Summer 8-5-2016

Micronutrient Intake in Children Diagnosed with Autism Spectrum Disorder and Food Selectivity

Lisa Janik

ACCEPTANCE

This thesis, MICRONUTRIENT INTAKE IN CHILDREN DIAGNOSED WITH AUTISM SPECTRUM DISORDER AND FOOD SELECTIVITY, by Lisa K. Janik was prepared under the direction of the Master's Thesis Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Master of Science in the Byrdine F. Lewis School of Nursing and Health Professions, Georgia State University. The Master's Thesis Advisory Committee, as representatives of the faculty, certify that this thesis has met all standards of excellence and scholarship as determined by the faculty.

Anita M. Nucci, PhD, RD, LD
Committee Chair

Sarah T. Henes, PhD, RD, LD
Committee Member

Rashelle Berry, MPH, MS, RD, CSP, LD
Committee Member

July 13, 2016
Date

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Lisa Janik
3538 Estates Landing Drive
Kennesaw, GA 30144

The director of this thesis is:

Anita M. Nucci, PhD, RD, LD
Associate Professor
Department of Nutrition
Byrdine F. Lewis School of Nursing and Health Professions
Georgia State University
Atlanta, Georgia 30302

VITA

Lisa Janik

ADDRESS: 3538 Estates Landing Drive

Kennesaw, GA 30144

EDUCATION:

M.S.	8/2016	Georgia State University	Health Sciences
B.A.	5/2001	DePaul University	Psychology

PROFESSIONAL EXPERIENCE:

- Graduate Teaching Assistant — 2015-2016
  Georgia State University, Atlanta, GA
- Professional Development Coordinator — 2008-2013
  Alston & Bird, LLP, Atlanta, GA
- Attorney Hiring & Development Administrative Assistant — 2006-2008
  Alston & Bird, LLP, Atlanta, GA
- Legal Case Clerk — 2005-2006
  Alston & Bird, LLP, Atlanta, GA
- Account Manager, Higher Education Group — 2002 – 2004
  SPSS Inc., Chicago, IL

SUPERVISED PRACTICE:

Completing an ACEND accredited Coordinated Program consisting of 1200 hours of supervised practice with an urban health emphasis.

MEMBERSHIPS:

- Academy of Nutrition and Dietetics — 2014-present
- Greater Atlanta Dietetic Association — 2015-present

ABSTRACT

MICRONUTRIENT INTAKE IN CHILDREN
DIAGNOSED WITH AUTISM SPECTRUM DISORDER AND FOOD SELECTIVITY

by

Lisa Janik

Background: The prevalence of feeding difficulties in children with Autism Spectrum Disorder (ASD) has been observed to be from 46% to 89%. Children who have both ASD and feeding difficulties such as food selectivity may not be meeting their nutritional requirements, particularly micronutrient needs. Previous research that has examined the adequacy of micronutrient intake in this population has been inconsistent.

Objective: The purpose of the study was to examine the micronutrient intake and food group acceptance of a population of children diagnosed with both ASD and food selectivity.

Participants/Setting: A cohort study was conducted in 21 children with a diagnosis of both ASD and food selectivity who were evaluated at the Pediatric Feeding Disorders Program of the Marcus Autism Center between August 2015 and February 2016. Demographic, anthropometric and nutrient intake data from a three-day food record were retrospectively reviewed.

Statistical Analysis: Frequency statistics were used to describe the demographic and anthropometric characteristics of the population as well as compare food group acceptance and micronutrient intake for 28 nutrients to the estimated average requirement (EAR). For those micronutrients that do not have an established EAR, an adequate intake (AI) was used. The Chi-square statistic was used to evaluate the association between food group consumption status and whether or not the child met the EAR/AI for select micronutrients.

Results: The majority of the population were male (91%) with a mean age of 7 $\pm$ 4 years. None of the micronutrient EARs/AIs were met by all children. Less than 50% of the population met the EAR/AI for 11 nutrients while $\geq$50% but <100% of the children met the EAR/AI for 14 nutrients. No child met the EAR/AI for chromium, fluoride or potassium. Children who consumed fruit were significantly more likely to meet the EAR for vitamin C vs. those who did not eat fruit (86% vs. 14%, respectively; p=0.017). No other associations between micronutrient intake and food group acceptance were observed.

Conclusion: Children with ASD and food selectivity may not be meeting the dietary micronutrient intake recommendations. Further studies should be conducted with larger study populations to examine the micronutrient deficiency status of children with ASD and food selectivity.

MICRONUTRIENT INTAKE IN CHILDREN DIAGNOSED WITH AUTISM SPECTRUM DISORDER AND FOOD SELECTIVITY

by

Lisa Janik

A Thesis

Presented in Partial Fulfillment of Requirements for the Degree of

Master of Science in Health Sciences

The Byrdine F. Lewis School of Nursing and Health Professions

Department of Nutrition

Georgia State University

Atlanta, Georgia
2016

ACKNOWLEDGMENTS

I am beyond grateful for the support and guidance that Dr. Anita Nucci provided to me throughout this process. I also owe my thanks to the other members of my thesis committee, Rashelle Berry and Dr. Sarah Henes, for their assistance and feedback during the research and writing of this thesis. Finally, thank you to my family and friends who were supportive during the year that it took to complete this process.

TABLE OF CONTENTS

LIST OF TABLES

Page

ABBREVIATIONS

AI	Adequate Intake
ARFID	Avoidant Restrictive Food Intake Disorder
ASD	Autism Spectrum Disorder
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
cm	centimeter
CHOA	Children's Healthcare of Atlanta
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5^{th} Edition
EAR	Estimated Average Requirement
kg	kilograms
mcg	micrograms
mg	milligrams
RDA	Recommended Dietary Allowance
RNI	Recommended Nutrient Intake

CHAPTER I

MICRONUTRIENT INTAKE IN CHILDREN DIAGNOSED WITH AUTISM SPECTRUM DISORDER AND FOOD SELECTIVITY

INTRODUCTION

Autism Spectrum Disorder (ASD) is a term used to describe a group of disorders, including autistic disorder, childhood disintegrative disorder, pervasive developmental disorder-not otherwise specified and Asperger syndrome.[1–3] Prior to May 2013, the term ASD did not apply to this entire group of disorders and each disorder was recognized individually.[1] ASD was first used to describe this group of disorders in the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). According to the DSM-5, a diagnosis of ASD requires both of the following: "…deficits in social communication and social interaction and restricted repetitive behaviors, interests, and activities." [4] Symptoms of ASD begin to appear in early childhood and the most recent estimates indicate that 1 in 68 children have ASD.[1–3]

Children with ASD may also display feeding difficulties, including refusing foods, eating a limited variety of foods, and eating too much of certain foods.[5,6] The two feeding difficulties that are most frequently seen in children with ASD are "food selectivity and low rates of overall acceptance...".[7] Based on descriptive studies, the prevalence of feeding difficulties in children with ASD has been found to be anywhere from 46% to 89%.[7,8] There is a concern that children who have both ASD and feeding difficulties may not be meeting their dietary needs, including their micronutrient needs.[7] However, despite the potential detrimental health effects of micronutrient deficiencies, and the possible effect of food selectivity on dietary intake, there is little research on these topics specific to the ASD population. Results from the research that has been conducted on dietary intake, micronutrient status and food selectivity in those with ASD has not reached a consensus. In fact, the results of many studies have contradicted one another. One possible reason for this contradiction is the lack of a standardized definition of food selectivity.[9] Another possible issue is that some studies examining autistic children have not distinguished between those who have food selectivity and those who don't.[10] Finally, relying on caregiver report of food consumption may produce inaccurate results.[11] There also does not seem to be much research that has examined dietary intake and micronutrient status in children who have been officially diagnosed by medical professionals with both ASD and food selectivity.[8]

Marcus Autism Center, a subsidiary of Children's Healthcare of Atlanta (CHOA), is a not-for-profit organization that treats children diagnosed with ASD and related disorders. One service line of the Marcus Autism Center is the Pediatric Feeding Disorders Program. The Pediatric Feeding Disorders Program conducts multidisciplinary assessments to diagnose feeding disorders and provides treatment to children, both with and without autism spectrum disorder, who have been diagnosed with feeding disorders. Marcus Autism Center describes their criteria for diagnosis as follows, "A pediatric feeding disorder is diagnosed when children fail to consume an adequate quantity or quality of solids or liquids to sustain growth."[12] Marcus Autism Center classifies this diagnosis as either medical or behavioral. The term for the medical diagnosis is Feeding Difficulties and Mismanagement (code R63.3), while the behavioral diagnosis is referred to as Avoidant Restrictive Food Intake Disorder (ARFID). According to the DSM-5 the diagnosis of ARFID is "An eating or feeding disturbance (e.g., apparent lack of interest in eating or food; avoidance based on the sensory characteristics of food; concern about aversive consequences of eating) as manifested by persistent failure to meet appropriate nutritional and/or energy needs associated with one (or more) of the following: Significant weight loss (or failure to achieve expected weight gain or faltering growth in children); Significant nutritional deficiency; Dependence on enteral feeding or oral nutritional supplements; Marked interference with psychosocial functioning."[13]

Micronutrients are substances including vitamins and minerals that are required in small amounts and are essential for proper growth and development.[14] They are found in foods and beverages, either naturally or as part of fortification. Deficiencies of vitamins and minerals can cause serious health issues. A deficiency of iron, which is a mineral, can lead to anemia, which can have a negative impact on cognition and immunity.[15] If an individual is deficient in vitamin D or calcium, which is a mineral, bones may not be strong and might be more likely to break.[16-17] The micronutrient intake of children with ASD and food selectivity as well as the adequacy of micronutrient intake compared to recommended dietary intake guidelines in this population is unknown. In addition, we do not yet know how food group acceptance affects the adequacy of micronutrient intake in children with ASD and food selectivity. The purpose of this study was to evaluate the adequacy of the micronutrient intake of children at the Marcus Autism Center who were diagnosed with ASD and food selectivity. Because of the importance of micronutrients to health, we wanted to examine all micronutrients that had either an Estimated Average Requirement (EAR) or Adequate Intake (AI).We examined anthropometric parameters as well as the number of food groups represented in the diet and the micronutrient intake of children in the population. Food group and micronutrient intake was compared with recommended dietary guidelines and the EAR or AI for age and gender. We also examined the association between food group and micronutrient intake for common nutrients found in each food group in this population.[18]

Specific Aim 1: Compare the micronutrient intake of children with ASD and food selectivity with recommended dietary intake guidelines.

Research Hypothesis 1: Micronutrient intake will be lower than recommended dietary intake guidelines children in children with ASD and food selectivity

Null Hypothesis 1: There will be no difference between micronutrient intake and recommended dietary intake guidelines in children with ASD and food selectivity

Specific Aim 2: Examine the association between the number of food groups represented in the diet and micronutrient intake in children with ASD and food selectivity.

Research Hypothesis 2: Food group acceptance by children with ASD and food selectivity will be associated with meeting micronutrient intake requirements for common nutrients found in each food group

Null Hypothesis 2: No association will be observed between food group acceptance by children with ASD and food selectivity and micronutrient intake for common nutrients found in each food group

CHAPTER II

LITERATURE REVIEW

Autism Spectrum Disorder

Before ASD became the term used to describe autistic disorder, childhood disintegrative disorder, pervasive developmental disorder-not otherwise specified and Asperger syndrome, these disorders were identified separately.[1] Therefore, in much of the research that has been conducted, the subjects are identified as having one of these specific disorders, such as Asperger syndrome, rather than the blanket diagnosis of ASD. Individuals with ASD may display difficulties with communication and socialization, as well as a tendency towards routine and repetition.[1] While each of these disorders includes aspects of these symptoms, the distinguishing factor has to do with the gravity of the symptoms.[4] In autistic disorder issues with communication, socialization, routine and repetition develop by the age of three.[19] In contrast, children with childhood disintegrative disorder develop communication and socialization skills, but those skills disappear around age three or four.[20] Children with pervasive developmental disorder-not otherwise specified may not have all of the symptoms of autistic disorder or their symptoms may not be as severe.[21] Finally, children with Asperger syndrome may have the same symptoms as those with autistic disorder, but be better able to function.[22]

Food Selectivity and Dietary Intake in Children with ASD

Many researchers have noted that there is no standard definition of food selectivity.[5,6] Food selectivity has been considered to include picky eating, refusal of food, lack of variety of foods eaten, and food preferences based on the type, texture or color of the food.[5,7] Several studies have attempted to define food selectivity. In a study by Bandini et al. (2010), the definition included three separate components: "food refusal, limited food repertoire, and high frequency single food intake".[5] The study found that, compared to typically developing children, children with ASD had higher levels of food refusal and a more limited amount of foods eaten. Schreck et al. (2004) compared the dietary intake of 138 children with ASD with a control group of 298 children.[11] Compared to the children in the control group, children with ASD consumed fewer foods from each of the following food groups: fruits, dairy, vegetables, proteins and starches. This study found that children with ASD have more feeding problems than typically developing children. In a later study by Schreck and Williams (2006), that expanded on the data obtained from the 2004 study, foods that were accepted by more than 50% of the children with autism were identified and categorized into food groups.[23] These groups included fruits, juices, vegetables, proteins, starches and dairy. The food groups with the most individual foods accepted included proteins and starches, while the food groups with the least amount of individual foods accepted were vegetables, dairy, juices and fruits.

Emond et al. (2010) evaluated seventy-nine children with ASD compared to 12,901 children in a control group, those with ASD were found to consume fewer vegetables and fresh fruits.[24] The children with ASD also ate a lower variety of foods than those in the control group. However, despite these findings, the researchers did not find a difference in the amount of carbohydrates, fats and proteins consumed between the children with ASD and the children in the control group. Ho et al. (1997) conducted a study of 54 children in Canada who met the criteria for ASD; researchers evaluated a three-day food record to compare their intake of macronutrients to Recommended Nutrient Intake.[25] Recommended Nutrient Intake (RNI) is the Canadian equivalent of the United States' Recommended Dietary Allowance (RDA). The researchers also wanted to see if the children were consuming proper quantities of food from each food group. They found that protein intake was sufficient overall, while carbohydrate intake was high and fat intake was low. For the food groups, only 7% met recommendations for bread/cereal, milk/dairy, meat/alternates and fruits/vegetables.

Sharp et al. (2011) conducted a retrospective chart review of 13 children who participated in the Pediatric Feeding Disorders Program at Marcus Autism Center.[7] The children were all confirmed to have both ASD and food selectivity. In addition to direct observation, three-day food diaries, as well as a list of commonly accepted foods were reviewed for the children. Before participating in the treatment program, the children did not have a high acceptance of foods from the fruit, vegetable or protein groups. However, after treatment, the amount of foods accepted increased, including foods from those groups.

Micronutrient Status in Children with ASD

<u>Serum Micronutrient Levels</u>

Latif et al. (2002) examined the iron status of fifty-two children with autism and forty-four children with Asperger syndrome.[26] Evaluation of iron status was conducted using full blood count. Measurements of serum ferritin were also examined, although this measurement was not available for all children. The study found that six of the children who were autistic and two of the children with Asperger syndrome had iron deficiency anemia. Twelve of the twenty-three autistic children who had serum ferritin measurements available were iron deficient. Three of the twenty-two children with Asperger syndrome who had serum ferritin measurements available were iron deficient. The researchers concluded that iron deficiency is a significant issue for children with ASD and that the deficiency could be a result of food selectivity.

Micronutrient Intake

In a study by Shearer et al. (1982) a three-day food record of twelve children with ASD was evaluated to determine the status of niacin, thiamin, riboflavin, ascorbate, Vitamin A, calcium, phosphorous and iron.[27] The children's intake, based on the three-day food record, was compared to the RDA for those micronutrients. The results indicated that the children were near or above the RDA for all micronutrients studied, with the lowest levels of calcium (92 ± 10, as a percent of RDA) and thiamin (103 ± 7, as a percent of RDA). From these results the researchers concluded that children with ASD were consuming a diet that provided sufficient amounts of micronutrients. However, they did recognize that children with ASD were more likely to experience issues with obtaining sufficient nutrition as a result of their preferences related to food. In a retrospective chart review of 13 children with ASD conducted by Sharp et al. (2011), the researchers found "…most participants missing key vitamins (e.g., B-6, E, pantothenic acid, folate) and minerals (e.g., copper, magnesium, potassium)."[7]

A Canadian study by Ho et al. (1997) of 54 children with ASD examined the three-day food record of children with ASD and compared the micronutrient intake to

RNI.[25] Some of the children were taking vitamin and mineral supplements, which could have skewed the results of the study. Eighteen of the children who were receiving some form of supplementation met RNI. However, 18 children who were not receiving calcium supplementation had a low intake of calcium. Three children were found to have low levels of serum iron. The researchers identified calcium and iron as the two micronutrients that were lacking for some of the children. In a study by Bandini et al. (2010) that examined food selectivity and micronutrient status, the researchers evaluated three-day food records of 53 children with ASD.[5] The researchers compared the intake of calcium, vitamin A, vitamin C, vitamin D, vitamin E, zinc and iron to the EAR or AI for that particular micronutrient. The highest levels of inadequacy were found for vitamin D, vitamin E and calcium. 79.2% did not meet the EAR or AI for vitamin D, 62.5% did not meet the EAR or AI for vitamin E and 64.6% did not meet the EAR or AI for calcium. The researchers concluded that these inadequacies could be related to the limited number of foods consumed by the children with ASD. A study by Schmitt et al. (2008) examined the nutrient intake of 20 children with ASD and 18 children without ASD who served as a control group.[28] Parents of all children completed a questionnaire, which included questions about nutrition, as well as a three-day food record. Researchers compared the food intake to the RDA and reported that the autistic children only had insufficient intakes of vitamins E and K.

CHAPTER III

METHODS

Sample Population

The study population included all children with a diagnosis of both food selectivity and autism spectrum disorder who were evaluated at the Pediatric Feeding Disorders Program of Marcus Autism Center between August 2015 and February 2016 as participants of the IRB approved "Dietary Diversity and Feeding Behavior of Children with Pediatric Feeding Disorders Before and After Admission to an Interdisciplinary Feeding Disorders Treatment Program" study. De-identified patient data was extracted from the study database of Children's Healthcare of Atlanta, Marcus Autism Center by The Marcus Autism Center Lead Nutritionist. The de-identified data was entered into a SPSS database. To ensure privacy and confidentiality, patients were assigned a unique and random numeric identification code. Non-human subjects' research approval was requested and approved from Georgia State University IRB.

Study Design

The design of this study is a retrospective cohort study. The study data provided by the Lead Nutritionist included demographic data (age, gender) and anthropometric data (length or height in cm, weight in kg). Body mass index (BMI) was calculated using the weight and length or height measurements. The data provided also included the foods usually accepted by the child, current medications and supplements and a three-day food record. The number of food groups represented in the diet and micronutrient intake was determined for each child.

Data Analysis

Analysis of the three-day food record was conducted using Food Processor Nutrition Analysis software (ESHA Research, Oregon). The demographic, anthropometric and food as well as nutrient intake of the population was described using frequency statistics. Normality statistics were conducted to determine the appropriate measure of central tendency for reporting purposes. Frequency statistics were used to compare micronutrient intake to the EAR. For those micronutrients that did not have an established EAR, an AI was used. The EAR or AI value was determined by life stage groups that are specified by the Food and Nutrition Board of the Institute of Medicine.[29] Frequency statistics were used to determine the number of children who met the EAR or AI by whether or not a food group was consumed. Not all food groups are good sources of each micronutrient. For example, the fruit group is a good source of vitamin C while the protein group is a good source of iron. Five of the most common micronutrients provided by each food group were identified using a nutrition reference text.[18] The common micronutrients provided by these food groups were examined individually to determine if consuming the food group led to meeting the EAR or AI of that micronutrient. The growth percentiles of the children were plotted using the Centers for Disease Control and Prevention (CDC) growth charts for children 2 to 20 years of age. The children were plotted for weight-for-age, stature-for-age and calculated BMI-for-age. A BMI plotted between the 5th percentile to less than the 85th percentile was considered to be a healthy weight. A BMI plotted between the 85th percentile and less than the 95th percentile was considered overweight. A BMI plotted at equal to or greater than the 95th percentile was considered obese.[30] All statistical analyses were performed using SPSS (version 22.0, IBM Corporation, Armonk, New York)

CHAPTER IV

RESULTS

The demographic and anthropometric characteristics of the population are shown in Table 1. The vast majority of the study population was male (90.5%) with a mean age of 7 ± 4 years (range, 2 to 17 years). Approximately half (57%) of the children had a BMI within the healthy range. Of the children in the study, 19% were overweight and 19% were obese. Only one child (5%) was underweight.

Table 1: Demographic and Anthropometric Characteristics of the Total Population

Characteristic	**Total Population (N=21)**
Age (years)*	7 ± 4
Gender [n (%)]	
Male	19 (90.5)
Female	2 (9.5)
Weight (kg)*	27.1 ± 13.1
Height (cm)*	121.0 ± 22.8
BMI (kg/m^2)*	17.6 ± 2.7

*Mean ± SD
kg – kilograms, cm – centimeters

The micronutrient intake of the total population can be found in Appendix A. The micronutrients selected represent those measured by the Food Processor software program that have an EAR or AI. The results are provided as either mean ± standard deviation or as the median with associated interquartile ranges of 25% and 75% based on the outcome of normality testing. The percentage of children who met the EAR or AI for each micronutrient subdivided by age group is shown in Table 2. None of the micronutrient EARs or AIs were met by all children in all of the age groups. Fewer than 50% of the population met the EAR/AI for 11 nutrients while $\geq$50% but <100% of the children met the EAR/AI for 14 nutrients. No child met the EAR/AI for chromium, fluoride or potassium. Eight children were receiving either a multivitamin, multivitamin with iron or other mineral supplement.

Table 2: Percentage of the Population that Met the Estimated Average Requirement or Adequate Intake

Nutrients* [n (%)]	Age Group			
	1 – 3 years (n=4)	**4 – 8 years (n=10)**	**9 – 13 years (n=5)**	**14 – 18 years (n=2)**
Vitamin A (mcg)	4 (100)[1]	5 (50)[3]	2 (40)[1]	0 (0)
Vitamin B1 (mg)	3 (75)[1]	10 (100)[5]	2 (40)[1]	1 (50)
Vitamin B2 (mg)	4 (100)[1]	9 (90)[5]	2 (40)[1]	1 (50)
Vitamin B3 (mg)	3 (75)[1]	8 (80)[5]	3 (60)[1]	1 (50)
Vitamin B6 (mg)	4 (100)[1]	8 (80)[5]	3 (60)[1]	1 (50)
Vitamin B12 (mcg)	4 (100)[1]	6 (60)[2]	3 (60)[1]	1 (50)
Biotin (mcg)**	2 (50)	2 (22) [n=9]	0 (0) [n=3]	1 (50)
Vitamin C (mg)	4 (100)[1]	7 (70)[4]	2 (40)	1 (50)
Vitamin D (mcg)	0 (0)	3 (30)[1]	0	1 (50)
Vitamin E (mg)	1 (25)[1]	1 (10)[1]	2 (40)	0 (0)
Folate (mcg)	1 (25)[1]	4 (40)[2]	1 (20)[1]	0 (0)
Vitamin K (mcg)**	0 (0)	1 (10)[1]	0 (0)	0 (0)
Pantothenic Acid (mg)**	2 (50)[1]	5 (50)[2]	0 (0)	0 (0)
Calcium (mg)	3 (75)[1]	3 (30)[1]	0 (0)	1 (50)
Chromium (mcg)**	0 (0)	0 (0) [n=7]	0 (0)	0 (0)

*Estimated Average Requirement unless otherwise noted, **Adequate Intake
[1]one child was taking a supplement, [2]two children were taking a supplement, [3]three children were taking a supplement, [4]four children were taking a supplement, [5]five children were taking a supplement
mcg – micrograms, mg – milligrams

Table 2: Percentage of Population that Met the Estimated Average Requirement or Adequate Intake (continued)

Copper (mg)	3 (75)[1]	8 (80)[5]	0 (0)	0 (0)
Fluoride (mg)**	0 (0)	0 (0) [n=8]	0 (0)	0 (0)
Iodine (mcg)	2 (50)	3 (43) [n=7][1]	1 (33) [n=3]	1 (50)
Iron (mg)	4 (100)[1]	10 (100)[5]	4 (80)[2]	2 (100)
Magnesium (mg)	4 (100)[1]	7 (70)[4]	0 (0)	0 (0)
Manganese (mg)**	2 (50)[1]	4 (40)[4]	0 (0)	1 (50)
Molybdenum (mcg)	0 (0)	3 (60) [n=5]	0 (0) [n=3]	0 (0)
Phosphorous (mg)	3 (75)[1]	8 (80)[5]	0 (0)	1 (50)
Potassium (mg)**	0 (0)	0 (0)	0 (0)	0 (0)
Selenium (mcg)	3 (75)[1]	10 (100)[5]	1 (20)	1 (50)
Sodium (mg)**	4 (100)[1]	9 (90)[4]	4 (80)[1]	2 (100)
Zinc (mg)	4 (100)[1]	6 (60)[4]	1 (20)	0 (0)
Choline (mg)**	0 (0)	1 (10)	0 (0)	0 (0)

*Estimated Average Requirement unless otherwise noted, **Adequate Intake
[1]one child was taking a supplement, [2]two children were taking a supplement, [3]three children were taking a supplement, [4]four children were taking a supplement, [5]five children were taking a supplement
mcg – micrograms, mg – milligrams

Food group acceptance for each food group is shown in Table 3. No food group was universally accepted by all children in this study. All but one child accepted foods from the grain group. The vegetable group had the lowest rate of acceptance, with approximately half (52.4%) of the children not accepting foods from that group.

Table 3: Percent Acceptance of Each Food Group in the Total Population

Food Group	**Accepts** **[n (%)]**	**Does Not Accept** **[n (%)]**
Fruit	14 (66.7)	7 (33.3)
Protein	18 (85.7)	3 (14.3)
Grain	20 (95.2)	1 (4.8)
Vegetable	10 (47.6)	11 (52.4)
Dairy	14 (66.7)	7 (33.3)

Tables 4 – 8 show five micronutrients that are commonly obtained from each food group and whether or not there was an association between food group acceptance status and adequacy of micronutrient intake. Of the children who consumed fruit, 12 of 14 (86%), met the EAR for vitamin C vs. only 2 of 7 who did not consume fruit ($p=0.017$). No other significant associations were observed.

Table 4: Adequacy of Micronutrient Intake by Fruit Food Group Acceptance

Micronutrient EAR or AI Status	Accepted* n=14	Did Not Accept* n=7	P-value
Vitamin A			
Met	8 (38.1)	3 (14.3)	0.659
Did Not Meet	6 (28.6)	4 (19)	
Vitamin C			
Met	12 (57.1)	2 (9.5)	**0.017**
Did Not Meet	2 (9.5)	5 (23.8)	
Folate			
Met	3 (14.3)	3 (14.3)	0.354
Did Not Meet	11 (52.4)	4 (19)	
Manganese			
Met	5 (23.8)	2 (9.5)	1.00
Did Not Meet	9 (42.9)	5 (23.8)	
Potassium			
Met	0 (0)	0 (0)	**
Did Not Meet	14 (66.7)	7 (33.3)	

EAR – estimated average requirement, AI – adequate intake
*n (%)
**No statistics computed because the value is a constant

Table 5: Adequacy of Micronutrient Intake by Protein Food Group Acceptance

Micronutrient EAR or AI Status	Accepted* n=18	Did Not Accept* n=3	P-value
Vitamin B3			
Met	13 (61.9)	2 (9.5)	1.00
Did Not Meet	5 (23.8)	1 (4.8)	
Vitamin B6			
Met	14 (66.7)	2 (9.5)	1.00
Did Not Meet	4 (19)	1 (4.8)	
Vitamin B12			
Met	11 (52.4)	3 (14.3)	0.521
Did Not Meet	7 (33.3)	0 (0)	
Iron			
Met	17 (81)	3 (14.3)	1.00
Did Not Meet	1 (4.8)	0 (0)	
Zinc			
Met	9 (42.9)	2 (9.5)	1.00
Did Not Meet	9 (42.9)	1 (4.8)	

EAR – estimated average requirement, AI – adequate intake
*n (%)

Table 6: Adequacy of Micronutrient Intake by Grain Food Group Acceptance

Micronutrient EAR or AI Status	Accepted* n=20	Did Not Accept* n=1	P-value
Vitamin B1			
Met	15 (71.4)	1 (4.8)	1.00
Did Not Meet	5 (23.8)	0 (0)	
Vitamin B2			
Met	15 (71.4)	1 (4.8)	1.00
Did Not Meet	5 (23.8)	0 (0)	
Vitamin B6			
Met	15 (71.4)	1 (4.8)	1.00
Did Not Meet	5 (23.8)	0 (0)	
Selenium			
Met	14 (66.7)	1 (4.8)	1.00
Did Not Meet	6 (28.6)	0 (0)	
Zinc			
Met	10 (47.6)	1 (4.8)	1.00
Did Not Meet	10 (47.6)	0 (0)	

EAR – estimated average requirement, AI – adequate intake
*n (%)

Table 7: Adequacy of Micronutrient Intake by Vegetable Food Group Acceptance

Micronutrient EAR or AI Status	Accepted* n=10	Did Not Accept* n=11	P-value
Vitamin A			
Met	5 (23.8)	6 (28.6)	1.00
Did Not Meet	5 (23.8)	5 (23.8)	
Vitamin E			
Met	2 (9.5)	2 (9.5)	1.00
Did Not Meet	8 (38.1)	9 (42.9)	
Vitamin K			
Met	0 (0)	1 (4.8)	1.00
Did Not Meet	10 (47.6)	10 (47.6)	
Magnesium			
Met	6 (28.6)	5 (23.8)	0.670
Did Not Meet	4 (19)	6 (28.6)	
Potassium			
Met	0 (0)	0 (0)	**
Did Not Meet	10 (47.6)	11 (52.4)	

EAR – estimated average requirement, AI – adequate intake
*n (%)
**No statistics computed because the value is a constant

Table 8: Adequacy of Micronutrient Intake by Dairy Food Group Acceptance

Micronutrient EAR/AI Status	Accepted* n=14	Did Not Accept* n=7	P-value
Vitamin A			
Met	9 (42.9)	2 (9.5)	0.183
Did Not Meet	5 (23.8)	5 (23.8)	
Vitamin B12			
Met	10 (47.6)	4 (19)	0.638
Did Not Meet	4 (19)	3 (14.3)	
Vitamin D			
Met	3 (14.3)	1 (4.8)	1.00
Did Not Meet	11 (52.4)	6 (28.6)	
Calcium			
Met	6 (28.6)	1 (4.8)	0.337
Did Not Meet	8 (38.1)	6 (28.6)	
Phosphorous			
Met	9 (42.9)	3 (14.3)	0.397
Did Not Meet	5 (23.8)	4 (19)	

EAR – estimated average requirement, AI – adequate intake
*n (%)

CHAPTER V

DISCUSSION

The purpose of this study was to examine the micronutrient intake of children diagnosed with both ASD and food selectivity. The micronutrient intake of the children in this study was compared to both recommended dietary guidelines as well as the food groups accepted by the children. The majority of the children did not meet their overall micronutrient needs. In particular, older children (9 – 18 years of age) were less likely to meet the recommended dietary guidelines than younger children (1 – 8 years of age). In general, micronutrient intake in our population was not consistent with recommended dietary intake guidelines. Therefore, we reject null hypothesis 1 that there will be no difference between micronutrient intake and recommended dietary intake guidelines in children with ASD and food selectivity.

A higher percentage of children who accepted foods from the protein, grain and dairy groups were more likely to meet the EAR or AI for some of the common micronutrients found in those foods than children that did not accept foods from those groups. For example, children who accepted protein were more likely to meet iron requirements, children who accepted grains were more likely to meet vitamin B1 requirements and children who accepted dairy were more likely to meet vitamin B12 requirements. However, these associations were not statistically significant. The percentages of children who accepted foods in the fruit and vegetable group and also met requirements for the common micronutrients were low. Notably, no child met the requirements for potassium, even though 67% of the children accepted fruit. There are a number of possible explanations for that result, including that consumption of fruit overall may have been limited or that the fruit consumed was not a good source of potassium. When we examined the association between adequacy of micronutrient intake (met vs. did not meet the dietary guidelines) and food group acceptance (accepted vs. not accepted), the only significant relationship found was with the acceptance of fruit and adequate vitamin C intake. Therefore, we fail to reject null hypothesis 2 that no association will be observed between food group acceptance by children with ASD and food selectivity and micronutrient intake for the majority of the common nutrients found in each food group. Some children met the EAR or AI of common micronutrients without consuming foods high in those nutrients which may have been due to supplementation.

Over half of the children in this study had a BMI within the healthy range. However, 38% had a BMI that categorized them as either overweight or obese. To explain the high prevalence of overweight/obesity, it is important to look at the foods being consumed by the children in this study. Those foods included pizza, cookies, French fries, chicken nuggets and potato chips, all of which could contribute to weight gain. A study by Schreck et al. (2006) of children with ASD found similar results in terms of food consumption. In that study, some of the foods eaten by the majority of the children included cake, cookies, French fries, pizza and potato chips.[23]

In our study population, the EAR for iron was met by most children (95%). The majority of children in the current study (18 of 21) accepted protein. In addition, many foods are fortified with vitamins and minerals, so it is possible that iron requirements were met through fortified foods as well. In a previous study by Latif et al. (2002), the iron status of fifty-two children with autism and forty-four children with Asperger syndrome was examined.[26] The researchers found that eight of the children had iron deficiency anemia. Of the forty five children who had serum ferritin measurements available, fifteen (33%) were iron deficient. The current study did not include laboratory data. Therefore, we were unable to determine the number of children who were iron deficient. Another study conducted by Shearer et al. (1982) utilized a three-day food diary to evaluate the micronutrient status of niacin, thiamin, riboflavin, vitamin C, and vitamin A, calcium, phosphorous and iron in a population of children with autism.[27] This study compared intake to the RDA for those micronutrients. The RDA is a higher value than the EAR or AI, yet the study still found that the children were near or above the RDA for all micronutrients examined. In our study, most children did not meet the EAR or AI for these micronutrients. One possible explanation for these contradictory findings could be that the children in the previous study were not truly food selective, whereas our study population had been medically diagnosed with food selectivity. Another possible explanation for the divergent results compared to our study could have to do with Shearer et al. (1982) being an older study. The definition and methods of diagnosis of ASD have evolved over time, so the population for their study may not have been similar to ours in terms of ASD. Schmitt et al. (2008) also compared intake to RDA and only found inadequate intakes for vitamin E and K.[28] However, they did report that 45% of the autistic children were taking some form of supplementation, which could have skewed the results.

Sharp et al. (2011), looked at three-day food diaries and lists of foods frequently consumed, as well as gathered data from the observation of 13 children with ASD. They found micronutrient deficiencies, including for “key vitamins (e.g., B-6, E, pantothenic acid, folate) and minerals (e.g., copper, magnesium, potassium).”[7] While our study did find that most or all of the children weren’t meeting requirements for vitamin E, pantothenic acid, folate and potassium, the majority of children in our study were meeting requirements for vitamin B6, magnesium and copper. This variability in findings could be due to the reference intakes used. Our study used EAR or AI, but the reference value used does not seem to be specified in their article. A Canadian study conducted by Ho et al. (1997) evaluated the micronutrient intake of 54 children with ASD.[25] Using a three-day food diary, the researchers compared intake of energy, carbohydrate, protein, fat and select vitamins and minerals with the RNI. Approximately one-third (n=18) of the children were receiving vitamin/mineral supplementation and met the RNI for all nutrients examined, while eighteen children who were not taking calcium supplements had a low intake of calcium and three children had low intake levels of iron. Eight of the children in our study were receiving vitamin/mineral supplementation, but those children did not meet the EAR or AI for all micronutrients. It is possible that the children in the Canadian study were taking more supplements or supplements that contained higher levels of micronutrients. In a study by Bandini et al. (2010) the three-day food diaries of 53 children with ASD were analyzed and the intake of calcium, vitamin A, vitamin C, vitamin D, vitamin E, zinc and iron were compared the corresponding EAR or AI.[5] The micronutrients least likely to have met the recommended requirements were vitamin D, vitamin E and calcium with only 20.8%, 37.5%, and 35.4% of the population meeting the requirements, respectively. In the current study, fewer children met the EAR for these nutrients (19%, 19% and 33%, respectively). Calcium and vitamin D are commonly found in dairy products, while vitamin E is often found in vegetables. In the current study, approximately two-thirds (67%) of the population accepted dairy while only half (48%) accepted vegetables.

We observed no food group accepted by all children in our study and the food group with the least acceptance was the vegetable group. This is similar to the results found in other studies. A study by Schreck et al. (2004) compared 138 children with ASD with a control group of 298 children.[11] The children with ASD consumed fewer foods than the control group from each of the following food groups: fruits, dairy, vegetables, proteins and starches. Another study by Emond et al. (2010) examined seventy-nine children with ASD compared to a control group of 12,901 children and found that those with ASD consumed fewer vegetables and fresh fruits.[24] Ho et al. (1997) evaluated the three-day food diary of 54 children in Canada with ASD and reported that the children were consuming enough protein, but only 7% met recommendations for bread/cereal, milk/dairy, meat/alternates and fruits/vegetables.[25] In the retrospective chart review of 13 children with ASD conducted by Sharp et al. (2011), foods from the fruit, vegetable and protein groups were minimally accepted before the start of treatment for food selectivity.[7]

The current study has several limitations. The sample size was small compared to the populations in previous studies. In addition, a retrospective cohort study design does not permit researchers to clarify any food diary or food group data that are unclear. The lack of access to laboratory tests for serum micronutrient levels prohibited us from determining if there is an association between micronutrient adequacy and serum micronutrient status. The micronutrient intake for this study population was based on the analysis of a three-day food diary provided by the caregiver of the child, but food diaries can be inaccurate, omitting foods consumed or providing incorrect portion sizes. The study also could have been limited by the Food Processor software used to analyze the children’s food diaries. The nutrition information for some micronutrients and foods in the Food Processor database may be missing which would lead to incorrect micronutrient intake results.

In conclusion, the population of children with ASD and food selectivity at the Marcus Autism Center did not meet all of the recommended dietary micronutrient intake guidelines. Adequacy of micronutrient intake was not related to food group acceptance. There is a lack of research evaluating the micronutrient status of children officially diagnosed by medical professionals with both ASD and food selectivity. It seems that our population was one of the few that had the dual diagnosis confirmed by medical professionals. Our results indicate that micronutrient deficiencies are likely a concern in children with ASD and food selectivity. These findings, while preliminary, can help guide medical professionals who are treating patients with ASD. Micronutrient status of children with ASD should be evaluated to ensure that micronutrient requirements are being met through diet or supplements. Since most previous studies of children with feeding disorders have not examined populations where the children have been medically diagnosed with both ASD and food selectivity, future research should be focused on this population. Future research should also include larger populations of children with both diagnoses and include serum micronutrient data to confirm or deny the presence of micronutrient deficiencies.

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Appendix A: Micronutrient Intake of the Total Population

Nutrient*	Total Population (N=21)+
Vitamin A (mcg)	325.40 ± 240.63
Vitamin B1 (mg)	1.06 ± 0.77
Vitamin B2 (mg)	1.50 ± 1.30
Vitamin B3 (mg)	13.16 ± 8.76
Vitamin B6 (mg)	0.97 ± 0.63
Vitamin B12 (mcg)	2.83 ± 2.65
Biotin (mcg)	15.12 ± 19.56
Vitamin C (mg)	62.77 ± 59.64
Vitamin D (mcg)	4.60 ± 4.60
Vitamin E (mg)**	2.42 (0.64, 4.27)
Folate (mcg)	155.11 ± 105.86
Vitamin K (mcg)	13.47 ± 19.49
Pantothenic Acid (mg)	2.47 ± 1.61
Calcium (mg)	735.91 ± 528.79
Chromium (mcg)** [n=15]	0.36 (0.24, 1.43)
Copper (mg)	0.50 ± 0.24
Fluoride (mg) [n=17]	0.72 ± 2.32
Iodine (mcg)** [n=16]	60.92 (17.46, 197.35)
Iron (mg)	14.51 ± 13.12
Magnesium (mg)**	132.07 (79.58, 183.53)
Manganese (mg)	1.13 ± 0.58
Molybdenum (mcg)** [n=14]	8.30 (4.00, 18.10)
Phosphorous (mg)	663.00 ± 335.90
Potassium (mg)	1676.46 ± 964.92
Selenium (mcg)	39.72 ± 31.00
Sodium (mg)	2454.81 ± 1597.84
Zinc (mg)	5.97 ± 3.16
Choline (mg)	107.71 ± 98.07

*Mean ± SD unless otherwise noted
**Median (Interquartile range 25%, 75%)
+N=21 unless otherwise noted, mcg – micrograms, mg - milligrams