenic acid intake only after the addition of a dietary supplement. It is expected that linolenic acid improvements may be slightly underreported in this analysis because ESHA Food Processor software® currently does not have a gummy Omega-3 children's supplement within its database, inhibiting the ability to analyze linolenic acid after supplementation. This information also could not be manually entered because no label regulation exists to ensure documentation of quantity of linolenic acid in the supplement.

DISCUSSION

This study revealed a large selection of micronutrients that are inadequately consumed through diet alone in a sample of young children with ASD. Nutrients most

under-consumed in this sample were those that play a role in bone health, digestion and metabolism, and brain health. Several previous studies similarly noted a similar trend of nutrient deficit for nutrients associated with bone health (calcium, vitamins A, D, E, and K) (17, 39, 40). Several studies also noted inadequate fiber intake in the ASD population (14, 17, 39) as did this study.

Interestingly, no studies to date have analyzed intakes of the omega fatty acids. With recent research suggesting there may be a link between omega-3 fatty acids and autism (36), these findings of deficient linolenic acid intake (83.3% of participants failed to meet at least 80% of the DRI for linolenic acid) are even more pertinent and timely. More research is warranted in this area. In addition, no research to date has noted such deficient intakes of chromium, iodine, magnesium, manganese, molybdenum, potassium, selenium, or choline, though many studies fail to disclose an analysis of a full micronutrient profile. Finally, a deficit in pantothenic acid and biotin intakes has not been previously cited in the literature, but was documented in this sample.

While many consumers may depend on enriched grains to achieve sufficient intakes of the B vitamins, the enrichment process, regulated by the Food and Drug Administration (FDA), only mandates that thiamin, niacin, riboflavin, folate, and iron be added to select grain products (22). Pantothenic acid and biotin are not mandated and may be left out of "enriched" and "fortified" products, which may be indicative of the findings here. Furthermore, children with autism consuming a GFCF diet, may further display deficiencies in the B vitamins and folate, such as the one participant described previously who consumed low amounts of these nutrients, as the FDA does not mandate enrichment for gluten-free products at this time.

Despite this study's findings of extensive limitations in nutrient intakes, a few studies have previously found that children with ASD consume more than neurotypical peers for some nutrients, especially protein (8, 19, 20). While many nutrients were underconsumed in this sample, protein was consumed well above daily needs. In fact, not one participant failed to meet at least 100% of the DRI for protein, and the mean %DRI consumed for protein was 278.5% of daily needs, with a range of intake from 138.5%-572.2% of the DRI for protein needs. However, it is important to remember that protein needs for a child age 3-9 are relatively low, and exceeding such a need may not be difficult through use of fortified milks powders, Pediasure® or other fortified beverae use, or even enriched grains, as were noted among daily consumption in this sample. Future research should consider analyzing a full amino acid profile to develop a full protein profile, a capability that is now possible using ESHA® food processing software. This may help decipher the discrepancy between protein overconsumption while findings also revealed limited selections of both milk group foods and meat group foods in this sample. In addition, a larger sample size would improve the statistical power and reduce the effects of outliers, which also contribute to these discrepancies.

This study revealed a high incidence of food aversion or food selectivity with regards to MyPyramid recommendations for the vegetable group and the milk and dairy group, with only 20.8% of participants meeting 80% or more of the recommended servings for either food group. Similarly, a recent study by Herndon et al (17) found that children with ASD consumed significantly less dairy while consuming significantly more non-dairy proteins than neurotypical peers. Johnson et al (40) also found a significantly reduced vegetable intake in children with autism. While these two food groups were

least consumed in this study, less than three-fourths of the sample met 80% of the recommended servings for *any* of the food groups. Ho and Eaves also documented such inadequate intakes, with only 7.4% of 54 children with ASD meeting recommended servings for all food groups (19).

No studies to date have completed a nutrient analysis that included the contribution of dietary supplementation, a practice that is popular in this population. The use of these supplements is not always warranted for the individual and is not always safe. This study suggests that only marginal benefits (in terms of nutrient intakes) were experienced from self-selected dietary supplementation. This indicates that the participants who chose to consume dietary supplements were consuming supplements mismatched for their need. Nutrient deficiencies during childhood, a period of intense growth, can have negative short-term and long-term effects on the child's development and quality of life. The dietitian's role in analyzing the needs of the child with ASD, their dietary deficiencies, and possible areas for needed supplementation is evident.

A limitation of this study is the lack of a control group of age-matched neurotypical peers, inhibiting the ability to determine whether these nutrient deficiencies as well as the overconsumption of protein are representative solely in the ASD population or are actually characteristic of the general population of all children. Another limitation is the inability to fully analyze linolenic acid due to missing nutritional supplements in the ESHA® food database. The small sample size also creates limitations, as the frequency of supplement use and modified diet use may not coincide with true frequencies of use. Extreme outliers in this small sample may affect the deficiencies of some of the nutrients noted.

CONCLUSION

Great variation in food selection patterns and dietary intakes of macro and micronutrients was documented in this sample of children with autism. Areas of concern most prevalent were nutrients lacking that play a role in bone health, digestion and metabolism, and brain health. The health care provider should be aware of characteristics of ASD that may impair nutritional quality and possible deficiencies that may result. Individualized nutrition assessment and counseling, especially regarding the use of appropriate supplementation, may be useful for children with autism.

Study	*ASD (n)*	*Control (n)*	*Dietary Tool*	*Significant Findings*
Raiten & Massaro, 1986	40	34	7-day Diet Record	• ASD group had significantly greater intake of protein, carbohydrates, niacin, thiamin, riboflavin, calcium, phosphorus, and iron ($p<0.02$) • No significant difference in vitamin A, C, or fat.
Ho & Eaves, 1997	54	N/A	3-day Diet Record	• Only 4 subjects with ASD (7.4%) met recommended servings from all food groups. • All subjects had adequate protein intake, but had lower fat intake and higher carbohydrate intake than recommended nutrient intake for Canadians (RNI). • 42.6% of subjects were obese.
Herndon et al, 2009	46	31	3-day Diet Record	• ASD children consumed significantly less calcium but consumed increasingly more Vitamin B6 and E than controls. • ASD children consumed significantly more non-dairy proteins and fewer dairy items. • Both groups did not meet RDI for fiber, calcium, iron, vitamin D, and vitamin E
Lockner et al, 2008	20	20	3-day Diet Record	• Vitamin E and A were the least likely to be met by EAR for both groups • ASD subjects consumed less calcium and fiber, but with no established EAR, significance was not determined
Levy et al, 2007	52	N/A	3-day Diet Record	• The ASD subjects met 95-101% of RDA guidelines for calories, carbohydrates, and fat • ASD subjects over-consumed protein at 211% of RDA with a range of 67-436% RDA among subjects • This study used 77% of RDA consumption as adequate diet • No micronutrients assessed
Schmitt et al, 2008	20	18	3-day Diet Record	• This study defined adequate consumption as >67% of Dietary Reference Intake • Both groups consumed <67% for fiber • ASD group consumed <67% for vitamins E and K
Johnson et al, 2008	19	15	24-hr Recall	• This study considered <80% of RDAs or DRIs as inadequate • ASD group consumed significantly less vitamin K and significantly less food choices from the vegetable group
Lindsay et al, 2006	20	N/A	FFQ	• This study considered <80% of RDAs or DRIs as inadequate • 45% consumed <80% Calcium, 30% consumed <80% pantothenic acid, 25% consumed <80% Vitamin D, 40% consumed <80% Vitamin K

TABLE 4.1 Studies Investigating Nutritional Quality in Children with ASD

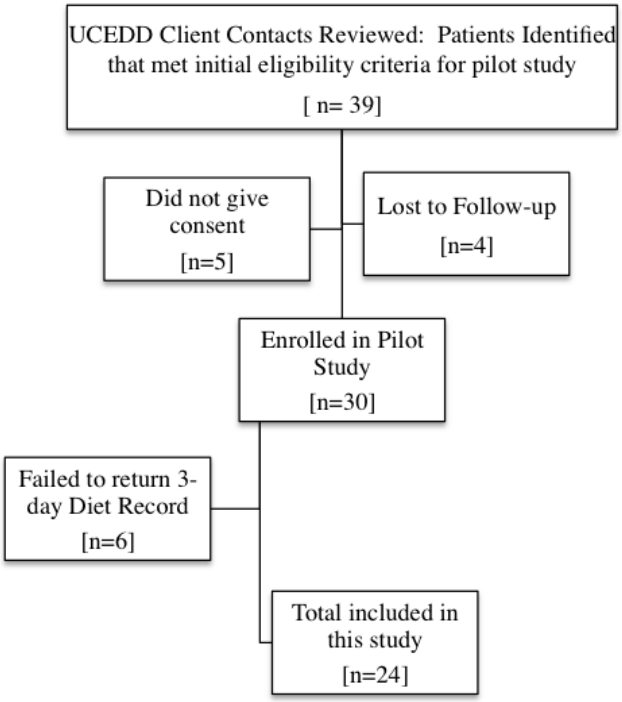

FIGURE 4.1 Participant Flow Chart

Characteristic	N	Mean ± SD
Age (yrs)	24	6.6 ± 1.78
Weight (lb)	24	52.8 ± 15.57
Height (in)	24	47.3 ± 4.25
BMI	24	16.37 ± 3.34*

*Mean BMI is within healthy range of 18.0-24.9

TABLE 4.2 Baseline Anthropometrics of Participants

Nutrient	% ≤ 80% of DRI (n=24)	Mean	Median	Range	DRI	Standard Deviation	Standard Error
Chromium (mcg)	100.0% (24)	1.6	1.5	0.1-3.4	11*, 15**, 21-25***	0.96	0.20
Choline (mg)	95.8% (23)	87.0	55.9	2.5- 387.4	200*, 250**, 375***	83.98	17.14
Molybdenum (mcg)	91.7% (22)	7.4	4.7	0-22.9	**17*, 22**, 34*****	7.36	1.50
Vitamin K (mcg)	91.7% (22)	22.0	16.7	2.5-109.5	30*, 55**, 60***	22.08	4.51
Linoleic Acid (g)	88.5% (21)	4.74	4.66	1.2-11.97	7*, 10**, 12***	2.76	0.56
Dietary Fiber (g)	83.3% (20)	13.8	12.8	4.4-29.5	19*, 25**, 26-31***	6.52	1.33
Iodine (mcg)	83.3% (20)	50.0	46.8	0-200.5	**90*(**), 120*****	51.61	10.54
Linolenic Acid (g)	83.3% (20)	0.45	0.45	0.08-0.93	0.7*, 0.9**, 1.2***	0.23	0.04
Potassium (mg)	83.3% (20)	1938.9	1591.2	907.9-5689.4	3000*,3800**,45000***	1113.60	227.31
MUFA (g)	70.8% (17)	14.4	13.6	6.9-23.2	Varies by Individual	5.45	1.11
Vitamin E (mg)	70.8% (17)	5.2	3.7	0.5-32.9	**6*, 7**, 11*****	6.65	1.36
Manganese (mg)	58.3% (14)	1.6	1.0	0.3-8.3	1.2mg*, 1.5**,1.6-1.9***	1.68	0.34
Vitamin A (RAE)	58.3% (14)	450.7	288.7	68.0-3261.1	**300*, 400**, 600*****	631.44	128.89
Vitamin D (mcg)	58.3% (14)	4.3	3.4	0-13.8	5	3.59	0.73
Biotin (mcg)	54.2% (13)	24.8	7.2	0-204.6	8*, 12**,20***	52.12	10.64
Pantothenic Acid (mg)	54.2% (13)	2.8	2.2	0.9-7.2	2*, 3**, 4***	1.63	0.33
Calcium (mg)	41.7% (10)	820.7	678.4	196.3-2294.8	500*, 800**, 1300***	452.58	92.38
Magnesium (mg)	33.3% (8)	168.5	134.9	36.1-590.1	**80*, 130*, 240*****	115.00	23.48
Selenium (mcg)	33.3% (8)	48.9	51.4	5.4-105.7	**20*, 30**, 40*****	29.42	6.00

DRIs include both Recommended Dietary Allowances (RDAs) in bold and Adequate Intakes (AIs) in regular font
*(ages 1-3),** (ages 4-8),*** (ages 9-13)

TABLE 4.3 Nutrients of Most Concern

Nutrient	% ≤ 80% of DRI (n=24)	Nutrient Function	Food Sources
Chromium	100.0% (24)	Glucose metabolism	Corn oil, clams, whole-grain cereals, brewer's yeast, meats
Choline	95.8% (23)	Phospholipid and neurotransmitter synthesis	Eggs, liver, legumes, pork
Molybdenum	91.7% (22)	Oxidation-reduction activity	Legumes, whole grain cereals, dark green, leafy vegetables, organ meats
Vitamin K	91.7% (22)	Bone and tooth formation, blood coagulation	Dark, green vegetables, fish, legumes
Linoleic Acid	88.5% (21)	An essential Om-3 fatty acid that is required for proper functioning of all physiological systems; can also be converted to other fatty acids needed by the body such as aracidonic acid	Nuts, corn, safflower, soybean, cottonseed, sunflower seeds, and peanut oil
Dietary Fiber	83.3% (20)	Maintains low serum and LDL cholesterol levels, bowel regularity	Whole grains, bran, wheat, oats, barley, legumes, fruits, vegetables, and some edible seeds such as flax
Iodine	83.3% (20)	Synthesis of thyroid hormones	Iodized salt, seafood, may exist in vegetables grown soil high in iodide
Linolenic Acid	83.3% (20)	An essential Om-6 fatty acid that is required for proper functioning of all physiological systems; can also be converted to other fatty acids needed by the body such as EPA and DHA	Canola, soybean, flaxseed, and other seed oils
Potassium	83.3% (20)	Maintains fluid balance, muscle function, nerve function, energy metabolism	Potatoes, bananas, tomatoes, oranges, legumes, dairy products
MUFA	70.8% (17)	Provides energy, facilitates digestion and is essential for absorption of fat-soluble vitamins and phytochemicals, maintains low serum and LDL cholesterols and triglycerides	Butterfat, some fish oils, olive oil, canola oil
Vitamin E	70.8% (17)	Antioxidant, eye health, heart health	Vegetable oil, nuts, seeds
Manganese	58.3% (14)	Cofactor for metalloenzymes, involved in bone formation and glucose production	Whole grains, pineapple, nuts, legumes
Vitamin A	58.3% (14)	Bone health, immune system, cell differentiation, reproduction, vision	Dairy products, organ meats, fatty fish, liver

TABLE 4.4 Nutrients of Concern and Physiologic Functions and Food Sources.

Nutrient	% ≤ 80% of DRI (n=24)	Nutrient Function	Food Sources
Vitamin D	58.3% (14)	Calcium homeostasis, bone health, cell differentiation, gene expression, cancer protection	Milk, egg yolks, fish oils, mushrooms
Biotin	54.2% (13)	Coenzyme, energy metabolism, regulation of gene expression	Peanuts, almonds, mushrooms, egg yolks, tomatoes
Pantothenic Acid	54.2% (13)	Carbohydrate, fat, and protein metabolism, energy production	Present in all plant and animal tissues
Calcium	41.7% (10)	Bone health, intracellular messenger	Dairy products
Magnesium	33.3% (8)	Bone formation, energy metabolism	Green, leafy vegetables, seafood, legumes, dairy products, chocolate, whole grains
Selenium	33.3% (8)	Fat metabolism, antioxidant	Grains, onions, meats, milk, varying amounts in vegetables depending on soil content

TABLE 4.4 Nutrients of Concern and Physiologic Functions and Food Sources. (continued)

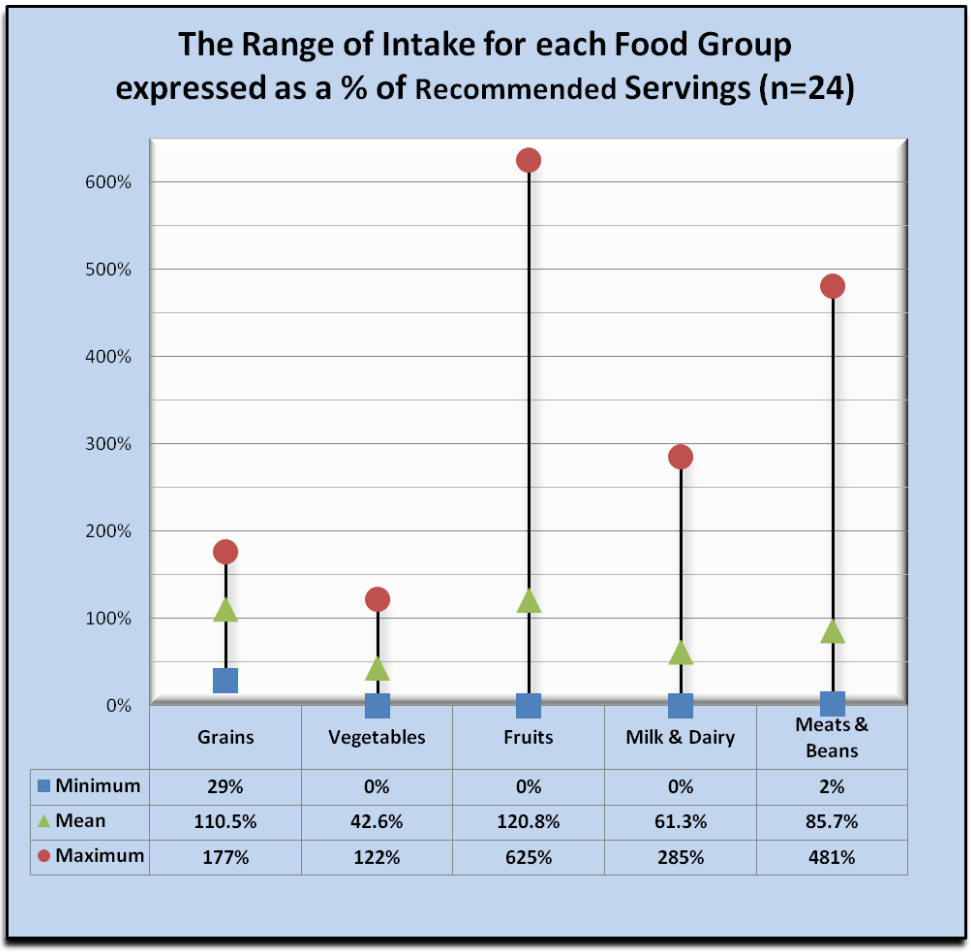

Figure 4.2 Mean, Minimum, and Maximum Distributions of Food Selections as a Percentage of MyPyramid Recommended Servings

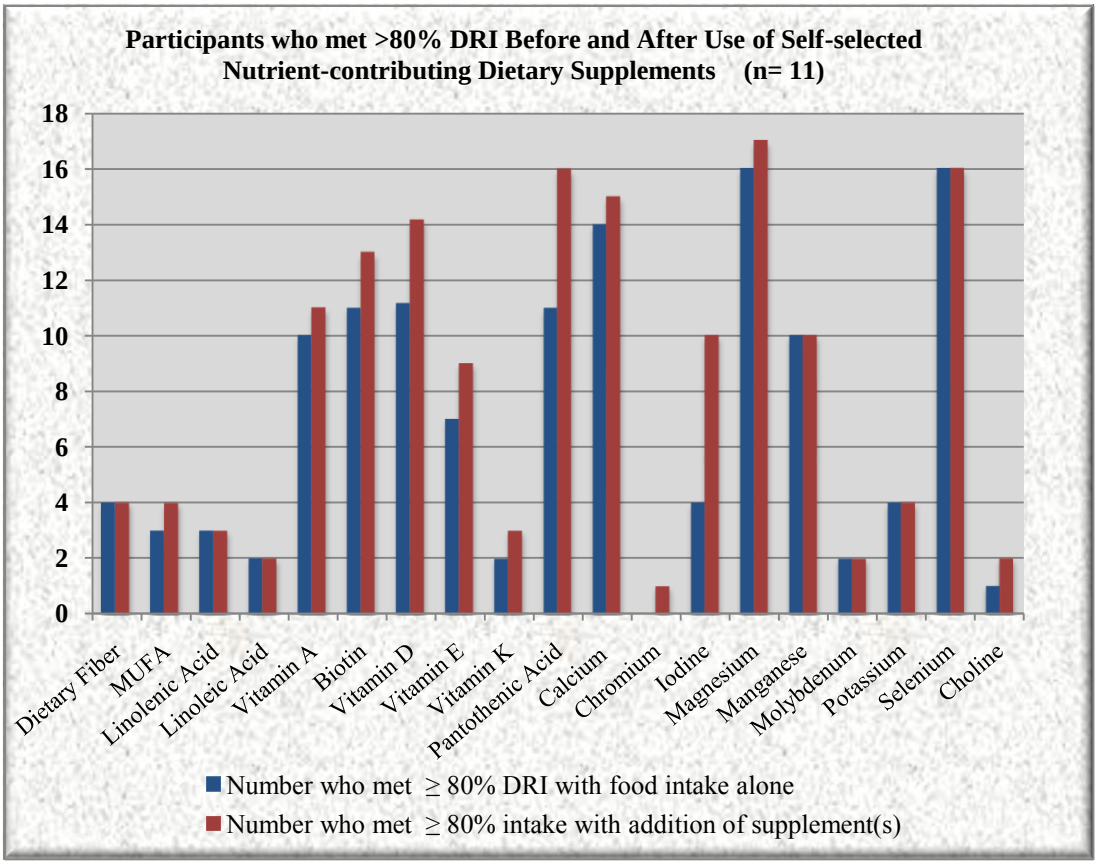

Figure 4.3 Nutrient Improvements after Self Supplementation.

CHAPTER 5

SUMMARY AND CONCLUSIONS

RESULTS SUMMARY

This study revealed inadequate dietary intakes for a wide range of micronutrients in this sample of children with autism, especially nutrients that play a role in bone health, digestion and metabolic pathways, and brain health. Results also revealed limited, suboptimal food choices from the five food groups established by MyPyramid, with foods from the milk/dairy and vegetables groups least consumed in this sample. Modified diets (Gluten avoidance and Gluten-Free, Casein-Free Diet) were reported at a relatively low rate (12.5% or n=3), while use of nutrient-contributing dietary supplement use was reported at a much higher rate (45.8% or n=11). Despite regular use of dietary supplementation in nearly half of the participants, nutrient analysis revealed that benefits from supplementation were marginal.

DISCUSSION

Studies investigating the quality of dietary intakes in children with autism are limited and inconclusive. Several studies have noted an unexpected increase in dietary intakes of select nutrients (8, 17, 19, 20) while other findings have indicated that children with autism generally do not meet dietary needs for a variety of nutrients (14, 17, 19, 39, 40). However, it is difficult to draw conclusions from these findings because of differing

methodologies, including use of, or lack of, a control population of neurotypical peers, varying and limited sample sizes, differing nutrient standards (such as Dietary Reference Intakes, Adequate Intakes only, Recommended Dietary Allowances only, Estimated Average Requirements, or standards developed by other nations), and even varying interpretations of "adequate" versus "inadequate" intakes with regards to established standards. Regardless, several of the findings were consistent with findings from the previous literature, including a trend in limited intakes of bone health nutrients (17, 39, 40) and limited intakes of fiber (14, 17, 39). However, this study revealed two trends not previously identified in the literature—low consumption of nutrients associated with both brain health and digestion/metabolic pathways in children with autism. These trends, as well as the previously documented inadequacies of dietary intakes in bone health nutrients, may have severe implications on the growth and development of these children, and should be investigated further.

The low intakes of a wide range of micronutrients in this study may be explained by limited food selections from the vegetable and milk/dairy groups, with only 5 of 24 participants meeting daily recommended servings from either of these groups. This is consistent with past research. One study showed significantly less food selections from the vegetable group for children with autism as compared to neurotypical peers (40) and another study noted children with autism consumed significantly fewer dairy foods and significantly more non-dairy proteins as compared to neurotypical peers (17). While these food groups may be the most infrequently selected, Ho and Eaves noted that only 7.4% of 54 children with autism met recommendations for all food groups (19), indicating limited intakes across the food pyramid.

Of the 24 participants, 17 participants met recommended daily servings from the grain group, the most highly chosen by participants of all MyPyramid food groups. Foods from the grain group generally provide a plentiful supply of folate, iron, and some of the B vitamins (thiamin, niacin, and riboflavin), as mandated in the fortification process regulated by the U.S. Food and Drug Administration (FDA). This may explain why these nutrients were, on average, consumed in adequate amounts in this sample. However, the FDA does not currently mandate that pantothenic acid and biotin (also B vitamins) are included in the fortification process, and these vitamins were found to be deficient in the diets of this sample, with over half of the participants (54.2%) failing to meet at least 80% of the daily needs for either of these nutrients. It should also be noted that gluten-free products are not currently mandated to follow any of the nutrient fortification or enrichment guidelines, and may be deplete of all of these nutrients. Three participants in this sample reported following a strict gluten avoidance, with two of these participants following a fully implemented Gluten-Free, Casein-Free Diet and one following a gluten avoidance only due to a secondary diagnosis of Celiac Disease. These participants, as well as other participants experiencing a limited variety in their diet, could benefit substantially from dietary supplementation.

Nearly half (45.8%) of the participants in this study reported use of nutrient-contributing dietary supplement. This is consistent with the available literature that estimates that 50-75% of children with autism utilize Complementary and Alternative Medicine (CAM) therapies (13, 29). However, despite the high incidence of use, benefits from dietary supplementation were marginal. Iodine and pantothenic acid intakes improved most through supplementation, with 6 and 5 participants, respectively, meeting

daily needs meeting dietary needs only after supplementation. These findings indicate that dietary supplement use was largely mismatched for the participants' needs. A multivitamin/mineral supplement with iron would improve nutrient intakes across a spectrum of nutrients, but only two participants reported this form of supplementation. However, six caregivers reported frequent use of a gummy multivitamin/mineral without iron.

This study revealed inadequate intakes for a wide range of micronutrients as well as limited, suboptimal numbers of food choices from the five food groups established by MyPyramid in this population of children with autism. However, great variation in both nutrient intakes and food selection was documented in this sample, indicating the need for individualized nutrition assessment and counseling, especially on the use of appropriate supplementation to match actual deficits in the diet. It underscores the need for health care providers to recognize deficient nutrient intakes in this population and to provide efficacious, timely nutrition interventions.

LIMITATIONS AND IMPLICATIONS FOR FURTHER RESEARCH

Limitations of this study include a small sample size and a lack of a control population of neurotypical peers, inhibiting the ability to distinguish whether nutrient intakes are characteristic of the autism population or of children, aged 3-9, in general. Another limitation is that the ESHA® foods database did not contain a children's gummy fish oil supplement, which inhibited the ability to truly analyze the benefits of fish oil supplementation (n=5) on linolenic acid intakes. As 83.3% of this sample failed to meet 80% of the DRI for linolenic acid intakes through the diet, the addition of a gummy fish oil supplement in the ESHA® database could thoroughly improve future research. One

recent paper has suggested there may be a link between omega-3 fatty acids and autism (36), so this topic is evermore pertinent and timely. Finally, ESHA® software now has the ability to determine amino acid profiles among dietary protein sources. This function may improve future research, in that protein quality of dietary intakes in children with autism may be distinguished.

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APPENDIX

Nutrient	*Min*	*Max*	*Mean*	*SD*	*SEM*	*Dietary Reference Intake (DRI)*	*% Met ≥80% DRI*
Calories	1106.3	3514.4	2058.9	635.51	129.72	Varies by individual †	87.5%
Protein (g)	25.2	110.1	60.2	22.62	4.62	**13*, 19**, 34*****	100%
Carbohydrates (g)	137.2	495.23	281.1	81.84	16.70	**130**	87.5%
Dietary Fiber (g)	4.4	29.5	13.8	6.52	1.33	19*, 25**, 26-31***	16.7%
Soluble Fiber (g)	0	2.3	0.6	0.59	0.12	Not Determined	N/A
Total Fat (g)	38.0	160.3	73.9	32.23	6.58	Varies by individual †	87.5%
Saturated Fat (g)	9.2	53.1	23.4	11.41	2.33	Varies by individual †	75%
MUFA (g)	6.9	23.2	14.4	5.45	1.11	Varies by individual †	29.2%
Linolenic Acid (g)	0.08	0.93	0.45	0.24	0.05	0.7*, 0.9**, 1.2***	16.7%
Linoleic Acid (g)	1.2	11.7	4.75	2.76	0.56	7*, 10**, 12***	12.5%
Vitamin A (RAE)	68.0	3261	450.7	631.44	128.89	**300mcg*, 400mcg**, 600mcg*****	41.7%
Beta Carotene (mcg)	4.8	3393	632.5	939.46	191.77	Not Determined	N/A
Thiamin (mg)	0.5	3.6	1.4	0.63	0.13	**0.5*, 0.6**, 0.9*****	100%
Riboflavin (mg)	0.6	5.0	1.7	0.92	0.19	**0.5*, 0.6**, 0.9*****	100%
Niacin (mg)	4.3	51.4	17.3	9.34	1.91	**6*, 8**, 12*****	91.7%
Vitamin B6 (mg)	0.3	4.7	1.6	0.93	0.19	**0.5*, 0.6**, 1.0*****	95.8%
Vitamin B12 (mg)	1.1	6.8	3.6	1.51	0.31	**0.9*,1.2**,1.8*****	100%
Biotin (mcg)	0	204.6	24.8	52.12	10.64	8*, 12**,20***	45.8%
Vitamin C (mg)	5.1	693.5	99.5	133.69	27.29	**15*,25**,45*****	91.7%
Vitamin D (mcg)	0	13.8	4.3	3.59	0.73	5	46.5%
Vitamin E (mg)	0.5	32.9	5.2	6.65	1.36	**6*, 7**, 11*****	29.2%
Folate (mcg)	112.3	703.2	293.1	142.36	29.06	**150*, 200**, 300*****	83.3%
Vitamin K (mcg)	2.5	109.5	22.01	22.08	4.51	30*, 55**, 60***	8.3%

DRIs include both Recommended Dietary Allowances (RDAs) in bold and Adequate Intakes (AIs) in regular font

*(ages 3),** (ages 4-8),*** (ages 9-13)

† Nutrient Software utilized Estimated Energy Requirements (EER) to identify calorie needs, and used calculated DRIs for fat needs as a percentage of calories.

Appendix Table A1 Complete Nutrient Analysis Without Supplementation

Nutrient	*Min*	*Max*	*Mean*	*SD*	*SEM*	*Dietary Reference Intake (DRI)*	*% Met ≥80% DRI*
Pantothenic Acid (mg)	0.9	7.2	2.8	1.63	0.33	2*, 3**, 4***	45.8%
Calcium (mg)	196.3	2294.8	820.7	452.58	92.38	500*, 800**, 1300***	58.3%
Chromium (mcg)	0.1	3.4	1.6	0.96	0.20	11*, 15**, 21-25***	0%
Copper (mg)	0.2	1.4	0.6	0.29	0.06	**0.34*, 0.44**, 0.7*****	79.2%
Fluoride (mg)	0	0.6	0.2	0.21	0.04	0.7*, 1**, 2***	0%
Iodine (mcg)	0	200.5	50	51.61	10.54	**90*(**), 120*****	16.7%
Iron (mg)	4.8	28.6	14.5	6.25	1.28	**7*, 10**, 8*****	91.7%
Magnesium (mg)	36.1	590.1	168.5	115.00	23.48	**80*, 130**, 240*****	66.7%
Manganese (mg)	0.3	8.3	1.6	1.68	0.34	**1.2*, 1.5**,1.6-1.9*****	41.7%
Molybdenum (mcg)	0	22.9	7.4	7.36	1.50	17*, 22**, 34***	8.3%
Phosphorus (mg)	251.4	1924.2	865.5	374.15	76.37	**460*,500**,1250*****	87.5%
Potassium (mg)	907.9	5689.4	1938.9	1113.60	227.31	3000*,3800**,45000***	16.7%
Selenium (mcg)	5.4	105.7	48.9	29.42	6.00	**20*, 30**, 40*****	66.7%
Sodium (mg)	634.2	5674.9	2890.6	1310.00	267.40	1000*, 1200**, 1500***	91.7%
Zinc (mg)	2.5	12.	7.2	2.42	0.49	**3*, 5**, 8*****	91.7%
Omega-3 FA (g)	0.1	1.0	0.4	0.23	0.05	Not Determined	N/A
Omega-6 FA (g)	1.3	12.3	4.8	2.80	0.57	Not Determined	N/A
Choline (mg)	2.5	387.4	87.0	83.98	17.14	200*, 250**, 375***	4.2%

DRIs include both Recommended Dietary Allowances (RDAs) in bold and Adequate Intakes (AIs) in regular font

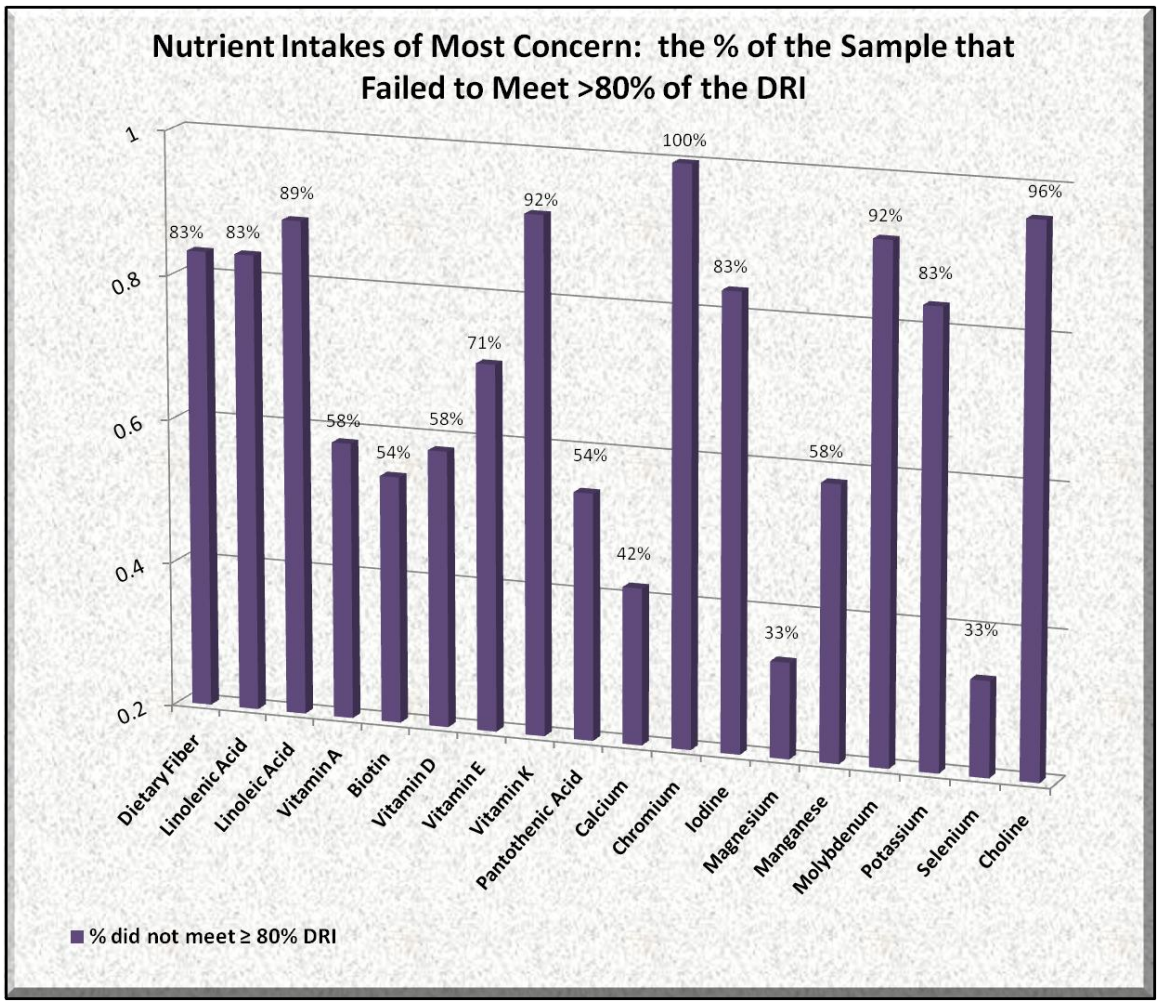
*(ages 3),** (ages 4-8),*** (ages 9-13)

† Nutrient Software utilized Estimated Energy Requirements (EER) to identify calorie needs, and used calculated DRIs for fat needs as a percentage of calories.

Appendix Table A1 Complete Nutrient Analysis Without Supplementation (continued)

Food Groups	% ≥ 80% of recommended servings	Mean (% of recommended servings)	Minimum	Maximum	SD	SEM
Grains	70.8% (n=17)	110.5%	29%	177%	45.93	9.38
Vegetables	20.8% (n=5)	42.6%	0%	122%	36.72	7.49
Fruits	54.2% (n=13)	120.8%	0%	625%	126.37	25.80
Milk & Dairy	20.8% (n=5)	61.25%	0%	285%	58.89	12.02
Meats & Beans	33.3% (n=8)	85.7%	2%	481%	104.84	21.40

Appendix Table A2 Food Selections from the MyPyramid Food Group



Appendix Figure A1 Nutrient Intakes of Most Concern, as % of Participants that do not consume >80% of DRI

Nutrient	% did not meet ≥ 80% DRI, of those who used supplements (n=11)	#Additional MET DRI with Supplement (n=11)	# of Supplement Takers who Increased Intake unnecessarily (already met)
Dietary Fiber	81.82% (n=9)	0	0
MUFA	72.73% (n=8)	1	0
Linolenic Acid	72.73% (n=8)	0	0
Linoleic Acid	81.82% (n=9)	0	0
Vitamin A	45.45% (n=5)	1	1
Biotin	27.27% (n=3)	2	7
Vitamin D	63.64% (n=7)	3	0
Vitamin E	81.82% (n=9)	2	0
Vitamin K	90.91% (n=10)	1	0
Pantothenic Acid	45.45% (n=5)	5	4
Calcium	36.36% (n=4)	1	2
Chromium	100% (n=11)	1	0
Iodine	72.73% (n=8)	5	2
Magnesium	27.27% (n=3)	1	6
Manganese	36.36% (n=4)	0	1
Molybdenum	90.91% (n=10)	0	1
Potassium	81.82% (n=9)	0	0
Selenium	9.09% (n=1)	0	1
Choline	90.91% (n=10)	1	0

Dietary supplements noted in this sample included gummy multivitamin/mineral (n=6), chewable multivitamin/mineral (n=2), liquid multivitamin/mineral (n=1), fish oil/omegat-3 (n=5), calcium citrate (n=2), vitamin K (n=2), zinc (n=1), vitamin B12 lollipop (n=1), amino acid blend (n=1), biotin (n=1), folinic acid (n=1)

Appendix Table A3 Nutrient Intakes met with Self-Supplementation of dietary supplements.