VALIDATION OF A FOOD FREQUENCY QUESTIONNAIRE TO A 3-DAY DIET RECORD IN CHILDREN WITH AUTISM SPECTRUM DISORDER

A Thesis

Presented in Partial Fulfillment of the Requirements for

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By

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ABSTRACT

Autism-specific characteristics exacerbate difficulties common in validation studies of typically-developing children and present additional challenges in assessing nutritional status. This comparative study assesses level of agreement for estimated intake of 23 nutrients and nutritional adequacy reported by a FFQ compared to a 3-day diet record in 22 children with ASDs aged 3-9 years. Parents or caregivers completed 3-day diet records and FFQs. Nutritional adequacy was defined as ≥ 100% EAR/AI. Correlational analyses included mean nutrient intakes, standard deviations, difference between the means, percent of dietary intake recommendations and tertile groupings to determine level of agreement across methods. In general, a low level of agreement was observed for estimated nutrient intakes. The 3-day diet record reported higher estimates for 17 of 23 nutrients. A moderate level of agreement was observed for approximately 50% of estimated mean nutrient intakes. When grouped into tertiles of intakes, poor agreement was observed for most nutrients. Although both methods were likely to identify individuals with inadequate intakes of key nutrients, level of inadequacy (mean % below EAR/AI) varied across methods for individual nutrients. Mean percentage of the recommended intake levels were above the EAR/AI for 15 and 14 nutrients from the 3-day diet record and FFQ, respectively; potassium, fiber and vitamin D were approximately 50% EAR/AI. A moderate to high level of agreement for nutrient
inadequacy was observed for 15 nutrients, including nutrients frequently identified as problematic in children with autism or ASDs. However, the FFQ tended to report lower levels of inadequacy for fiber, calcium and vitamin D. Based on these results, a 3-day diet record seems to be the best choice for estimating nutrient intakes and assessing nutrient adequacy in children with ASDs.
DEDICATION

To the Medical Dietetics faculty and staff – an unprecedented collective of
compassionate and gifted professionals
ACKNOWLEDGMENTS

The completion of this endeavor marks the end of a difficult life journey. First and foremost, my faith and trust in Jesus Christ provided structure and clarity to the chaos and frustrations encountered as well as the accomplishments celebrated. Many individuals lent personal encouragement: Dr. Taylor – thank you for your professional guidance, personal patience and overwhelming hospitality. Dr. Nelms and Dr. Habash – thank you for your individual efforts and inquiries that molded and shaped my work, but most of all, thanks for the smiles and encouragement. Dr. Geraghty – you are one of a kind. Words cannot express my gratitude for your efforts on my behalf – thank you so much. Dr. Wolf – you are the consummate example of a compassionate, humble and highly effective leader. Your efforts during my tenure in this program continuously exceeded my expectations, and were far beyond what I deserved. It is difficult to articulate in words my admiration for you and my sincere gratitude for everything that you did on my behalf; I can only hope to repay you through future accomplishments within the field of dietetics, accomplishments that will undoubtedly be directly attributable to you. Finally, I would not have reached this point in my life without the love of truly remarkable parents. Mom and Dad – you will never understand the refuge you provided during my lowest points, of which there were many. Your collective thoughts and prayers were immeasurable. I love you both and am privileged to have you in my life.
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Field of Study

Major Field: Dietetics
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CHAPTER 1

INTRODUCTION

Background of Problem

To better understand the relationship between food and health, diet assessment and nutrient analysis are critical.\(^1\) Diet assessment methods frequently utilized in research include diet records and recalls, food frequency questionnaires (FFQs), diet histories, brief assessment instruments, blended instruments, interviews and observations.\(^2\) Each diet assessment method is relatively unique in its purpose, strengths and weaknesses, although biases among methods can be similar as evidenced by an FFQ and diet record or recall, both of which rely on respondent report for diet information.\(^3\) Because of the inherent biases and flaws associated with each method, estimation of nutrient intake void of some level of error is likely impossible\(^1\), as misreporting (e.g. underestimation and overestimation) of nutrient intake is frequently observed.\(^4\) Error observed in studies of diet assessment is largely predicated by the diet assessment method chosen and the population in which it is used.\(^1\) It has been posited that in general, diet records and recalls underestimate intake\(^5\), while FFQs overestimate intake\(^6\), especially those with a longer food list.\(^7\) In order to prevent inaccurate and skewed analysis and interpretation of results,
a comprehensive understanding of error structure and utilization of statistical methodology that recognizes and manages error is essential. Given the methodology utilized in this study, a more detailed description of a FFQ is indicated in terms of development, purpose, strengths and weaknesses and validation. In general, the purpose of a FFQ is to report usual intake and frequency of individual foods from a list of foods over a specified time period; if absolute nutrient intake is needed, portion size must be included. Development of the food list is critical to the efficacy of a FFQ within a given population and should reflect food preferences as well as seasonal and/or new foods. Although considerable variance exists in the number of foods included on a FFQ food list, it has been reported that increasing the detail of a FFQ yields a decreasing marginal gain in information collected. Also, the frequency range assigned to each food should reflect the study’s time frame. Purported FFQ strengths include its ability to collect information on the total diet, a diminished effect on altering a respondent’s usual eating habits and assessment of individual usual intake, and its low investigator cost. However, substantial measurement error is associated with FFQ assessment. A FFQ presents cognitive challenges for a respondent in terms of estimating intake frequency (and portion size in some cases) which results in misreporting of intake; additionally, a FFQ does not provide precise quantifiable measurements. These FFQ characteristics are considered methodological weaknesses.

Validation of any diet assessment method is significantly complicated due to the absence of a true “gold standard” in terms of a validation reference; therefore, a validation study is really a comparison study in which one method’s validity is determined based on its agreement with a second diet assessment method. In an effort
to establish some level of validation in a given study, the inherent biases of the diet assessment method should be independent of the inherent biases of the validation standard; if both methods share similar biases, calculated correlations between methods are likely falsely elevated.\(^3\) Additionally, variance between methods’ purposes and referent periods exacerbate difficulty in validation.\(^3\) In contrast, some consider the diet record as the “gold standard” in diet assessment methodology.\(^{15,16}\)

When validating a FFQ, it is important to consider the age, ethnic group, gender, sex and health status of the target population, as these variables can affect the outcomes of validation studies.\(^{10}\) Additionally, reported dietary intake from subjects who self-select to participate in a FFQ validation study (or any diet assessment method validation study) potentially has a higher degree of accuracy compared to dietary intake reported from non-volunteers and must be considered when interpreting FFQ validation.\(^{10}\) In a systematic review of 227 FFQ validation studies, Cade and colleagues found that 75 percent of studies validated an FFQ compared to another diet assessment method and 19 percent compared to a biomarker. Investigators concluded that weighed food records or diet records should be selected first as a validation reference in a FFQ validation study, and cited a study by Stram et al 1995 in which it was reported that in most settings, no more than 4 to 5 days of diet records are needed. Finally, Cade et al also recommended that the chosen validation standard’s referent intake period should coincide with that of the FFQ (usual, current or past); for example, if the FFQ assesses intake over a 6-month period, several diet records should be collected in intervals during the intervening time frame, thereby increasing the accuracy of validation interpretation between the two methods.\(^{10}\)
Although considered more challenging in comparison to adult assessment\(^2\), diet assessment in children continues to increase in terms of current research being conducted as the connection between dietary habits of children and adolescents and incidence of adult chronic disease is further elucidated.\(^{16;17}\) A plethora of variables complicate measurement of dietary intake in children including age, gender, ethnicity, socioeconomic status and obesity\(^3\) as well as a child’s rapidly changing food habits and high variability in terms of daily food intake.\(^2;6\) Furthermore, because children have a limited ability to record or remember diet intake and possess a generally decreased knowledge of food and preparation methods\(^{16}\), reliance on parental and/or caregiver report for daily food intake is required.\(^2;6\) However, as children increase in age, more meals are consumed away from home thereby potentiating a decrease in accuracy of parental and/or caregiver report.\(^6;16\) Finally, as children become adolescents and are able to self-report, it is possible that they may have less interest in providing accurate diet information\(^2\), and the accuracy of reported diet intake is dependent on the child’s age, cognitive ability and understanding of the diet assessment method used in the study.\(^3\)

Although all methods have been used in diet assessment of children\(^{18-23}\) including diet recalls, records, histories and FFQs\(^{16}\), there is no consensus on preferred method.\(^3\) In a review of validity and reliability diet assessment studies among school-aged children aged 5-18 years, McPherson et al found that for validation studies, when compared to doubly labeled water (DLW), food records generally underestimated energy intake in children; in contrast, FFQs tended to overestimate energy intake, although varying referent periods of and potential overestimation or underestimation of intake by validation references could have biased this observation of FFQ overestimation of energy.
intake. However, it has been reported that in diet assessment studies of school-aged children, a FFQ is the most frequently used validation method; additionally, a diet recall or diet record is the most frequently used validation reference. This finding is significant within the context of this study’s research method, as a FFQ was validated in a sub-population of children with a 3-day diet record.

The literature has established that when compared to adults, diet assessment in children is increasingly challenging due to the aforementioned collection of factors unique to the population. However, the challenges present in a population of typically developing children pale in comparison to those recognized in children with autism or ASD. To the best of our knowledge, no diet assessment instrument has been developed to date specifically for this population, and limited validation studies have been conducted. Of the nutritional adequacy studies conducted in children with autism or ASD, the diet record has been used most frequently, whereas the FFQ has seen limited use; this conflicts with the McPherson et al review in which the FFQ was the most frequently used diet assessment method in typically developing children.

In addition to the aforementioned challenges recognized in diet assessment of typically developing children, an overview of current literature indicates that children with autism or ASD present with specific physiological, behavioral and contextual issues which must be considered during the execution of diet assessment research and the interpretation of reported results within this population. When assessing the nutritional status of a child with autism, it is important to consider time since diagnosis, as it is likely that nutritional status is affected by the length of time over which treatments (both physician-prescribed and/or parent-facilitated) have been used. The Autism Research
Institute’s Web site refers to these treatments as “biomedical” interventions and has developed the following categories: 1) drugs; 2) biomedical, nondrug (dietary and herbal) supplements; and 3) special diets.\textsuperscript{32} It has been reported that in families’ of a child with autism, daily use of one or more dietary supplement ranges from 50 to 83 percent; in a second study, 54 percent of 112 families used biomedical therapies.\textsuperscript{32}

In a recent two-part review of nutritional intake and therapies in autism and clinical recommendations, Geraghty and colleagues reported that problem eating behaviors are commonly observed in children with autism or ASD, with prevalence estimated to range between 46 to 89 percent. Problem eating behaviors are qualified as food selectivity, mealtime rituals (e.g. need for same eating utensil, food position on plate), food preferences and/or refusal based on texture, temperature and smell as well as a reduced variance in dietary intake.\textsuperscript{33} Sensory processing difficulties are also commonly observed in this population and are described as the way in which a child responds to tactile, vestibular, auditory, visual, gustatory and olfactory stimuli. Hypersensitivity to food smells, tastes and textures as well as auditory sensitivities to mealtime environments have been associated with increased potential for food avoidance and restriction.\textsuperscript{33}

Furthermore, the reviewers described family factors experienced by parent(s) or caregiver(s) of a child with autism and their potential affect on the child’s dietary intake and subsequent nutritional status, as parents and caregivers generally have a more negative view of their child’s eating habits compared to parents of typically developing children.\textsuperscript{33} Parental control of a child’s diet, stress\textsuperscript{33} and time constraints possibly impacts
a child’s diet; additionally, a correlation between family food preferences and a child’s food preferences has been reported, in that fewer foods eaten by family members resulted in a reduced number of foods eaten by a child with autism.\textsuperscript{34}

Finally, the reviewers noted that the nutritional status of children with autism is likely impacted by commonly observed gastrointestinal (GI) symptoms and interactions between nutrients and classes of drugs sometimes prescribed for children with autism. Studies suggest that 30 to 80 percent of children with autism experience GI symptoms such as bloating, abdominal distension and chronic constipation and/or diarrhea; additionally, 43 percent of children with no GI symptoms and 76 percent with GI symptoms may have increased intestinal permeability; and compared to typical children, children with autism have altered intestinal microflora.\textsuperscript{33} Intuitively, chronic presence of GI symptoms could cause significant variation in a child’s day-to-day dietary intake, thereby complicating diet assessment and skewing interpretation of reported results. Classes of drugs sometimes prescribed for children with autism and subsequent nutrient interactions include: 1) stimulants (e.g. for ADHD treatment) can decrease appetite and can cause nausea, vomiting, diarrhea and constipation; 2) anticonvulsants (e.g. for epilepsy treatment) can cause GI irritation, nausea, vomiting and diarrhea; and 3) antipsychotics can increase appetite and cause weight gain and/or sedation.\textsuperscript{33} As with GI symptoms, the potential effects of drugs on appetite and the GI system could possibly contribute to dietary intake and nutritional status in children prescribed one or more of the medications, further exacerbating the difficulty of assessment and interpretation of diet intake data irrespective of diet assessment methodology.
Significance of Problem

The literature has clearly established that regardless of the method, dietary assessment in typically developing children is difficult, and reported results are highly variable depending on the target population’s age, sex, ethnicity, socioeconomic status, cognitive ability, health status, variability in daily food intake and, in some cases, reliance on surrogate report.\textsuperscript{3,6,18-23} Although these variables complicate dietary assessment in children with autism or who fall somewhere on the autism disorder spectrum, additional dynamics unique to this population further exacerbate the difficulty of dietary assessment.

Autism is often defined as a developmental disorder in which commonly observed diagnostic features include qualitative impairment in social interactions and communication (e.g. lack of language development and repetitive use of language), and restricted repetitive and stereotyped patterns of behavior, interests and activities.\textsuperscript{33,35} The diagnostic features have several implications on diet assessment and validation. In terms of communication difficulty within the context of diet assessment, the ability to participate in diet recall, either through assisting a parent or caregiver or through self reporting, theoretically increases in typically developing children as they age and develop neurologically; in contrast, a proportional relationship between age and cognitive ability is not necessarily recognized in children with autism or ASD. Because these children often experience difficulty in communication\textsuperscript{33,35} they likely are unable to express food preferences or recall diet intake information. Therefore, information on dietary intake in this population is generally completely reliant on parent and/or caregiver report, thereby increasing the potential for bias.
Problem eating behaviors, sensory processing difficulties and family factors constitute behavioral and contextual issues within the autistic population and likely affect a child’s nutritional status\textsuperscript{33}, and collectively could confound diet assessment independent of methodology. First, heightened parental or caregiver awareness of daily dietary intake related to the common manifestation of core autism characteristics including problem eating behaviors (e.g. picky eating, selective food refusal and nonfunctional mealtime rituals) and sensory processing difficulties could potentially bias reported intake on any given diet assessment method. Second, additional bias relative to reported diet intake could result as parent(s) or caregiver(s) often exert significant control over the types and amounts of foods available and frequently impose dietary restrictions as a method of treatment (e.g. gluten-free casein-free diet, special carbohydrate diet).\textsuperscript{32} Third, the frequent use of dietary supplements and complementary and alternative medicine (CAM) within this population\textsuperscript{32} likely has a concomitant effect on the accuracy of assessment of nutritional status based on daily dietary intake. Fourth, in addition to control of dietary intake, parental stress, emotional responses and family food preferences are factors that possibly influence a child’s eating behavior and subsequently contribute to the questionable nutritional status of children with autism\textsuperscript{33}, all of which confound diet assessment and method validation. Lastly, in addition to problem eating behaviors, sensory processing difficulties and family factors, gastrointestinal symptoms\textsuperscript{33} likely impact usual and day-to-day food intake, increasing the risk of sub-optimal nutritional status. In conclusion, these unique variables commonly observed within the autism population collectively and independent of one another increase potential for bias and likely have a significant effect on the accuracy of reported dietary intake as well as the
validity of any diet assessment methodology used to assess nutritional status, thereby
necessitating comprehensive analysis and consideration in nutrient adequacy and
validation studies.

Conflicting outcome measures have largely been reported in the literature for
application of the various diet assessment tools in children with autism or ASD. Diet
records (3 and 7 day)\textsuperscript{24-31}, FFQs (limited use)\textsuperscript{36} and 24-hour food recalls.\textsuperscript{35} have reported
both adequate and inadequate nutrient intake in children with autism or ASD. However, it
is important to note that a comparison of nutrient adequacy studies is confounded by
several variables, including the lack of a standardized definition for nutrient adequacy,
use of a control group, and variance in diet assessment method and sample size.\textsuperscript{37} The
limited use of a FFQ in the available literature to assess nutrient adequacy and the lack of
dietary assessment validation studies in children with autism or ASD is evidence that
more research needs to be conducted in order to further elucidate the nutritional status of
this population and to help identify a valid method for assessing adequacy of dietary
intake.

**Research Objectives**

This research was part of a pilot study sub-set that was the first to systematically
examine the nutritional quality of dietary intake for children with autism in terms of food
selections from major food groups and a full range of macro and micronutrients while
accounting for the contribution of dietary supplementation to help meet individual
nutritional needs. The purpose of the prospective study was to identify trends in dietary
intake and the contribution of dietary supplementation in attaining Dietary Reference
Intakes (DRIs) for both macro and micronutrients in children with autism.\textsuperscript{31} The original
A pilot study examined the correlation between problem eating behaviors in children with autism and other autism-associated factors (e.g., nutritional quality of dietary intake, nutrition-specific genetic differences, sensory processing characteristics, and intestinal microfloral abnormalities) in order to define phenotypic presentations of mealtime behaviors and determine appropriate and effective interventions for autism and autism spectrum disorder.\textsuperscript{31,38}

This secondary sub-set of the original pilot study was designed to meet the gaps in the available literature by assessing concurrent validity of diet assessment methodologies in children with autism. For the purposes of this study, a food frequency questionnaire (FFQ) was used as the diet assessment instrument while a 3-day diet record simultaneously administered in the first sub-set of the pilot study was used as the validation reference. The objectives of this research are as follows:

1. To investigate validity between estimated intakes from a food frequency questionnaire and a 3-day diet record in children with autism or autism spectrum disorder by:
   a. using statistical analysis to compare correlated estimates of nutrient intake and percent of dietary intake recommendations (DRIs) for the appropriate age category across both diet assessment methods.
   b. comparing the level of nutrient intake across both estimators of nutrient intake using tertile groupings.
   c. comparing categories of nutrient adequacy across both diet assessment methods; categories of nutrient adequacy are defined as
1) meets or exceeds recommended dietary intake 2) falls below recommended dietary intake.

**Research Approach**

For the original pilot study, 30 children aged 3 to 9 diagnosed with an autism spectrum disorder were recruited by clinician/researchers of a Midwestern University Center for Excellence in Developmental Disabilities. Twenty-four of the 30 children for whom a completed 3-day diet record and food frequency questionnaire was returned were included as participants in the first sub-set prospective study (n=20 with an autism diagnosis, n=4 with a diagnosis of PDD-NOS), although the investigator only reported on data analysis for the 3-day diet record. Prior to submission, each study participant’s consenting parent or caregiver attended one data collection session at which both the 3-day diet record and FFQ were distributed along with self-addressed envelopes for easy return. A research assistant explained each diet assessment method and collected information from the parent or caregiver on diet restriction and/or supplementation (including type, brand name, typical dose consumed and frequency of consumption). For the 3-day diet record, parent(s) or caregiver(s) were asked to complete the record for the study participant by recording dietary intake for two consecutive weekdays followed by one consecutive typical weekend day (e.g. Thursday, Friday, Saturday or Sunday, Monday, Tuesday). The investigator used ESHA Food Processor SQL® Nutrition and Fitness Software\(^{39}\) to analyze the 3-day diet record in order to evaluate quality of dietary intake in terms of food group selection and macro and micronutrient levels of foods consumed; in addition, a secondary analysis was conducted to examine the contribution of dietary supplements in achieving DRIs for macro and micronutrients.
The FFQ was a 2004 90-item Block Questionnaire for children aged 2 to 7. Individual portion size was asked for beverages only. The questionnaire’s food list was developed from the NHANES III dietary recall data and the nutrient database was developed from the USDA Nutrient Database for Standard Reference.\(^4\) Parents or caregivers were asked to complete the Block Questionnaire for the study participant’s usual eating habits over the past six months. The parents were instructed to take their time while answering the questions in the FFQ as its completion would likely take approximately 30 minutes. Additionally, because the computer would not read a selection on the FFQ for which the lead marks were not neatly done, the research assistant recommended the use of a No. 2 pencil and emphasized the importance of keeping lead marks inside the oval. FFQ intake data was analyzed by NutritionQuest (Berkeley, California).
LIST OF TERMS

**Food Frequency Questionnaire (FFQ):** A food frequency questionnaire is a diet assessment method that reports usual intake and frequency of an individual food from a list of foods over a specified time period; portion size is sometimes included. Overall nutrient intake is determined by adding the products of reported frequency for each food by the nutrient amount in a serving.\(^8,9\)

**Diet record:** Thompson and Subar define a diet record as a diet assessment method in which respondent records the amounts of foods and beverages consumed over a period of one or more days (e.g. 3-day diet record); amounts are measured using a scale, household measures (e.g. cups, tablespoons) or are estimated using models, pictures or without aid.\(^2\)

**Dietary Reference Intakes (DRI):** The Dietary Reference Intakes act as nutrient intake goals and include four sets of values, including: Recommended Dietary Allowances (RDA) and Adequate Intake (AI).\(^41\)

**Recommended Dietary Allowances (RDA):** One of four values included in the Dietary Reference Intakes, the Recommended Dietary Allowances define the average daily amount of a given nutrient that is considered adequate to meet the needs most health people.\(^41\)

**Adequate Intake (AI):** One of four values included in the Dietary Reference Intakes, Adequate Intake is set when there is insufficient evidence to determine the Recommended Dietary Allowance for a nutrient.\(^41\)

**Estimated Average Requirement (EAR):** One of four values included in the Dietary Reference Intakes, the Estimated Average Requirement is the daily dietary intake level
estimated to meet the nutrient requirement of 50 percent of healthy individuals in a particular life stage and gender group.\textsuperscript{41}

**Validation study:** A validation study frequently refers to a study in which diet assessment methods are compared.\textsuperscript{42}

**Doubly-labeled Water (DLW):** A technique used to measure energy expenditure in which a subject drinks a known amount of two different isotopic forms of water—\( \text{H}_2^{18}\text{O} \) and \(^2\text{H}_2\text{O}\). Over a period of 1-3 weeks, the subject submits urine samples that are used to measure the rate at which the two isotopes disappear from the body, and that rate is then used to calculate the subject’s energy expenditure.\textsuperscript{43}

**Autism:** Autism is often defined as a developmental disorder in which commonly observed diagnostic features include qualitative impairment in social interactions and communication (e.g. lack of language development and repetitive use of language), and restricted repetitive and stereotyped patterns of behavior, interests and activities.\textsuperscript{33,35}

**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.\textsuperscript{31}

**Pervasive Developmental Disorder-Not Otherwise Specified (PPD-NOS):** PDD-NOS is a diagnosis for individuals who only meet some (not all) of the diagnostic criteria for autism or Asperger’s syndrome. Social and communication challenges may be the only symptoms.\textsuperscript{31}
**Sensory Processing Difficulties:** The terminology *sensory processing* describes a child’s response to tactile, vestibular, auditory, visual, gustatory and olfactory stimuli. Although not included in the diagnostic criteria for autism, sensory processing difficulties are often described as core symptoms.\(^{33}\)

**Problem Eating Behaviors:** Often associated with sensory processing difficulties, problem eating behaviors are a core autism characteristic that potentially affects nutrient intake and adequacy of children with autism or ASD. Problem eating behaviors are qualified as food selectivity, mealtime rituals (e.g. need for same eating utensil, food position on plate), food preferences and/or refusal based on texture, temperature and smell as well as a reduced variance in dietary intake.\(^{33}\)

**Complementary and Alternative Medicine (CAM):** In an effort to address the etiology of an illness (as interpreted by a practitioner), Complementary and Alternative Medicine practices incorporate the health and involvement of a patient into the healing process. Mind-body medicine, biologically based practices, manipulative and body-based practices and energy medicine are considered to be CAM therapies.\(^{31}\)
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<tr>
<td>FFQ</td>
<td>Food Frequency Questionnaire</td>
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<tr>
<td>PDD-NOS</td>
<td>Pervasive Developmental Disorder-Not Otherwise Specified</td>
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<tr>
<td>CAM</td>
<td>Complementary and Alternative Medicine</td>
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<tr>
<td>DLW</td>
<td>Doubly-labeled water</td>
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<tr>
<td>DRI</td>
<td>Dietary Reference Intakes</td>
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<tr>
<td>RDA</td>
<td>Recommended Dietary Allowances</td>
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<tr>
<td>AI</td>
<td>Adequate Intake</td>
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<tr>
<td>EAR</td>
<td>Estimated Average Requirement</td>
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<td>GI</td>
<td>Gastrointestinal</td>
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CHAPTER 2

REVIEW OF LITERATURE

Dietary Assessment

Dietary assessment is used to quantify and qualify the nutritional status of various populations often differentiated by health status, age, sex and ethnicity. Assessment occurs at the national, household and individual level. Data collected can be used to assess and amend current nutritional recommendations in health populations; in addition, the correlation between diet and the prevention and treatment of chronic diseases has facilitated investigation and subsequent improvement of diet assessment methodologies. Common diet assessment techniques include dietary records, 24-hour dietary recall, food frequency questionnaire, brief dietary assessment instruments, diet history and blended instruments. Inherent strengths and weaknesses of individual techniques in the general population have been discussed in the literature and educational texts.

For the purpose of this study, a brief explanation of FFQ and diet record purposes, strengths and weaknesses is indicated. A FFQ reports usual intake and frequency of an individual food from a list of foods over a specified time period; portion size is sometimes included. Overall nutrient intake is determined by adding the products of reported frequency for each food by the nutrient amount in a serving. FFQ strength
include: usual individual intake asked; information on total diet obtained; low investigator cost; and does not affect eating behavior. FFQ weaknesses include: not quantifiably precise; difficult cognitive task for respondent; intake often misreported.11-13

Alternately, a diet record records food, beverages and amounts consumed over one or more days; if more than one day is needed, 3-4 days are typically recorded. Diet record strengths include: intake quantified45; potential enhancement of self-monitoring for weight control46 or other dietary behavior change47; does not require recall of foods eaten.2 Diet record weaknesses include: high respondent burden2; affects eating behavior48;49; intake often underreported46;50-61; extensive respondent training and motivation required2; many days needed to capture usual intake; and reports of intake decrease with time.62

Assessment of nutritional adequacy in children presents additional challenges2, in that diet assessment techniques are difficult to manage, limited in terms of methodology and rely on parent and/or child recall of nutrient intake.2,3 Researchers have utilized all methodologies in assessment of children’s diets18-23; diet recall in pre-school aged children is generally reliant on surrogate report, while older children and adolescents self report.2 In terms of accuracy, it has been posited that accuracy of diet recall increases when multiple surrogates and the pre-school aged child participate in a consensus recall method (group report on a 24-hour dietary recall).63,64 Although consensus on a preferred method of diet assessment for older children and adolescents is lacking2, the food frequency questionnaire was used most extensively in dietary assessment validation studies among children over three decades spanning from 1970 to 1999, with food records or recalls utilized most frequently as validation standards.3 In terms of a
definitive FFQ validation study design, a non-intrusive long-term diet observation would be preferential. Due to limiting factors, utilization of a diet record or diet recall over a period of time is more practical and is subsequently reflected by the methodology demonstrated in the literature. Unfortunately, inherent methodological flaws (biases) in the diet record and diet recall limit one’s ability to assess relative (and concurrent) validity compared to the FFQ. A more comprehensive discussion of diet assessment, bias and validity will follow. Alternatively, the biomarker study design acts as a non-biased validation standard (external criterion validity) and is available for energy (doubly-labeled water), protein (urinary nitrogen) and serum micronutrients; however, its use in validation studies involving children has been limited, and the lack of direct correlation between food intake and physiologic endpoints is problematic.

**Historical Overview of Diet Assessment in Children**

In a discussion of diet assessment in children and adolescents, Rockett and Colditz traced the historical progression of diet assessment studies in children beginning in 1882 with Hasse’s study of the dietary intake of Swiss and Russian girls aged 2-11 years. In the decades that followed, subsequent diet assessment studies were conducted by researchers in Germany, Finland and the United States. The focus of these early studies was to determine nutrient requirements for children beginning with macronutrients and progressing to an inclusion of micronutrients as vitamins and minerals were discovered. The authors referenced several twentieth century historic landmark studies of diet assessment in children, including Burke’s Longitudinal Studies of Child Health and Development in the 1940s, Beal’s Denver Infant and Child Study of the 1950s, the U.S. government’s Ten State Nutritional Survey of the 1960s, and the
National Health and Nutrition Examination Survey (NHANES), the Nationwide Food Consumption Survey (NFCS), and the Bogalusa Heart Study of the 1970s. More recent studies include NHANES III, NFCS, a Hispanic NHANES, and continuation of the Bogalusa Heart Study as well as newer studies including the Child and Adolescent Trial for Cardiovascular Health (CATCH) and the Gimme5 study.16

Validation of Diet Assessment Methods

A study in which diet assessment methods are compared is often referred to as a validation study42; although it is generally accepted that all diet assessment methods are inherently flawed1:3:44, in a validation study, it is ideal for the diet assessment method biases to be independent of the biases inherent to the validation standard. If both share common errors, correlations between the method and validation standard will be artificially inflated.3 For example, in a FFQ validation study in which a diet record or recall serves as the validation standard, it is theorized that biases commonly associated with a FFQ are independent of those associated with a diet record or recall. Regrettably this is not the case, as a FFQ and diet record or recall share similar errors: First, both rely on the respondent for dietary intake information.3 Second, social desirability on the part of the respondent completing any of the three methods could potentially influence recording and/or recalling of food intake; additionally, errors in estimation of portion sizes (diet record/recall) and intake (FFQ) are similar biases42 that could affect correlations between methods. Finally, varying referent periods (e.g. FFQ=usual consumption over 6-12 months; diet record=food intake on a day-to-day basis)3 and
measurement aspects of diet (e.g. FFQ=summaries/averages of food intake; diet record=direct report of individual intake) further exacerbate the inability to draw generalized conclusions of validity between methods.

**FFQ Validation Studies**

The number of FFQ validation studies in the literature is considerable. However, reported results among these studies vary significantly depending on the type and length of the FFQ, the target population, population demographics (e.g. age, sex, ethnicity etc.) and the validation standard used, among other factors. Variability in FFQ validation studies has been reported in the adult population. For example, Posner and colleagues used a random sample of adults (n=150; female=73 mean age 47.4 years; male=77 mean age 52.9 years) from the Framingham Offspring/Spouse Study to compare nutrient intake using a FFQ, 3-day diet record, and 24-hour food recall. Investigators reported similar estimated mean group nutrient intake (<10% difference for most nutrients) for men and women as reported by the 3-day diet record and 24-hour food recall; results reported by the FFQ differed from the other two methods. In males, the FFQ reported lower estimates of mean nutrient intake compared to the 3-day diet record and 24-hour recall and higher estimates in females. Spearman rank correlations for estimates of individual nutrient intake between the three methods were modest (r=0.08-0.68; most nutrients <0.50). In contrast, Patterson and colleagues found that in 113 women (mean age 63 years) participating in the Women’s Health Initiative research program, overall nutrient estimates as reported by a FFQ were slightly lower when compared to intake data from 4 separate 24-hour food recalls and a 4-day diet record, although for most nutrients, FFQ mean estimated intakes were within 10 percent of those reported by the other two methods.
methods. This result conflicts directly with higher FFQ estimated mean nutrient intake in females reported by Posner and colleagues; however, it is important to note that variability between mean estimated nutrient intakes for females as reported by a FFQ could be related to differences between studies in terms of mean age, FFQ used and validation references.

Similar variability exists in reported results for FFQ validation studies among adolescents. FFQs designed to assess specific nutrient intake among adolescents have shown modest correlations (r=0.42 for folate, r=0.56 for calcium) compared to varying validation standards (24-hour recall, doubly-labeled water). When validated using one or more 24-hour food recalls, FFQs underestimate, overestimate, or generally agree with nutrient and food intake (from different food groups). Finally, Matthys et al used a 3-day diet record to validate an adolescent web-based FFQ in 104 subjects aged 12-18 years and found no significant differences between both methods for water, fruit, breakfast cereals, fish/eggs/meat, pasta/rice, and potatoes. However, the FFQ showed significantly lower estimated intakes of soft drinks, sweet/savory snacks/fillings, sauces/fat spreads, cheese, pasta/rice and vegetables (for those subjects who consumed these foods).

Results of validation studies in pre-school and school-aged children suggest that in general, a FFQ overestimates nutrient intake. In three separate reviews of dietary assessment, authors concluded that although variability across the reviewed studies made it difficult to draw generalized conclusions, the majority of study results indicated that FFQs overestimated energy and nutrient intake in children. However, mixed results were reported by other individual studies. FFQs developed to assess specific
nutrient intake (e.g. calcium and Vitamin D) and validated with a diet record both overestimated intake\textsuperscript{80} and demonstrated relative agreement between the two methods.\textsuperscript{81,82} In a study using a FFQ to assess energy and macronutrient intake and validated with a 3-day diet record, investigators reported that the FFQ significantly overestimated mean intake of energy (+25%), protein (+19%), carbohydrate (+22%) and fat (+33%) compared to a 3-day diet record in 61 girls aged 4-9 years, with low to moderate correlations (r=0.40-0.55) shown between the two methods.\textsuperscript{83} Conflicting results were also reported when serum biomarkers and doubly-labeled water (DLW) was used to validate a FFQ; one study reported that the FFQ overestimated energy intake by 59 percent compared to total energy expenditure measurements determined using DLW\textsuperscript{75}, whereas investigators in another study using serum samples of carotene and Vitamin C as the validation reference concluded that a FFQ can estimate a child’s usual intake (r=0.30 and r=0.34 for carotene and Vitamin C, respectively).\textsuperscript{84}

Finally, results from FFQ validation studies in toddlers reflect the mixed results previously discussed in other age groups. Authors reported that in toddlers, FFQs generally overestimate energy intake and are more useful for ranking rather than quantifying usual intake\textsuperscript{6,14}; in one study reviewed, a FFQ overestimated energy intake by more than 70 percent compared to 4 quarterly 24-hour food recalls.\textsuperscript{6} However, when validated using a 3-day diet record, a FFQ showed an average validity correlation of 0.41; additionally, investigators reported significant correlations for all nine food groups (r=0.41) and found that the FFQ and 3-day diet record correctly classified 36 percent of children into the same quartile for food group and intake and 78 percent into the same or
within one quartile. When validated with serum biomarkers, investigators reported mostly good correlations for the FFQ, which the highest correlations for Vitamin C (r=0.51) and Vitamin E (r=0.48).

**Nutrient adequacy in children with autism or ASD: 3-day diet record**

In a review of validation studies for dietary assessment methods in children and a discussion of assessment issues, Livingstone et al noted that diet records were the most common instrument used in the diet assessment of children and adolescents. While the diet record had been shown to provide an unbiased estimate of energy intake in children up to 9 years of age, studies demonstrated that the food frequency questionnaire overestimated energy intake in children aged 4 to 7. Several studies have used the 3-day diet record to assess nutritional adequacy in children with autism or ASD; unfortunately, conflicting results have been reported. In addition, the conflicting results are exacerbated further by the heterogeneity in study designs: lack of a control group, variance in use of standardized diet recommendations for comparison and large ranges in sample size contribute to the difficulty in reaching definitive conclusions.

In an earlier study, Shearer et al used a 3-day diet record to assess nutritional adequacy of 12 children with autism compared to 12 typical children. Nutritional adequacy for each group was compared to the 1980 Recommended Dietary Allowance (RDA) and food group adequacy for each group was compared to 1965 USDA food groups. Shearer and colleagues reported no difference in nutritional adequacy for most nutrients between children with autism and the control group; although not significantly below RDA, children with autism consumed significantly less calcium and riboflavin compared to the control group and consumed fewer dairy foods. Similar findings were
reported in later studies in which a control group and 3-day diet record was used. Although nutrient intake was highly variable in 20 children with ASD aged 7-10, Schmidt et al reported that on average, nutrient intake was similar for ASD children compared to 18 typical children; there was no significant difference for intake of energy, macronutrients, vitamins and minerals (p>.05). In ASD subjects, nutrient intake was adequate (>67% RDA) except for fiber (inadequate in both groups) and vitamins E and K. In a similar sized study, in which nutrient adequacy was compared to Estimated Average Requirement (EAR) for children aged 4-8 (and Adequate Intake for nutrients in which an EAR has not been established), Lockner et al found similar nutrient intakes for both groups; interestingly, for the majority of nutrients, intakes exceeded recommended amounts. Nutrients most likely to be consumed in inadequate amounts were Vitamins A and E, calcium, and fiber. In a study of 46 children with ASD and 31 typical children, Herndon and colleagues hypothesized that intake of macro- and micronutrient would be less in ASD subjects compared to controls; however, this was only true for calcium, although ASD subjects did consume significantly more Vitamin B6 and Vitamin E compared to control subjects. Both groups had intakes below the Dietary Recommended Intake (DRI) for fiber, calcium and Vitamins D and E. In a more recent study utilizing a 3-day diet record and control group, conflicting results were reported. In a sample size of 53 children with ASD and 58 typical children aged 3-11 years, Bandini et al reported that overall, ASD subjects had a significantly greater number of inadequate intake of nutrients compared to control subjects (p=.03). In ASD subjects, inadequate intake of calcium and Vitamin D occurred more frequently
compared to control subjects; additionally, both groups had inadequate intake of fiber, calcium and Vitamins D and E\textsuperscript{28}, which is consistent with results reported by Herndon and colleagues.\textsuperscript{27}

Three studies used a 3-day diet record to assess nutrient adequacy in children with autism or ASD but did not implement a control group; lack of a control group significantly weakens study strength, and results must be interpreted with caution. Ho and Eaves compared nutrient intake of 54 children with autism aged 12.4-15.8 years to the Canadian Recommend Nutrient Intake (RNI). It is important to note that 42.6 percent of subjects were obese. Investigators reported that only 7 percent of subjects met the recommended number of daily servings for four basic food groups, and that all children consuming less than 2 servings of milk per day were also low in calcium intake. Compared to a typical Canadian child, ASD subjects had similar energy intake and adequate protein intake; in contrast, ASD subjects consumed more carbohydrate and fat than an average Canadian child. It is interesting to note that 37 percent of ASD subjects taking a vitamin supplement had adequate vitamin intake, while 33 percent of non-supplemented ASD subjects had inadequate calcium intake.\textsuperscript{30} In a similar sized study of 52 children with ASD aged 3-8 years, Levy et al\textsuperscript{86} defined nutrient adequacy as 77 percent of RDA. Investigators found that parent-reported intakes of ASD subjects met 95 to 101 percent of RDA for energy, carbohydrate, and fat, and exceeded RDA for protein at 211 percent, although intake range was considerably wide (67% to 436%). Another study used a 3-day diet record and food frequency questionnaire to assess nutrient adequacy in 17 children with autism aged 3-10 years compared to the Canadian RNI. Cornish reported
that 53 percent of children with autism had intakes less than the RNI for one or more of the following nutrients: Vitamins C and D, iron, niacin, riboflavin, Vitamin B6, calcium and zinc. Additionally, 13 of 17 children drank more milk than the RNI.\textsuperscript{87}

It is clear from the mixed results reported by these studies that a definitive conclusion in regards to the nutritional adequacy of children with autism or ASD cannot be reached. However, in studies with a control group, several generalized trends emerge. First, there seems to be little difference in nutritional adequacy between children with autism or ASD compared to typical children\textsuperscript{24,26,27,29}; second, commonly reported inadequate nutrients included fiber\textsuperscript{24,27-29}, calcium\textsuperscript{24,26-28} and Vitamins D\textsuperscript{27,28}, E\textsuperscript{24,27-29} and K.\textsuperscript{29} Unfortunately, because of the lack of a standard definition for “nutritional adequacy” in terms of intake comparison to a single set of dietary recommendations as well as considerable variance in sample size, these trends are difficult to interpret. Still, the majority of studies discussed in this report used a 3-day diet record to assess nutrient adequacy in children with autism and ASD; therefore, the use of a 3-day diet record as a validation reference in this study is not without merit and seems to be the best instrument with which to measure concurrent validity of a food frequency questionnaire.

**Nutrient adequacy in children with autism or ASD: Food frequency questionnaire**

Based on the limited number of studies conducted to date in which a food frequency questionnaire (FFQ) was used to assess nutrient adequacy in children with autism or ASD, a gap in the literature exists; there is little evidence with which to compare nutrient intake data reported by a 3-day diet record to nutrient data reported by a FFQ. Therefore, the need for this study as a facilitator to closing this gap is evident.
In a recent study, Lindsay and colleagues assessed the nutrient adequacy of 20 children with ASD aged 5-13 years by comparing intakes to the 2000 RDA/DRI for children aged 4-8 years and 9-12 years, respectively. Unfortunately, no control group was used. The investigators reported that on average, grouped data indicated that children with ASD met nutritional standards, although an assessment of individual intake showed significant deficiency for certain vitamins and minerals. More specifically, percentages of children with inadequate intake of a certain nutrient include: calcium (45%), pantothenic acid (30%), Vitamin D (25%) and Vitamin K (40%). Additionally, one subject had inadequate intake of riboflavin.36

This single study of nutritional adequacy in children with autism or ASD using a FFQ reported results similar to the general trends observed in studies using a 3-day diet record: While nutritional intake was seemingly adequate for ASD subjects, common nutrients reported as inadequate included calcium and Vitamin D. Again, the absence of other studies using a FFQ, the lack of a control group, and the small sample size make it difficult to interpret the importance of these results, and therefore the need for this study is further established.

Nutrient adequacy in children with autism or ASD: 7-day diet record

Two subsequent studies were identified in which a 7-day diet record was used to assess nutritional adequacy in children with autism or ASD. Although a cross-comparison of study results to data reported from studies using a 3-day diet record and/or a FFQ and determination of valid conclusions is difficult at best, observation of trends within these studies help to contextualize the reliability of the other studies’ findings in terms of commonly reported nutrient inadequacies and assessment of overall intake. In an older
study, Raiten and Massaro assessed the nutrient adequacy of 40 children with autism in comparison to 34 control subjects. Nutritional adequacy was determined using the 1980 RDA for age and sex. The investigators reported overall similarity in diet adequacy for both groups; however, compared to control subjects, children with autism had significantly greater intakes of nutrients except for fat and Vitamins A and C. It is important to note that upon further analysis, age and sex caused variability in nutrient intake between groups; children with autism were older and mostly male. As both groups aged, males consumed more than females, causing a significant difference in nutrient intake between groups. In a smaller study of 26 children with autism and no control group, Bowers reported that all but two children had energy and protein intakes that met or exceeded 1991 Department of Health Dietary Reference Values but were deficient in all other nutrients. These results are somewhat consistent with results reported by Ho and Eaves and Levy et al, although different standards of nutritional adequacy in terms of dietary recommendations were used across all studies. Finally, these studies report results that both coincide and conflict with the general trends observed in the previous studies using a 3-day diet record and FFQ. While Raiten and Massaro reported overall diet adequacy between both groups, Bowers reported inadequate intake for children with autism of all nutrients excluding energy and protein. Again, interpretation of these results within the framework of the general trends observed in previous studies is difficult due to differences in dietary assessment instrument, diet recommendations for nutritional adequacy, use of control group and sample size.
Nutrient adequacy in children with autism or ASD: 24-hour food recall

One study was identified in which a 24-hour recall and a FFQ were used to assess nutritional adequacy in children with autism or ASD. As mentioned previously, it is difficult to make definitive conclusions via a cross-comparison of study results from a 24-hour recall to data reported by a 3-day diet record and/or a FFQ. Still, data reported from a 24-hour recall add perspective to findings from a 3-day diet record and/or a FFQ in terms of commonly reported nutrient inadequacies and assessment of overall intake. Johnson et al used a 24-hour recall and FFQ to assess the nutrient adequacy of 19 children with autism (mean age 39.2 months) compared to 15 typical children (mean age 36.4 months). The investigators defined nutritional adequacy as 100 percent 2000 DRI/RDA; nutritional inadequacy was defined as less than 80 percent of the DRI/RDA. Compared to the control subjects, the investigators reported no significant difference in intake of total calories, carbohydrates, protein or fats for children with autism, although they did consume significantly less food choices from the vegetable group. Greater than 50 percent of children in both groups had inadequate intake of fiber, and children with autism consumed significantly less Vitamin K. Compared to the FFQ, the 24-hour recall found a larger percentage of nutrient inadequacy. These findings are similar to the trends identified in the aforementioned 3-day diet record and FFQ studies: in general, nutrient intake of children with autism is adequate compared to typical children, while common nutrient inadequacies include fiber and Vitamin K.35

Finally, in a recent review of literature, Cermak examined research that addressed food selectivity and nutritional adequacy of dietary intake in children with ASD. Seven studies on nutritional adequacy and dietary intake met study criteria; a control group was
used in four of seven studies. Cermak et al found conflicting results: Nutritional adequacy was reported as below, above, or the same as typical children, and studies comparing intakes to dietary standards failed to include a control group, thereby preventing an interpretation of whether or not the data reported was unique to children with ASD. Although the literature reviewed here reflects Cermak’s conclusions to an extent, a synthesis of the findings reported indicate that in general, children with autism or ASD have adequate nutrient intake compared to typically developing children. Nutrients at greatest risk for inadequate intake include fiber, calcium, Vitamin D, Vitamin E and Vitamin K. A 3-day diet record was the most common instrument used to assess nutritional adequacy in children with autism or ASD and mostly reported similar findings; subsequent diet instruments including diet records, diet recalls and food frequency questionnaires generally reported findings consistent with those of 3-day diet records. Limitations on valid conclusions drawn from a cross-comparison of the studies include inclusion or exclusion of a control group, type of diet assessment instrument, definition of nutritional adequacy and sample size. Finally, there is a definitive gap in the literature in terms of the assessment of nutritional adequacy of children with autism or ASD using a food frequency questionnaire; therefore the need for this study is indicated.

**Concurrent validity: Effect of behavior/contextual issues**

Problem eating behaviors, sensory processing difficulties and family factors comprise behavior and contextual issues observed and reported in children with autism or ASD. A recent review of research addressing food selectivity (e.g. problem eating behavior) in children with ASD concluded that food selectivity is a significant problem.
These issues affect the nutritional status of children with autism or ASD in terms of intake and adequacy\textsuperscript{33}, and could potentially confound the validity of diet assessment instruments such as the FFQ used in this study.

In a study conducted by Schreck and colleagues of 138 children with ASD aged 7-9.5 years compared to 298 typical children, parents completed the Children’s Eating Behavior Inventory to evaluate mealtime and eating behaviors and the Food Preference Inventory to assess food selectivity. Investigators found that compared to control subjects, parents reported significantly more feeding problems in children with ASD as well as more food refusal and a less varied diet. Children with ASD consumed a significantly narrower range of foods within each category (fruits, dairy, vegetables, proteins, starches) compared to typical children and consumed about half the number of foods in each group excluding starches.\textsuperscript{89} In an earlier study, Raiten and Massaro reported similar findings: Compared to 34 children in the control group, 40 children with autism were more likely to adhere to the same foods and demonstrated more food preferences.\textsuperscript{88} Additionally, Schmitt and colleagues used a parent questionnaire and 3-day diet record to compare nutrient intake and eating behavior in 20 boys with autism to 18 typically developing boys aged 7-10 years. The investigators reported that boys with autism ate a smaller variety of foods compared to control subjects and more frequently made food choices based on texture (autism=70%; control=11%). Finally, parents of boys with autism reported experiencing greater difficulty in regards to getting their child to eat.\textsuperscript{29}

Several studies compared eating behaviors of children with autism or ASD to children with other disabilities. In a retrospective chart review of 26 children with autism...
and 45 children with a developmental disability, Field and colleagues found that the prevalence of food selectivity by food type was higher in children with autism (62%) compared to the developmental disability group. However, the prevalence of food refusal was significantly lower in the autism group.\textsuperscript{90} Similarly, Dominick et al, in a study of 67 children with autism and 39 language-impaired children, found that 76.4 percent of children with autism had demonstrated atypical eating behaviors compared to only 15.4 percent of language-impaired children. Additionally, 63 percent of children with autism consumed a restricted range of foods with 58 percent demonstrating a preference for specific foods. Over 30 percent of parents of a child with autism reported food preference based on texture.\textsuperscript{91} In a recent study, Bandini et al reported similar results in a study of food selectivity between 53 children with ASDs and 58 typically developing children. Investigators concluded that food selectivity was more common in children with ASDs compared to typically developing children; additionally, study results suggested that a limited food repertoire may be associated with nutrient inadequacies. Children with ASDs demonstrated more food refusal than typically developing children (41.7% refusal vs. 18.9% refusal of foods offered, P<.0001) and had a more limited food repertoire (19.0 foods vs. 22.5 foods, P<.001).\textsuperscript{28}

Matson et al used a more complex study design to evaluate current food behavior in four groups: 72 children with autism; 40 children with PPD-NOS; 53 atypically developing children; and 114 typically developing children. The investigators combined food-related items from two separate autism diagnostic tools and asked parents to complete the form (9 items total). Matson and colleagues reported that the autism and PPD-NOS groups displayed more eating problems compared to the atypically developing
and typically developing groups. Several trends were reported, including the following: There were no significant differences between the ASD group compared to the PPD-NOS group for any diagnostic item; in addition, the ASD group had significantly higher rates of feedings problems across all nine items compared to atypically and typically developing groups. However, in a similarly designed study, conflicting results were reported. Williams et al used a parent reported FFQ and 3-day diet record to compare 45 children with autism to 45 children with a developmental disability and 69 typically developing children. The investigators reported no difference in the types and variety of foods consumed among the groups; children with autism and children in the developmental disability group did not exhibit higher frequencies of most mealtime behavior problems compared to typically developing children.

Several weaker designed studies were identified that assessed eating behavior problems in children with autism but did not use a control group. Ahearn et al utilized a laboratory-based observational study to assess food acceptance in 21 children with autism and 9 children with PPD-NOS. Significant findings reported include: 17 children were categorized as having low food acceptance; and 17 children were categorized as selecting food based on type or texture. Interestingly, the investigators concluded that observed patterns of food acceptance can only be validated in children with autism when compared to feeding patterns of typical children and developmentally disabled children. Similar findings were reported by Cornish in which 10 of 17 children consumed less than 20 foods as reported by a 3-day diet record and FFQ. In a survey of 100 parents of children with autism, Williams and colleagues found that 67 percent of parents reported that their child was a picky eater, although 73 percent reported that their child had a good appetite.
for foods they liked. Texture, appearance, taste, smell and temperature were parent-reported factors of food selectivity; additionally, the most frequently reported eating and oral behaviors included reluctance to try new foods, eating too few foods and rituals surrounding eating.\textsuperscript{95}

In contrast, Klein et al surveyed parents of 43 subjects with autism aged 4-26 years and found that 68 percent of adult caregivers reported regular eating patterns in children with autism; although 53 percent of children were reluctant to try new foods, 56 percent reported no food preferences.\textsuperscript{96} Additionally, using data from a previous study, Schreck and Williams found no evidence that food selectivity in 138 children with autism was related to symptoms of autism.\textsuperscript{34} This finding is consistent with those reported by Bandini and colleagues.\textsuperscript{28} Schreck and Williams also found that across all food groups, children consumed fewer food types compared to family members; however, food preferences were related to the family’s reported food preferences (e.g. the fewer foods eaten by family members, the fewer foods eaten by the child with autism).\textsuperscript{34}

Finally, in a recent review of literature on food selectivity and nutritional adequacy in children with ASD, Cermak et al identified 12 studies that met the review criteria; 5 studies had no comparison group; 4 studies used a comparison group of typically developing children; and 3 studies used a control group of special needs children. Several of these studies have been cited in this report. Cermak and colleagues concluded that food selectivity was a significant problem in children with ASD; however, assessing the magnitude of the problem is difficult due to the lack of a clear definition of food selectivity, the small number of subjects in the majority of the studies and the lack of a control group in 5 of the studies.\textsuperscript{37} The conclusions are consistent with the literature
reviewed in this report; also, the studies discussed in this section share cross-comparison limitations mentioned in the previous section on nutritional adequacy in children with autism and ASD. Additionally, the studies referenced in this section reported mixed results and were weakened by the absence of a control group (for several studies) as well as variability in sample size, all of which contribute to the difficulty recognized in drawing definitive conclusions. However, in the context of this study, the literature clearly indicates the existence of behavior and contextual issues (including food selectivity) in children with autism and ASD; therefore the effect of these issues must be strongly considered when assessing concurrent validity between a FFQ and 3-day diet record in children with autism and ASD.

**Concurrent validity: Gastrointestinal problems**

Gastrointestinal (GI) symptoms are commonly observed in children with autism or ASD. To date, studies addressing abnormalities in GI function (e.g. gastroesophageal reflux, chronic diarrhea or constipation, chronic abdominal pain or discomfort, abdominal distention and pain) suggest that 30 to 80 percent of children with autism have some type of GI symptom; 43 percent of children without GI complications and 76 percent of children with GI complications possibly have increased intestinal permeability; and compared to typical children, children with autism have altered intestinal microflora. In theory, the presence of GI problems likely affects a child’s nutritional intake, further compromising their purported tenuous nutritional status and potentially affecting the validity of a dietary assessment tool used to assess nutrient intake. For example, exacerbation of a child’s GI symptoms occurring during the referent period for a dietary record or recall could alter current or typical intake; thus, assessment of concurrent
validity between a diet record or recall and a FFQ (assessing usual intake) may be skewed. As discussed in previous sections, consideration of a confounding effect of GI symptoms on concurrent validity between a FFQ and 3-day diet record must be strongly considered during cross-comparison analysis of reported data for each instrument, respectively.

**Conclusion**

Although many benefits result from analyses of outcome measures determined for specific populations, the multitude of varying factors affecting reported results make dietary assessment and its subsequent methodologies an inexact science at best. The literature clearly suggests that validation studies for food frequency questionnaires in particular yield highly variable and conflicting results depending on a given study’s population demographics (e.g. age, sex and health status), FFQ used (original vs. adapted) and its intended purpose (e.g. diet assessment vs. specific nutrient), validation standard and referent period, nutrients assessed and statistical analyses applied. One review qualified validation studies of dietary assessment methods in this way:

“Because dietary intake cannot be measured with absolute precision in free-living populations, there is no true validation standards. Thus, validation studies are best seen as comparative studies, with the validity of the dietary method being assessed established by how well it compares with a second method of dietary assessment. Ideally, the errors inherent in the validation standard are independent of those in the method being assessed; to the extent that errors in the two methods are related, the comparison of the two methods will lead to artificially inflated correlations.”

14"
That being said, it has been reported that in pre-school and school-aged children, a FFQ is frequently used to assess dietary status and nutrient intake with a diet record or recall chosen as the validation standard\(^3\); therefore, use of a 3-day diet record as the validation reference in this FFQ validation study is indicated. Moreover, due to the limited number of FFQ diet assessment studies in children with autism or ASD, part of this study’s purpose is to help fill a gap in the literature. Finally, essential to the interpretation of this study’s results is consideration of confounding variables specific to the unique population studied (children with autism or ASD) such as problem eating behaviors, sensory processing difficulties, family factors and gastrointestinal symptoms and their individual and collective effect on the validity of the food frequency questionnaire as a diet assessment instrument as well as its concurrent validity with a 3-day diet record.
CHAPTER 3

METHODOLOGY

Introduction

This research was part of a pilot study sub-set that was the first to systematically examine the nutritional quality of dietary intake for children with autism in terms of food selections from major food groups and a full range of macro and micronutrients while accounting for the contribution of dietary supplementation to help meet individual nutritional needs. The purpose of the prospective study was to identify trends in dietary intake and the contribution of dietary supplementation in attaining Dietary Reference Intakes (DRIs) for both macro and micronutrients in children with autism. The original pilot study examined the correlation between problem eating behaviors in children with autism and other autism-associated factors (e.g. nutritional quality of dietary intake, nutrition-specific genetic differences, sensory processing characteristics, and intestinal microfloral abnormalities) in order to define phenotypic presentations of mealtime behaviors and determine appropriate and effective interventions for autism and autism spectrum disorder.
Research Aims

Conflicting outcome measures have largely been reported in the literature for application of the various diet assessment tools in children with autism or ASD. Diet records and recalls, FFQs, and 24-hour food recalls have reported both adequate and inadequate nutrient intake in children with autism or ASD. Additionally, the literature has also reported that a comparison of nutrient adequacy studies is confounded by several variables, including the lack of a standardized definition for nutrient adequacy, lack of a control group, and variance in diet assessment method and sample size. The limited use of a FFQ in the literature to assess nutrient adequacy and the lack of dietary assessment validation studies in children with autism or ASD is evidence that more research needs to be conducted in order to further elucidate the nutritional status of this population and to help identify a valid method for assessing adequacy of dietary intake. The aim of this comparative study was to meet the gaps in the available literature by assessing concurrent validity of diet assessment methodologies in children with autism. For the purposes of this study, a food frequency questionnaire (FFQ) was used as the diet assessment instrument while a 3-day diet record was used as the validation reference.

Research Objectives

1. To investigate validity between estimated intakes from a food frequency questionnaire and a 3-day diet record in children with autism or autism spectrum disorder by:
   a. using statistical analysis to compare correlated estimates of nutrient intake and percent of dietary intake recommendations
(DRIs) for the appropriate age category across both diet
assessment methods.

b. comparing the level of nutrient intake across both estimators of
nutrient intake using tertile groupings.

c. comparing categories of nutrient adequacy across both diet
assessment methods; categories of nutrient adequacy are defined as
1) meets or exceeds recommended dietary intake 2) falls below
recommended dietary intake.

Research Design

This comparative study compared two data sets collected during a prospective
study. These data represent a pilot study conducted at a Midwestern University Center for
Excellence in Developmental Disabilities (UCEDD). The purpose of the original autism
pilot study was two-fold: to describe problem eating behaviors in children with autism;
and to assess the relations among problem eating behaviors and other factors associated
with autism, including: nutritional quality of dietary intake, sensory processing
characteristics and intestinal microfloral abnormalities. The study research protocol was
approved through the university’s Institutional Review Board and the Office of
Responsible Research; additionally, informed consent was obtained from the parent or
caregiver of each study participant.

Sample. Study participants were recruited by clinicians of a Midwestern
University Center for Excellence in Developmental Disability. A verbal invitation was
provided for clients new to the center and a letter of invitation detailing the study was
mailed to past clients. Pilot study investigators aimed to enroll 30 children with an ASD,
ages 3-9 at time of enrollment. Participant eligibility criteria for the pilot study included 1) a confirmed diagnosis of ASD 2) ages 3-9 years 3) informed consent provided by a parent or care-giver and 4) returned a 3-day diet record and food frequency questionnaire.

Eligible participants for the first sub-set of the pilot study had a confirmed diagnosis of ASD, were ages 3-9, had a parent or caregiver from which informed consent was obtained, and returned a 3-day diet record. In addition to these criteria, eligible study participants for this second sub-set of the pilot study were required to return a completed food frequency questionnaire in addition to the 3-day diet record.

Data collection. Parents or caregivers from whom informed consent was obtained attended a single data collection session during which instruction for the completion of a 3-day diet record and FFQ was provided. To increase the representativeness of the 3-day diet record, the parent or caregiver was instructed to use one typical weekend day and two consecutive typical weekdays for the child; this process acted to ensure typical diet intake while reducing bias for weekday or weekend food choices. Inclusion of all food and beverages, cooking methods and portion sizes was part of the instructions provided to the parent or caregiver. Also, the parent or caregiver was asked to include the name of the restaurant or eatery if the child ate away from home. In addition, the parent or caregiver was prompted by the Research Assistant during the session to disclose the following information: 1) any dietary supplement (and brand name if known) taken by the child during days of “typical intake” and 2) the typical dose and frequency of the supplement (number of times per day the dose was taken). Finally, the parent or caregiver was asked by the Research Assistant for information concerning a modified or restricted diet followed by the child while intake was recorded.
For completion of the FFQ, the parent or caregiver was instructed to complete the Block Questionnaire for the child’s usual eating habits over the past six months. The parent or caregiver was instructed to take their time while answering the questions in the FFQ as its completion would likely take approximately 30 minutes. Additionally, because the computer would not read a selection on the FFQ for which the lead marks were not neatly done, the Research Assistant instructed the parent or caregiver to use a No. 2 pencil and emphasized the importance of keeping lead marks inside the oval.

**Data Preparation.** For the prospective study, the investigator used ESHA Food Processor SQL® Nutrition and Fitness Software 10.5\(^39\) to analyze 3-day diet record data. Two separate analyses were conducted. In the first analysis, 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 were reported. Use of any self-supplemented nutrient-contributing dietary supplement(s) was included in the second analysis. The investigator defined nutrient-contributing supplements as “any supplement that contributes macro or micronutrients” and noted that because dietary supplements that did not contribute to macro or micronutrient intakes (e.g. probiotics, digestive enzymes or melatonin) would not change nutrient analyses, these supplements were identified but excluded from nutrient analysis. Individual nutrient intake and food group selections were reported as a 3-day average, and each nutrient was expressed as a percentage of age-specific Dietary Reference Intakes (DRIs). For comparative purposes, the average of the three days of intake was calculated to represent total nutrient intakes from the 3-d food record. To classify nutrient estimations from the FFQ and 3-d food record, nutrient intakes of key nutrients were categorized into tertiles of intake. These efforts allowed for
the comparison of ranked intakes without specific reliance on individual variability. Dietary intakes from each of the assessment methods were compared to the EAR/AI; children who met or exceeded the DRI will be classified as “met DRI”.

**Data Analysis/Statistical Procedures.** To compare the nutrient estimations across the two dietary intake assessments, correlational analyses were performed to determine the levels of concordance across various nutrients. Mean nutrient intakes, standard deviations and standard errors were computed as an average across the three days of the diet records as well as from the FFQ. Similarly, individuals were categorized by tertiles of intakes among nutrients for each dietary intake assessment method. To assess the level of agreement in nutrient intake, bivariate correlations were computed between estimations of key nutrients by assessment method. Cross-tabulations with Kappa statistic were conducted to identify the distribution of tertile placement via the FFQ across tertiles of diet record classification across key nutrients. To assess the likelihood of meeting DRI recommendations, cross-tabulations with Kappa statistic were conducted for meeting DRI levels across the two assessment methods.
CHAPTER 4

VALIDATION OF A FOOD FREQUENCY QUESTIONNAIRE TO A 3-DAY DIET RECORD IN CHILDREN WITH AUTISM SPECTRUM DISORDER

Abstract

BACKGROUND: Autism-specific characteristics exacerbate difficulties common in validation studies of typically-developing children and present additional challenges in assessing nutritional status.

METHODS: This comparative study assessed level of agreement for estimated intake of 23 nutrients and nutritional adequacy reported by a FFQ compared to a 3-day diet record in children with ASDs aged 3-9 years (n=22). Nutritional adequacy was defined as ≥ 100% EAR/AI. Correlational analyses were performed to calculate mean nutrient intakes, standard deviations, difference between the means, and percent of dietary intake recommendations. Individuals were categorized by tertiles of intakes for each method, and Kappa statistic was used to determine level of agreement.

RESULTS: The 3-day diet record reported higher estimates for 17 of 23 nutrients (73.9%). For estimated intakes, a moderate level of agreement was observed for approximately 50% of nutrients. Significant correlations for estimated intakes were observed for protein and sodium; strong correlations were observed for calcium and fiber.
Mean percentage of the recommended intake levels were above the EAR/AI for 15 and 14 nutrients from the 3-day diet record and FFQ, respectively; potassium, fiber and vitamin D were approximately 50% EAR/AI. A moderate to high level of agreement for nutrient inadequacy was observed for 15 nutrients. Kappa statistic found a low level of agreement for fiber and vitamin D.

CONCLUSION: Poor agreement was observed between a FFQ and a 3-day diet record for nutrient intake and adequacy in this sample. A 3-day diet record is preferred for nutritional assessment in children with ASDs.

Introduction and Statement Of Purpose

Autism Spectrum Disorders (ASDs) have become a common health concern, with 1 in 110 children aged 3-17 years reported to have a current diagnosis of ASDs. This condition is a collection of developmental disorders that includes Asperger syndrome, Rett syndrome, childhood disintegrative disorder and pervasive developmental disorder not otherwise specified (PPD-NOS). Commonly observed diagnostic features of this condition include qualitative impairment in social interactions and communication (e.g. lack of language development and repetitive use of language), and restricted repetitive and stereotyped patterns of behavior, interests and activities.

Problem eating behaviors such as food selectivity, food aversion and food avoidance or refusal are common in this population, which presents a challenge in overall dietary assessment. Children with ASDs reportedly consume a narrower range of foods within each food category, adhere to the same foods and more frequently make food choices based on texture. Sensory processing difficulties are also commonly observed, and are described as the way in which a child responds to tactile, vestibular, auditory,
visual, gustatory and olfactory stimuli. Hypersensitivity to food smells, tastes and textures as well as auditory sensitivities to mealtime environments have been associated with increased potential for food avoidance and restriction.\textsuperscript{33} There is little systematic data to describe the impact of these challenges on nutrient intakes in children with autism or ASDs. These eating problems result in a concern about fiber, calcium and vitamins D, E and K.\textsuperscript{24,26-29,36} Collectively, these tendencies present a challenge in selecting a dietary intake assessment instrument with the sensitivity to address these patterns and provide an accurate estimate of usual dietary intakes.

Numerous methods have been used to estimate the dietary intakes of children\textsuperscript{18-23} including diet recalls, records, histories and FFQs\textsuperscript{16}; however, consensus on a preferred method has not yet been established.\textsuperscript{3} Validating any diet assessment instrument against another is difficult as different conclusions are reported by different methods; however, the diet record has been posited as the gold standard against which any diet assessment instrument should be measured.\textsuperscript{15,16} In diet assessment studies of school-aged children, a FFQ is the most frequently used validation method, while the diet recall or diet record is the most frequently used validation reference.\textsuperscript{3}

In normal developing children, age, sex, ethnicity, socioeconomic status, cognitive ability, health status, variability in daily food intake and, in some cases, reliance on surrogate report\textsuperscript{3,6,18-23} are variables that complicate measurement of dietary intake. Of the nutritional adequacy studies conducted in children with autism or ASDs, the diet record has been used most frequently.\textsuperscript{24-31} Because parents or caregivers of children with autism or ASDs often exert significant control over the types and amounts of foods available\textsuperscript{32}, they are likely to be very thorough when completing a diet record;
however, one potential drawback could be the time required to complete the diet record, as parents frequently experience stress when caring for their child. Therefore, the purpose of this study was to assess validity of a food frequency questionnaire against a 3-day diet record in children aged 3-9 years with autism or ASDs.

**Methods**

This comparative study examined the similarities and differences in the estimated nutrition intakes from two different dietary assessments in a sample of children with autism or ASDs. These data were collected as part of a pilot study conducted at a Midwestern university center for developmental disabilities. The purpose of the original autism pilot study was three-fold: to estimate nutrient intakes in children with autism; describe problem eating behaviors; and to assess intestinal microfloral abnormalities. The pilot study research protocol was approved through the university’s Institutional Review Board.

**Sample.** Study participants were recruited by clinicians of a Midwestern University center for developmental disabilities. A verbal invitation was provided for clients new to the center and a letter of invitation explaining the study was mailed to past clients. Eligible participants for the prospective study had a confirmed diagnosis of ASDs, were ages 3-9 years, had a parent or caregiver from which informed consent was obtained, and returned a 3-day diet record. Study participants for this sub-set of the pilot study were required to return a completed food frequency questionnaire in addition to the 3-day diet record.

**Data Collection.** Parents or caregivers attended a single 20-minute session to provide instructions on the completion of a 3-day diet record and FFQ. To increase the
representativeness of the 3-day diet record, the parent or caregiver was instructed to use one typical weekend day and two consecutive typical weekdays for the child to improve representation of typical dietary intakes. Inclusion of all food and beverages, cooking methods and portion sizes was part of the instructions provided to the parent or caregiver. Specific instructions were provided for foods consumed away from home, especially the documentation of the name of the restaurant or eatery. Finally, the parent or caregiver was asked for information concerning a modified or restricted diet followed by the child while intake was recorded. For completion of the FFQ, the parent or caregiver was instructed to complete a 2004 90-item Block Questionnaire for the child’s usual eating habits over the past six months. Food Processor SQL® Nutrition and Fitness Software (version 10.5, Esha Research, Salem, OR) was used to analyze 3-day diet records and FFQ intake data was analyzed by NutritionQuest (Berkeley, California).

Macro and micronutrients from estimated intakes were reported for both methods. For the 3-day diet record, nutrient intake was expressed as an average across the three days of record. To assess adequacy, nutrients were expressed as a percentage of Dietary Reference Intakes (DRIs) from the Estimated Average Requirement (EAR) or the Adequate Intake (AI) for the appropriate age and gender.\textsuperscript{98} Percentages were computed using the following equation:

\[
\frac{\text{Estimated intake}}{\text{EAR or AI}} \times 100
\]

Individuals were categorized as adequate/likely adequate based on intake that met or exceeded 100% of DRIs.\textsuperscript{99-103}
**Data Analysis.** The 23 nutrients analyzed included: energy (kcal), protein, fat, carbohydrate, calcium, phosphorus, iron, sodium, potassium, vitamin A (RE), thiamin, riboflavin, niacin, vitamin C, saturated fat, fiber, folate, vitamin E, zinc, vitamin B6, magnesium, vitamin D and selenium. To compare the nutrient estimations across the two dietary intake assessments, correlational analyses were performed to determine the levels of concordance across 23 nutrients. Mean nutrient intakes, standard deviations and difference between the means were computed as an average across the three days of the diet records as well as from the FFQ. Similarly, individuals were categorized by tertiles of intakes among nutrients for each dietary intake assessment method.

To assess the level of agreement in nutrient intake, mean differences were computed from estimates of FFQ subtracted from estimates from 3-day diet record. Individuals were categorized as adequate/likely adequate based on intake that met or exceeded 100% of DRIs. Number of participants with inadequate intake was reported for all nutrients, and percentage of the sample with inadequate intake was calculated. For the above results, level of agreement was interpreted as difference in percentiles across estimators: high (<5.0% difference), moderate (5-10% difference) or low (>20% difference).

Bivariate correlational analyses were conducted to assess level of agreement for estimated nutrient intakes across methods. Kappa statistics were computed to assess the consistency across the two measures at determining tertile distributions and adequacy of meeting EAR/AI levels. Bivariate correlations and Kappa statistics were interpreted as low (0.1-0.3), moderate (0.4-0.6), or high (0.7-1.0) levels of agreement between dietary intake assessment methods.
Results

Thirty children with ASDs, aged 3–9 years, were enrolled in the autism pilot study. Twenty-two of the 30 (73%) participants enrolled in the autism pilot study returned both a 3-day diet record and a food frequency questionnaire and therefore were included in this study. Of the 22 participants, 86% were male (n=19) and 14% were female (n=3). All 22 participants had a diagnosis of ASDs, 77% with an autism diagnosis (n=17) and 18% with a diagnosis of PPD-NOS (n=4).

Energy and Macronutrients. For energy (kcal) and macronutrients, higher mean intakes were reported by the 3-day diet record compared to the FFQ (Tables 4.1-4.2). Differences in mean intakes between both estimators showed a low level of agreement; estimates reported by the FFQ were 69% to 79% lower than estimates reported by the 3-day diet record. For estimated mean protein and carbohydrate intakes, a moderate level of agreement across estimators was observed (R=0.465 and R=0.415, respectively); however, the correlation was only significant for protein (P=0.029). Interestingly, a moderate level of agreement was also observed for percent of energy from protein (R=0.430) and carbohydrate (R=0.430) across both estimators, but the correlation was only significant for percent of energy from carbohydrate intakes (P=0.046).

When raw estimates of energy and macronutrient intakes were grouped into tertiles, Kappa statistics showed a poor level of agreement across both assessment methods (K<0.248). Whereas both measurement methods reported mean percentages of the recommended carbohydrate intakes as above the DRI, the 3-day diet record was less likely to report inadequate intakes. However, because these results for likelihood of
finding inadequate levels for carbohydrate intakes are based on a difference across estimators of one individual (<5% of the sample), the level of agreement across estimators for finding participants with inadequate intakes of these nutrients was high. For individual nutrients, number of participants with inadequate intake is reported in Table 4.4.

**Dietary Fiber.** Higher mean intakes for dietary fiber were reported by the 3-day diet record compared to the FFQ. A low level of agreement for mean differences was observed, with FFQ estimates 73% lower than the estimated intakes from the 3-day diet record. In addition, a modest correlation for estimated intakes of dietary fiber (R=0.421, P=0.051) across both estimators was observed, but was not significant.

There was a low but significant agreement (K=0.317, P=0.036) for categorization into tertiles of fiber intakes. Whereas both the 3-day diet record and FFQ reported mean percentages of the recommended dietary fiber intakes as below the AI (55.6% and 40.3%, respectively), the 3-day diet record was less likely to find inadequate intakes. However, because these results for likelihood of finding inadequate levels for fiber intakes are based on a difference across estimators of two individuals (<10% of the sample), the level of agreement across estimators for finding participants with inadequate intakes of these nutrients was moderate.

**Calcium and Vitamin D.** Higher mean intakes for calcium and vitamin D were reported by the 3-day diet record compared to the FFQ. However, a low level of agreement for differences in mean intakes was observed; FFQ estimates were 65% and 75% lower for vitamin D and calcium, respectively, compared to estimated intakes from
the 3-day diet record. Although not significant, a moderate correlation for estimated
intakes of calcium (R=0.415, P=0.055) across both estimators was noted.

When estimated intakes of calcium and vitamin D were grouped into tertiles,
there was a low level of agreement across both assessment methods for calcium
(K=0.112, P=0.459) and a moderate but significant level of agreement for vitamin D
(K=0.385, P=0.011). Mean intake percentages of the EAR/AI for calcium and vitamin D
varied across diet assessment methods. Mean proportions of the DRI were above AI
values (107.7%) for the 3-day diet record, while estimates from FFQ reported mean
percentages below the AI (77.7%). Conversely, both the 3-day diet record and FFQ
reported mean adequacy percentages below the EAR for vitamin D (90.0% and 58.4%,
respectively). Whereas a 3-day diet record was less like likely to show inadequate intakes
of vitamin D compared to the FFQ, it was more likely to find inadequate levels of
calcium. However, because these results for likelihood of finding inadequate levels for
calcium or vitamin D are based on a difference across estimators of two individuals
(<10% of the sample), the level of agreement across estimators for finding participants
with inadequate intakes of these nutrients was moderate.

Potassium and Vitamin E. Lower mean intakes for potassium were reported by
the 3-day diet record compared to the FFQ; conversely, higher mean intakes of vitamin E
were reported by the 3-day diet record compared to the FFQ. A high level of agreement
for differences in mean intakes of potassium and vitamin E was observed; mean
differences between both estimators were within 1% to 2% of estimated intakes from the
3-day diet record.
When estimated intakes of potassium and vitamin E were grouped into tertiles, Kappa statistics showed a low level of agreement across both assessment methods. Mean intake percentages of the DRI for potassium and vitamin E were similar across diet assessment methods. Both the 3-day diet record and FFQ reported mean intake percentages for potassium at nearly half of the AI (53.3% and 53.8%, respectively). Similarly, for vitamin E, both estimators reported mean adequacy below the EAR (92.3% and 87.1%, respectively). Although a 3-day diet record was less likely to find inadequate intakes of potassium and vitamin E, these results were based on a difference of 1 to 2 study participants (<10% of the sample); therefore level of agreement across estimators for finding participants with inadequate intakes of these nutrients was moderate.

**Discussion**

Assessment of nutritional adequacy in typically-developing children presents specific challenges, while core autism deficits and treatment approaches (e.g. dietary supplements, modified and restricted diets) common in children with ASDs further exacerbate the difficulty of dietary assessment. These deficits include specific physiological, behavioral and contextual issues that affect dietary intake and increase the likelihood of nutrient inadequacies, as well as time since diagnosis, as it is likely that nutritional status is affected by the length of time over which treatments (both physician-prescribed and/or parent-facilitated) have been used. Collectively, these variables increase the risk of inadequate intake of key nutrients in the autistic population, including fiber, calcium, and vitamin D, vitamin E, and vitamin K.

These data suggest an additional challenge in assessing the dietary intake habits of children with ASD. Limited validation studies have been conducted in ASD children to
determine the most effective means of estimating dietary intakes. Livingstone et al\textsuperscript{65} noted that diet records were the most common instrument used in the diet assessment of children and adolescents; however, several studies have indicated that the food frequency questionnaire (FFQ) regularly overestimated energy and nutrient intakes in children aged 4 to 7 years.\textsuperscript{3,6,65,75-79} When FFQs were developed to assess specific nutrient intakes (e.g. calcium and vitamin D) and validated with a diet record, both overestimated intake\textsuperscript{80} and demonstrated relative agreement between the two methods.\textsuperscript{81,82} In the present study, however, the FFQ underestimated approximately 74\% of nutrients analyzed in children with autism or ASDs aged 3 to 9 years, including energy, calcium and vitamin D.

The conflicting results with ASD children could partially be explained by a lack of sensitivity in the FFQ. The Block FFQ used in this study was originally developed for typically-developing children aged 2 to 7 years. It is possible that the food list generated based on a healthy population of children was not sensitive to the autism-specific physiological, behavioral and contextual characteristics and treatment interventions that affect food intake in this population. Therefore, foods listed in the Block FFQ, although reflective of healthy children, were frequently avoided or refused by children with ASDs; consequently, estimated nutrient intake reported by the FFQ was falsely low. Because a FFQ has not been developed specifically for children with autism or ASDs, additional FFQ validation studies are needed to develop sensitive diet assessment methods that identify nutritional inadequacies. With the increase in studies examining ASDs and the diet factors linked to this diagnosis, there is a need to assess the capacity for accurate dietary intake assessments to support these endeavors. Also, as the role of dietary intake and subsequent nutrient inadequacies is investigated as a potential etiological factor for
autism and ASDs, further research efforts are vital to the development and implementation of efficacious nutritional and medical treatment approaches that could increase the quality of life for children with ASDs and their families.

Due to the lack of similar validation studies in children with autism and ASDs, qualifying this study’s findings for level of agreement for differences in mean estimated intakes between a FFQ and 3-day diet record within the context of previous validation studies is not possible. However, two studies were identified in which a 3-day diet record was used to assess nutritional status in children and mean estimated intakes for various nutrients were reported. Therefore, level of agreement for estimated intakes for key nutrients reported by a 3-day diet record in this study compared to two previous studies can be made.

Age, rapid changes in food habits and high variability of daily food intake have been posited as variables that contribute to the difficulty of diet assessment in children. A comparison of estimated nutrient intakes from this study against similar studies previously conducted support these ideas. In a younger sample of boys with ASDs (aged 55.9±13.9 months), Herndon et al reported lower estimated mean intakes for energy and macronutrients compared to the same nutrients reported in this study. Conversely, Schmitt et al, in a study of slightly older boys with autism (aged 7-10 years), reported findings similar to this study for estimated intakes from a 3-day diet for energy, carbohydrate, fat and dietary fiber. Variance in age of sample populations likely explains differences in mean estimated nutrient intakes across studies; intuitively, as children age, daily food intake increases to support growth and development.
A lower level of agreement for estimated mean nutrient intakes reported by FFQs was observed. Lindsay et al.\textsuperscript{36} used a FFQ to assess nutritional status in a sample of boys with autism (aged 5-13 years). Compared to this study’s findings, Lindsay reported higher estimated intakes for energy, protein, fat, calcium and vitamin D. The low level of agreement could be explained by differences in assessment of usual intake across FFQs. Lindsay used a FFQ that reported usual serving size relative to a standardized serving. In the present study, the FFQ did not assess portion size (except for beverages). Therefore, in addition to a potentially insensitive food list for a sample of children with autism or ASDs, lack of portion size assessment could account for differences in estimated mean intakes across studies.

In a study of 112 families of a child with autism, 54\% reportedly used biomedical therapies, which include biomedical, nondrug (dietary and herbal) supplements and special diets.\textsuperscript{32} Also, prevalence of problem eating behaviors (e.g. food selectivity, mealtime rituals, food preferences and/or refusal and reduced variance in dietary intake) is estimated to range between 46 to 89\% in children with autism or ASDs.\textsuperscript{33} These observations are reflected in differences for estimated intakes of select nutrients reported by this study and Schmitt.\textsuperscript{29} Compared to this study, Schmitt reported higher mean estimated intakes of calcium (811mg vs. 948mg) and vitamin D (4.5mcg vs. 10mcg). Differences in mean estimated intakes of these nutrients could be explained by variance in implementation of modified or restricted diets (gluten free, casein free), supplement use (multivitamin and/or calcium supplementation) or presentation of problem eating behaviors across study samples.
Although a definitive recommendation cannot be made in terms of preferred method for estimating nutrient intakes in children with autism or ASDs, due in part to variance in age, gender and sample size across studies and the lack of studies in which a FFQ has been used to assess nutritional status, comparisons between this study to previous studies indicate a higher level of agreement across 3-day diet records for estimating nutrient intakes compared to FFQs. Given this conclusion, use of a 3-day diet record to assess estimated intakes of nutrients in children with autism or ASDs is merited.

Conflicting outcome measures have largely been reported for various diet assessment tools used to assess nutritional adequacy in children with autism or ASDs. Diet records (3 and 7 day) and recalls\textsuperscript{24-31}, a FFQ\textsuperscript{36} and 24-hour food recalls\textsuperscript{35} have reported both adequate and inadequate nutrient intakes in this population. The high variability in outcome measures from these studies is likely related to several variables, including a lack of a standardized definition for nutrient adequacy, a lack of a control group, and variance in diet assessment method and sample size across all studies.\textsuperscript{37}

Similar conflicting results were noted when the present study’s adequacy findings reported by the 3-day diet record were compared to previous studies in which a 3-day diet record was used to assess nutritional adequacy in children with autism or ASDs. A high level of agreement for nutrient adequacy was observed between the present study and Herndon et al (2009).\textsuperscript{27} Adequate intakes of energy and macronutrients for the majority of subjects with ASDs were found in both studies. For dietary fiber, 93.5\% of subjects had intakes <100\%DRI, which agrees with findings from this study, in which 90.9\% of subjects had inadequate dietary fiber intake. Additionally, 43.5\% and 67.4\% of subjects had intakes <100\%DRI$s for calcium and vitamin D, respectively, which reflect this
study’s findings. Finally, Herndon reported 58.7% of subjects had vitamin E intakes <100%DRI; similarly, this study found 50.0% of subjects with inadequate intakes of vitamin E.

Conversely, although findings reported for nutrient adequacy by Schmitt et al (2008)²⁹ coincide with those found in the present study, differing adequacy definitions make interpretation of the findings problematic. Schmitt reported adequate intakes for protein, carbohydrate and total fat and inadequate intakes of dietary fiber, all of which coincide with the present study’s findings. However Schmitt defined adequacy as ≥67% of the daily reference value, compared to ≥100% EAR/AI in the present study. Consequently, the lack of a standardized definition for nutrient adequacy diminishes the high level of agreement for adequacy findings reported across studies.

Similarly, differences in adequacy definitions between this study and a previous study by Lindsay et al³⁶ for FFQs complicate interpretations of findings. Lindsay used DRIs (RDA and AI) to define nutrient intake as adequate (≥100%DRI), low (80-99%DRI) or inadequate (<80%DRI). In most subjects, Lindsay reported adequacy for energy, carbohydrates, protein and fat; these results coincide with this study’s findings. Level of agreement for adequacy of calcium and vitamin D intake showed more variance. Approximately 50% of Lindsay’s subjects had low or inadequate calcium and vitamin D intakes; in the present study, approximately 70% of subjects had inadequate intakes of calcium and vitamin D. As was the case with Schmitt et al²⁹ for 3-day diet records, lack of a standardized definition for adequacy makes it difficult to interpret these findings across studies. It is likely that the differences in level of agreement for adequacy (or
inadequacy) of energy, macronutrients, calcium and vitamin D are a result of the difference in definitions for nutrient adequacy, and therefore a valid and reliable determination of adequacy risk for select nutrients across samples is unlikely.

Nutritional adequacy is a functional outcome of nutritional estimates and independent of level of agreement between assessment methods. Although variance in level of agreement for mean estimated nutrient intakes between the FFQ and 3-day diet record was observed in this study, it is clear from the data that several nutrients may be problematic in this sample. It has been posited that children with autism or ASDs are at increased risk for nutrient inadequacies due in part to deficits unique to this population. Causative factors likely include problem eating behaviors qualified as food selectivity, limited food preference, and low food acceptance or refusal. Four nutrients have frequently been reported as inadequate in children with autism or ASDs, which include: calcium\textsuperscript{24,26-28,30,36,87}, fiber\textsuperscript{24,27-29}, vitamin D\textsuperscript{27,28,36,87} and vitamin E\textsuperscript{24,27-29}. Data from the present study demonstrated consistent estimates of calcium and fiber previously described but less congruence in vitamins D and E and potassium. At least 60\% of the sample had intake levels below the EAR/AI for calcium and vitamins D and E, and at least 90\% of the sample had intake levels below the AI for fiber and potassium. It is probable that fiber\textsuperscript{89} and potassium inadequacy in this population is related to low fruit and vegetable intake and/or low acceptance of whole grains, while inadequate calcium and vitamin D is likely related to low intake of dairy foods. Low intakes for these food groups are also contributable to parent(s) or caregiver(s) exertion of control over the types and amounts of foods available and frequent imposition of dietary restrictions as a method of treatment (e.g. gluten-free casein-free diet, special carbohydrate diet).\textsuperscript{32} These
dietary restrictions likely contribute to fiber, calcium and vitamin D inadequacy. Additionally, the high prevalence of gastrointestinal symptoms observed in this population\textsuperscript{33} may contribute to these nutrient inadequacies via reduced intake or complete avoidance of fruits, vegetables, whole grains, and dairy.

Agreement varied across both methods for level of inadequacy (mean % below EAR/AI). A high level of agreement was observed for potassium and vitamin E between the 3-day diet record and FFQ. Conversely, a low level of agreement was observed for fiber, calcium and vitamin D; the FFQ reported low levels of adequacy for all three nutrients compared to the 3-day diet record. Based on these results, inadequacy for fiber, potassium, calcium and vitamins D and E is probable in children with autism or ASDs; however, level of inadequacy varies across assessment methods.

In general, a low level of agreement was observed for estimated mean intakes for most nutrients across diet assessment methods. Higher estimated intakes of energy, macronutrients, dietary fiber, calcium and vitamin D were reported by the 3-day diet record compared to the FFQ. Because the FFQ was more likely to underestimate mean nutrient intake, use of the 3-day diet record to assess overall levels of nutrient intakes in a small sample of children with autism or ASDs is indicated. A relative high level of agreement was observed across both methods for identification of nutrient inadequacy, including nutrients frequently identified as problematic in children with autism or ASDs. However, level of inadequacy varied across methods. Compared to the 3-day diet record, the FFQ tended to report lower levels of inadequacy for fiber, calcium and vitamin D.
Because an accurate level of nutrient inadequacy is critical for the development of an efficacious treatment approach, use of a 3-day diet record to assess nutrient adequacy in a small sample of this population is preferred.

There were some limitations that affect the validity of this study’s results, including a small sample size comprised mostly of male participants, self-report for usual and actual dietary intake by parents or caregivers, and high variability in individual nutrient intake related to the variance in referent periods for the diet record (three days) compared to the FFQ (six months).

Sensitivity of the FFQ to problem eating behaviors in children with autism or ASDs is another limitation. The Block FFQ was originally developed for typically-developing children aged 2 to 7 years. It is possible that the food list lacked sensitivity to problem eating behaviors and treatment interventions affecting dietary intake in this population. Foods listed in the Block FFQ may have been frequently avoided or refused by children with ASDs, and therefore estimated nutrient intakes reported by the FFQ in this study may have been falsely low. In addition, lack of portion size quantification is another potential study limitation. Despite sensitivity issues, assessment of potential nutrient inadequacies in children with autism or ASDs using current or adapted instruments is important, as inadequate intakes of key nutrients commonly observed in this population could have negative effects on normal physiological growth and bone development. Presently, an autism-sensitive FFQ has not been developed. Additional validation studies are needed to develop sensitive diet assessment methods that identify nutritional inadequacies and facilitate the development of efficacious nutritional and medical treatment approaches.
Assessment of the level of nutritional adequacy is another limitation. In this study, adequate intake was defined as $\geq 100\%$ of recommended dietary intakes for EAR/AI within specified ranges of age and gender (when indicated) for healthy children; recommended dietary intakes for children with autism or ASDs do not exist. Therefore, use of current recommended dietary intakes for healthy children to assess nutritional adequacy in a sample of children with autism or ASDs is necessary.

**Conclusion**

Behavioral, sensory, contextual and physiological characteristics unique to children with autism or ASDs increase the risk for suboptimal nutritional status, and are exacerbated by various treatment approaches including use of dietary and herbal supplements and modified and/or restricted diets. A low level of agreement was observed between a food frequency questionnaire and a 3-day diet record for estimated nutrient intakes and level of nutritional adequacy in this sample of children with autism or ASDs. Valid and reliable assessment of nutrient intakes is essential to the development of dietary intervention and treatment approaches. Based on this study’s results, use of a 3-day diet record to assess nutritional status in children with autism or ASDs is preferred to a food frequency questionnaire.
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>3-d Food Record</th>
<th>FFQ</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
<td>2024</td>
<td>1398</td>
<td>626</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>57.1</td>
<td>45.3</td>
<td>11.8</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>71.0</td>
<td>51.8</td>
<td>19.2</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>281</td>
<td>195</td>
<td>85.9</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>811</td>
<td>611</td>
<td>200</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>863</td>
<td>862</td>
<td>-83</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>14.0</td>
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<td>3.5</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>2698</td>
<td>1927</td>
<td>771</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>1969</td>
<td>2008</td>
<td>-39.1</td>
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<tr>
<td>Vitamin A (RE)</td>
<td>449</td>
<td>681</td>
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</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.4</td>
<td>1.2</td>
<td>.23</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.7</td>
<td>1.5</td>
<td>.24</td>
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<td>Niacin (mg)</td>
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<td>3.1</td>
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<td>Vitamin C (mg)</td>
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<td>6.4</td>
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<tr>
<td>Folate (mg)</td>
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<td>Vitamin E (mcg)</td>
<td>5.4</td>
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<td>.06</td>
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<tr>
<td>Zinc (mcg)</td>
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<td>2.0</td>
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<td>Vitamin B6 (mg)</td>
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<td>.23</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>169</td>
<td>180</td>
<td>-11.0</td>
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<td>Vitamin D (mcg)</td>
<td>4.5</td>
<td>3.0</td>
<td>1.6</td>
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<td>Selenium (mcg)</td>
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<td>59.9</td>
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<td>Fat (% kcals)</td>
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<tr>
<td>Carbohydrate (% kcals)</td>
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Table 4.1: Mean Estimated Nutrient Intakes From Two Dietary Intake Assessment Methods
# Correlation

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<thead>
<tr>
<th>Nutrient</th>
<th>R</th>
<th>P</th>
</tr>
</thead>
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<tr>
<td>Energy (kcal)</td>
<td>0.250</td>
<td>0.262</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>0.465</td>
<td>0.029</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>0.183</td>
<td>0.416</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>-0.021</td>
<td>0.928</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>0.415</td>
<td>0.055</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>-0.005</td>
<td>0.981</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>0.390</td>
<td>0.073</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>0.559</td>
<td>0.007</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>0.119</td>
<td>0.597</td>
</tr>
<tr>
<td>Vitamin A (RE)</td>
<td>-0.035</td>
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<tr>
<td>Thiamin (mg)</td>
<td>-0.103</td>
<td>0.648</td>
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<tr>
<td>Riboflavin (mg)</td>
<td>0.258</td>
<td>0.246</td>
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<tr>
<td>Niacin (mg)</td>
<td>0.125</td>
<td>0.579</td>
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<tr>
<td>Vitamin C (mg)</td>
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<td>Saturated Fat (g)</td>
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<td>0.485</td>
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<tr>
<td>Fiber (g)</td>
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<tr>
<td>Folate (mg)</td>
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<td>0.211</td>
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<td>Vitamin E (mcg)</td>
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<tr>
<td>Zinc (mcg)</td>
<td>0.132</td>
<td>0.560</td>
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<tr>
<td>Vitamin B6 (mg)</td>
<td>-0.039</td>
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</tr>
<tr>
<td>Magnesium (mg)</td>
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</tr>
<tr>
<td>Vitamin D (mcg)</td>
<td>0.131</td>
<td>0.562</td>
</tr>
<tr>
<td>Selenium (mcg)</td>
<td>0.313</td>
<td>0.156</td>
</tr>
<tr>
<td>Fat (% kcals)</td>
<td>0.202</td>
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<tr>
<td>Protein (% kcals)</td>
<td>0.403</td>
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<tr>
<td>Carbohydrate (% kcals)</td>
<td>0.430</td>
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Table 4.2: Differences in Mean Estimated Nutrient Intakes From Two Dietary Intake Assessment Methods
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<thead>
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<th>FFQ</th>
</tr>
</thead>
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<tr>
<td></td>
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<td>SD</td>
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<tr>
<td>Carbohydrate</td>
<td>281</td>
<td>85.0</td>
</tr>
<tr>
<td>Calcium</td>
<td>108</td>
<td>80.3</td>
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<tr>
<td>Phosphorus</td>
<td>196</td>
<td>107</td>
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<tr>
<td>Iron</td>
<td>337</td>
<td>138</td>
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<tr>
<td>Sodium</td>
<td>224</td>
<td>97.1</td>
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<tr>
<td>Potassium</td>
<td>53.3</td>
<td>32.7</td>
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<td>Vitamin A (RE)</td>
<td>162</td>
<td>240</td>
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<td>128</td>
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<td>202</td>
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<td>Niacin</td>
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<td>153</td>
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<td>Vitamin C</td>
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<td>225</td>
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<td>Fiber</td>
<td>55.6</td>
<td>28.7</td>
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<td>Folate</td>
<td>175</td>
<td>86.9</td>
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<tr>
<td>Vitamin E</td>
<td>92.3</td>
<td>136</td>
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<tr>
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<td>61.9</td>
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<td>Vitamin B6</td>
<td>304</td>
<td>179</td>
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<tr>
<td>Magnesium</td>
<td>169</td>
<td>181</td>
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<tr>
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Table 4.3: Percent of Recommended Intake Level
<table>
<thead>
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<th>FFQ Below EAR/AI</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>0</td>
<td>.0%</td>
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<tr>
<td>Calcium</td>
<td>17</td>
<td>77.3%</td>
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<tr>
<td>Phosphorus</td>
<td>4</td>
<td>18.2%</td>
</tr>
<tr>
<td>Iron</td>
<td>0</td>
<td>.0%</td>
</tr>
<tr>
<td>Sodium</td>
<td>3</td>
<td>13.6%</td>
</tr>
<tr>
<td>Potassium</td>
<td>20</td>
<td>90.9%</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>11</td>
<td>50.0%</td>
</tr>
<tr>
<td>Thiamin</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0</td>
<td>.0%</td>
</tr>
<tr>
<td>Niacin</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td>Fiber</td>
<td>20</td>
<td>90.9%</td>
</tr>
<tr>
<td>Folate</td>
<td>4</td>
<td>18.2%</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>15</td>
<td>68.2%</td>
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<tr>
<td>Zinc</td>
<td>1</td>
<td>4.5%</td>
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<tr>
<td>Vitamin B6</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>8</td>
<td>36.4%</td>
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<tr>
<td>Vitamin D</td>
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<td>63.6%</td>
</tr>
<tr>
<td>Selenium</td>
<td>8</td>
<td>36.4%</td>
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Table 4.4: Proportion Meeting Recommended Intake Level
<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal)</td>
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</tr>
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<td>Protein</td>
<td>0.248</td>
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<tr>
<td>Fat</td>
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<td>0.1</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>0.112</td>
<td>0.459</td>
</tr>
<tr>
<td>Calcium</td>
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<td>0.459</td>
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<tr>
<td>Phosphorus</td>
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<td>Iron</td>
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<tr>
<td>Sodium</td>
<td>0.522</td>
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<tr>
<td>Potassium</td>
<td>0.043</td>
<td>0.773</td>
</tr>
<tr>
<td>Vitamin A (RE)</td>
<td>0.18</td>
<td>0.233</td>
</tr>
<tr>
<td>Thiamin</td>
<td>0.043</td>
<td>0.773</td>
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<tr>
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<td>0.238</td>
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<td>Niacin</td>
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<tr>
<td>Vitamin C</td>
<td>0.18</td>
<td>0.233</td>
</tr>
<tr>
<td>Saturated fat</td>
<td>0.043</td>
<td>0.773</td>
</tr>
<tr>
<td>Fiber</td>
<td>0.317</td>
<td>0.036</td>
</tr>
<tr>
<td>Folate</td>
<td>0.18</td>
<td>0.233</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>-0.025</td>
<td>0.869</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.043</td>
<td>0.773</td>
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<td>Vitamin B6</td>
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<td>Magnesium</td>
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<tr>
<td>Vitamin D</td>
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<tr>
<td>Selenium</td>
<td>0.317</td>
<td>0.036</td>
</tr>
</tbody>
</table>

Table 4.5: Kappa Statistics of Agreement of Tertiles of Intake Across Two Dietary Intake Assessment Methods
CHAPTER 5

SUMMARY AND CONCLUSIONS

Results Summary

In this sample of children with autism or ASD, a food frequency questionnaire was more likely to underestimate nutrient intake compared to a 3-day diet record. Higher estimates were reported by the 3-day food record for 17 of 23 nutrients (73.9%). For approximately 50% of estimated nutrient intakes, there was a fair level of agreement between the FFQ and 3-day diet record for mean difference. A significant correlation for mean difference was observed for protein (11.8±19.5 g, \(P=0.029\)) and sodium (771.1±972.5 mg, \(P=0.007\)), and high (non-significant) correlation was observed for calcium (199.8±429.7 mg, \(P=0.055\)) and fiber (3.6±6.2 g, \(P=0.051\)). For this study, nutritional adequacy was defined as ≥100% EAR/AI. Mean percentage of the recommended intake levels exceeded the EAR/AI for 15 and 14 nutrients from the 3-day diet record and FFQ, respectively. Nutrients reported as approximately one half of the EAR/AI included potassium and fiber (3-day diet record) and potassium and vitamin D (FFQ). Although a moderate to high level of agreement for nutrient inadequacy was observed for 15 of 23 nutrients (65%), considerable variance was observed for level of inadequacy across both methods. A high level of agreement was observed for potassium
and vitamin E; conversely, the FFQ reported lower levels of adequacy for fiber, calcium and vitamin D compared to the 3-day diet record. Kappa statistic found a low level of agreement for fiber (K=0.317, P=0.036), vitamin D (K=0.385, P=0.011) and selenium (K=0.317, P=0.036), and a moderate level of agreement for sodium (K=0.522, K=0.001). When level of nutrient intake was grouped into tertiles across both estimators, poor agreement was reported for most nutrients.

Discussion

Although a paucity of diet assessment validation studies exist in the literature for typically-developing children, few studies have been conducted in children with autism or ASD. Additionally, most diet assessment instruments were developed for an age-specific population of healthy children; unfortunately, commonly observed characteristics unique to children with autism or ASD alter daily dietary intake and potentially place these children at risk for nutritional inadequacies. Consequently, estimated nutrient intakes reported by these diet assessment methods in this population potentially lack a desired degree of accuracy, and further research is needed to develop autism-specific diet assessment methods.

In the interim, use or adaptation of existing diet instruments to assess the nutritional intake and adequacy of children with autism or ASD is important to the development of appropriate nutritional interventions. In terms of estimated mean intake, results from this study agree with previous data reported. Although variance existed across this study and previous studies for age and gender of sample populations, similarities existed for reported estimated nutrient intake. For most nutrients, a higher level of agreement for mean estimated intake across 3-day diet records was observed.
compared to FFQs. This observation is somewhat biased due to a lack of FFQ use in previous studies. Although a true “gold standard” does not exist for diet assessment method, based on the evidence available, a 3-day diet record seems to be the most appropriate instrument to assess estimated nutrient intake in this population.

Accurate assessment of nutrient intake is critical to the assessment of diet adequacy. Conflicting findings from various diet assessment methods have been reported in the literature for nutrient adequacy in children with autism or ASD.\textsuperscript{24,31,35,36} Interpretation of the reported findings is confounded by the lack of a standardized definition for nutrient adequacy as well as use or non-use of a control group and variance in diet assessment method and sample size.\textsuperscript{37} Several studies have used Estimated Average Requirement (EAR) and Adequate Intake (AI) to interpret estimated nutrient intakes reported by a 3-day food record. Lockner et al compared estimated nutrient intakes from a 3-day diet record to EAR/AI in typically-developing children and children with ASD; a low percentage of children in both groups had inadequate intake of most nutrients. Nutrient intake reported as most frequently inadequate for both groups included vitamin A, vitamin E, fiber and calcium. Variance in level of inadequacy for some of these nutrients was noted between groups.\textsuperscript{24} Additionally, Bandini et al found that compared to typically-developing children, children with ASD had a greater number of nutrient inadequacies based on EAR/AI. In both groups, estimated intakes of fiber, vitamin D, vitamin E and calcium were inadequate, although children with ASD were more likely to have inadequate intakes of vitamin D and calcium.\textsuperscript{28} In this study, EAR/AI was also used to assess nutrient adequacy. Similar results were found for estimated nutrient intakes reported by the 3-day diet record. Estimated intake for 15 nutrients was
above the EAR/AI. Nutrients falling below the EAR/AI included potassium, fiber, vitamin D and vitamin E. To the best of our knowledge, no previous study has compared estimated nutrient intakes reported by a FFQ to the EAR/AI to assess nutritional adequacy. Lindsay et al used a FFQ to assess nutritional adequacy of 20 children with ASD but compared results to the 2000 RDA/DRI. Nutrients reported as inadequate included calcium, pantothenic acid, vitamin D and vitamin K. Compared to the EAR/AI, inadequate nutrient intake was reported by the FFQ in this study for fiber, calcium, potassium, vitamin D and vitamin E. Although some level of agreement for likely nutrient inadequacy exists, comparisons between FFQ results reported by this study to those reported by Lindsay et al are difficult due to variance in standards used to determine adequacy. Finally, because a high level of agreement was observed for the 3-day diet record in this study compared to previous studies for estimated nutrient intake in addition to nutrient adequacy when compared to the EAR/AI, use of a 3-day diet record to assess nutrient adequacy in children with autism and ASD is indicated.

Limitations and Implications for Further Research

Several limitations exist in this study. Considerable variability was observed in individual nutrient intake between the 3-day diet record and FFQ. Part of this variability is likely attributable to differing referent periods for each respective instrument. Whereas a FFQ generally attempts to assess diet intake over a period of 6-12 months (depending on how the researcher frames the FFQ), the diet record in this study assessed diet intake over consecutive days (2 typical weekdays and 1 typical weekend day); therefore some degree of variance in individual nutrient intake would be expected. In addition, unlike the 3-day diet record, the FFQ used in this study did not use portion sizes to quantify
estimated food intake, which likely exacerbated the differences observed in estimated
nutrient intake across both methods. Generalizability of this study’s findings is difficult
due in part to a small gender-biased (male) sample size and lack of a control group of
typically-developing children. Because a control group was not used, it is difficult to
assess whether the general poor agreement observed across estimators for estimated
intake and individual nutrient inadequacy is sole a function of the uniqueness of this
special population. Finally, the validated FFQ used in this study was originally developed
for typically-developing children aged 2-7, therefore it is highly probable that error exists
in reported estimated nutrient intakes due to characteristics unique to the autistic
population that are likely to affect dietary intake.

Because a FFQ has not been developed specifically for children with autism or
ASD, additional FFQ validation studies are needed. Individual strengths and weaknesses
are inherent in diet records and FFQs, respectively. Development of a FFQ that
incorporates a food list sensitive to behavioral, sensory, contextual and physiological
characteristics commonly observed in this population as well as development of a portion
size guide to quantify usual intake could significantly increase accuracy of diet
assessment in terms of estimated intake and nutrient inadequacy. This study revealed that
children with autism and ASD are at risk for certain nutrient deficiencies. Therefore,
进一步 research efforts to develop sensitive diet assessment methods that identify
nutritional inadequacies are vital to the development and implementation of efficacious
nutritional and medical treatment approaches.
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