Nutrient Intake From Food in Children With Autism

AUTHORS: Susan L. Hyman, MD,[a] Patricia A. Stewart, PhD, RD,[a,b] Brianne Schmidt, RD,[a] Usa Cain, BA,[c] Nicole Lemcke, MS, RD,[a] Jennifer T. Foley, BS,[a] Robin Peck, DT,[b] Traci Clemons, PhD,[d] Ann Reynolds, MD,[e] Cynthia Johnson, PhD,[f,g] Benjamin Handen, PhD,[g] S. Jill James, PhD,[h] Patty Manning Courtney, MD,[i] Cynthia Molloy, MD, and Philip K. Ng, BS[b]

[a]Department of Pediatrics, University of Rochester Medical Center, Rochester, New York; [b]Clinical and Translational Science Institute, University of Rochester School of Medicine, Rochester, New York; [c]Boston University School of Medicine, Boston, Massachusetts; [d]EMMES Corporation, Baltimore, Maryland; [e]Department of Pediatrics, University of Colorado School of Medicine, Denver, Colorado; [f]Departments of Pediatrics and [g]Department of Psychiatry, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania; [h]Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, Arkansas; and [i]Department of Pediatrics, University of Cincinnati College of Medicine, Cincinnati, Ohio

KEY WORDS

autism, diet, nutrition, supplements

ABBREVIATIONS

AI—average intake
AMDR—acceptable macronutrient distribution range
ASD—autism spectrum disorder
ATN—Autism Treatment Network
DRI—daily recommended intake
EAR—estimated average requirement
NCI—National Cancer Institute
NDSR—Nutrition Data System for Research
RDA—recommended daily allowance
UL—upper limit
WWEIA—What We Eat In America

This manuscript has been read and approved by all authors. This article is unique and not under consideration by any other publication and has not been published elsewhere.

www.pediatrics.org/cgi/doi/10.1542/peds.2012-0900L

doi:10.1542/peds.2012-0900L

Accepted for publication Aug 8, 2012

Address correspondence to Susan Hyman, MD, 601 Elmwood Ave, Box 671, Rochester, NY 14642. E-mail: susan_hyman@urmc.rochester.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: *The authors have indicated they have no financial relationships relevant to this article to disclose.*

abstract

OBJECTIVE: The impact of abnormal feeding behaviors reported for children with autism spectrum disorders (ASDs) on their nutritional status is unknown. We compared nutrient intake from food consumed by children with and without ASD and examined nutrient deficiency and excess.

METHODS: Prospective 3-day food records and BMI for children (2–11 years) with ASD participating in the Autism Treatment Network (Arkansas, Cincinnati, Colorado, Pittsburgh, and Rochester) were compared with both the National Health and Nutrition Examination Survey data and a matched subset based on age, gender, family income, and race/ethnicity (N = 252 analyzed food records).

RESULTS: Children with ASD and matched controls consumed similar amounts of nutrients from food. Only children with ASD aged 4 to 8 years consumed significantly less energy, vitamins A and C, and the mineral Zn; and those 9 to 11 years consumed less phosphorous. A greater percentage of children with ASD met recommendations for vitamins K and E. Few children in either group met the recommended intakes for fiber, choline, calcium, vitamin D, vitamin K, and potassium. Specific age groups consumed excessive amounts of sodium, folate, manganese, zinc, vitamin A (retinol), selenium, and copper. No differences were observed in nutritional sufficiency of children given restricted diets. Children aged 2 to 5 years with ASD had more overweight and obesity, and children 5 to 11 years had more underweight.

CONCLUSIONS: Children with ASD, like other children in America, consume less than the recommended amounts of certain nutrients from food. Primary care for all children should include nutritional surveillance and attention to BMI. *Pediatrics* 2012;130:S145–S153

Children with autism spectrum disorders (ASDs) are reported to have food aversions and habitual eating behaviors.[1–5] The authors of previous studies have examined the nutritional intake of children with ASDs by using 3-day diet diaries,[4–9] 24-hour recalls,[10] food frequency questionnaires,[8,10–14] food preference,[15] and food variety measures.[5,12,16] Compared with siblings, children with ASDs ate a more limited variety of foods.[3,16] However, although food variety was less,[5,8,12,17] no significant difference in nutrition compared with typically developing controls was consistently identified.[4,5,7,9,10,13,18] The nutrients most commonly reported to be consumed in insufficient amounts include fiber, calcium, iron, and vitamins A, C, and D.[6–8,10–13,17–19] Vitamins E, K, B6, B12, folic acid, and zinc have been found to be eaten in insufficient amounts in at least 1 study each.[5–7,11–14,19,20] Few authors have examined the additional impact of restricted diets.[19,21] Conversely, the limited yet repetitive intake of children with ASDs may place them at risk for nutritional excess.[6,22] BMI (body mass index) is only a gross indicator of nutrition status. Although children with ASDs are reported to have BMI in the typical range,[23] it does not necessarily reflect nutrient sufficiency.

The methodology for dietary analysis of nutrient intake in individuals and populations has been outlined by the Institute of Medicine[24] but has not been uniformly applied in dietary studies of children with ASDs.[4,7,9,10,13,14,19,25] An additional problem that impacts the interpretation of several studies involving children with ASDs is the use of nutritional analysis software with an incomplete database, which may underestimate nutrient intake thereby overestimating inadequacy.[4,5,10] Other studies used the recommended daily allowance (RDA) to measure nutrient adequacy. The RDA is the intake at which 97% to 98% of the population exceeds their needs. Defining the RDA or a percentage of the RDA as insufficient also overestimates the prevalence of deficiency.

This study was undertaken to characterize the nutritional intake of children with ASDs and assess the impact of reported food aversions and restricted diets. It is the largest sample of dietary intake and BMI status of children with ASDs collected and analyzed using current methodology. In this article, the diet and BMI of children with ASDs are compared with the general pediatric population by using the National Health and Nutrition Examination Survey (NHANES) data.[26] Accurate understanding of the unique nutritional risk of children with ASDs relative to other children is important to clinicians who are responsible for nutritional surveillance in primary care and to parents who are concerned about the effects of limited or restricted diets.

METHODS

Sample

Children (2–11 years; N = 367) were recruited between November 2009 and June 2011 from 5 participating Autism Treatment Network (ATN) sites. The ATN is a collaboration of 17 centers across North America funded by Autism Speaks and the Health Resources and Services Administration to establish and study the medical standard of care for individuals with ASDs.[27] Clinical diagnoses of ASDs are supported by the *Diagnostic and Statistical Manual IV* criteria[28] and the Autism Diagnostic Observation Schedule.[29] De-identified health and behavioral data for participating families who consented through institutional review board-approved protocols are submitted to a central database. Newly enrolled and existing ATN families were invited to participate in this study by the site ATN clinicians and study coordinators. Recruitment was not based on concern about diet or feeding behavior.

Procedures

Height and weight were measured 3 times, and the 2 closest measurements were averaged. BMI and BMI percentile were calculated. History of the child's dietary restrictions was collected. Total family income was endorsed by the family in the same incremental ranges as the NHANES.[30]

Parents completed a 3-day food record containing all food, beverage, and supplements ingested by the child over 3 consecutive days including 1 weekend day. A registered dietitian or trained research assistant at each site used a standardized method to instruct parents how to record intake. The importance of measurement, added ingredients, brands, and label claims was emphasized. The completed form was returned to the ATN site by mail, e-mail, or fax. Supplements, including any vitamins, minerals, botanicals, and amino acids, were recorded on a separate form, which will be analyzed in a future publication. Meal replacements such as specialized formulas were analyzed as a food component and were included in this analysis. Dietitians at each site reviewed the records and contacted the parents for missing details. De-identified food records were sent to the University of Rochester for analysis.

Dietary intake data, the dependent variable, were determined from the 3-day food record by using Nutrition Data System for Research (NDSR) software versions 2009 and 2010, developed by the Nutrition Coordinating Center (University of Minnesota, Minneapolis, MN).[31] NDSR has an extensive food list including 18 000 foods and 7000 brand name items and specialty items. Products may be added to the database. NDSR imputes nutrient content from nutrition facts labels and ingredients existing in the program so the total nutrient intake is not underestimated due to missing values. The NDSR analysis was used to produce average nutrient intakes for 160 nutrients.

Nutrition Variables

The estimated average requirement (EAR) is the average daily nutrient intake level estimated to meet the requirements of half of the healthy individuals in a group for nutrients for which an RDA is scientifically established. The cut point method, which reflects the proportion of individuals within a group with inadequate intake, was used to determine the percentage of individuals with intakes below the EAR.[24] Because of its skewed requirement distribution, the full probability approach was used to determine the prevalence of insufficient iron intake.[32]

The average intake (AI) is the recommended daily intake based on observed or experimentally determined approximations. It is used for nutrients where data are insufficient to establish an EAR. Intake levels above the AI imply a low prevalence of inadequate intake. Statements regarding inadequacy cannot be made when intakes are below the AI. Therefore, the percentage of children with intakes greater than the AI was determined to reflect sufficiency for those nutrients.[24]

Tolerable upper limit (UL) is the highest recommended daily intake level of a nutrient likely to pose no risk of adverse health effects.[24] It is used to assess the potential risk of excessive intake. The percentage of children with intakes greater than the UL from food alone was determined.

BMI status was categorized by using NHANES criteria: <5th percentile, underweight; >85th percentile, overweight; and >95th percentile, obese.

Data Analysis

The demographic data were summarized with descriptive statistics. To obtain an estimate of usual (or long term) intake data from NDSR, data were adjusted for day to day variability by using the National Cancer Institute (NCI) method.[33,34] The NCI method models Box-Cox–transformed 24-hour intake observations as a function of observed fixed-effect covariates, unobserved individual-level random effects, and within-individual error. The covariates (sequence and weekend versus weekday) are "nuisance effects" that are explicitly adjusted for in the estimation of usual intake. Complete details of the NCI method and the SAS (SAS Institute Inc, Cary, NC) macros necessary to fit this model and to perform the Monte Carlo-based estimation of usual intake distributions can be found at the NCI Web site.[34] The adjusted nutrient intake was then compared with age and gender appropriate daily recommended intake (DRI) to examine nutritional sufficiency as established by the Institute of Medicine Food and Nutrition Board.[24] The DRIs are a set of reference values used to plan and assess nutrient intakes of healthy people and include the RDA, EAR, AI, and ULs. One sample tests for proportions were used to compare the proportion of our population above or below the DRIs as compared with population-based estimates.[26] All analyses were conducted by using SAS version 9.1 (SAS Institute Inc).

The nutrient intake from diet was also compared with a general population of children collected through NHANES.[35] The NHANES is a continuous survey of ~5000 people per year from 15 nationally representative communities. It surveys the health and nutritional status of adults and children in the United States by using a complex, stratified, multistage probability cluster sampling design. The NHANES analysis compared with the DRIs lags behind data collection. The most current micronutrient dietary analysis available is from the NHANES 2001–2002 What We Eat In America (WWEIA).[26] A subset of nutrients important to bone health (vitamin D, calcium, phosphorus, and magnesium) was analyzed by using WWEIA 2005–2006.[36] To compare macronutrient intake and BMI data from our sample with those from the general US population, we selected comparison groups of boys and girls of similar age from NHANES 2007–2008.[37,38]

Participants in this study were matched on race, ethnicity, and income to the NHANES[30] participants because of the potential impact of these factors on food choice.[39] In most cases, 2 matches from the NHANES were found per study participant. The NHANES 2007–2008[37,38] was the most recently analyzed sample for BMI and macronutrients and was used for comparison by *t* test for continuous variables (nutrient intake) and by χ^2 tests for categorical variables (BMI category). We used PROC SURVEYMEANS and PROC SURVEYFREQ in SAS 9.1 and appropriate 4-year sample weights.

RESULTS

Participants in this study were 367 children with ASD (2–11 years); 295 completed and returned the 3-day food records. A total of 72 participants agreed to participate in the study, completed BMI and initial forms, but did not complete the 3-day food records. Three 3-day food records were not analyzed because of reported illness in the recording interval. The nutrition data are based on 252 records analyzed at the time of manuscript preparation. The demographics of the sample are described in Table 1.

Special Diets and Nutritional Supplement Use

A dietary restriction of gluten, casein, or processed sugars as an intervention for ASDs or food allergies/intolerances was reported for 18% of participants.

TABLE 1 Demographic Description of Study Population

	Total ATN Subjects Age 2–11 y (*n* = 3360)	Total Number of Participants (*n* = 367)	Analyzed Food Records (*n* = 252)
By ATN[a] site, %			
Little Rock	NA	13	16
Denver	NA	20	17
Pittsburgh	NA	24	20
Cincinnati	NA	18	19
Rochester	NA	25	27
Characteristic			
Age in years (SD)	5.17 (2.51)	5.37 (2.43)	5.58 (2.51)
Gender (% boys)	84	86	86
Race/ethnicity[a]			
White	72	84	85
African American	6	5	5
Asian American	5	2	2
Other	6	3	3
Hispanic	10	6	15
Mean household income (SD)[b]			
<$15K	NA	5	5
$15–<$25K	NA	9	8
$25–<$35K	NA	9	10
$35–<$50K	NA	19	19
$50–<$75K	NA	19	19
≥$75K	NA	39	39
Primary caregiver education[c]			
Highest grade completed			
Less than high school	4	2	1
High school	16	13	15
Some college, trade school	32	33	32
College degree	29	33	31
Post graduate	19	18	20

NA, not applicable.
[a] Missing for *N* = 50; *N* = 10; and *N* = 7, respectively.
[b] Missing for *N* = 30 and *N* = 9, respectively.
[c] Missing for *N* = 230; *N* = 29; and *N* = 18, respectively.

Supplement use was defined as the use of vitamins, minerals, herbal, or botanical compounds and was reported by 66% of study participants. This compared with 35% of children ages 2 to 13 years in the NHANES and 61% in a national sample of children with chronic disease.[40,41]

BMI

Data on 362 participants were compared with a matched NHANES (2007–2008) population by BMI category (Table 2). The age ranges for the BMI data differ from the DRIs used in nutrient analysis. Children with ASDs aged 2 to 5 years were more likely to be overweight ($P < .05$) or obese ($P < .001$) than the NHANES matched cohort. Among children aged 6 to 11 years, proportionately more children with ASDs were underweight than in the NHANES matched cohort ($P < .05$). Children on restricted diets were more likely to be underweight than those not on restricted diets ($P = .02$).

TABLE 2 BMI Data on 362 Children With ASDs Compared With NHANES 2007–2008

	Age, 2–5 y		Age, 6–11 y	
	ASD	NHANES Matched[a]	ASD	NHANES Matched[a]
N	213	302	149	257
BMI category, %				
Underweight (<5th%)	7	6	7	2*
Healthy weight (5th–85th%)	63	78*	66	64
Overweight (>85th–95th%)	16	7*	11	13
Obese (>95th%)	14	9**	16	21

* $P < .001$; ** $P < .05$.
[a] NHANES 2007–2008 matched for socioeconomic status, age, gender, and race.

Macronutrient Intake

Children with ASDs (ages 4–8 years) consumed less energy and lower percentage of protein and greater percentage of carbohydrates on average than the NHANES (2007–2008) matched sample.[37] However, all macronutrient intakes were within the acceptable macronutrient distribution range (AMDR) by age. No differences in macronutrient consumption were found for children younger than 4 and older than 8 years of age (Table 3).

Micronutrients Examined by EAR

Insufficient intake of vitamin D in children with ASDs was common with 87% of children younger than 4 years, 89% of those 4 to 8 years, and 79% of those 9 to 11 years below the EAR. There is no comparison group from the NHANES because the vitamin D intake from the 2005–2006 survey was analyzed as an AI not an EAR. A greater percentage of the NHANES controls did not meet vitamin E recommendations although both groups had less than the recommended intake. Children with ASDs ages 4 to 8 years had lower reported intakes of vitamin A, vitamin C, and zinc compared with the NHANES controls. Children ages 9 to 11 years had lower levels of phosphorus intake. The percentage of children with nutrient intake less than the EAR increased with

TABLE 3 Mean Macronutrient Intake of Children With ASD Compared With NHANES 2007–2008 Matched Cohort

Nutrient Intake	Age Range (y)[a]	*n*	DRI/AMDR[b]	ASD Mean	NHANES (mean)[c]
Energy, kcal	1–3	61	—	1375.9	1440.4
	4–8	153	—	1683.9	1911.2***
	9–11	35	—	2003.2	2178.8
Protein, g	1–3	61	13	42.94	49.72*
	4–8	153	19	50.85	64.11****
	9–11	35	34	68.29	73.38
% Protein	1–3	61	5–20	12.55	13.84**
	4–8	153	10–30	12.20	13.54****
	9–11	35	10–30	13.74	13.51
% Carbohydrate, g	1–3	61	45–65	57.20	55.91
	4–8	153	45–65	58.25	55.21****
	9–11	35	45–65	56.40	56.78
% Fat, g	1–3	61	30–40	31.94	31.54
	4–8	153	25–35	31.36	32.57
	9–11	35	25–35	31.58	31.05
Fiber, g	1–3	61	19	10.17	9.09
	4–8	153	25	13.15	11.86
	9–11	35	31	16.74	13.75

* $P < .05$; ** $P = .04$; *** $P = .001$; **** $P < .001$.

[a] Nine through 11 years age category includes boys only because there were too few girls in this age category for analysis.

[b] AMDR is the range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients. If an individual consumes in excess of the AMDR, there is a potential of increasing the risk of chronic diseases and/or insufficient intake of essential nutrients from other macronutrients.

[c] NHANES population matched for age, gender, race/ethnicity, and socioeconomic status.

age for vitamins A, C, E, B12, and folate and the minerals zinc and magnesium (Table 4).

Micronutrients Examined by AI

Consistent with the NHANES data, very few children with ASDs consumed adequate fiber and potassium (Table 5). There was no difference in the number of nutrients consumed in sufficient amounts, above the EAR/AI, for children in the different weight categories. There was no difference in the number of nutrients consumed in adequate amounts by children with ASDs reported to be on restricted diets and those not on restricted diets ($P = .55$).

Excess Intake

Many children with ASDs had nutrient intakes above the UL from food alone such as copper, retinol (vitamin A), folic acid, zinc, and manganese (Table 6). Elevated intake of sodium was seen for all age groups studied and was greater in the NHANES control group than in the children with ASDs.

DISCUSSION

Our data, on a large, geographically diverse cohort of children with ASDs, identified lower than recommended intakes of vitamins A, D, and K, as well as calcium, choline, fiber, magnesium, phosphorus, and potassium from food sources. These findings confirm previous reports of insufficient intake of calcium, fiber, zinc, and vitamins A, D, and K.[6–8,10,11,13,14,17–19] However, we did not find that children with ASDs consumed insufficient iron, B6, B12, or folic acid.[6,7,11–14,19,20] Analysis of Vitamin D intake was complicated by recent changes in reference values,[42] but over 3 quarters of the participants had vitamin D intakes below the EAR. Of note, <3% of children in the NHANES 2005–2006 sample had adequate vitamin D intake.[36] Patterns of insufficient nutrient consumption by age were identified. Younger children with ASDs were less likely to have insufficient nutrient intake. This may be due to lower absolute requirements and more parental control of foods offered to younger children.

To address the accuracy and reliability of the nutrient data in this study, we focused on 3 critical elements of study design: the tools used to collect intake data, the completeness of the nutrient analysis software, and the appropriateness of the DRI and statistical methods selected to interpret results. Only 1 previous study[8] used both the recommended statistical analyses to assess insufficiency and nutritional analysis software complete enough to provide accurate data. However, that study of 53 children with ASDs and 58 controls reported on a limited number of nutrients. The careful collection and analysis of the data on this ATN cohort provide for the most accurate description of what children with ASDs eat in the United States to date.

The use of a matched NHANES control group further expands upon previous work that compares the nutrition of children with ASDs to controls with typical development.[4,8,10,12,15,18] Although many children with ASDs do not consume recommended levels of nutrient intake, this is consistent with intake of the general pediatric population in the United States. Most families of children with ASDs can be counseled that although their child may not be consuming the recommended diet, they may not differ from children without ASDs in their nutritional intake. No general recommendation for vitamin or mineral supplementation can be made based on the food intake data reported in this study. Specific nutrient supplementation should be based on individual assessment.

Although the purpose of this study was to examine the nutrient intake from food in children with ASDs as a group, there were isolated children with very restricted diets. Some of these children

TABLE 4 Micronutrient Intake EAR Analysis of Children With ASDs Compared With WWEIA 2001–2002

Nutrient	Age Range (y)[a]	ASD (% <EAR)	WWEIA (% <EAR)
Calcium[b]	1–3	85.8	NA
	4–8	57.9	NA
	9–13	29.0	NA
Copper	1–3	0.1	<3
	4–8	0.4	<3
	9–13	0.2	<3
Dietary folate	1–3	2.7	<3
Equivalents	4–8	2.7	<3
	9–13	4.9	<3
Iron	1–3	0.2	<3
	4–8	0.5	<3
	9–13	0.2	<3
Magnesium[c]	1–3	0.1	<3
	4–8	2.3	<3
	9–13	18.1	22
Niacin[d]	1–3	0.6	<3
	4–8	0.3	<3
	9–13	0.0	<3
Phosphorus[c]	1–3	2.0	<3
	4–8	1.0	<3
	9–13	28.9	16*
Riboflavin	1–3	0.4	<3
	4–8	0.5	<3
	9–13	0.8	<3
Selenium	1–3	0.0	<3
	4–8	0.1	<3
	9–13	0.0	<3
Thiamine	1–3	0.4	<3
	4–8	0.2	<3
	9–13	0.2	<3
Vitamin A	1–3	3.8	<3
Retinol activity equivalents	4–8	9.1	4***
	9–13	17.4	13
Vitamin B12	1–3	3.5	<3
	4–8	4.3	<3
	9–13	5.0	<3
Vitamin B6	1–3	0.2	<3
	4–8	0.4	<3
	9–13	0.1	<3
Vitamin C	1–3	2.4	<3
	4–8	8.2	<3****
	9–13	10.2	8
Vitamin D[b]	1–3	86.9	NA
	4–8	89.2	NA
	9–13	79.1	NA
Vitamin E	1–3	35.1	80****
	4–8	42.0	80****
	9–13	55.9	97****
Zinc	1–3	1.0	<3
	4–8	6.3	<3**
	9–13	8.4	<3

NA, not applicable. *P = .04; **P = .02; ***P = .001; ****P < .001.

[a] Nine through 11 years age category includes boys only because there were too few girls in this age category for analysis.

[b] DRIs for calcium and vitamin D changed from AI to EAR. Appropriate comparison is not available.

[c] Compared with 2005–2006 WWEIA.

[d] Reflects preformed niacin only and does not include contribution from tryptophan; therefore, there may be an overestimated percentage below EAR.

TABLE 5 Micronutrient Intake AI Analysis of Children With ASDs Compared With WWEIA 2001–2002

Nutrient	Age Range (y)[a]	ASD (% >AI)	WWEIA (% >AI)
Choline	1–3	30.2	NA
	4–8	18.2	NA
	9–13	5.5	NA
Fiber	1–3	2.4	<3
	4–8	1.3	<3
	9–13	1.6	<3
Manganese	1–3	86.8	NA
	4–8	86.3	NA
	9–13	84.7	NA
Pantothenic acid	1–3	89.9	NA
	4–8	66.0	NA
	9–13	73.5	NA
Potassium	1–3	1.9	6
	4–8	0.1	<3
	9–13	0.0	<3
Sodium	1–3	94.1	>97
	4–8	97.2	>97
	9–13	98.8	>97
Vitamin K	1–3	69.2	47**
	4–8	21.1	14*
	9–13	34.7	27

NA, not applicable. *P = .01; **P < .001.

[a] Nine through 11 years age category includes boys only because there were too few girls in this age category for analysis.

were able to achieve nutrient adequacy and others were not. The fortification of foods commonly eaten by children may greatly impact their nutritional status.

Although food frequency questionnaires have been used to assess dietary adequacy, existing tools may not be appropriate for studying the intake of children with ASDs given their selective, repetitive intake.[8,10–14]

The risk for nutritional insufficiency of children on restricted diets remains an area of concern. Hediger et al[21] found decreased bone cortical thickness in children following a casein-free diet. Decreased calcium intake was not reported by Cornish[19] in a very small postal sample of children with ASDs on casein-free diets, however. Although dairy products and fortified gluten-containing products are an important source of nutrients, we did not find a greater number of nutrient deficits in children reported to be on special diets. The ATN data record all special diets as 1 category. Future analysis of these data will further examine this subset of children.

There is no consensus among previous studies comparing the BMI of children with ASDs and controls.[5,11,12,16,43,44] Children with ASDs younger than 5 years of age are more frequently

TABLE 6 Intake Above the UL for Micronutrients in Children With ASDs Compared With WWEIA 2001–2002

Nutrient	Age Range (y)[a]	ASD (% >UL)	WWEIA (%>UL)
Calcium	1–3	0.1	<3
	4–8	0.1	<3
	9–13	0.2	NA
Copper	1–3	13.0	15
	4–8	0.0	<3
	9–13	0.0	<3
Folic Acid	1–3	7.3	5
(Synthetic)	4–8	7.3	4*
	9–13	3.1	<3
Iron	1–3	0.0	<3
	4–8	0.1	<3
	9–13	0.0	<3
Manganese	1–3	39.9	NA
	4–8	20.3	NA
	9–13	2.5	NA
Phosphorus	1–3	0.0	<3
	4–8	0.0	<3
	9–13	0.0	<3
Selenium	1–3	7.1	8
	4–8	0.4	<3
	9–13	0.0	<3
Sodium	1–3	65.1	83***
	4–8	70.6	94***
	9–13	86.7	>97***
Vitamin A	1–3	29.8	12***
(Retinol)	4–8	9.0	<3***
	9–13	0.2	<3
Vitamin B_6	1–3	0.0	<3
	4–8	0.0	<3
	9–13	0.0	<3
Vitamin C	1–3	0.7	<3
	4–8	0.0	<3
	9–13	0.0	<3
Vitamin D	1–3	0.0	NA
	4–8	0.0	NA
	9–13	0.0	NA
Zinc	1–3	40.9	69***
	4–8	13.0	22**
	9–13	0.1	<3

NA, not applicable. **P* = .04; ***P* ≤ .01; ****P* < .001.
[a] Nine through 11 years age category includes boys only because there were too few girls in this age category for analysis.

overweight or obese. Underweight was more common for children with ASDs aged 6 to 11 years than for the NHANES controls. Preschool children with ASDs spend more time in therapeutic activities, where snacks may be used to reinforce participation, and where children may have less opportunity or interest in active play resulting in overweight. Children with typical development may have more autonomy in food choices and access to food when they reach school age. Although BMI is an important indicator for healthy weight, it is not necessarily a good indicator of nutrient status. Among children with ASD, there was no difference in the number of nutrients consumed in insufficient amounts across weight categories.

LIMITATIONS

Although this is the largest study of nutrient intake from food in children with ASDs to date, volunteers were predominantly white. It is possible that volunteers for this study who completed the 3-day food record might have been either more concerned about their child's nutrition or had children with more challenging behaviors. The nutritional data are only as good as the accuracy of the food record and the completeness of nutrition analysis software. This is true for NHANES as well. Despite our efforts, inaccuracies in recording and the database may still exist. Another limitation is the use of the DRIs, which were established for physically healthy individuals with and without developmental disabilities. Whether these recommendations are applicable to children with ASDs is unknown and will require prospective study. Currently they are the best available estimate of nutrient needs of children.

This analysis was complicated by other issues affecting nutritional science including differences in units between the DRIs and food labels, the differences in bioavailability of fortified nutrients, and the changing and extensive fortification of foods. We attempted to address all of these concerns in the analysis. The comparison of micronutrients to the NHANES from 2001 to 2002 was necessary because this is the most recent complete NHANES/DRI comparison available although BMI and macronutrients were compared with data from 2007 to 2008. Specific analyses were matched by age categories; however, there were not enough girls in the oldest age category to allow for analysis of this group.

SPECIFIC RECOMMENDATIONS AND CONCLUSIONS

The data from this study have several implications. The results indicate the importance of nutritional surveillance in primary care for all children, not just children with ASDs. The rate of nutritional insufficiency is noteworthy in both the children with ASDs and the NHANES controls. Although there is not a simple nutrition screening tool available for children with ASDs at this time, clinicians should obtain a history of mealtime behavior and dietary intake in the context of well child care.[45] Although a varied diet is typically associated with better nutrition, fortification of foods given to children in this age range may allow a less varied diet to meet most nutrient needs. Just because a child with ASDs has a limited variety does not mean that he or she needs additional vitamins or a food supplement. Dietary assessment needs to be considered individually, corroborated with anthropometric and laboratory data, and include consideration of referral to a registered dietitian as necessary.

ACKNOWLEDGMENTS

We thank Nellie Wixom, RD, for her assistance in data management; Diana Fernandez, MD, MPH, PhD, Stephen Cook, MD, MPH, Peggy Auinger, MS, and Alanna Moshfegh, MS, RD, for their advice; and the Cornell Dietetic Interns for help with literature review. We thank Harriet Austin, PhD, Dana Barvinchak, Terri Mitchell, Margaret Pauly, MS, RD, LD, Erin Bailey, Esther Hsueh, Dave Maloney, Ann C. Meyers, MS, RD, LDN, Mindy Reagan, RD, LD, and Nikki Withrow, MS, RD for their tireless work with the families. We acknowledge the Autism Treatment Network for use of the data, and we thank the families who participated in the registry.

REFERENCES

1. Bennetto L, Kuschner ES, Hyman SL. Olfaction and taste processing in autism. *Biol Psychiatry*. 2007;62(9):1015–1021
2. Valicenti-McDermott M, McVicar K, Rapin I, Wershil BK, Cohen H, Shinnar S. Frequency of gastrointestinal symptoms in children with autistic spectrum disorders and association with family history of autoimmune disease. *J Dev Behav Pediatr*. 2006;27 (suppl 2):S128–S136
3. Schreck KA, Williams K, Smith AF. A comparison of eating behaviors between children with and without autism. *J Autism Dev Disord*. 2004;34(4):433–438
4. Lockner DW, Crowe TK, Skipper BJ. Dietary intake and parents' perception of mealtime behaviors in preschool-age children with autism spectrum disorder and in typically developing children. *J Am Diet Assoc*. 2008; 108(8):1360–1363
5. Schmitt L, Heiss CJ, Campbell EE. A comparison of nutrient intake and eating behaviors of boys with and without autism. *Topics Clin Nutr*. 2008;23(1):23–31 doi: 10.1097/1001.TIN.0000312077.0000345953.0000312076c
6. Xia W, Zhou Y, Sun C, Wang J, Wu L. A preliminary study on nutritional status and intake in Chinese children with autism. *Eur J Pediatr*. 2010;169(10):1201–1206
7. Herndon AC, DiGuiseppi C, Johnson SL, Leiferman J, Reynolds A. Does nutritional intake differ between children with autism spectrum disorders and children with typical development? *J Autism Dev Disord*. 2009;39(2):212–222
8. Bandini LG, Anderson SE, Curtin C, et al. Food selectivity in children with autism spectrum disorders and typically developing children. *J Pediatr*. 2010;157(2): 259–264
9. Levy SE, Souders MC, Ittenbach RF, Giarelli E, Mulberg AE, Pinto-Martin JA. Relationship of dietary intake to gastrointestinal symptoms in children with autistic spectrum disorders. *Biol Psychiatry*. 2007;61(4): 492–497
10. Johnson CR, Handen BL, Mayer-Costa M, Sacco K. Eating habits and dietary status in young children with autism. *J Dev Phys Disabil*. 2008;20:437–448
11. Lindsay RL, Eugene Arnold L, Aman MG, et al. Dietary status and impact of risperidone on nutritional balance in children with autism: a pilot study. *J Intellect Dev Disabil*. 2006;31(4):204–209
12. Emond A, Emmett P, Steer C, Golding J. Feeding symptoms, dietary patterns, and growth in young children with autism spectrum disorders. *Pediatrics*. 2010;126 (2). Available at: www.pediatrics.org/cgi/content/full/126/2/e337
13. Zimmer MH, Hart LC, Manning-Courtney P, Murray DS, Bing NM, Summer S. Food variety as a predictor of nutritional status among children with autism. *J Autism Dev Disord*. 2012;42(4):549–556
14. Cornish E. A balanced approach towards healthy eating in autism. *J Hum Nutr Diet*. 1998;11(6):501–509
15. Schreck KA, Williams K. Food preferences and factors influencing food selectivity for children with autism spectrum disorders. *Res Dev Disabil*. 2006;27(4):353–363
16. Berlin KS, Lobato DJ, Pinkos B, Cerezo CS, LeLeiko NS. Patterns of medical and developmental comorbidities among children presenting with feeding problems: a latent class analysis. *J Dev Behav Pediatr*. 2011;32 (1):41–47
17. Ho HH, Eaves LC, Peabody D. Nutrient intake and obesity in children with autism. *Focus Autism Other Dev Disabl*. 1997;12(3):187–192
18. Raiten DJ, Massaro T. Perspectives on the nutritional ecology of autistic children. *J Autism Dev Disord*. 1986;16(2):133–143
19. Cornish E. Gluten and casein free diets in autism: a study of the effects on food choice and nutrition. *J Hum Nutr Diet*. 2002;15(4):261–269
20. Dosman CF, Drmic IE, Brian JA, et al. Ferritin as an indicator of suspected iron deficiency in children with autism spectrum disorder: prevalence of low serum ferritin concentration. *Dev Med Child Neurol*. 2006;48(12): 1008–1009
21. Hediger ML, England LJ, Molloy CA, Yu KF, Manning-Courtney P, Mills JL. Reduced bone cortical thickness in boys with autism or autism spectrum disorder. *J Autism Dev Disord*. 2008;38(5):848–856
22. Bailey RL, McDowell MA, Dodd KW, Gahche JJ, Dwyer JT, Picciano MF. Total folate and folic acid intakes from foods and dietary supplements of US children aged 1–13 y. *Am J Clin Nutr*. 2010;92(2):353–358
23. Curtin C, Anderson SE, Must A, Bandini L. The prevalence of obesity in children with autism: a secondary data analysis using nationally representative data from the National Survey of Children's Health. *BMC Pediatr*. 2010;10:11
24. Institute of Medicine. *Dietary Reference Intakes: Applications and Dietary Assessment*. Washington, DC: National Academy Press; 2000
25. Dosman CF, Brian JA, Drmic IE, et al. Children with autism: effect of iron supplementation on sleep and ferritin. *Pediatr Neurol*. 2007;36(3):152–158
26. Moshfegh A, Goldman J, Clevelan L. What we eat in America, NHANES 2001–2002: Usual nutrient intakes from food compared to dietary reference intakes. US Department of Agriculture, Agricultural Research Service. Available at: www.ars.usda.gov/SP2UserFiles/Place/12355000/pdf/0102/usualintaketables2001-02.pdf. Accessed August 22, 2012
27. Coury D, Jones NE, Klatka K, Winklosky B, Perrin JM. Healthcare for children with autism: the Autism Treatment Network. *Curr Opin Pediatr*. 2009;21(6):828–832
28. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed. Washington, DC: American Psychiatric Association; 1994
29. Lord C, Rutter M, DiLavore P, Risi S. *Autism Diagnostic Observation Schedule*. Los Angeles, CA: Western Psych Corp; 1999
30. Centers for Disease Control and Prevention. The National Health and Nutrition Examination Survey (NHANES): analytic and reporting guidelines. Available at: www.cdc.gov/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_guidelines_dec_2005.pdf. Accessed August 22, 2012
31. Schakel S. Maintaining a nutrient database in a changing marketplace: keeping pace with changing food products—a research perspective. *J Food Compost Anal*. 2001;14: 315–322
32. Murphy SP, White KK, Park S-Y, Sharma S. Multivitamin-multimineral supplements' effect on total nutrient intake. *Am J Clin Nutr*. 2007;85(1):280S–284S
33. Tooze JA, Kipnis V, Buckman DW, et al. A mixed-effects model approach for estimating the distribution of usual intake of nutrients: the NCI method. *Stat Med*. 2010; 29(27):2857–2868
34. National Cancer Institute. Usual dietary intakes: food intakes, US population, 2001–2004. Available at: http://riskfactor.cancer.gov/diet/usualintakes/pop/. Accessed August 22, 2012
35. US Department of Health and Human Services, Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey Data. Available at: www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm. Accessed August 22, 2012
36. Moshfegh A, Goldman J, Ahuja J, Rhodes D, LaComb R. What we eat in America, NHANES 2005–2006: usual nutrient intakes from food and water compared to 1997 dietary reference intakes for vitamin D, calcium, phosphorus, and magnesium. Available at: www.ars.usda.gov/SP2UserFiles/Place/12355000/pdf/0506/usual_nutrient_intake_

vitD_ca_phos_mg_2005-06.pdf. Accessed August 22, 2012

37. US Department of Agriculture, Agricultural Research Service. Nutrient intakes from food: mean amounts consumed per individual, by race/ethnicity and age, what we eat in America, NHANES 2007–2008. Available at: www.ars.usda.gov/ba/bhnrc/fsrg. Accessed August 22, 2012
38. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey, 2007–2008 examination files, body measure. www.cdc.gov/nchs/nhanes/nhanes2007-2008/exam07_08.htm. Accessed August 22, 2012
39. Wang Y, Chen X. How much of racial/ethnic disparities in dietary intakes, exercise, and weight status can be explained by nutrition- and health-related psychosocial factors and socioeconomic status among US adults? *J Am Diet Assoc*. 2011;111(12):1904–1911
40. Ball SD, Kertesz D, Moyer-Mileur LJ. Dietary supplement use is prevalent among children with a chronic illness. *J Am Diet Assoc*. 2005;105(1):78–84
41. Picciano MF, Dwyer JT, Radimer KL, et al Dietary supplement use among infants, children, and adolescents in the United States, 1999–2002. *Arch Pediatr Adolesc Med*. 2007;161(10):978–985
42. Holick MF, Binkley NC, Bischoff-Ferrari HA, et al Evaluation, treatment, and prevention of vitamin d deficiency: an endocrine society clinical practice guideline. *J Clin Endocrinol Metab*. 2011;96(7):1911–1930
43. Hendy HM, Williams KE, Riegel K, Paul C. Parent mealtime actions that mediate associations between children's fussy-eating and their weight and diet. *Appetite*. 2010;54(1):191–195
44. Curtin C, Bandini LG, Perrin EC, Tybor DJ, Must A. Prevalence of overweight in children and adolescents with attention deficit hyperactivity disorder and autism spectrum disorders: a chart review. *BMC Pediatr*. 2005;5:48
45. American Academy of Pediatrics. Bright Futures Nutrition, 3rd ed. Elk Grove Village, IL: American Academy of Pediatrics; 2011

PEDIATRICS®
OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Nutrient Intake From Food in Children With Autism

Susan L. Hyman, Patricia A. Stewart, Brianne Schmidt, Usa Cain, Nicole Lemcke, Jennifer T. Foley, Robin Peck, Traci Clemons, Ann Reynolds, Cynthia Johnson, Benjamin Handen, S. Jill James, Patty Manning Courtney, Cynthia Molloy and Philip K. Ng

Pediatrics 2012;130;S145
DOI: 10.1542/peds.2012-0900L