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Dietary Intake and Food Preferences of Autistic Children Versus Children with Typical Development: A Comparative Cross-Sectional Study

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Abstract

Consumption of macro- and micronutrients and food group servings by children aged 4–13 with autism spectrum disorders (ASDs; n = 103) and typical development (TDs; n = 188) were compared using 3-day diet records. More than 50 percent of ASD children did not meet the RDA levels of adequacy for daily intake of energy, carbohydrate, and fiber. Similarly, TD children (more than 50%) also did not meet the 100 percent RDA requirement for intake of energy and fiber. No significant difference in level of adequacy for protein was observed between ASD and TD groups ($p = 0.106$). However, a significant difference was recorded for the other macronutrients for age group (4 - 13) between ASD and TD children. With the exception of vitamin D ($p < 0.001$), no significant differences were observed in the daily intake of vitamins between ASD and TD children ($p > 0.05$). No significant difference was found in the intake of iron between the two groups ($p = 0.517$), whereas the difference in calcium consumption was highly significant ($p = 0.010$). TD children's calcium intake tended to be much higher than that of ASD children. In summary, a large portion of the sample of children with ASD and TD did not meet the nutritional recommendation for macronutrients, micronutrients, and minerals.

Keywords: *Autism; Dietary Intake; Feeding Disorder; Food Selectivity; Typically Developing Children*

Introduction

Autism spectrum disorder (ASD) refers to a group of complex neurodevelopment disorders characterized by repetitive and impaired social communication and interaction. ASD affects all racial and ethnic groups, across all socioeconomic levels. However, ASD occurs more commonly in boys than in girls [1]. The severity of symptoms varies from one individual to another. The term ASD encompasses a spectrum including autistic disorder, Rett's disorder, childhood disintegrative disorder, Asperger's disorder, and pervasive developmental disorders not otherwise specified (PDD-NOS). For a diagnosis of any of these, a child must exhibit a "triad of impairments" in their social communication, social interaction, and imaginative understanding [2]. The healthy lifestyle of a child includes a balanced diet and physical activity [3], as well as an emotionally healthy relationship between parent and child [4,5]. Eating disorders (EDs) as stated in the DSM-5, "are characterized by a persistent disturbance of eating or eating-related behavior that results in the altered consumption or absorption of food and that significantly impairs physical health or psychosocial functioning" [6]. EDs are common in normally developing children, affecting 20 - 50 percent [7,8]. However, EDs are higher in children with developmental disabilities (70 - 89%) [9-11]. The long-term health effects of EDs can be profound and even fatal [12].

EDs in ASD children present in various ways, as documented in many case studies over the past two decades [2-5,13,14]. Repetitive behaviors and restricted interests, a core feature of autism, may play a role in dietary selectivity. Children with ASDs tend to avoid trying anything new, so getting them to taste new foods may be particularly difficult. Furthermore, it is common for ASD children to have sensory hypersensitivities, which would lead them to reject food items based on characteristics other than the obvious ones of taste and smell, such as texture, temperature and visual appeal [15-18]. Children with ASDs thus frequently have severely restricted diets, which means a higher risk of malnutrition [3,5]. Early childhood is a critical nutritional stage that involves the shift from a milk-based diet to a more complete diet that includes solid foods [19]. This phase involves the introduction of a variety of foods that reflect the family diet. It is believed that dietary exposures during this intermediate stage contribute to future food and taste preferences [19-21]. From a very early age, TD children can express their food likes and dislikes by behavior and/or through speech [22]. As children grow older, individual variances appear in food-related behaviors: some children are easy to feed and some are not. Parental feeding practices play an important role in the development of children's eating behaviors [22-26]. Selective eating disorder (SED) which is also known as fussy eating or picky eating syndrome, can be defined as eating a narrow range of food varieties combined with the refusal to eat or taste new foods [7].

Some studies suggested that TD toddlers who are considered "picky eaters" have lower dietary intake than non-picky eaters. Other factors, such as family environment and both authoritarian and permissive styles/strategies are positively associated with problematic eating behaviors in children, such as pickiness and neophobia [24-26]. Other studies found that the willingness of TD children to eat new foods and accept particular foods is an inherited trait, controlled by exposing the child early on to a variety of suitable foods as the child is weaned [21,27]. Apart from the concern about possible malnutrition, SED is also considered a problem when it restricts the child's daily routine or social integration [28]. Over the past two decades, a number of studies have observed severely limited food acceptance, or picky eating, as a significant problem in patients with ASD, associated with poor nutrition and other negative effects [4,5,7,15,28-33].

Another early study on nutritional evaluation of children with ASD reported the overall adequacy of nutrients intake to be similar compared to controls [34]. Similar results were observed more recently by several teams of investigators [2,35-37], suggesting that despite the selectivity, the energy and macronutrient and requirements are met. However, other studies reported inadequate of one or more micronutrients. For example, low intake in vitamins A and E, fiber and calcium [36]; deficiencies in iron, calcium, and vitamins B6, C, and D [5]; inadequate intakes of calcium and vitamins A and D [38]; insufficient consumption of vitamins C and D [39]; deficiencies in calcium, zinc, and vitamins B_{12} and D [2]; and inadequate intake of fiber, iron, and vitamins D and E [15].

Still other studies indicated no significant differences in macro- and micronutrient intake between ASD and TD children [37,40,41]. Overall, results so far are very mixed. In a study evaluating food acceptance in patients with autism or PDD-NOS (Ahearn., *et al*. 2001), some participants regularly accepted or rejected various sorts of food. The authors recommended that patterns of food acceptance in such children be compared with feeding patterns of TD children and children with other types of developmental delays the present paper describes one such comparative investigation.

The specific aims of this study were to investigate the nutritional status of children diagnosed with ASD as compared to typically developing (TD) children, using three-day food diaries (including two working days and one weekend day). Our primary hypothesis was that children with ASD would have: (1) different anthropometric measures to those of TD children; (2) lower macro- and micronutrient intake compared to children with typical development; and (3) intakes that differed from the nutritional recommendations for the Omani population.

Data for each group was compared with the recommended nutrient intakes for the Omani population as found in the Omani Ministry of Health's publication The Omani Guide to Healthy Eating [42]. The RDA used for comparison was based on information obtained from the food-based dietary guidelines developed to advise the public on the types and quantities of foods to consume in order to satisfy their nutritional requirements and prevent disease. Nutrient intake obtained from the 3-day food record was compared with the reference RDA for the appropriate age, and comparison was made for specific macronutrients and micronutrients.

Subjects and Methods

This study was conducted in the Sultanate of Oman, situated in the Arabian Peninsula, between the Arabian Sea, the Gulf of Oman, and the Arabian/Persian Gulf, and bordering Yemen, Saudi Arabia, and United Arab Emirates. In area Oman measures, approximately 309,500 km^3, with a population of 3.28 million [43]. A cross-sectional design was employed from 1 June 2014 to 1 June 2015 to collect the data. The study was conducted at several sites located in different provinces in Oman: Sultan Qaboos University Hospital (SQUH), Developmental Medicine Clinic, Muscat Autism Center, Early Intervention Center for Children with Disabilities, and Al Waffa Rehabilitation Centers. The study included a total of 375 children aged between 4 and 13 years, both male and female. The children were randomly selected from 8 governorates- Muscat, Dhofar, Musandam Al Buraymi, A'Dakhiliyah, North Al Batinah, South Al Batinah, North A'Sharqiyah, South A'Sharqiyah, and Dhahirah. The age range-matched typically developed children were recruited with similar background and from the same provinces. Of 375 children, 304 completed the 3-day food record; 13 children with restricted diets were excluded. The study sample comprised 103 ASD and 188 TD children.

Data Collection

All data was collected via questionnaire. The demographics of caregivers included age range, their relation to the child, marital status, level of education, and monthly income (in OMR). For the subjects (the children) the variables related with demographics were birth weight, sex, number of siblings and anthropometric measurements.

Body Mass Index (BMI)

At the time of the visit, anthropometric measurements were carried out for every subject (both ASD and TD). These were recorded by the principle investigator and six registered dietitians, according to procedure described by WHO [44]. Weight (in kilograms): The individual was weighed with light clothing and without shoes, with the body weight distributed on both feet, using a beam scale which was calibrated and checked against a known weight prior to use. Weight was recorded to the nearest 0.5 kg. Height (in centimeters): The individual was measured bareheaded, barefoot or in socks, heels together and head position perpendicular to the body. This was done using a vertical board with attached metric ruler and a horizontal headboard in contact with the uppermost part of the head. The subjects were asked to look forward so that the line vision was parallel to the floor with arms hanging down at the sides. Height was measured to the nearest 0.5 cm. BMI was calculated as weight divided by height (kg/m^2).

Estimate of Nutrients

The three-day food record is a method used to compare nutrient intake (quantity and quality) and eating behaviors of subjects; it has been used in Saudi Arabia [45] and many other studies worldwide [36,39]. Participants were asked to recall events about their child during three days (two week days and one weekend) in a sequence, starting with the time the child woke up in the morning until the time the child went to bed. Parents or caregivers recorded the amount and type of all food and drink consumed by the child that day. To increase the accuracy of reporting, parents and caregivers were asked to use measuring cups and spoons while estimating the amount of food eaten.

The information from the 3-day food record was used to calculate the estimate of total daily intake of macronutrients and micronutrients using a computer and the average over the three days was calculated using nutrient analysis program (NutriBase 11.0). The chemical composition of traditional Omani dishes was determined from the SQUH laboratory data on the composition of food and from the already published literature [46,47]. The calculated nutrient intake of children was compared with the recommended nutrient intakes from The Omani Guide to Healthy Eating [42] mentioned in section 1. Nutrient intake obtained from the 3-day food record was compared with the reference RDA for the appropriate age, and comparison was made for the following nutrients: macronutrients, namely carbohydrates, dietary fiber, protein, total fat, saturated fat and cholesterol and micronutrients, in the form of vitamins: vitamin A, thiamin (vitamin B_1), riboflavin (vitamin B_2), niacin (vitamin B_3), pyridoxine (vitamin B_6), cobalamin (vitamin B_{12}), ascorbate (vitamin C), folate, vitamin D, vitamin E, and vitamin K and minerals: calcium and iron.

Ethical Approval and Confidentiality

A written informed consent in Arabic was obtained from all parents willing to participate in the study before obtaining any child's information. A clear, detailed explanation of the study was given to all parents, who were duly informed that they were free to refuse, participate or to withdraw at any phase during the study without any disadvantage or prejudice. The explanation included details of the tools used and type of measurements to be taken. They were guaranteed that the information collected would only be used for the purpose of scientific research as a group and not as individual cases. Confidentiality and privacy of the collected information was strictly ensured by giving a code number for each subject, and this information will be used only for scientific purposes. This study has been approved by the Medical Research Committee in the college of Medicine and Health Sciences, Sultan Qaboos University, (MREC#899).

Statistical Analysis

The collected data was reviewed for completeness and accuracy and statistically analyzed using a statistical analysis software package (SPSS v.20). The following statistical tests were used: The student's t-test was used to compare socio-demographic data. The chi-square (x^2) test was used to assess the statistical significance of differences among categorical data. The non-parametric Fisher's exact test (two-tailed) was used instead of Chi-square test in cases of very small sample size. The odds ratios (OR) and 95% confidence intervals (CI) were calculated in comparison between ASD and TD. A significant association is considered if the 95% CI does not include the value 1.0, and a cut-off p-value of less than 0.05 was used for all tests of statistical significance in this study.

Results

Table 1 shows the socio-demographic characteristics study groups. The age range of caregivers was not significantly different (p = 0.261). The majority of caregivers of study groups were between 31 to 40 years of age. The percentages of caregiver within this age range was 63% for ASD group while 55% in TD group. Similarly, no significant differences (p = 0.551) between the two study groups in education level was observed. A good number of caregivers were educated, either with a school certificate or college degree. An insignificant difference (p = 0.078) was observed in the monthly income of caregivers as well. However, there was a significant difference in terms of marital status (p = 0.005). Table 1 shows the socio-demographic characteristics of ASD and TD children. The gender distribution was significantly different between the two groups (p = 0.000). It is evident from the table that the ASD group included 129 males and 34 females and the TD group included 104 males and 108 females, giving a proportion of 79% and 49% male for ASD and TD groups, respectively. The average age of the children in the 4 to 13 age group was 7.2 ± 2.5 and 7.7 ± 2.6 years respectively for ASD and TD groups and no significant difference was found (p = 0.075). A significantly greater number of children with ASD (about 29.4% of this group) consumed medication as compared to TD children (4.2% of this group). Furthermore, more side effects were reported in the ASD children (p < 0.05).

*Characteristic		ASD (n = 163)	TD (n = 212)	p-value
		n (%)	n (%)	
Parents/ Caregivers Age	≥ 20 - 30	36 (22.1)	52 (24.5)	0.261
	31 - 40	102 (62.6)	116 (54.7)	
	41 - 50	25 (15.3)	44 (20.8)	
Marital Status	Single	1 (0.6)	9 (4.2)	0.005
	Married	159 (97.5)	197 (92.9)	
	Divorced	3 (1.8)	1 (0.5)	
	Widow	0 (0.0)	5 (2.5)	

Education Level	Read and write	24 (14.7%)	32 (15.1%)	0.551
	School education	67 (41.1%)	96 (45.3%)	
	College education	51 (31.3%)	66 (31.1%)	
	Above college	21 (12.9%)	18 (8.5%)	
Monthly income level (OMR)	<500	42 (25.8)	63 (29.7)	0.078
	500 - 1000	78 (47.9)	107 (50.5)	
	1000 - 1500	19 (11.7%)	28 (13.2%)	
	>1500	24 (14.7%)	14 (6.6%)	
Children Sex	Male	129 (79.1)	104 (49.1)*	0.000
	Female	34 (20.9%)	108 (50.9%)	
Medication	Use of medication	48 (29.4)	9 (4.2)	<0.001
	Medication side effect	12 (8.1)	2 (1.2)	0.002

Table 1: *Socio-demographic characteristics of study groups.*

*[a] and [b] are presented by mean (SD); *diagnostic groups significantly different at p < 0.05*

Table 2 shows the mean BMI of ASD (15.4 ± 2.5) and TD (15.4 ± 2.6) children; it was not significantly different (p = 0.816). Likewise, no significant differences (p = 0.301) were observed between the two groups' corresponding BMI percentiles of underweight (< 5th), healthy weight (5th-85th), overweight (85th-95th), and obese (> 95th). Both study groups had a similar percentage of healthy weight: 56 percent of ASD versus 59 percent of TD children. However, 32 percent of TD children were underweight compared to 29 percent of ASD children. A greater number of ASD children were overweight compared to TD children (16% vs. 8%).

Diagnosis		**ASD (*n* = 103)**	**TD (*n* = 103)**	**p-value [a]**
		n (%)	*n* (%)	
BMI (kg/m^2)[b]		15.44 (2.48)	15.37 (2.57)	0.816
BMI Percentile	Under weight	47 (28.8)	67 (31.6)	0.301
	Healthy weight	91 (55.8)	126 (59.4)	
	Over weight	22 (13.5)	17 (8.0)	
	Obese	3 (1.8)	2 (0.9)	

Table 2: *Distribution of BMI percentiles in ASD and TD children.*

BMI = body mass index, ASD = autism spectrum disorder, TD = typically developing

[a] Statistically significant differences at [b] p < 0.05, BMI Presented in mean ± SD

The results indicated the contrasts of the average daily intake of the four macronutrients for the study samples of the age range (4 - 13 years) of ASD and TD children. The average daily intake of energy between ASD and TD children was significantly different (p = 0.005). Less energy intake was observed in ASD children (1389.6 Kcal/day) compared to TD children (1594.9 Kcal/day). The ASD children also consumed significantly less protein (p = 0.002), fiber (p = 0.017), total fat and saturated fat as compared to the TD children. No significant difference was observed in the average daily carbohydrate intake between ASD (229.2g/day) and TD children (247.9g/day) (p = 0.160). There was a significant difference between ASD and TD in both total fat (p = 0.015) and saturated fat (p < 0.000). However no significant

difference was observed in cholesterol between ASD and TD children (p = 0.057). With the exception of vitamin D (p < 0.001), no significant differences were observed in the average daily intake of most vitamins between ASD and TD children (p > 0.05). There was no significant difference in the intake of iron between the two groups (p = 0.517), but the difference in the calcium intake was highly significant (p = 0.010). TD children's calcium intake tends to be much higher than that of ASD children (Table 3).

Nutrient	ASD	TD	p-value
	(*n* = 103)	(*n* = 188)	
	Mean (SE)	Mean (SE)	
Energy (Kcal)	1389.6 (56.6)	1594.9 (43.2)	0.005
Protein (g)	47.5 (1.8)	55.4 (1.6)	0.002
Carbohydrate (g)	229.2 (11.1)	248.0 (7.8)	0.160
Fiber (g)	9.8 (0.7)	12.5 (0.7)	0.017
Total fat (g)	38.9 (3.3)	47.4 (1.8)	0.015
Saturated fat (g)	9.4 (0.9)	14.4 (0.7)	<0.001
Cholesterol (mg)	122.2 (12.7)	153.3 (10.0)	0.057
Vitamin A (µg)	281.6 (65.2)	306.6 (29.5)	0.689
Thiamin (mg)	1.2 (0.1)	1.2 (0.1)	0.913
Riboflavin(mg)	1.4 (0.2)	1.5 (0.1)	0.615
Niacin (mg)	15.4 (0.9)	15.2 (0.8)	0.861
Pyridoxine (mg)	1.2 (0.19)	1.3 (0.1)	0.416
Vitamin B_{12} (µg)	1.9 (0.7)	1.9 (0.1)	0.993
Folate (µg)	297.9 (16.1)	297.2 (14.8)	0.977
Vitamin C (mg)	47.2 (4.6)	61.0 (4.7)	0.057
Vitamin D (µg)	1.9 (0.2)	3.0 (0.2)	0.000
Vitamin E (mg)	1.9 (0.3)	2.2 (0.2)	0.361
Vitamin K (µg)	17.4 (5.5)	12.7 (1.2)	0.406
Calcium (mg)	389.0 (28.4)	484.6 (22.4)	0.010
Iron (mg)	12.1 (1.0)	12.9 (0.7)	0.517

Table 3: *Comparison between average macronutrient intake in ASD and TD in age group (4–13).*

**Independent sample t-test, significant at p value < 0.05*

Table 4 contrasts the results for the macronutrient intakes for age groups 4 - 8) and (9 - 13), with respect to the dietary reference intake values set for these age groups. It shows that the actual average intake of energy by children with autism was less than the dietary reference intake value set for the 4 – 8 (p = 0.049), while for TD children the actual intake mean value was above the reference point. It also showed there was a significant difference (p = 0.042) between the average intake of energy of ASD and TD children in age group 9 - 13. However, both groups were below the RDA set for age group 9-13. Daily protein intakes by children with autism and TD were not significantly different (p = 0.160), and for the 4-8 age range dietary intakes from both groups were above the dietary reference intake values set. However, for the age range 9-13, significantly different protein intake levels (p = 0.002) were reported. While children with ASD had intake of protein within the RDA range, TD children were well above the RDA reference level. The actual average intake of carbohydrate by ASD and TD children were well within the dietary reference intake value set for ages 4-8, and at the same time showed no significant

difference in the average intake (p = 0.115) between groups. There was also no significant differences (p = 0.668) between the two study groups in the age range 9–13, and their daily intakes were within the RDA range (Table 4). In both age groups, there were no significant differences observed in the average fiber intakes between ASD and TD children (p = 0.095 and p = 0.082, respectively). Moreover, no significant difference was found between the two study groups in the age range 9-13, and their daily intakes were within the RDA range, while the difference in the two groups for the 4-8 age range appeared to be marginal.

Furthermore, Table 4 shows there is a significant difference between ASD children and TD children in total fat intake for the age range 4–8. Children with ASD had higher intake than TD (p = 0.017). However no significant difference was observed in age group 9-13. Saturated fat consumption was significantly higher in ASD compared to TD ($p < 0.05$) for both age groups. In addition, cholesterol was not significantly different between ASD and TD for both age groups ($p > 0.05$). When the subjects are split into two age ranges (4–8 years and 9-13 years), it was observed that the TD children exceed the ASD children's vitamin intake only in vitamin C (p = 0.039) and vitamin D (p = 0.002) in the age range 4-8. No significant differences were observed between the two groups when split according to the two age categories. Table 4 also gives information on how the two groups fare in meeting the RDA levels of adequacy in their vitamin intake. For both age groups, intakes for vitamins A, D, E, and K of the ASD and TD children alike are far below recommended ranges. As for the other vitamins, the average intake levels are either within or slightly above the recommended ranges. When data were divided according to the two age groups, only levels of intake of vitamin C and D of the age group 4-8 were found to be significantly different between the ASD and TD children.

Table 4 summarizes the results of the comparison of the RDA adequacy levels, of the average mineral intakes of ASD and TD children split into two age groups of 4-8 and 9-13 years. The average intakes of calcium by both ASD (410.4) and TD (475.6) children of age group 4–8 meet the RDA adequacy range of 350 - 560mg. The recorded levels for iron were even higher than the RDA. For age group 9 - 13, ASD children's average calcium intake (352.3) was found well below the recommended range of 500 - 800mg. Moreover, it was also significantly lower than that of the TD children of the same age group (p = 0.026), which was just within the recommended RDA range. In brief, when data were analyzed according to the two age categories, it was clear that only calcium intake in the age group (9 - 13) was significantly lower in the ASD children as compared to the TD children.

Nutrient	Age	RDA Range	ASD (n = 103)	TD (n = 188)	p-value
			Mean (SE)	Mean (SE)	
Energy (Kcal)	4-8	1400	1359.7 (63.2)	1516.2 (47.2)	0.049
	9-13	2000/1900	1440.7 (109.5)	1724.6 (81.9)	0.042
Protein (g)	4-8	28-35	47.6 (2.2)	52.0 (1.9)	0.160
	9-13	40-50/38-47.5	47.3 (3.3)	61.0 (2.6)	0.002
Carbohydrate (g)	4-8	192.5-262.5	214.9 (11.3)	237.7 (8.7)	0.115
	9-13	275-375/261.3-356.3	253.7 (22.8)	264.9 (14.6)	0.668
Fiber (g)	4-8	11-28	9.9 (0.9)	11.6 (0.5)	0.095
	9-13	16-40/15-38	9.8 (1.2)	14.1 (1.7)	0.049
Total fat (g)	4-8	NA	36.2 (2.6)	43.7 (1.8)	0.017
	9-13	NA	43.5 (7.8)	53.4 (3.6)	0.195
Saturated fat (g)	4-8	NA	9.1 (1.1)	13.8 (0.8)	<0.001
	9-13	NA	9.8 (1.5)	15.5 (1.2)	0.004
Cholesterol (mg)	4-8	NA	113.2 (13.0)	148.2 (11.9)	0.063
	9-13	NA	137.5(26.2)	161.8 (17.3)	0.426

Vitamin A (µg)	4-8	490-700	299.2 (101.1)	284.2(21.1)	0.852
	9-13	700-1000/665-950	251.5 (38.8)	343.6(69.9)	0.358
Thiamin (mg)	4-8	0.7-1.12	1.2 (0.1)	1.2(0.1)	0.577
	9-13	1-1.6/0.9-1.6	1.3 (0.1)	1.2(0.1)	0.587
Riboflavin (mg)	4-8	0.8-1.3	1.2 (0.1)	1.6(0.2)	0.063
	9-13	1.2-1.8/1.1-1.7	1.8 (0.4)	1.3(0.1)	0.284
Niacin (mg)	4-8	8.4-14	14.6 (1.1)	14.7(0.9)	0.973
	9-13	12-20/11.4-19	16.7 (1.5)	16.0(1.3)	0.739
Pyridoxine (mg)	4-8	0.7-1.4	1.1 (0.1)	1.2(0.1)	0.427
	9-13	1-2/0.9-1.9	1.3 (0.2)	1.4(0.1)	0.773
Vitamin B12 (µg)	4-8	0.7-1.4	2.3 (1.1)	1.9(0.2)	0.611
	9-13	1-2/0.9-1.9	1.2 (0.2)	1.9(0.3)	0.061
Folate (µg)	4-8	210-280	302.5 (22.5)	291.4(17.9)	0.705
	9-13	300-400/285-380	290.0 (21.0)	306.8(25.8)	0.662
Vitamin C (mg)	4-8	35-42	42.8 (5.3)	63.2(6.7)	0.039
	9-13	50-60/47.5-57	54.7 (8.4)	57.4(6.0)	0.790
Vitamin D (µg)	4-8	3.5-7	1.9 (0.3)	3.0(0.3)	0.002
	9-13	5-10/4.8-9.5	1.8 (0.4)	2.9(0.4)	0.081
Vitamin E (mg)	4-8	4.9-7.0	1.6 (0.2)	2.0(0.2)	0.192
	9-13	7.0-10.0/6.7-9.5	2.4 (0.6)	2.5(0.4)	0.821
Vitamin K (µg)	4-8	28-56	12.7 (2.9)	12.6(1.6)	0.986
	9-13	40-80/38-76	25.5 (14.0)	12.9(1.5)	0.378
Calcium (mg)	4-8	350-560	410.4 (38.0)	475.6(25.3)	0.142
	9-13	500-800/475-760	352.3 (40.9)	499.5 (42.4)	0.026
Iron (mg)	4-8	7.7	12.3 (1.2)	13.4 (1.0)	0.492
	9-13	11.0/10.5	11.8 (1.9)	12.1 (1.0)	0.871

Table 4: *Nutrition analysis for ASD and typical groups and dietary intake (RDA).*

**Independent sample t-test, significant at p value < 0.05*

Table 5 shows that more than 50 percent of ASD children did not meet the RDA levels of adequacy in their daily intake of energy (66% of ASD children), carbohydrate (57.3%), and fiber (74.8%). A similar percentage of TD children also did not meet the 100% RDA requirement in the intake of energy (51.6% of TD children) and fiber (54.8%). No significant difference in level of adequacy for protein was observed between ASD and TD groups (p = 0.106). However, a significant difference between ASD and TD children was recorded for the other macronutrients for age group 4 - 13. The OR showed that ASD children were twice as likely as TD children to fail to meet the RDA for carbohydrates (OR = 2.02; 95% CI = 1.24, 3.28; p = 0.006). In addition, the likelihood of not meeting RDA adequacy level in energy was significantly higher in ASD compared to TD children (OR = 1.82; 95% CI = 1.10, 2.99; p = 0.024), and for fiber it was 2.44 (OR = 2.44; 95% CI = 1.44, 4.14; p = 0.001). For protein, the ASD and TD children may be equally at risk of failing to meet recommendations for protein (OR=1.82; 95% CI = 0.93, 3.51); (p = 0.106). Table 5 also shows that more than 50 percent of ASD children do not meet the 100% RDA levels of adequacy in the daily intake of vitamin A (93% of ASD group), vitamin C (56%), vitamin D (84.5%), vitamin E (97.1%), and vitamin K (92.2%). As for the TD children, more than 50% do not meet RDA levels of adequacy for the same vitamins except Vitamin C (44.7% of

TD group). With the exception of two vitamins (B_{12} and D), both ASD and TD children were equally likely to not meet the RDA levels of adequacy in their daily vitamin intakes (p-values > 0.05). For Vitamin B_{12} (OR = 1.84; 95% CI = 1.08, 3.15; p = 0.034) and Vitamin D (OR = 2.13; 95% CI = 1.14, 3.97; p = 0.022), ASD children were about two times as likely as TD children not to meet RDA levels of adequacy.

Table 5 also summarizes how well the subjects have met the RDA adequacy levels of the mineral intakes. It was found that more than 50 percent of ASD children have not met the RDA adequacy levels in their daily intakes of both calcium (65% of ASD children) and iron (54.4%). For TD children, just under half of them did not meet the adequacy levels of their daily intakes of the two minerals. While both ASD and TD children were equally likely to fail to meet the RDA adequacy level of their daily intake of iron (OR = 1.44; 95% CI = 0.89, 2.33; p = 0.170), ASD children were more than twice as likely to miss the RDA adequacy level for calcium (OR = 2.16; 95% CI = 1.31, 3.54; p = 0.003).

Nutrient	ASD *n* = 103	TD *n* = 188			*p-value*
	***n* (%)**	***n* (%)**	**OR**	**95% (CI)**	
Kilocalories (Kcal)	68 (66.0)	97 (51.6)	1.82	1.10 -2.99	0.024
Protein (g)	20 (19.4)	22 (11.7)	1.81	0.93 -3.51	0.106
Carbohydrate (g)	59 (57.3)	75 (39.9)	2.02	1.2 4 -3.28	0.006
Fiber (g)	77 (74.8)	103 (54.8)	2.44	1.44 -4.14	0.001
Vitamin A (µg)	96 (93.2)	168 (89.4)	1.63	0.66 -4.00	0.385
Thiamin (mg)	18 (17.5)	25 (13.3)	1.38	0.71 -2.67	0.431
Riboflavin (mg)	35 (34.0)	62 (33.0)	1.04	0.62 -1.74	0.965
Niacin (mg)	35 (34.0)	74 (39.4)	0.79	0.48 -1.31	0.435
Pyridoxine (mg)	31 (30.1)	49 (26.1)	1.22	0.71 -2.08	0.549
Vitamin B_{12} (µg)	35 (34.0)	41 (21.8)	1.84	1.08 -3.15	0.034
Folate (µg)	46 (44.7)	85 (45.2)	0.97	0.60 -1.58	1.000
Vitamin C (mg)	58 (56.3)	84 (44.7)	1.59	0.98 -2.58	0.076
Vitamin D (µg)	87 (84.5)	135 (71.8)	2.13	1.14 -3.97	0.022
Vitamin E (mg)	100 (97.1)	180 (95.7)	1.48	0.38 -5.71	0.800
Vitamin K (µg)	95 (92.2)	172 (91.5)	1.10	0.45 -2.67	1.000
Calcium (mg)	67 (65.0)	87 (46.3)	2.16	1.31-3.54	0.003
Iron (mg)	56 (54.4)	85 (45.2)	1.44	0.89-2.33	0.170

***Table 5**: Nutrient inadequacy in ASD and TD.*

**Data analyzed by chi square, ORs significant at p value < 0.05*

Discussion

Approximately a total number of 500 ASD children were within the age range 4 - 13. However, a total of 163 participants were recruited by our study, representing about 33% of the ASD sample population. About 80 percent of ASD children were male and this proportion is in line with previous studies [48,49]. Anthropometric measurement, especially BMI percentile, did not show any significant differences between ASD and TD children. This data is similar to that of Zimmer., *et al.* [2]. The distribution of BMI percentile in the ASD children was slightly different than that reported by Memari., *et al*. [49], especially in the percentage of underweight and overweight population of ASD children. They reported a low percentage of underweight and higher percentage of overweight. High rate of obesity among ASD children was also found in other studies [49-53] and this was believed to be attributed to the adverse effects of psychotropic medications, which

lead to weight gain [54]. In our study, only 29.4 percent of ASD children were reported to use medication, and 40 percent of ASD children who were on medication were found to be overweight. Weight gain or loss is a not uncommon side effect of various medications for treating ASD and associated symptoms [55]. It must be kept in mind that such medical treatment will be used only when the patient's behavior is intolerable and the parents are in desperate need to reduce hyperactivity in their child. Some indications for such medical treatment are severe sleep problems, excessive hyperactivity and self-mutilation, all of which affect the family quality of life [49,54]. Therefore, elevated BMI among ASD children on medications is likely to be the result of reduced physical activity, due to the sedative effect of medication, rather than a result of increased caloric intake. In general, previous research has found very mixed results concerning height, weight and BMI in children with ASD [3,14,39,35,48], indicating the presence of other confounding contributing factors, including the use of medications.

Our study shows significant differences in food intake between the ASD and TD children in the overall group (4 - 13). It was hypothesized that children with ASD would consume less macro- and micronutrients than TD children. However, the study shows that this is the case only in the average intake of energy, protein, fiber, vitamin C, vitamin D and calcium when compared to typically developing children. No significant difference was observed between the two groups in average intake of carbohydrate, vitamin A, thiamin, riboflavin, niacin, pyridoxine, vitamin B_{12}, foliate, vitamin E, vitamin K or iron. The ASD children were about two times as likely as TD children not to meet RDA levels of adequacy. Furthermore, our study indicates that more than 50 percent of ASD children do not meet the RDA levels of adequacy in the daily intake of Vitamin A, Vitamin C, Vitamin D, Vitamin E, and Vitamin K. similar results were observed, for the TD children.

Although both ASD and TD children were equally likely to fail to meet the RDA adequacy level of their daily intake of iron, ASD children were more than twice as likely as TD children to fail the RDA adequacy level for calcium. Similar results for the intakes of macro- and micronutrients were noted in the age groups 4–8 and 9–13 years for both ASD and TD children. Our findings of lower intake in vitamin D and calcium were consistent with the results obtained in several other studies [2,56]. Other investigations report that children with ASD are at higher risk for calcium and vitamin D deficiencies [2,15], thus corroborating our finding. More recently, Vitamin D deficiency was suggested to be associated with ASD [57-59]. However, still other studies have found no significant differences in vitamin D intakes between ASD and TD children [15,41].

Our study did not find any significant differences in the average intakes of most micronutrients between ASD and TD children, which indicates that large proportions of children in both study groups and both age groups did not meet dietary reference intake RDA recommendations for these micronutrients. However, calcium intake lower than the RDA was observed in children with ASD in age group 9 - 13. With the exception of energy and carbohydrates, our results were consistent with other studies on the inadequacy of intake of fiber, vitamin D, and folate [15,41]. Our results are also consistent with other studies regarding the average consumption of nutrients from food [3,15,41].

Children with autism were not significantly different from TD children in their average intake of certain macronutrients such as carbohydrates, nor of most micronutrients. However, vitamins A, E, and K were below adequate by more than 90 percent of RDA. Galloway., *et al*. [60] indicated that because of the resulting severely restricted diets of picky eaters, they tend to consume low amounts of vitamin C, vitamin E, calcium, magnesium, and fiber [60]. Vegetables are important source of fiber, vitamin and minerals. Vegetables are rich in vitamins A, E, and C. The study showed that children with autism spectrum disorder ate fewer vegetables. Therefore, it was not surprising that they manifested inadequate intake of these nutrients.

Conclusion

In conclusion, children with ASD had significantly lower average intakes of macronutrients (energy, protein and fiber) and carbohydrate compared to TD children, whereas similar intakes of micronutrients were recorded in both ASD and TD children with the exception of vitamin D. With regard to minerals, ASD and TD children had similar intake of iron, but ASD children had significantly lower intake of calcium as compared to TD children. Both groups failed to meet the 100% RDA in most of the macro and micronutrients. Although children with ASD tend to picky eaters who are often more selective in their food choices than TD children, studies have shown consistent

between-group differences in the nutrient adequacy of children's diets. Overall, we found few differences in average nutrients intakes between children with ASDs and children with typical development, although the intake was generally higher in TD children than ASD children.

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