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DIETARY SURVEYS AND NUTRITIONAL EPIDEMIOLOGY

Nutritional status survey of children with autism and typically developing children aged 4–6 years in Heilongjiang Province, China

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Abstract

Autism is a neurodevelopmental disability that may affect nutritional management of children with autism. This study aimed to compare the nutritional status of children with autism with that of typically developing children (aged 4–6 years) in China. Nutritional status was assessed by means of nutritional data, anthropometric data, biochemical assessment, physical examination for nutrient deficiencies and providing a questionnaire to parents. A total of fifty-three children with autism and fifty-three typically developing children were enrolled in this study. The parents were asked to complete the questionnaire regarding the eating behaviour and gastrointestinal symptoms of their children. They were also asked to provide a 3 d food diary. Children with autism exhibited several abnormalities in terms of eating behaviour and gastrointestinal symptoms. The levels of vitamins A and B_6, Zn and Ca intakes were <80 % of the dietary reference intakes in both groups. In addition, the proportions of vitamin C and Ca intake deficiencies in the autism group were significantly higher than those in the control group. Serum Zn level was less than the normal reference range in both the groups. Serum Ca, vitamin A and folate levels in children with autism were significantly lower when compared with children without autism. According to the anthropometric data, the mean BMI, weight-for-height *Z*-score (Z_{WH}) and BMI for age *Z*-score (Z_{BMIA}) of children with autism were significantly higher than those of the typically developing children. Thus, nutritional inadequacies were observed in children with autism and typically developing children in China, which were, however, more pronounced among children with autism.

Key words: **Children with autism: Eating behaviour: Nutrient intake: Biochemical assessment: Anthropometry**

Autism is a neurodevelopmental disability that is characterised by deficiencies in social reciprocity and language skills that are associated with repetitive behaviours and restricted interests[1]. The incidence of autism has rapidly increased since the 1970s. According to reports, the prevalence rates are approximately 4·1 cases per 1000 children in Australia[2] and 6·5 cases per 1000 children in Canada[3], which are consistent with the prevalence estimates from the USA and the UK for several years[4–7]. Although nationwide epidemiological data on children with autism are not available in China, several regional studies have suggested that the prevalence of autism is 1·1–2·3 per 1000 children[8–11]. Children with autism are frequently observed to have peculiar eating habits that result from the connatural disease characteristics[12]. Although studies on nutrient intake of children with autism have shown conflicting results[13–15], most studies have reported that the dietary intake of children with autism is less than the recommended amounts of some minerals and vitamins[16,17]. They may also select fewer food categories[18], which may jeopardise their nutritional status, compared with that in children without autism[13]. Moreover, a high prevalence of gastrointestinal ailments may aggravate the digestive

Abbreviation: DRI, dietary reference intake.

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and absorption functions among children with autism[19,20]. The interaction between different genetic backgrounds and nutrients may also result in different metabolic models and utility levels of nutrients, regardless of the same quantity and quality of food intake[21,22]. Therefore, appraisal of the nutritional status of children with autism should not be based solely on their dietary intake.

In Heilongjiang Province, located in the northeast region of China, the economic condition is not as thriving as that in the southern part of the country. Thus, malnutrition in the children in this area is more common, for example vitamin A, Ca and Zn deficiencies[23]. In the present study, we hypothesised that children with autism in this area have inadequate nutrient intake and lower serum micronutrient level than children who underwent normal developmental stages based on a cross-sectional case–control study. We also assessed whether or not the poor nutritional state is associated with anthropometric data and clinical symptoms of nutrient deficiencies, given that these factors may have important implications in nutritional management of children with autism.

Materials and methods

Participants

A total of fifty-three children with autism (forty-five boys and eight girls; aged 4–6 years) who visited the Children Development and Behavior Research Center of Harbin Medical University (Harbin, China) from November 2009 to June 2011 were included in this study. Diagnosis was based on the criteria for autism defined in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) as well as on a childhood autism rating scale score of thirty according to a diagnostic interview conducted by a developmental paediatrician. The exclusion criteria included Asperger's disorder, pervasive developmental disorder, chronic seizures and recent infection as well as the use of any nutritional supplements. The study also recruited fifty-three children considered to be typically developing children from nursery schools around the Harbin Medical University. These participants were typically developing children who, according to their parents, had not experienced delays in motor and language development or behavioural problems. These children matched the age bracket (within 4 months), sex, occupations of parents and family economic status of the enrolled children with autism. All of the participants were of Han ethnicity.

This study was conducted according to the guidelines stated in the Declaration of Helsinki. All the procedures that involved human subjects were approved by the Research and Ethics Committee of Harbin Medical University. Written informed consent was obtained from the parents of each participant prior to enrolment.

General condition survey

The parents of the children with and without autism completed the questionnaire in which information regarding the children's eating behaviour, gastrointestinal symptoms and general condition was obtained. Before the survey was conducted, we calculated Cronbach's α coefficients to estimate the reliability of the reported factors in the questionnaire (α coefficients >0·70).

The questionnaire survey was conducted through face-to-face interviews between the investigators and the parents of both groups. The following data were obtained from the questionnaire: name, age, date of birth, birth condition, eating habits (such as food selectiveness (fastidious about their food), resisting trying new foods (refusing to eat those foods not tried before), eating independence and attention (the eating time for a meal is more than 30 min)), gastrointestinal ailments (such as abdominal pain (gastrospasm or enterospasm), constipation (reduced defecation frequency, decreased faeces, dry stool, need great effort to defecate), chronic diarrhoea (increased defecation frequency and loose stools for more than 2 months), excessive flatulence (often hiccup or pass gas) and disgorging), sleep status, food or drug allergies, self-injurious behaviour, tantrums, aggression, oppositional behaviour, family information, etc.

Dietary assessment

The parents of each subject were requested to provide a 3 d food diary of their children for two weekdays and one weekend (covering the consumption over 24 h on each of the 3 d). A picture booklet that includes local consumed food types, food pictures, the proportion of a serving and the estimated weight was handed out to the parents of each participant so that they could qualitatively and quantitatively describe all types of food consumed by their children and estimate the food intake.

A registered dietitian analysed the 3 d diet diaries by using the nutrient calculator software (Fei Hua V2.3, The Institute for Nutrition and Food Security, Chinese Center for Disease Control and Prevention). The study used the dietary reference intakes (DRI), including the recommended nutrient intakes and the adequate intakes recommended by the Chinese Nutrition Academy (2000), as norms for individual intake[24]. Results were converted to recommended nutrient intakes or adequate intakes percentages for energies and various nutrients per day based on DRI with respect to the age group. In this study, 'sufficient intake' is defined as ≥100 % of the DRI, 'borderline intake' corresponds to 80–99 % of the DRI and 'inadequate intake' indicates <80 % of the DRI.

Detection of the biochemical index for nutritional levels

Fasted blood samples (5 ml) were obtained from the participants through venipuncture. Approximately 1 ml of blood was collected and placed into an EDTA-coated tube for Hb determination (Hb automatic blood cell analyser, Sysmex Corporation). The remaining blood was centrifuged. Fe, Zn and Ca in the serum were separated by flame atomic absorption spectroscopy (AA6300 C atomic absorption spectrophotometer, Shimadzu) at 248·3, 213·9 and 422·7 nm, respectively, by using various hollow cathode lamps

(Perkin-Elmer). Vitamin A was determined with the HPLC technique according to Miller's method[25] (Waters 2960 Instrument). Vitamin B_{12} and folic acid levels were assessed by using a commercial RIA kit (Navy Gen Hospital), in which vitamin B_{12} and folic acid were labelled with radioactive ^{57}Co and ^{125}I. The values were determined using an automatic GC 911 gamma counter system (USTC Development Corporation).

Physical examinations for malnutrition (undernutrition)

Physical examinations were conducted by trained paediatricians. The examined parts of the body, symptoms and potential underlying nutrient deficiencies are listed in Table 1.

Anthropometric data

All of the required gauger trainings were completed before the measurement was carried out. Anthropometric data were collected using an HCS-200-RT weightometer and an HGM-200 wall anthropometer (Haerbin Biomedical Company). The accuracy of both instruments was confirmed before use: accuracies for body weight and stature were ±0·1 kg and ±0·1 cm, respectively. The children were examined with light clothing and bare feet. Height and weight values were obtained twice and the averages of height and weight for each child were obtained.

The evaluation of the development status was completed using the standardised WHO procedures[26]. The height for age, weight for age, BMI for age and weight for height (age <60 months) *Z*-scores (Z_{HA}, Z_{WA}, Z_{BMIA} and Z_{WH}, respectively) were calculated using the WHO Child Growth Standard (WHO Anthro software, version 3.01)[27]. These growth indicators were interpreted according to the Training Course on Child Growth Assessment (Geneva, WHO)[28].

Data analysis

The data on the general condition questionnaire were encoded in a computer by using EpiData V 3.02 software (Chinese Center for Disease Control and Prevention). The study used the Fei Hua (V2.3) nutrient calculator to compute energy and various nutrient intakes per day based on the data from the dietary questionnaire. The χ^2 test, two-sample/group *t* test and Fisher's exact test were used to determine the significance level. The Monte Carlo exact test was also used to evaluate the growth problem distribution of the children in both autism and control groups. *P* values <0·05 were considered statistically significant.

Results

Participant characteristics

The mean ages of the fifty-three children with autism and fifty-three typically developing children were 59·3 (SD 7·4) (50–78 months) and 59·4 (SD 7·5) (50–79 months) months, respectively. The parents of the children with autism were more likely to report the eating problems of their children (e.g. selectiveness, resisting trying new foods and inability to focus and eat independently compared with the parents of the typically developing children) ($P < 0·01$; Table 2). Children with autism experienced constipation and chronic diarrhoea to a higher extent and had a family history of allergies or immune diseases ($P < 0·001$). A higher number of children with autism also exhibited food or drug allergies, self-injurious behaviour, tantrums and aggressive or oppositional behaviour compared with the typically developing children ($P < 0·01$). No significant differences were observed in other gastrointestinal symptoms and sleep status between the two groups.

Dietary intake

Table 3 summarises the average intake of various nutrients per day of children with autism and those with typical development after the 3 d diet diaries were analysed. Inadequate vitamin A, vitamin B_6, Ca and Zn intakes were generally observed in both groups. The mean vitamin C intake was also inadequate for children with autism except for the previously mentioned nutrients. The mean dietary vitamin E, niacin, Mg and Fe intakes were sufficient, whereas the mean dietary vitamin B_1, vitamin B_2 and folic acid intakes were at the borderline for both groups. The numbers of typically developing children with inadequate dietary vitamin C and Ca intakes were significantly less than those of children with autism ($P < 0·05$). No statistical differences were found between autism and normally developing groups in terms of the number of children who had sufficient or borderline intakes of other nutrients.

Also, no statistically significant difference in the mean protein, carbohydrates and fat intakes was observed between the two groups. However, the mean contribution of energy

Table 1. Part of the body examined, symptoms and nutrient deficiencies

Body part/system	Clinical symptoms	Potential nutrient deficiency
Whole body	Emaciation, anasarca, anaemia	Protein, Fe
Skin	Dryness, roughness, petechia, seborrheicdermatitis, pellagra	Vitamin A, vitamin C, vitamin B_2, niacin
Hair	Scarcity, dryness, brittleness	Protein, Zn, Fe
Eyes	Bitot's spot, corneal drying, pale conjunctiva	Vitamin A, Fe
Lips	Angular chilitis, cheilitis	Vitamin B_2
Oral	Gingiva bleeding, scarlet geographical tongue, glossitis	Vitamin C, niacin, vitamin B_2
Nails	Scaphoid, unfairness	Fe, Zn
Skeleton	Squared skull, rib eversion, pectus carinatum, rachitic rosary, O- or X-shaped legs	Vitamin D, Ca
Nervous system	Muscle weakness, tingling sensation	Vitamin B_{12}, vitamin B_1

Table 2. Comparison of the general condition, eating behaviour, gastrointestinal symptoms, sleep status, agnostic behaviour and family history between children with autism and typically developing children (*n* 53)
(Number and percentage)

	Children with autism		Typically developing children		
General condition and symptoms	*n*	%	*n*	%	*P**
Sex					
Male	45	84·9	45	84·9	1·000
Female	8	15·1	8	15·1	
Age years					
4	31	58·5	31	58·5	1·000
5	18	34·0	18	34·0	
6	4	7·5	4	7·5	
Occupation of mother					
Intellectual work	36	67·9	40	75·5	0·388
Physical work	17	32·1	13	24·5	
Occupation of father					
Intellectual work	37	69·8	38	71·1	0·831
Physical work	16	30·2	15	28·3	
Family income per capita per month					
≥3000 Chinese Yuan	27	50·9	23	43·3	0·436
<3000 Chinese Yuan	26	49·1	30	56·6	
Food selectiveness	23	43·4	9	17·0	0·003
Resists trying new foods	33	62·3	15	28·3	<0·001
Bad eating independence and attention	33	62·3	3	5·7	<0·0001
Abdominal pain	11	20·8	2	3·8	0·008
Constipation	21	39·6	3	5·7	<0·0001
Chronic diarrhoea	14	26·4	0	0	<0·0001
Excessive flatulence	10	18·9	4	7·5	0·085
Disgorging	5	9·4	1	1·9	0·207
Sleep disturbance	11	20·8	4	7·5	0·051
Food or drug allergy	15	28·3	4	7·5	0·005
Self-injurious behaviour, tantrums, aggression, oppositional behaviour	20	37·7	6	11·3	0·002
Family history of allergy or immunity to diseases	28	52·8	10	18·9	<0·0001
Father/mother with a moderate or severe gastrointestinal problem	23	43·4	18	34·0	0·319

* χ^2 test.

intake from dietary fat (27·2 %) in children with autism was lower than the recommended percentage distribution (30–35 % for children aged 4–6 years).

Biochemical determination for nutritional levels

Table 4 shows the results of the biochemical determination for nutritional levels. No significant difference was observed in the Hb contents between children with and without autism. Also, no statistical differences were found in the mean Zn and Fe levels between the two groups, but the mean serum Ca level in children with autism was significantly lower than that in typically developing children ($P < 0·01$). It is clinically noteworthy that the mean serum Ca level in the autism group and the serum Zn levels in both groups were lower than the reference range. In addition, the mean serum vitamin A and folic acid levels, not the vitamin B_{12} level, in children with autism were significantly lower than those in typically developing children ($P < 0·01$ and $P < 0·05$, respectively). All of the three detected vitamins were within the reference ranges in both groups.

Physical examinations for malnutrition

Physical examinations were conducted to assess the nutritional status of both groups. No significant differences were observed in the clinical symptoms between the groups. Among the fifty-three children with autism, one child had pale conjunctiva, six had scarce, dry and brittle hair, three had dry skin, one had cheilitis and three had rib eversion (Table 5). Among the typically developing children, four subjects had scarce, dry and brittle hair, two had dry skin, one had non-smooth nails and two had rib eversion. No other symptoms for malnutrition were found among the participants.

Anthropometry

Table 6 summarises the average body height, body weight and general nutritional condition (*Z* score) of the fifty-three children with autism and fifty-three typically developing children. No statistical differences in height and weight were observed between the two groups. The mean BMI and the mean Z_{BMIA} in children with autism were significantly higher than those in typically developing children ($P < 0·05$). No statistical differences in the mean Z_{WA} and Z_{HA} between the two groups were observed. However, the mean Z_{WH} for children aged <60 months in the autism group was significantly higher than that in the typically developing children ($P < 0·05$).

Discussion

This cross-sectional study compared the nutritional status of children with autism with that of typically developing children

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Table 3. Daily intakes of energy and nutrients for autistic and typically developing children, compared with the dietary reference intake (DRI)*, and a comparison of the inadequate intakes (<80 % DRI) of the case and control groups
(Median values and ranges, percentage of recommended nutrient intake (RNI) or adequate intake (AI) and inadequate intake number and percentage)

		Autistic group					Typically developing group				
					Inadequate intake					Inadequate intake	
Nutrients	DRI (RNI or AI)	Median	Range	% of RNI or AI	*n*	%	Median	Range	% of RNI or AI	*n*	%
Energy				98·6	3	5·7			100·9	0	0
kJ	6485	6397	4619–8962				6544	5213–8924			
kcal	1550	1529	1104–2142				1564	1246–2133			
Protein (g)	50	51·9	35·6–98·3	103·8	3	5·7	53·9	41·7–94·6	107·8	0	0
Carbohydrates (g)	50–60 %†	226·3	163·4–317·0	59·2†	6	11·3	222·5	177·2–303·4	56·9†	1	1·9
Fat (g)	30–35 %†	46·2	33·4–64·7	27·2†	7	13·2	50·9	40·6–69·4	29·3†	2	3·8
Vitamin A (μg RE)	500	309	153–667	61·8	43	81·1	343	181–702	68·6	40	75·5
Vitamin B_1 (mg)	0·7	0·56	0·39–1·01	80·0	28	52·8	0·58	0·33–0·99	82·9	26	49·1
Vitamin B_2 (mg)	0·7	0·59	0·26–0·99	84·3	23	43·4	0·56	0·27–1·30	80·0	25	47·2
Vitamin B_6 (mg)	0·6	0·15	0·03–0·53	25·0	51	96·2	0·17	0·06–0·64	28·3	49	92·5
Folate (μg DFE)	200	184·6	64–326	92·0	27	50·9	177	54–339	88·5	23	43·4
Niacin (mg NE)	7	8·7	5·6–20·3	124·3	0	0	8·5	6·7–16·0	121·4		0
Vitamin C (mg)	70	52·6	17·7–115	75·1	31	58·5	60·2	30·6–123·2	86·0	6	11·3‡
Vitamin E (mg α-TE)	5	11·7	4·4–17·3	234·0	0	0	13·5	7·9–25·7	270·0		0
Ca (mg)	800	377	107–840	47·1	49	92·5	582	219–1021	72·8	30	56·6‡
Mg (mg)	150	164	80–375	109·3	3	5·6	165	84–350	110·0	2	3·8
Fe (mg)	12	12·5	7·7–24·9	104·2	8	15·1	13·4	6·3–23·8	11·7	7	13·2
Zn (μg)	12	6·3	2·6–14·9	52·5	30	56·6	7·1	4·0–16·4	59·2	29	54·7

RE, retinol equivalent; DFE, dietary folate equivalent; NE, niacin equivalent; α-TE, α-tocopherol.
* DRI for the 4–6 years old group recommended by the Chinese Nutrition Society.
† The contribution rate for energy intake.
‡ Significant difference at $P < 0·05$ (with χ^2 tests).

Table 4. Comparison of the biochemical nutritional levels of autistic and normally developing children (*n* 53) (Mean values and standard deviations)

Item	Reference range	Autism group		Normally developing group		
		Mean	SD	Mean	SD	*P**
Hb (g/l)	>120	123	6·1	123	6·7	0·740
Zn (μmol/l)	76·5–140·0	72·9	8·2	73·5	15·0	0·790
Ca (mmol/l)	1·55–2·10	1·54	0·04	1·59	0·12	0·007
Fe (mmol/l)	7·52–11·82	8·17	0·59	7·98	0·91	0·218
Vitamin A (μg/dl)	25–56	28	5·9	41	7·8	<0·0001
Folate (nmol/l)	5·31–39·86	24·32	10·86	29·13	10·95	0·025
Vitamin B_{12} (pmol/l)	139·86–653·42	464·47	192·18	556·13	328·78	0·083

* Two-sample/group *t* test.

in China. An inadequate nutritional status was observed in children with and without autism. Children with autism exhibited more abnormalities in terms of eating behaviour and gastrointestinal symptoms, higher proportions of vitamin C and Ca intake inadequacies, as well as lower levels of serum Ca, vitamin A and folate. According to the anthropometry data, higher mean BMI, Z_{WH} and Z_{BMIA} were observed in children with autism than in typically developing children.

Eating problems are more frequent in children with autism than in typically developing children. This finding agrees with that in several previous reports, in which children with autism have higher incidence of food refusal and limited food repertoire than typically developing children[15,18]. Strict adherence to rituals and routines, which is a core feature of autism, has been suggested as a possible explanation for these eating problems[12]. Sensory integration dysfunction and sensory sensitivity that can cause eating discomfort also contribute to the food selectiveness of a child with autism[29]. Such behaviours as food selectiveness and resisting trying new foods may indicate an attempt to compensate for this discomfort[30]. Parents of children with autism often report a high rate of gastrointestinal symptoms[31,32] despite the lack of medical causes. Similar results were also found in the present study. Levy *et al.*[33] reported that some gastrointestinal symptoms may be the result of opioid peptides that are formed from the incomplete breakdown of foods that contain gluten and casein. However, several studies have shown that a gluten-free, casein-free diet does not significantly alter the symptoms in children with autism[34]. Commercial gluten-free, casein-free products are not yet available in China and the dietary intakes of children with autism in our study were not restricted. Hence, the mechanism by which gastrointestinal problems occur in children with autism should be further investigated.

Table 5. Physical examination for malnutrition in children with autism and typically developing children (*n* 53)

Symptoms	Autistic group		Typically developing group		*P**
	n	%*	*n*	%	
Pale conjunctiva	1	1·9	0	0·0	1·000
Scare, dry and brittle hair	6	11·3	4	7·5	0·506
Dry skin	3	5·7	2	3·8	0·647
Cheilitis	1	1·9	0	0·0	1·000
Non-smooth nails	0	0·0	1	1·9	1·000
Rib eversion†	3	5·7	2	3·8	0·647

* Fisher's exact test.
† Rib eversion: the bottom two ribs are prominent over the periphery of bony thorax.

The limited number of published studies on nutrient intakes in children with autism have yielded conflicting results[13,14,35]. Our results showed that the mean dietary intakes of vitamins A and B_6, Ca and Zn in children with autism and typically developing children were <80 % of the DRI. This result indicated that the intakes of these nutrients were commonly inadequate among Chinese children. Based on the 2002 National Survey of Resident Nutritional Status in China, the rates of inadequacy intake and the borderline inadequacy intake were 9·1 and 41·8 % for vitamin A, respectively; the dietary Ca intake was 238 mg/d, which is only one-third of the adequate intakes in Chinese children below 6 years of age[36]. Several studies have also found that children with autism consume significantly lower amounts of Ca than those without autism[14,37–39], a trend that was also observed in the present study. Based on the detected serum biochemical assessment, serum vitamin A and Ca levels in children with autism were significantly lower compared with those in children without autism (the serum Ca level of children with autism was also less than the reference range), which is consistent with the findings of the dietary assessment. A previous study reported that no significant difference is observed in the serum Ca levels between children with and without autism, and the detected values are within the normal reference range[40]. However, the serum Ca level is increased when the Ca deposited in the skeleton is mobilised, thereby resolving Ca inadequacy. The proportion of Zn intake inadequacy in Chinese children is approximately 50 %[41]. In the present study, although serum Zn levels were less than the reference range, no statistical difference was observed between the two groups. Therefore, Zn deficiency may be related with the characteristics of the Chinese diet, in which cereals constitute the main staple food. Moreover, the participants of our study live in the northernmost parts of China; fruit consumption in this region is much lower and vegetables are the primary source of vitamin C. The mean vitamin C intake level in children with autism was inadequate and significantly lower than that in typically developing children. This result is similar to

Table 6. Anthropometric data and *Z* scores of children with autism and typically developing children (*n* 53) (Minimum to maximum, mean values and standard deviations)

	Autism group			Typically developing group			
	Minimum to maximum	Mean	SD	Minimum to maximum	Mean	SD	*P**
Age (months)	50–78	59·3	7·43	50–79	59·4	7·51	0·948
Height (cm)	95·1–125·2	111·2	7·34	98·5–124·0	111·2	5·78	0·997
Weight (kg)	13·0–35·4	21·2	4·23	15·0–33·4	19·9	3·61	0·087
BMI (kg/m^2)	10·9–23·2	17·1	2·56	12·9–22·1	16·0	1·78	0·017
Z_{WH}†	−1·34 to 4·36	1·10	1·57	−1·99 to 3·10	0·41	1·04	0·045
Z_{WA}	−2·84 to 4·55	0·94	1·24	−1·63 to 3·40	0·51	1·03	0·052
Z_{HA}	−2·91 to 2·54	0·41	1·22	−1·82 to 2·07	0·39	0·85	0·918
Z_{BMIA}	−4·37 to 4·44	1·06	1·67	−2·10 to 3·62	0·44	1·13	0·028

* Two-sample/group *t* test.
† The score was used for children aged below 60 months.

a previous report that children with autism tend to refuse vegetables to a higher extent than typically developing children[15]. No differences were observed in vitamin B_{12} levels between children with and without autism in our study. However, the serum folate levels in children with autism significantly decreased. A recent study has reported that serum homocysteine levels significantly increase and folate and vitamin B_{12} levels significantly decrease in children with autism compared with those in typically developing controls[42]. Some studies have also demonstrated that children with autism exhibit impaired methylation and homocysteine metabolism[43,44]. Folate and vitamin B_{12} have an important function in homocysteine metabolism[40]. Therefore, the folate defect observed in our study may lead to homocysteine accumulation in the body of children with autism.

The results of this study showed that the mean BMI, Z_{WH} and Z_{BMIA} of children with autism were significantly higher and the minimum to maximum extent of the above-mentioned parameters were wider compared with that in children without autism. This result indicated that a few children with autism were stunted, which suggests a possibility of becoming overweight and an increased risk of the more autistic children being obese. A previous work has indicated that children with autism also have the potential to be obese in addition to nutritional inadequacy[45]. Thus, priorities for future research are identified to advance the understanding and management of overweight and obesity problems in children with autism.

Given the thorough examination of the nutritional status, this study may provide contributions to the relevant literature on the nutritional status of children with autism. The biochemical indexes, which have not been completely investigated in several studies, were considered and a stricter definition of autism that potentially decreased the heterogeneity of the children under observation was used. Several limitations, however, require adequate attention. For instance, we only considered the nutritional status of vitamin D for children based on their clinical symptoms. We did not evaluate the vitamin D intake and the serum 25-OH-D_3 levels, which are the main limitations of this study. Another limitation of the food nutrient evaluation included the scope of the food diary, which was only observed based on a 3 d intake. These data may not adequately indicate the variety of a typical diet[46]. In addition, all the enrolled participants were from Heilongjiang Province, an area without a prosperous economy and with a 6 month-long winter. Thus, the results from this region may differ from those from other parts of China and from other countries.

In conclusion, nutritional inadequacies were observed in children with autism and typically developing children in China; these were, however, more pronounced among children with autism. Therefore, the nutritional status of children with autism should be regularly monitored to reduce these deficiencies by dietary means or by administering appropriate vitamin and mineral supplements.

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