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Nutritional deficiencies and overweight prevalence among children with autism spectrum disorder

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ABSTRACT

Children with autism spectrum disorder (ASD) are at risk of developing nutritional deviations. Three to six year old children with ASD were compared to their typically developing siblings and to a typically developing age and gender matched control group, in order to evaluate their intake and body mass index.

Nutrient intake was compared to the Dietary Reference Intake using three-day diet diaries completed by the parents. The sum percentage of nutritional deficiencies in the ASD group compared to the typical development group was 342.5% (±122.9%) vs. 275.9% (±106.8%), respectively ($P = 0.026$). A trend toward higher deficiency in the ASD group was observed as compared to the sibling group 363% (±122.9%) vs. 283.2% (±94.7%) ($P = 0.071$). A higher body mass index was found in the ASD group compared to their counterparts, despite their nutritional deficiencies. In conclusion, children with ASD are more likely to suffer from nutritional deficiencies despite higher body mass index.

1. Introduction

Dietary habits and preferences of children with Autism Spectrum Disorder (ASD) have been investigated in recent years and have become a recognized clue for diagnosis (American Psychiatric Association, 2013). Most studies support the presence of feeding difficulties in ASD children and the additional challenges these difficulties add to the familial burden of care. These difficulties often include: nutritional consumption lower than the recommendations (Zimmer et al., 2012; Lockner, Crowe, & Skipper, 2008) and food refusal (Cornish, 1998), pica disorder (Emond et al., 2010) a limited variety, not using specific utensils (Schreck, Williams, & Smith, 2004), variance in amounts consumed from different food groups, such as less dairy products and more protein-rich products (Herndon, DiGuiseppi, Johnson, Leiferman, & Reynolds, 2009), throwing food, rejecting or preferring foods according to texture, color or temperature (Johnson, Handen, Mayer-Costa, & Sacco, 2008; Ahearn, Castine, Nault, & Green, 2001) and oral motor impairments (Williams, Gibbons, & Schreck, 2005). There are several case reports of children with ASD who suffered from various unrecognized nutrient deficiencies, with a degree of severity to subsequently cause health risks such as scurvy (Niwa et al., 2012; Cole, Warthan, Hirano, Gowen, & Williams, 2011; Duggan, Westra, & Rosenberg, 2007), rickets, and vitamin A deficiency related ophthalmological conditions (Clark, Rhoden, & Turner,

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1993; Steinemann & Christiansen, 1998). In previous studies, the average nutrient consumption was used to calculate deficiencies: Johnson et al. (2008) found that children with ASD had a lower average vitamin K consumption as compared to children with typical development, (6.8 mg/day vs. 8.9 mg/day, respectively $P < 0.025$). However, more children with typical developmental did not meet the recommended dietary intake (RDA) for magnesium, (using average intake) compared to ASD children (53% vs. 6%, respectively, $P < 0.025$). Herndon et al. (2009) found children with ASD had a lower average calcium consumption (747 mg/day vs. 894 mg/day, respectively $P < 0.05$), a higher average vitamin B6 consumption (1.5 g/day vs. 1.2 g/day, respectively $P < 0.05$) and a higher average vitamin E consumption (8 mg/day vs. 4 mg/day, respectively $P < 0.05$) as compared to their counterparts. Emond et al. (2010) also analyzed average nutrients' consumption. Compared with controls, children with ASD consumed less vitamin C ($P = .007$) and vitamin D ($P = .004$) and more iodine ($P = .01$). Zimmer et al. (2012) found lower consumption of protein (72.77 g/day vs. 92.64, respectively $P < 0.05$), calcium (945.18 mg/day vs. 1221.98 mg/day $P < 0.05$), magnesium (314.89 mg/day vs. 265.93 mg/day, respectively $P < 0.05$), vitamin B12 (4.69 μg/day vs. 6.66 μg/day, respectively $P < 0.05$), and vitamin D (198.62 IU/day vs. 319.86 IU/day, respectively $P < 0.05$). Therefore, there is paucity of evidence-based data to establish recommendations and guidelines for treatment (Raiten & Massaro, 1986; Schreck et al., 2004; Schmitt, Heiss, & Campbell, 2008; Lockner et al., 2008; Bandini et al., 2010).

In the current analysis we investigated the nutritional status of 3–6 year old children with ASD and herein report our preliminary findings. We addressed the nutritional assessment using a different approach which may better reflect the nutritional status of these children.

2. Methods

This study was conducted during 2009–2012 as a case–control, multi-center research. The study was approved by the Helsinki ethics committees of each center.

2.1. Subjects

2.1.1. ASD group

Eighty-four children between the ages of 3 and 6 years were treated at two Child Development Centers. The diagnosis was made by a multidisciplinary team (comprising neurodevelopmental pediatricians, psychologists, occupational therapist and speech pathologists), according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV) (American Psychiatric Association, 2000) using Childhood Autism Rating Scale (CARS) (Schopler, Reichler, DeVellis, & Daly, 1980) diagnostic questionnaire and corroborated by Autism Diagnostic Observation Schedule-Generic (ADOS) (Lord et al., 1989) and evaluation of intelligence using IQ measures. The ASD group includes children with subtypes of ASD: Autistic Disorder, Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), Asperger's Syndrome, but not with Rett syndrome or Childhood Disintegrative disorders. Families of children with ASD were recruited regardless of whether there were other siblings in the family. Response rate in this group was 60% (50 out of 84 families). Six families of the 84 families who enrolled their children were excluded from the current analysis due to consumption of food supplements.

2.1.2. First control group

First control group defined as *Siblings group* comprised of same household and closest in age sibling, between 3 and 12 years old, with typical development. The response rate in this group was 76% (16 out of 21 siblings). A total of four siblings were excluded due to ASD screening failure and/or incomplete questionnaires. The final number of siblings was 12.

2.1.3. Second control group

Second control group defined as *Typical development group* included children matched for age and gender, (recruited using advertisements in popular online forum and parenting groups), with typical development according to parent's reports. Response rate in this group was 72% (29 out of 40 families).

2.1.4. Exclusion criteria for all groups

Exclusion criteria for all groups included consumption of food supplements, metabolic disease, diabetes mellitus or celiac disease and the use of a gluten-free and casein-free diet, for any reason.

2.2. Questionnaires

2.2.1. Screening for ASD

Children were screened using Autism Screening Questionnaire (ASQ) with sensitivity of 0.85, specificity of 0.75, positive predictive value (PPV) of 0.93 and negative predictive value (NPV) of 0.55 (Berument, Rutter, Lord, Pickles, & Bailey, 1999).

2.2.2. Weight, height, body mass index (BMI)

Data for weight (kg) and height (metrics) were reported by parents. BMI (kg/m^2) was calculated. Comparison of weight, height and BMI between groups was calculated using World Health Organization (WHO) AnthroPlus software (World Health Organization, 2009). Due to many out-layers from normal scores, calculated *Z*-scores were used in the analyses.

2.2.3. Demographic variables

Demographic variables were collected using a self-administered questionnaire.

2.2.4. Nutritional consumption

Nutritional consumption was obtained with a self-administered semi-quantified food diary. Parents were trained to record and quantify the food consumption, in real time. They were instructed to complete entries for two weekdays and one weekend day, using a food guide developed by the Department of Nutrition of Public Health Services in the Israeli Ministry of Health (Israel Center for Disease Control, 2009). A registered dietitian reviewed the diet records immediately after data collection in order to capture possible missing details and she performed all the nutritional diagnoses. Intake of nutrients was compared to the Dietary Reference Intake (DRI) according to the DRI tables (Food and Nutrition Board 1997–2002). Only nutrients with a DRI were used in the analysis. The consumption of nutrients was calculated using 'Tzameret' – a dietary analysis program developed by the Israeli Ministry of Health (Nutrition Department, Israeli Ministry of Health, 2007).

2.3. Statistical analysis

Sample size was calculated using WinPepi (Abramson, 2004). Baseline demographic characteristics are presented as means and standard deviations (SD) for continuous variables or as numbers and percentages for categorical variables. For all DRI available, the percentage of the intake of nutrients was calculated. In order to prevent offsetting of one nutrient over the other, the sum of percentages of nutrients below the DRI were calculated and compared between groups using a-parametric test. Mann–Whitney test was used for ASD vs. typical development group (independent groups). Wilcoxon test was used for 12 children with ASD vs. their siblings (dependent groups). Nutrients with no DRI or no data of their amount in food items were excluded.

We calculated the total sum of percentages below the DRI for: calories, protein, carbohydrates, fiber, iron, magnesium, potassium, sodium, zinc, copper, vitamins A, E, C, D, B12, thiamin, riboflavin, niacin, pyridoxine and linoleic acid.

3. Results

Table 1 summarizes demographic and growth indices of the participants. No significant difference was found between the groups regarding demographic characteristics. No significant differences were found between the two medical centers (data not shown).

Children with ASD compared to the typical development group had significantly higher Z scores and SD for weight 0.57 (1.40) vs. −0.17 (1.03), respectively ($P = 0.027$ effect size: $d = 0.58$) and BMI percentiles 0.64 (1.55) vs. −0.31 (1.48), respectively ($P = 0.024$ effect size: $d = 0.62$). When comparing Z scores of the ASD group to Z scores of the siblings group, results are not significant: weight 0.57 (1.40) vs. −0.15 (1.05), respectively ($P = 0.248$. effect size: $d = 0.58$). BMI 0.64 (1.55) vs. 0.27 (1.21), respectively ($P = 0.347$. effect size: $d = 0.26$). There was no significant difference in height Z scores between the groups: ASD 0.14 (1.43), siblings −0.25 (1.13), typical development 0.09 (1.28).

Average consumption for each nutrient in the ASD group vs. the typical development group is presented in Table 2. Several nutrients, including calcium and iron were consumed in significantly lower amounts in the ASD group as compared to the typical development group. However, in both groups the average consumption for each nutrient was above the DRI, excluding calcium: ASD vs. the typical development group was 484.6 mg (202) vs. 571.9 mg (178), respectively; and iron 8.0 mg (2.5) vs. 9.5 mg (3.1), respectively.

Table 1
Description of participants ($n = 91$).

	ASD ($n = 50$)	Siblings ($n = 12$)	Typical development ($n = 29$)
Male sex n (%)	41 (80.4)	10 (71.4)	22 (75.9)
Mean age (months) (SD)	54.1 (11.1)	77 (32)	51.6 (11.6)
Father's education >12th grade (%)	33 (76.7)	33 (76.7)	17 (60.7)
Mother's education >12th grade n (%)	36 (73.5)	36 (73.5)	20 (69.0)
Marital status – married n (%)	46 (90.20)	46 (90.20)	29 (100)
Religion			
Secular	11 (22.45)	11 (22.45)	6 (20.69)
Traditional	3 (6.12)	3 (6.12)	4 (13.79)
Orthodox	41 (80.39)	41 (80.39)	22 (75.86)
Mean anthropometric measurements Z-Score (SD)			
Weight-for-age	0.57 (1.40)	−0.15 (1.05)	−0.17 (1.03)[a]
Height-for-age	0.14 (1.43)	−0.25 (1.13)	0.09 (1.28)
BMI-for-age	0.64 (1.55)	−0.27 (1.21)	−0.31 (1.48)[b]

[a] Diagnostic groups (ASD vs. Control) significantly different at $P = 0.027$.
[b] Diagnostic groups (ASD vs. Control) significantly different at $P = 0.024$.

Table 2
Average intake of nutrients ASD group vs. typical development group.

	ASD $n = 50$ (SD)	Typical development $n = 29$ (SD)	DRI for average age
Average age (years)	4.5 (0.9)	4.3 (0.9)	
Protein (g)	50.1 (12.2)[a]	55.8 (12)[a]	19
Carbohydrates (g)	171.4 (93.9)	184.6 (115.3)	130
Fiber (g)	11.7 (4.1)	12.5 (5.7)	25
Calcium (mg)	484.6 (202)[a,b]	571.9 (178.0)[a,b]	1000
Iron (mg)	8.0 (2.5)[a,b]	9.5 (3.1)[a,b]	10
Magnesium (mg)	164.9 (45.4)	185.2 (61.0)	130
Phosphorus (mg)	812.8 (211.0)[a]	920.2 (181.0)[a]	500
Potassium (mg)	1556.7 (501.4)	1687.2 (492.1)	3800
Sodium (mg)	1845.1 (514.5)[a]	2108.7 (507.3)[a]	1200
Zinc (mg)	5.6 (1.6)[a]	6.7 (1.6) [a]	4
Vitamin E (mg)	4.7 (1.6)	4.3 (1.3)	7
Vitamin C (mg)	62.4 (15.9)	72.6 (12.8)	25
Thiamin (mg)	0.7 (0.2)	0.9 (0.4)	0.6
Riboflavin (mg)	1.2 (0.4)	1.5 (0.5)	0.6
Niacin (mg)	11.9 (3.8)	12.9 (5.0)	8
Pyridoxine (mg)	1.1 (0.3)	1.3 (0.5)	0.6
Vitamin B12 (μg)	2.4 (0.9)[a]	3.3 (1.4)[a]	1.2
Linolenic acid (g)	1.2 (0.7)	1.3 (0.6)	0.9

[a] Difference significant at $P > 0.05$.
[b] Below DRI.

Analyzing the sum of percentage for nutrients consumed below the DRI, for each child separately revealed a significant difference between the groups. Total mean (SD) average of deficiencies was higher in the ASD ($n = 45$) group vs. the typical development group ($n = 29$) 342.5% (122.9) and 275.9% (106.8), respectively ($P = 0.0266$. effect size: $d = 0.57$). There was a trend toward significantly higher deficiency in the ASD group ($n = 12$) and their siblings ($n = 12$) 363.0% (116.2) and 283.2% (94.7), respectively ($P = 0.071$. effect size: $d = 0.75$).

4. Discussion

4.1. BMI findings

The results of the current study show *Z* scores of weight and BMI for children with ASD were significantly higher than those of the typical development group, but not as compared to the siblings group. These data are also supported by a large phone interview study (85,272 American children aged 3–17 years) performed by the National Survey of Children's Health (NSCH). A nested case–control study by the NSCH found a higher percentage of children with ASD suffering from overweight and obesity (above the 85% percentile of the BMI index) compared to children with typical development, 30.4% vs. 23.6%, respectively (Curtin, Anderson, Must, & Bandini, 2010). Conversely, a study in England did not support these findings (Emond et al., 2010). Lack of significant differences between children with ASD and their siblings were probably due to the small sample size; however it is plausible that the child's unbalanced diet may affect the entire family or just the siblings' eating habits. Although this difference is not statistically significant ($P = 0.09$), a higher percentage of obesity (above the 95th percentile) was found in the ASD group ($n = 52$) compared to the typical development group ($n = 58$), (17% vs. 9%, respectively), in children aged 3–11 years. The tendency toward overweight in this ASD group is assumed to be related to unbalanced dietary intake, with a preference for higher consumption of processed foods, sweets and sweetened drinks (Evans et al., 2012). However, these differences can also be attributed to a sedentary lifestyle in ASD children (Must et al., 2013) and the use of antipsychotic drugs (Wink et al., 2014) that may cause weight gain.

4.2. Intake of specific nutrients

In order to more accurately analyze the intake of nutrients compared to the general intake, we used a different approach, thus we propose a novel model to calculate the rate of nutrients as part of the general intake, that may better reflect the specific deficiencies in this population.

Previous studies demonstrated that the use of the average intakes model does not consistently reflect the risk for insufficient intake of nutrients in children with ASD (Raiten & Massaro, 1986; Emond et al., 2010; Schreck et al., 2004; Schmitt et al., 2008; Herndon et al., 2009; Lockner et al., 2008; Johnson et al., 2008; Bandini et al., 2010; Zimmer et al., 2012).

Only after calculating the sum of percentage of nutrients below the DRI for each child separately we were able to neutralize the offset. A similar approach was used by Raiten and Massaro (1986), using a 7 day diet record and comparing it to the RDA. They found no significant difference between the ASD group ($n = 40$) and the typical development control group ($n = 34$). Albeit, taking into consideration 30 years ago the food variety and eating habits were markedly different than those today (Raiten & Massaro, 1986). Previous studies examining deficiencies in children with ASD presented average intake for each nutrient using one of the three methods: food diary, 24 h recall or food frequency questionnaire. However, some of these studies did not use reference values such as the DRI reference for detecting deficiencies (Emond et al., 2010; Schreck et al., 2004; Schmitt et al., 2008).

Alternatively, other studies compared rates of children who did not reach the recommended amount of a micro or macronutrient intake (Herndon et al., 2009; Lockner et al., 2008; Johnson et al., 2008; Bandini et al., 2010; Zimmer et al., 2012). A current meta-analysis of 17 prospective controlled trials found a significantly lower calcium and protein intake in children with ASD vs. children with typical development. In order to calculate the effect size (ES), either means frequencies or test statistics (e.g. Chi square and *t* tests.) were used. ES estimates were converted to standardized mean difference (SMD). A negative SMD ($SMD < 0$) indicates more nutritional deficits in children with ASD. Odds Ratio ($OR < 1$) indicates a lower consumption of a nutrient in a child with ASD compared to a child without ASD. The SMD, the OR and 95% confidence interval (95% CI) for calcium was SMD standard error (SE) = −0.65 (0.29), OR = 0.31 (95% CI 0.11–0.85) $P = 0.022$ indicating a lower calcium intake among children with ASD as compared to controls. The SMD (SE) for protein intake was −0.58 (0.25), OR = 0.35 (95% CI 0.14–1.86) $P = 0.021$ indicating a lower protein intake among children with ASD as compared to controls (Sharp et al., 2013). These deficiencies were also detected in the current study analysis.

The current study has several limitations: weight and height were reported rather than measured. However, there is no differential bias between the groups since children are routinely measured as part of the public health services. A potential bias may arise, since the study population was recruited from a limited area of the country, possibly with a differential socioeconomic status as compared to other areas.

5. Conclusions

The current study shows that although children with ASD had a higher *Z*-score for weight and BMI, they had more nutritional deficiencies than children with typical development. In the current analysis, children with ASD are more susceptible for various nutritional deficiencies as compared to a typical developed child and each child with ASD may have different deficiencies as compared to other ASD children.

We recommend that feeding problems in children with ASD should be addressed by individual assessment and a trained multidisciplinary team.

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