

Nutrient intake and adequacy of children with autism spectrum disorder: EPINED

EPIDEMIOLOGICAL STUDY

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Methods

Study design and sample

The participants were recruited from the Neurodevelopmental Disorders Epidemiological Research Project (EPINED).

The study was approved by the Research and Ethics Committee of the Sant Joan University Hospital (13-10-31/10proj5) and by the Catalan Department of Education.

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Abstract

The objective was to assess the nutritional intake and adequacy of school children with autism spectrum disorder (ASD), subclinical ASD and typical development (TD). 117 children with ASD and 333 with TD were assessed. Few nutritional differences were found between children with ASD and with TD. Pre-schoolers with ASD had a lower energy intake of MUFAs and a higher inadequacy of vitamin D, b-carotene and vitamin B12 than their TD peers. Primary school children with ASD had a higher intake of cholesterol, protein and a higher percentage of obesity than children with TD. All sample with ASD had a poorer quality diet than those with TD. Children with ASD and TD had an unbalanced energy intake (high content of free sugars, lipids, SFAs) and a very highly inadequate intake (80%-100%) of vitamins D and E, a highly (50%-80%) of fibre, b-carotene (except pre-schoolers with TD), calcium (except pre-school children) and magnesium, and a moderately (25%-50%) of vitamin C, folate and iron (primary school children). The few scarce differences between children with ASD and TD are possibly related to the low level of ASD severity in this school sample. We conclude that all children need nutrition advice, including ASD.

Keywords: Autism spectrum disorder, Nutrition, Vitamin, Mineral, Schoolchildren, Preschool.

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Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder of neurobiological origin that begins in childhood. It affects the development of both social communication and interaction, as well as behaviour, and is characterised by the presence of restricted or, repetitive patterns of behaviour, interests, or activities (APA, 2013). Over the last few years, research has recognized ASD as a continuum of severity, ranging from autistic traits to subclinical disorders (Constantino & Charman, 2016; Morales et al., 2017). The prevalence of ASD has increased in recent years, currently affecting 1 in 54 children (Maenner et al., 2020), and subclinical cases are found in rates in the population than cases of children diagnosed with ASD (Jussila et al., 2020; Morales et al., 2017).

Children with ASD have a fivefold-elevated risk of developing eating disorders. These problems may be related to the clinical characteristics of ASD itself, such as sensory abnormalities or insistence on sameness, but may also be related to the physical and psychological comorbidities present in people with ASD. Parents of children with ASD commonly report food selectivity related to hypersensitivity to food odours, temperatures, textures or colours (Jussila et al., 2020; Leader et al., 2020; Smith et al., 2020) which predisposes them to nutritional vulnerability (Ranjan & Nasser, 2015). Moreover, comorbidities associated with ASD may also affect food consumption (Barnhill et al., 2017; Matheson & Douglas, 2017). Some authors have reported a higher frequency of oral motor impairments, sleep problems, emotional disorders, abnormalities in microbiota composition and difficulties with digestion, intestinal absorption and nutrient utilisation in people with ASD (Adams et al., 2004; Mannion et al., 2013a, 2013b; Vanuza & Cordeiro, 2018; Williams et al., 2005). Other authors have highlighted an increased need for some antioxidant vitamins in the ASD population compared to children with TD, because oxidative stress biomarkers, among other metabolic abnormalities, were found to be higher in this population (Bjørklund et al., 2019; Geraghty et al., 2010; Leader et al., 2020).

Research on the food consumption and nutritional intake of children with ASD has reported little variety in the foods that comprise their diets, in which an overall preference for energy-dense

1 foods and fewer fruits, vegetables and dairy products predominates (Graf-Myles et al., 2013; Schreck
2 & Williams, 2006). This eating pattern could translate to a greater degree of nutritional inadequacy
3 in children with ASD compared to children with typical development (TD) in some nutrients (calcium,
4 iron, phosphorus, selenium, zinc, vitamin A, vitamin D, vitamin C; thiamine, riboflavin, niacin, vitamin
5 B6, vitamin B12 and/or folate), as reported in recent reviews and meta-analysis (Esteban-Figuerola
6 et al., 2019; Sharp et al., 2013). However, the results found in the literature are controversial. While
7 some research has observed an adequate intake of protein, phosphorus, selenium, thiamine,
8 riboflavin, and vitamin B12 in children with ASD (Esteban-Figuerola et al., 2019; Hyman et al., 2012),
9 others have found that the intake of these same nutrients was inadequate (Andrew & Sullivan, 2010;
10 Hyman et al., 2012; Vogelaar, 2000; Xia et al., 2010) or found deficiencies of other nutrients such as
11 vitamin A and fibre.

12 Therefore, the objective of this study was to assess the nutritional intake and adequacy in of
13 preschool and primary school age children with ASD, subclinical ASD and TD. We hypothesise that 1)
14 children with ASD will have a lower intake of some nutrients than children with TD; and 2) children
15 with ASD will have a lower intake of some nutrients than recommended.

16 **Methods**

17 **Study design and sample**

18 We conducted a two-phase epidemiological study in a representative school population of
19 preschool and primary school-children in Tarragona (Spain). The study, -----
20 -----, was conducted for the purpose of determining the prevalence
21 of ASD and ADHD diagnoses in children (DSM-5 criteria). It was approved by the Research and Ethics
22 Committee of the -----.

23 In the first phase of the project, 6,894 children of the two age groups (3,374 children from 3
24 to 6 year old and 3,520 children from 10 to 12 years old) were invited to participate. However, the
25 parents of only 3,713 children signed the informed consent form. These children comprised the

1 initial study sample. Teachers and parents filled out questionnaires to screen for ASD and ADHD risk
2 in the children.

3 In the second phase, children at risk for ASD and/or ADHD and children with TD were called
4 to assess their diagnoses. Of 760 children, 61 were diagnosed with ASD, 43 with subclinical ASD, 259
5 were diagnosed with ADHD and 397 had neither ASD nor ADHD. To increase the sample with ASD for
6 the present study, 18 children with ASD from clinical services were invited to participate (mean age
7 9.29 years \pm 3.7 SD). Children whose food questionnaires were not complete were excluded. A total
8 sample of 450 participants (199 pre-school and 251 primary school-children) were finally ultimately
9 included, of whom 77 were diagnosed with ASD, 40 classified as subclinical ASD, and 333 were
10 included as controls (TD). The control sample did not include subjects with any other
11 neurodevelopmental disorders (ADHD, intellectual disability).

12 The socio-economic status of all subjects was estimated using the Hollingshead index (Hollingshead,
13 2011).

14 ***Psychological assessment and diagnostic procedure***

15 In the first phase, to screen for the risk of ASD, the parents completed the Childhood Autism
16 Spectrum Test (CAST; Scott et al., 2002) and the teachers completed the EduTEA questionnaire
17 (<https://psico.fcep.urv.cat/Q4/EduTEA>; Morales-Hidalgo et al., 2017).

18 In the second phase, the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2;
19 Lord et al., 2012) and the Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003) were used
20 to diagnose ASD (DSM-5 criteria). Autism severity was classified based on the ADOS cut-offs
21 suggested by Gotham et al. (2009), where a score of <3 was 'non ASD', 4-5 'ASD' and 6-10 'autism'.
22 Children with manifestations of ASD but who did not fulfil all the DSM-5 criteria were classified as
23 subclinical ASD.

1 ***Anthropometric measures***

2 Anthropometric measures were taken in accordance with the International Society for the
3 Advancement of Kinanthropometry (ISAK) protocols. To measure height (cm), A SECA® stadiometer
4 accurate to 0.1 mm (PERILB-STND) was used, and TANITA scales (BC 420SMA) were used to measure
5 weight (kg). The body mass index (BMI) (kg/m^2) was obtained and recorded as z-scores (de Onis,
6 2007; WHO, 2007). BMIs recorded as z-scores were classified into the following categories:
7 normoweight, overweight and obese.

8 ***Energy and nutrient intake***

9 The children's food consumption frequency was recorded by the participants' parents using
10 the food frequency questionnaire (FFQ) validated in Spanish for young children with 41 items
11 (Esteban-Figuerola et al., 2019) and for adolescents with 45 items (Trinidad et al., 2008).

12 First, the frequency of consumption was transformed into grams per day based on the
13 portion size described for each item and age group in our population (ASPC, 2005). Next, the energy
14 and nutrients corresponding to each item were calculated using a composition table specifically
15 adapted to this questionnaire. For this calculation, the percentage of consumption of the foods
16 included in each item was considered for the population (for example fruit: %apples, %pears,
17 %peaches, etc.), based on food consumption assessment studies conducted by our research group
18 (Aparicio et al., 2015; Arijia et al., 1996a; Jardí et al., 2019a/b) in the same population. These
19 proportions were applied to the nutritional composition of each item in the REGAL food composition
20 table (Répertoire Général des Aliments) (Favier et al. 1997), complemented by the Mataix Verdú
21 food composition table for specific Spanish foods (Mataix, 2009). The total intake of natural sugars
22 and free sugars was calculated following WHO recommendations (WHO, 2015). The natural sugar
23 group included sugar group, included the sugars from whole fruits, vegetables, milk and savoury
24 cereals (rice, bread, pasta, flour). The free sugar group included the sugar in sweetened drinks and
25 juices (commercial and natural juice), sweet cereals, such as sweetened breakfast cereals, cookies,
26 cakes, and other sweet foods such as chocolate and dairy desserts.

1 We calculated the percentage of children with energy intakes exceeding 75% and 125% of
2 the Estimated Average Requirements (EAR) recommended by the European Food Safety Authority
3 (EFSA, 2017). The probability of inadequate intake was calculated as below the EAR based on the
4 EFSA recommended values (EFSA, 2017) using the following formula: $Z = 1 - (\text{CDF}(\text{AR} - \mu) / \text{SD}) * 100$,
5 where CDF assesses the cumulative distribution function, μ is the subject's nutrient intake, and SD is
6 the one standard deviation of AR (which is calculated as $\text{AR} * 0.1$ (IOM, 2000)). When AR was not
7 determined, we used the adequate intake, as in the case of magnesium, vitamin B12, vitamin D, and
8 vitamin E.

9 The percentage of energy provided by macronutrients was calculated and compared with
10 the values most frequently recommended by international organisations: protein 10%-30%,
11 carbohydrates >50%, fat <30% (IOM, 2000), saturated fatty acids (SFAs) <10%, polyunsaturated fatty
12 acids (PUFAs) 7%-10%, monounsaturated fatty acids (MUFAs) >12% (Aranceta et al., 2012) and free
13 sugars <10% (WHO, 2015).

14 ***Statistical analysis***

15 The variables were described and compared by age group and diagnosis (children with ASD,
16 subclinical ASD and TD/controls). ANOVA and Chi-square analyses were used to compare variables.
17 Results were expressed as mean and standard deviation for quantitative variables and in
18 percentages for qualitative variables. The significance level for all statistical comparisons was set at
19 $p < .05$. The data were analysed using SPSS Statistics 25.0.

20 **Results**

21 Table 1 shows the sociodemographic, anthropometrical and psychological characteristics by
22 age group and diagnosis (ASD, subclinical ASD and TD). Children with ASD scored lower in the diet
23 quality index. The mean ADOS-2 score for the children with ASD was in the non-severe range. The
24 primary school children with ASD had higher BMIs than those with TD.

1 Tables 2 and 3 describe the energy and nutrient intakes and the probability of inadequate
2 intake below EAR in the different groups. A high percentage of children had energy intakes
3 exceeding 125% of the EAR (21.1%-47.9%), with no differences between children with ASD and TD in
4 either age group. Protein (73.1 g/d) and cholesterol (286.6 mg) intake was higher in primary school
5 children with ASD than in children with TD (65.5 g/d and 240.8 mg/d, respectively). For
6 micronutrients, we observed a remarkably highly inadequate intake (80%-100%) of vitamin D and
7 vitamin E, and a high inadequacy (50%-80%) of fibre, b-carotene (except in the TD group) and
8 magnesium intake. Pre-schoolers also had a moderately inadequate intake (25%-50%) of calcium,
9 and primary school children had highly inadequate intake of calcium and retinol, and a moderately
10 inadequate intake (25%-50%) of vitamin C (in the ASD and TD group), folate (in the ASD and TD
11 group) and iron.

12 Among the children with ASD and subclinical ASD, we observed that the pre-schoolers with
13 ASD had a lower intake of vitamin B12 than those subclinical-ASD. And primary school children with
14 ASD had a higher intake of protein, thiamine, niacin and magnesium than children with subclinical
15 ASD.

16 Differences were found between children with different diagnoses only among the pre-school
17 group: preschool-age children with ASD had a lower intake of vitamin D (1.47 mcg/d vs 2.11 mcg/d),
18 and vitamin B12 (3.77 mcg/d vs 4.62 mcg/d), and higher inadequate intake of b-carotene (62.4% vs.
19 37.7%) than children with TD.

20 Tables 4 and 5 describe the percentage of energy provided by macronutrients and the
21 percentage of individuals below or above the recommended values. An adequate energy intake from
22 proteins and MUFAs was reported in all children. Energy provided from carbohydrates was lower
23 than recommended in a high percentage of children (between 71.8%-89.5%). In contrast, energy
24 provided by free sugars, total lipids and SFAs was higher than recommended. Primary school
25 children with ASD were found to consume an inadequate and higher percentage of proteins and
26 fewer MUFAs compared to those with TD.

1 relates the high protein intake of children with ASD to an increased prevalence of digestive disorders
2 in this population. These children appear to experience greater absorption of intestinal proteins, due
3 to greater intestinal permeability and an increased formation of peptides (Reichelt et al., 2012).

4 We found that an excessively high percentage of children exhibited an imbalance in the
5 energy intake provided by macronutrients, a pattern typical of developed countries. A lower
6 contribution of carbohydrates and PUFAs and a higher contribution of free sugars, total lipids and
7 SFAs were observed in all the groups studied. The energy intake of MUFAs, related to the
8 Mediterranean diet, was adequate. The imbalance that is the most potentially damaging to our
9 participants' health is related to the high consumption of free sugars, which affected between 52.6%
10 and 75% of the children, and of total lipids and SFAs, which affected between 88.9% and 100% of the
11 children in our study. We also found small differences indicative of a less healthy in children with
12 ASD compared to children with TD, with a higher contribution of protein (only in primary school
13 children) and a lower contribution of MUFAs to total energy intake.

14 In general, our data do not support the lower intake of energy (Neumeyer et al., 2018;
15 Zimmer et al., 2012), or protein (Malhi et al., 2017; Marí-Bauset et al., 2014; Munira et al., 2020;
16 Neumeyer et al., 2018; Tsujiguchi et al., 2020; Shmaya et al., 2014) or unbalanced energy (Meguid et
17 al., 2017; Neumeyer et al., 2018) observed in children with ASD at clinics or specialised schools
18 where subjects tend to have more severe ASD.

19 All the children in our study, regardless of age or diagnosis, had low intakes of
20 micronutrients, with a very high risk of inadequate intake (80%) of vitamin D and vitamin E and a
21 high risk (50%-80%) of inadequate b-carotene and magnesium intake. Inadequate calcium intake
22 affected primary school children more (72.6%-75.7%) than pre-schoolers (26.8%-41.9%). However,
23 although it is assumed that children with ASD may be at a higher risk of inadequate intake than
24 children with TD due to their food selectivity (Jussila et al., 2020; Leader et al., 2020; Smith et al.,
25 2020), our results indicate differences that are only narrowly significant. We detected a lower intake

1 of vitamin D (1.47 mcg/d vs 2.11 mcg/d), vitamin B12 (3.77 mcg/d vs 4.62 mcg/d) and a higher intake
2 of b-carotene (62.4% vs 37.7%) in children with ASD compared to children with TD. Other studies
3 have also found higher deficiencies in children with ASD than in TD children, which frequently
4 corresponds to samples of children with a higher degree of severity of the disorder (Attlee et al.,
5 2015; Malhi et al., 2017; Marí-Bauset et al. 2015; Marí-Bauset et al., 2016; Neumeyer et al., 2018;
6 Shmaya et al., 2014; Tsujiguchi et al., 2020; Zimmer et al., 2012).

7 The high intake some vitamins and minerals in our sample were very worrying, as they are
8 related to the pathophysiology of ASD: vitamin D and calcium, vitamin E, b-carotene, vitamin C, and
9 magnesium. Vitamin D has an important function at the cellular, organic, cognitive and bone level.
10 Deficiencies in this vitamin contribute to hypocalcaemia and, consequently, can affect bone mass
11 development. Molloy et al. (2010) reported a reduction in bone density in ASD children compared to
12 their peers. Related to vitamin D, the highly inadequate intake of calcium in primary school children
13 (62.1%-72.6%) may have an adverse effect on bone health. Low levels of calcium may increase the
14 risk of osteomalacia and osteoporosis due to its important role in bone osteogenesis during
15 childhood. One study (Guo et al., 2020) suggested that calcium deficiency may be associated with
16 the severity of social impairment in children with ASD. Moreover, some authors have found that
17 adequate levels of calcium and iron are correlated with appropriate cognitive and neurological
18 function and development in children with ASD. Other studies have also found deficient intakes of
19 vitamin D (Al-Thbiany et al., 2017; Attlee et al., 2015; Barnhill et al., 2017; Hyman et al., 2012;
20 Lockner et al., 2008; Marí-Bauset et al. 2015; Tsujiguchi et al., 2020) and calcium (Barnhill et al.,
21 2018; Marí-Bauset et al., 2015; Marí-Bauset et al., 2016; Herndon et al., 2009; Hyman et al., 2012;
22 Tsujiguchi et al., 2020; Vanuza & Cordeiro, 2018; Xia et al., 2020). Over 63% of our sample had an
23 inadequate intake of vitamin A (b-carotene and retinol), which plays an important role in growth,
24 vision and the central nervous system. In children with ASD, some authors have also described lower
25 vitamin A intakes (Hyman, 2012; Lockner, 2008; Tsujiguchi et al., 2020; Vanuza & Cordeiro, 2018)
26 which can exacerbate symptomatology and behavioural problems (Guo et al., 2020). Vitamins C and

1 vitamin E play an important role as antioxidants, preventing oxidative stress and performing a wide
2 range of physiological functions in the human body. Other authors have also observed at-risk intakes
3 of vitamins (Attlee et al., 2015; Hyman et al., 2012; Malhi et al., 2017; Tsujiguchi et al., 2020; Xia et
4 al., 2010), including vitamin E (Barnhill et al., 2017; Herndon et al., 2009; Hyman 2012; Lockner et al.,
5 2008; Marí-Bauset et al., 2015; Xia et al., 2020). Magnesium deficiencies cause irritability,
6 excitability, and noise discomfort that can exacerbate the symptoms of ASD. These deficiencies were
7 also found in Meguid et al. (2017), Tsujiguchi et al. (2020), Xia et al. (2020) and Zimmer et al. (2012).

8 In general, the results of previous studies illustrate the lack of consensus in the definition of
9 specific differences in the intake of vitamins and minerals in children with ASD compared to those
10 with TD. This may be related to several factors, including the characteristics of the sample studied in
11 terms of its age and, of course, in this case in terms of the diet of its social and family environment.
12 Diet is widely recognised as being closely tied to the socio-economic, cultural and religious
13 characteristics of the social environment and to family habits and relationships. Differences in diet
14 between children with ASD and those without it may also depend on the degree of severity of the
15 disorder. Our sample of children from the general school population is made up of cases with a
16 lower degree of ASD severity than those from clinics or special education schools used in other
17 studies. Children with more severe ASD tend to have more clinical characteristics related to the
18 adherence to sameness, sensory disturbances, gastrointestinal disorders, and psychopathological
19 comorbidities, which may affect their eating behaviours and therefore their nutritional status.

20 Despite the scarcity of differences found in micronutrient intakes between the different
21 groups, the set of small differences describes an intake pattern in children with ASD that is
22 somewhat different from that of children with TD. Children with ASD scored worse on the diet
23 quality index, had higher BMIs and represented more cases of obesity (a trend in preschool children
24 and a significant difference in primary school children). They had a higher intake of protein and
25 cholesterol and a lower intake of vitamin D and b-carotenes (preschool age children). They had a
26 lower energy contribution from MUFAs. All this, added to the other inadequate intakes shared with

1 children with TD, describe a deficient nutritional pattern that is related to an increased risk of future
2 cardiovascular diseases, obesity, type 2 diabetes mellitus, and osteoporosis, among others disorders
3 (Ludwing et al., 2018; Makarem et al., 2018).

4 A strong point of the design of this study is that the participants come from a representative
5 school sample in a Spanish province. This has made it possible to include children with ASD,
6 subclinical ASD and children with TD with the same age characteristics and geographical area,
7 avoiding biases due to samples from different sources. However, the number of subjects with ASD
8 and subclinical-ASD was not very high, limiting our ability to generalise the results from those
9 groups. At a methodological level, the ASD diagnostic procedure was very rigorous, and the
10 questionnaires used are validated.

11

12 **Conclusions**

13 Compared to children with TD, children with ASD were found to have a poorer quality diet
14 and a lower energy intake from MUFAs. At the preschool age, they were found to have a more
15 inadequate intake of vitamin D, b-carotene and vitamin B12, and at the primary school age, a higher
16 percentage of obesity and higher cholesterol and protein intake. Regardless of the ASD diagnosis,
17 energy and protein intake was moderately high, and the intake of free sugars, total lipids and SFAs
18 was very high, in all children. All of the children in our sample also had inadequate intakes of
19 vitamins D, E, fibre, b-carotene, magnesium, and calcium. The limited differences between children
20 with ASD and TD are possibly related to the school population origin of the sample of children with
21 ASD. We conclude that all children need nutrition advice, including those with ASD.

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Table 1.

Sociodemographic anthropometrical and psychological characteristics by age group and subgroups of diagnosis

	Preschool-age children				Primary-school-age children			
	ASD ^a	SUBCLINICAL ^b	TD ^c	P	ASD ^a	SUBCLINICAL ^b	TD ^c	P
	(n=36)	(n=21)	(n=142)		(n=41)	(n=19)	(n=191)	
Age (years) #	5.07 (0.67)	4.79 (0.40)	5.09 (0.51)	.05 (0.008) ^{bc}	11.19 (1.48)	10.96 (0.54)	11.06 (0.52)	.499
Gender (males). %(n)	80.60 (29)	71.40 (15)	57.70 (82)	.029 (.012) ^{ac}	85.40 (35)	84.20 (16)	56.00 (107)	<.001 (<.001) ^{ac} (.017) ^{bc}
Hollingshead classification. %(n)								
<i>Low</i>	22.20 (8)	23.80 (5)	12.00 (17)	.153	9.80 (4)	36.80 (7)	15.20 (29)	.024 (.012) ^{ab} (.017) ^{bc}
<i>Medium-High</i>	77.80 (28)	76.20 (16)	88.00 (125)		90.20 (37)	63.20 (12)	84.80 (162)	<.001 (.032) ^{ac} (.002) ^{ab} (.034) ^{bc}
Diet Quality Index (score)	57.07 (10.80)	61.05 (9.63)	61.66 (7.20)	.012 (.020) ^{ac}	56.84 (8.93)	64.50 (8.24)	60.08 (6.31)	
BMI-for-age categories (z-score). %(n)								
<i>Normoweight (Reference group)</i>	72.20 (26)	66.70 (14)	71.10 (101)		36.60 (15)	57.90 (11)	54.50 (104)	
<i>Overweight</i>	11.10 (4)	19.00 (4)	21.80 (31)	.474 .240	34.10 (14)	36.80 (7)	26.20 (50)	.249 .046
<i>Obese</i>	16.70 (6)	14.30 (3)	7.00 (10)		29.30 (12)	5.30 (1)	19.30 (37)	
Autism diagnostic severity (score) #	5.53 (1.91)	3.43 (1.91)	1.44 (1.00)	<.001 (<.001) ^{ac/ab/bc}	5.12 (2.10)	3.68 (1.74)	1.19 (0.60)	<.001 (<.001) ^{ac/bc} (.012) ^{ab}

Note. # Mean (SD). ASD: Autism Spectrum Disorder; TD: Children with typical development.

Table 2.

Energy and nutrients intake and their inadequacy in pre-school age children by diagnosis

Energy and Nutrients (units/day) in mean (SD). [EAR]	ASD ^a (n=36)			ASD SUBCLINICAL ^b (n=21)			TD ^c (n=142)			P Intake	P % Children	
	Intake Mean (SD)	% Children		Intake Mean (SD)	% Children		Intake Mean (SD)	% Children			<75% EAR	>125% EAR
		<75% EAR	>125% EAR		<75% EAR	>125% EAR		<75% EAR	>125% EAR			
Energy (kcal/d) [1719.1-2507.7]	1866.70 (443.5)	2.80	47.20	1835.40 (483.0)	0.00	33.30	1902.7 (523.7)	0.70	47.90	.815	<75% p=.451	>125% p=.455
	Intake Mean (SD)	Inadequacy intake %		Intake Mean (SD)	Inadequacy intake %		Intake Mean (SD)	Inadequacy intake %		P Intake	P Inadequacy intake	
Proteins (g/d)[¶] [9.6-15.7]	57.60 (19.0)	0.00		58.00 (18.7)	0.00		58.50 (15.9)	0.00		.952	1.000	
Carbohydrates (g/d)[‡]	200.00 (68.1)	-		173.50 (69.9)	-		191.00 (77.8)	-		.442	-	
Starch (g/d)	69.10 (22.5)	-		61.50 (14.5)	-		64.90 (28.4)	-		.547	-	
Free sugar (g/d)	63.30 (40.6)	-		51.10 (33.3)	-		57.50 (38.2)	-		.495	-	
Natural sugar (g/d)	18.90 (8.9)	-		18.10 (8.7)	-		19.90 (7.5)	-		.541	-	
Lipids (g/d)[‡]	66.80 (12.2)	-		68.50 (13.9)	-		68.90 (13.6)	-		.721	-	
SFA (g/d)	23.30 (5.2)	-		23.40 (6.5)	-		23.40 (6.2)	-		.995	-	
PUFA (g/d)	7.80 (2.0)	-		8.10 (1.7)	-		7.90 (1.6)	-		.737	-	
MUFA (g/d)	35.80 (7.58)	-		39.30 (6.2)	-		38.00 (5.9)	-		.078	-	
Cholesterol (mg/d)	212.30 (66.6)	-		238.10 (100.4)	-		234.40 (81.6)	-		.320	-	
Fibre (g/d) [10-14]	12.90 (5.2)	64.70		11.9 (4.875)	70.40		13.10 (4.6)	66.10		.563	.862	

Table 2.

Continued

Retinol (mcg/d) [245-320]	352.60 (126.7)	15.50	388.50 (136.2)	11.20	384.30 (142.1)	12.50	.448	.796
b-carotene (mcg/d) [1470-1920]	1648.40 (1851.7)	62.40	1558.00 (894.2)	64.00	1878.50 (903.0)	37.70	.321	.002 (.003) ^{ac} (.012) ^{bc}
Vitamin C (mg/d) [25-40]	65.10 (31.7)	4.90	69.00 (35.5)	4.00	74.60 (31.6)	0.29	.253	.153
Vitamin D (mcg/d) [15]	1.47 (1.16)	99.00	1.91 (1.05)	99.00	2.11 (1.09)	99.00	.008 (.002) ^{ac}	.826
Vitamin E (mg/d) [9]	7.21 (2.22)	86.40	7.53 (1.27)	81.80	7.32 (1.22)	85.40	.728	.804
Thiamine (mg/d) [0.40-0.48]	1.00 (0.29)	0.00	0.96 (0.29)	2.30	1.00 (0.30)	0.00	.871	.025
Riboflavin (mg/d) [0.6-0.8]	1.49 (0.37)	0.00	1.48 (0.49)	2.40	1.51 (0.44)	0.00	.915	.031
Niacin (mg/d) [7.3-8.7]	12.50 (4.4)	10.80	12.50 (4.3)	19.00	13.00 (4.2)	7.10	.763	.140
Vitamin B6 (mg/d) [0.6-0.9]	1.34 (0.45)	2.60	1.28 (0.47)	4.30	1.35 (0.44)	0.00	.790	.055
Vitamin B12 (mcg/d) [1.5-2.5]	3.77 (1.26)	5.10	4.60 (1.67)	1.50	4.62 (1.58)	0.00	.012 (.003) ^{ac} (.038) ^{ab}	.005
Folate (mcg/d) [110-160]	193.30 (70.0)	5.10	191.1 (69.3)	9.50	208.60 (72.0)	3.30	.353	.300
Calcium (mg) [680]	772.30 (218.6)	26.80	747.10 (291.1)	41.90	760.60 (233.1)	39.90	.926	.305
Iron (mg/d) [8]	8.80 (5.2)	10.60	7.60 (2.3)	6.90	8.20 (2.7)	3.50	.388	.379
Magnesium (mg/d) [230]	221.40 (91.2)	65.70	192.10 (54.4)	80.00	201.90 (56.3)	72.90	.172	.484

Note. ASD: Autism Spectrum Disorder; TD: Children with typical development; EAR: Estimated Average Requirements; Inadequacy intake: probability of inadequate intake below EAR; SFA: saturated fatty acid;

PUFA: polyunsaturated fatty acid; MUFA: monounsaturated fatty acid.

Table 3.

Nutrients intake and their inadequacy in primary-school-age children by diagnosis

	ASD ^a (n=41)			ASD SUBCLINICAL ^b (n=19)			TD ^c (n=191)			P Intake	P % Children	
Energy and Nutrients (units/day) in mean (SD). [EAR]]	Intake Mean (SD)	% Children		Intake Mean (SD)	% Children		Intake Mean (SD)	% Children				
		<75% EAR	>125% EAR		<75% EAR	>125% EAR		<75% EAR	>125% EAR			
Energy (kcal/d) [1719.1-2507.7]	2125.80 (450.8)	9.80	21.90	2066.70 (293.1)	5.30	21.10	2210.80 (530.8)	3.70	31.90	.351	<75% p=.168	>125% p=.030 (.012) ^{bc}
	Intake Mean (SD)	Inadequacy intake %		Intake Mean (SD)	Inadequacy intake %		Intake Mean (SD)	Inadequacy intake %		P Intake	P Inadequacy intake	
Proteins (g/d) [17.54-40.29 g/d]	73.10 (23.0)	0.00		61.00 (11.5)	0.00		65.50 (17.0)	0.00		.021 (.049) ^{ac} (.008) ^{ab}	.890	
Carbohydrates (g/d)[‡]	211.20 (61.1)	-		186.80 (45.6)	-		207.80 (75.7)	-		.439	-	
Starch (g/d)	95.10 (31.6)	-		80.20 (34.1)	-		89.40 (33.5)	-		.270	-	
Free sugar (g/d)	61.70 (36.7)	-		44.00 (21.7)	-		53.00 (33.8)	-		.137	-	
Natural sugar (g/d)	19.80 (8.1)	-		22.30 (7.4)	-		21.30 (10.3)	-		.576	-	
Lipids (g/d)[‡]	85.00 (24.0)	-		78.60 (7.3)	-		81.40 (13.1)	-		.245	-	
SFA (g/d)	26.80 (9.0)	-		24.20 (4.0)	-		25.50 (5.8)	-		.296	-	
PUFA (g/d)	10.20 (4.0)	-		9.30 (1.1)	-		9.50 (1.5)	-		.142	-	
MUFA (g/d)	44.50 (11.5)	-		46.10 (3.5)	-		46.70 (5.2)	-		.162	-	
Cholesterol (mg/d)	286.60 (113.4)	-		243.40 (54.7)	-		240.80 (68.5)	-		.003 (.016) ^{ac}	-	
Fibre (g/d) [16-19]	14.60 (5.2)	74.40		14.40 (3.3)	78.40		15.20 (5.2)	67.70		.685	.355	

Table 3.

Continued

Retinol (mcg/d) [320-480]	417.40 (522.5)	66.30	361.50 (75.4)	63.20	391.50 (122.6)	54.70	.678	.245
b-carotene (mcg/d) [1920-2880]	2015.80 (1989.2)	72.70	1901.70 (741.8)	76.00	2036.30 (1060.3)	67.20	.903	.560
Vitamin C (mg/d) [40-60]	74.20 (37.42)	34.10	87.70 (30.0)	8.90	84.80 (41.6)	21.30	.273	.046 (.009) ^{ab}
Vitamin D (mcg/d) [15]	1.94 (1.41)	99.00	1.80 (0.97)	99.00	2.00 (1.08)	99.00	.751	.351
Vitamin E (mg/d) [9-13]	8.93 (2.84)	85.30	8.90 (0.69)	96.50	8.99 (1.31)	92.60	.966	.038 (.029) ^{ab}
Thiamin (mg/d) [0.52-0.76]	1.28 (0.54)	2.33	1.06 (0.24)	0.00	1.13 (0.32)	2.20	.025 (.030) ^{ab}	.674
Riboflavin (mg/d) [0.8-1.1]	1.65 (0.56)	13.90	1.40 (0.27)	9.20	1.54 (0.45)	9.80	.234	.672
Niacin (mg/d) [9.4-13.7]	16.90 (6.5)	23.00	13.80 (3.6)	17.0	15.10 (4.6)	21.10	.047 (.023) ^{ab}	.835
Vitamin B6 (mg/d) [0.9-1.2]	1.63 (0.56)	19.50	1.50 (0.32)	12.10	1.55 (0.48)	16.30	.379	.700
Vitamin B12 (mg/d) [2.5-3.5]	4.92 (3.76)	21.40	4.40 (0.93)	8.20	4.81 (1.45)	10.80	.628	.082
Folate (mcg/d) [160-210]	242.70 (89.7)	30.30	238.0 (52.8)	17.90	244.50 (82.0)	26.90	.870	.516
Calcium (mg) [680-960]	745.30 (261.7)	72.60	695.40 (184.2)	72.60	754.70 (249.0)	62.10	.606	.447
Iron (mg/d) [8]	9.40 (2.9)	35.10	8.30 (1.7)	48.40	9.00 (2.7)	37.30	.288	.479
Magnesium (mg/d) [230- 300]	229.80 (69.2)	79.50	205.20 (30.1)	99.00	221.70 (62.5)	78.60	.360	.093 (.003) ^{ab} (<.001) ^{bc}

Note. ASD: Autism Spectrum Disorder; TD: Children with typical development; EAR: Estimated Average Requirements; Inadequacy intake: probability of inadequate intake below EAR; SFA: saturated fatty acid;

PUFA: polyunsaturated fatty acid; MUFA: monounsaturated fatty acid.

Table 4.

Percentage of energy provided by macronutrients and their inadequacy in pre-school by diagnosis

	ASD ^a (n=36)		ASD-SUBCLINICAL ^b (n=21)				TD ^c (n=142)		P % Energy	P % Children	
	% Energy	% Children		% Energy	% Children		% Energy	% Children			
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)			
		< RD	> RD	< RD	> RD	< RD	> RD	< RD			> RD
Proteins (%) [RD: 10% -30%]	14.30 (3.4)	5.60	0.00	15.0 (2.6)	0.00	0.00	14.70 (2.2)	1.40	0.00	.525	.116/.108
Carbohydrates (%) [RD: >50 %]	48.20 (6.6)	77.80		44.10 (7.6)	85.70		46.00 (6.9)	71.80		.070 (.032) ^{ab}	.051 (.012) ^{ab}
Starch (%)	16.90 (4.3)	-	-	16.30 (3.2)	-	-	15.90 (4.9)	-	-	.478	-
Free sugar (%) [RD: <10%]	14.80 (6.9)		75.00	12.60 (6.5)		61.90	13.20 (5.8)		73.20	.315	.315
Natural sugar (%)	4.80 (2.2)	-	-	4.70 (1.8)	-	-	5.10 (1.9)	-	-	.527	-
Lipids (%) [RD: <30 %]	37.50 (4.5)		94.40	40.90 (5.9)		90.50	39.30 (5.2)		98.60	.044 (.017) ^{ab}	.864
SFA (%) [RD: <10%]	13.10 (2.3)		88.90	13.90 (2.9)		90.50	13.20 (1.9)		95.80	.402	.402
PUFA (%) [RD: 7% -10%]	4.40 (1.0)	97.20	0.00	4.80 (0.7)	100.00	0.00	4.50 (0.7)	99.30	0.00	.099	.223 / .104
MUFA (%) RD: [>15%]	20.10 (3.9)	2.80		23.60 (3.6)	0.00		22.00 (3.9)	0.70		.003 (.010) ^{ac} (.001) ^{ab}	.104 (.027) ^{ab}

Note. ASD: Autism Spectrum Disorder; TD: Children with typical development; SFA: saturated fatty acid; PUFA: polyunsaturated fatty acid; MUFA: monounsaturated fatty acid. RD: Recommendations.

Table 5.

Percentage of energy provided by macronutrients and their inadequacy in school in school age children by diagnosis

	ASD ^a (n=41)		ASD-SUBCLINICAL ^b (n=19)				TD ^c (n=191)		P % Energy	P % children out RD	
	% Energy	% Children		V	% Children		% Energy	% Children			
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)			
		< RD	> RD		< RD	> RD		< RD			> RD
Proteins (%) [RD: 10% -30%]	15.30 (3.0)	2.40	0.00	14.40 (1.8)	5.30	0.00	14.50 (1.84)	1.00	0.00	.023 (.049) ^{ac} (.008) ^{ab}	.613 / .030
Carbohydrates (%) [RD: >50 %]	44.20 (6.7)	82.90		43.60 (4.6)	89.50		44.50 (6.06)	81.20		.799	.667
Starch (%)	20.20 (5.2)	-	-	18.50 (5.9)	-	-	19.40 (4.86)	-	-	.472	-
Free sugar (%) [RD: <10%]	12.50 (6.0)		63.40	10.10 (4.7)		52.60	11.00 (4.77)		53.90	.128	.128
Natural sugar (%)	4.30 (1.7)	-	-	5.40 (2.2)	-	-	4.70 (1.85)	-	-	.073 (.049) ^{ab}	-
Lipids (%) [RD: <30 %]	40.40 (5.5)	-	100.00	42.00 (4.2)	-	100.00	41.10 (5.16)	-	99.50	.502	1.000
SFA (%) [RD: <10%]	12.60 (2.0)	-	92.70	12.90 (2.0)	-	94.70	12.70 (1.72)	-	95.30	.796	.796
PUFA (%) [RD: 7% -10%]	4.80 (1.2)	92.70	7.30	5.00 (0.5)	100.00	0.00	4.80 (0.68)	100.00	0.00	.666	.001/ .031
MUFA (%) RD: [>15%]	21.50 (4.3)	0.00	-	24.70 (2.5)	0.00	-	23.90 (4.03)	0.00	-	.001 (.001) ^{ac} (.001) ^{ab}	.001 (.048) ^{ac} (.028) ^{ab}

Note. ASD: Autism Spectrum Disorder; TD: Children with typical development; SFA: saturated fatty acid; PUFA: polyunsaturated fatty acid; MUFA: monounsaturated fatty acid. RD: Recommendations.