

Do Children with Autism Spectrum Disorders Eat Differently and Less Adequately than Those with Subclinical ASD and Typical Development? EPINED Epidemiological Study

Abstract

The purpose of this study was to compare food consumption in children with ASD, subclinical ASD and typical development (TD), and to investigate the adequacy of their consumption in relation to dietary recommendations. From a school population, 77 children with ASD, 40 with subclinical ASD, and 333 with TD participated. However, compared to children with TD, pre-schoolers with ASD were found to eat fewer raw vegetables and less fish and eggs, while primary school children consume fewer legumes, raw vegetables, citrus fruits, cheese /yogurt and olive oil, and more meat. All groups consumed an excess of sugar but those with ASD consumed an even greater amount than their peers. The higher prevalence of obesity found in school children with ASD may be the consequence of a less healthy eating pattern sustained over time.

Keywords: Autism spectrum disorders; preschool children; primary school age children; food consumption; food groups; food variety.

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Autism spectrum disorder (ASD) is a neurodevelopmental disability whose prevalence has increased in recent decades. Now affecting 1 in 54 children, ASD is more common in boys than in girls (Maenner et al. 2020). In addition, subclinical ASD affects 2.6% of the school population (Morales-Hidalgo et al. 2017) and 14.5% of the population with risk factors for developmental alterations (very preterm children) (Vermeirsch et al. 2020). Some of the main characteristics of ASD, such as insistence on sameness, inflexible adherence to routines or hyper-or-hypo reactivity to sensory input, may affect subjects' daily functioning and could contribute to the development of eating disorders. Problems such as food selectivity, food refusal, picky eating and/or mealtime behaviour difficulties are reported in ASD populations with a wide range of impact, from 13 to 80% (Cermak, Curtin and Bandini 2010; Mari-Bauset et al. 2014; Nadon et al. 2011a, 2011b; Schreck, Williams and Smith 2004). These atypical eating behaviours may be related to sensory sensitivity about the type, temperature, texture or colour of food, and affect their consumption and the child's nutritional intake (Bandini et al. 2010; Castro et al. 2016; Curtin et al. 2015; Johnson et al. 2014; Mari-Bauset et al. 2014; Ranjan and Nasser 2015; Zimmer et al. 2012).

Other comorbid conditions can also affect the consumption and nutritional intake of the ASD population. Gastrointestinal (GI) symptoms, reported generally as abdominal pain, constipation, and diarrhoea, have been well documented in children with ASD, affecting from 49.3 to 82% of the population. Some authors indicate that children with ASD and GI concerns are at a higher risk of developing eating behaviour problems than those without them (Leader et al. 2020; Mannion, Leader and Healy. 2013; McElhanon 2014; Santocchi et al. 2016). Moreover, many disorders, including attention-deficit/hyperactivity disorder (ADHD), intellectual disabilities and emotional disorders, coexist with ASD, which constitute other factors that may contribute to these eating patterns (Barnhill et al. 2017; Salazar et al. 2015). The combination of all these factors may affect the diet quality, growth and optimal development of children with ASD (Bandini et al. 2017; Barnhill et al. 2017; Matheson and Douglas 2017).

Some authors have studied the consumption of children with ASD compared to those with typical development. In general, they found stronger preferences for energy-dense foods like snacks, sweets, sugary beverages and juice in children with ASD (Berding and Donovan 2018; Evans et al. 2012; Wallace et al. 2020). In contrast, children with ASD tend to eat less from food groups like vegetables (Bandini et al. 2010; Emond et al. 2010; Evans et al. 2012; Ranjan and Nasser 2015), fruit (Chistol et al. 2018; Evans et

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al. 2012; Schreck, Williams and Smith 2004; Smith et al. 2020) and dairy products (Herndon et al. 2009; Mari-Bauset et al. 2017; Neumeyer et al. 2018) than children with TD. However, a previous study conducted in Spain found that children with ASD followed a traditional Mediterranean diet and ate more legumes and vegetables than children with TD (Mari-Bauset et al. 2017). So, the studies undertaken to date do not coincide in all their observations, and although some studies have reported that the consumption of vegetables, fruit and dairy products among children with ASD is below that recommended (Al-Thbiany 2017; Diolordi et al. 2014; Webber et al. 2018), other research has not found this deficiency (Evans et al. 2012; Herndon et al. 2009), or has even found contradictory results, as in the case of the protein food group (Herndon et al. 2009; Schreck, Williams and Smith 2004).

Given that the inadequate consumption of some foods may affect optimal growth in children (Esteban-Figuerola et al. 2019; Mari-Bauset et al. 2017; Sharp et al. 2013), we believe it is important to analyse the degree of dietary imbalance compared to children without ASD and in relation to recommended daily intake in order to assess the degree of risk associated with their eating behaviours.

Therefore, the aim of this study was to investigate the food consumption of a school population with ASD (clinical and subclinical diagnosis) compared to children with TD, and to compare their food consumption to the dietary guidelines. We hypothesise that: 1) The consumption of vegetables, fruit and dairy products will be lower, and the consumption of sweet foods higher, among children with ASD than among those with TD. 2) Children with subclinical ASD will have an eating pattern more similar to those with ASD than to those with TD. 3) We will find the same food consumption characteristics among children with ASD of both preschool and primary school age. 4) For some food groups, like fruit and vegetables, children with ASD will consume less than that recommended in the dietary guidelines.

Material and methods

Study design and sample

The participants were recruited from EPINED Project (PSI2015-64837-P and RTI2018-097124-B-I00), which aimed to determine the prevalence of ASD and ADHD (DSM-5 criteria) in a representative school population of preschool and primary school children in the province of Tarragona (Catalonia, Spain). In the

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described by Gotham et al. (2009; i.e. ≤ 3 non ASD, 4–5 ASD, 6–10 autism). In terms of ASD case definition, diagnoses were considered positive when the child's score reached or exceeded the threshold in all the ADI-R diagnostic algorithm domains and in the ADOS-2 calibrated score of severity (score ≥ 4), or when a consensus in diagnosis was reached by two trained researchers (psychologist and psychiatrist with experience with ASD) based on the information from the two instruments. The ASD diagnosis was considered subclinical when the child obtained subthreshold scores in both the ADI-R and ADOS-2 and a clinical consensus was also reached.

The Wechsler Scales of Intelligence for preschool and primary school children (WPPSI-IV, Wechsler Preschool and Primary Scale of Intelligence; and WISC-IV, Wechsler Intelligence Scales for Children (Wechsler, 2003, 2012) were used to assess cognitive function. To collect data on the presence of ADHD diagnosis and assess the compliance with DSM-5 diagnostic criteria, the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS-PL; Kaufman et al. 1997) interview was administered to the families. All diagnoses and tests were performed by trained psychologists and psychiatrists.

Anthropometric measures

In the second phase, anthropometric measurements were taken by a certificated dietitian in accordance with the International Society for the Advancement of Kinanthropometry (ISAK) protocols. A SECA® stadiometer accurate to 0.1 mm (PERILB-STND) was used to measure height (cm), and TANITA scales (BC 420SMA) to measure weight (kg). Subjects' body mass index (BMI) (kg/m^2) was obtained based on the international World Health Organization Child Growth Standards (from birth to 5 years of age and children/teenagers 5–19 years of age (de Onis et al. 2007; World Health Organization [WHO] 2007)

Food consumption and the Healthy Eating Index

The participants' parents reported their children's eating habits and the weekly frequency of food consumption using the food frequency questionnaires (FFQ) validated in Spanish adolescents and consisting of 45 items (Trinidad et al. 2008) and the FFQ validated in preschool children with 41 items (Esteban-Figuerola et al. 2020). The questionnaires yielded data on servings/day, servings/week, and grams/day. Grams/day of food consumption was calculated based on the items in the daily consumption

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frequency questionnaire according to the reference gram ration for each item and age group (Agència de Salut Pública de Catalunya 2005), and in agreement with the experts in this field from our research group (Arija et al. 1996a, 1996b; Jardí et al. 2018, 2019; Aparicio et al. 2015).

Items were classified into the following seven main food groups and 23 subgroups: 1) *Starch group*: 1 - Savoury cereals and tubers (bread, pasta, rice, potatoes, breakfast cereals); 2 - sweet cereals (biscuits, pastries, cookies); 3 - legumes; 4 - nuts; 2) *Vegetable group*: 5 - boiled vegetables, 6 - raw vegetables; 3) *Fruit group*: 7 - citrus fruit, 8 - other fruit, 9 - preserved fruit, 10 - natural fruit juice (mostly orange juice), 11 - commercial fruit juice; 4) *Dairy products group*: 12 - cheese and yogurt, 13 - milk, 14 - dairy desserts; 5) *Fat group*: 15 - olive oil; 6) *Protein group* (also includes legumes): 16 – poultry (chicken, turkey, etc.), 17 - red and processed meat (beef, pork, etc.), 18 - oily fish, 19 - white fish, 20 - seafood, 21 - eggs; 7) *Sweets/Sugary Beverages group*: 22 - sweets, 23 - sugary beverages.

The average servings/day (s/d) or servings/week (s/w) per food group was compared with the recommended Spanish dietary/eating guidelines (R-DG) of the Spanish Society of Community Nutrition (Sociedad Española de Nutrición Comunitaria [SENC] 2018).

Diet quality was also estimated using the Spanish Quality Diet Index (SQDI) proposed by Norte Navarro and Ortiz Moncada (2011) based on the food recommendations of the SENC (2004). The SQDI includes nine food groups based on their nutritional quality. So, meat, fish and eggs were re-grouped into a single group, and sweets and sweet cereals also were grouped into a single group. The consumption of each group by serving was compared to the recommended consumption and scored 0–100. The final index scores were classified as ≥ 80 points ‘*healthy*’, 50–79 points ‘*needs to improve*’ and ≤ 49 points ‘*unhealthy*’.

Statistical analysis

All variables were described and compared by age group and diagnosis (ASD, subclinical ASD and control/TD). ANOVA and Chi-square analyses were used to compare quantitative and qualitative variables, respectively. Prior to their application, we confirmed the normality of the variables and the criteria for the

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application of the statistical tests. The significance level for all statistical comparisons was set at $P < 0.05$.

Data were analysed using SPSS Statistics 25.0.

Results

Table 1 shows the subjects' sociodemographic, psychological, and anthropometrical characteristics by age (preschool or primary school children) and by ASD diagnosis (ASD, subclinical and control). There were significantly more boys on the autism spectrum (ASD and subclinical level) than girls. Between 80% and 85% of the sample were autochthons, and no clear differences in socioeconomic status were found between the autism spectrum groups and the children with TD. Around 25% of the pre-school and primary school children with ASD fell within the unhealthy diet group. BMI values were higher in primary school children with ASD than with TD, but these significant differences were not observed in the pre-school group. The mean IQ score was in the normal range for all groups, but TD children exhibited the highest IQs. ASD severity (ADOS-2) was low-moderate. Comorbidity between ASD and ADHD was high and increased in relation to age. ADHD was not present in children with TD because we excluded subjects with other neurodevelopmental disorders from the control sample.

[Table 1]

Table 2 shows food group consumption in grams/day (g/d) and servings/day (s/d) or servings/week (s/w) by diagnosis status (ASD, subclinical ASD and TD), age, and recommended consumption. The consumption of children with ASD was similar to that of children with subclinical ASD in most food groups, including starches, dairy products, vegetables, fruit and fats. However, preschool children with ASD consumed fewer protein groups like legumes, fish (white fish) and eggs, and more sweets than pre-schoolers with subclinical ASD. Primary school children with ASD also consumed fewer legumes, but had a higher consumption of red and processed meat, commercial juices and sweets than those with subclinical ASD.

No differences were found between the diets of children with ASD (ASD and subclinical ASD) and that of children with TD in most food groups, including the starch, vegetable, fruit and dairy product, . However, some differences were found by age and food subgroups. Pre-schoolers with ASD consumed significantly

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fewer proteins and specifically lower g/d and servings of fish (both white and oily) and eggs. The primary school children with ASD consumed less in the subgroup of legumes, citrus fruit and natural fruit juices, cheese/yogurt and fat, and higher in other fruit, meats and sweets. The consumption of children with subclinical ASD was only significantly different from those of children with TD for raw vegetables and sweets in preschool children. At this age, preschool children with ASD consumed fewer raw vegetables than those with TD, a trend also observed in primary school children with ASD.

[Table 2]

We also studied how the children's food consumption compared to dietary guidelines (R-DG) (Table 2), and found that, in general, the children have adequate consumption, or close to the R-DG, for the starch (although lower than the R-DG for legumes and nuts, and higher for sweet cereals), dairy, visible fats and protein groups (although lower than the R-DG for eggs). In contrast, all of the children consumed much fewer vegetables and fruits and more sweet foods and sugary beverages than recommended. However, according to the R-DG, in some food groups the consumption of children with ASD put them at higher risk for the development of diet-related issues than those of TD children. For example, children with ASD consumed even fewer raw vegetables and more sweets than TD children. In addition, at the preschool age, they deviate from the recommendations consuming less fish and eggs than TD children. And primary school children with ASD deviate even more from the recommendations consuming fewer legumes, citrus fruits, natural fruit juices and olive oil, and more meat than did TD children.

Discussion

This study describes food consumption and compliance with the dietary guidelines in a school population sample (3–6 years and 10–12 years) of children with ASD (clinical and subclinical diagnosis) and TD. Although a poorer quality diet was reported for the children with ASD than for the subclinical and control sample, all of the groups need to improve their diet. Differential intakes of some types of food were found among children with ASD compared to those with TD, as well as a higher consumption of sweets, possibly related to the organoleptic characteristics of these foods and the idiosyncrasy of this pathology.

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1) Food consumption differences between children with ASD and TD

To our knowledge, this is the first study to compare the food consumption of children with subclinical ASD and ASD, and subclinical ASD and TD. The analysis comparing the food consumption of subclinical ASD and ASD subjects yielded few differences overall. However, differences were found between the subclinical ASD and TD subjects. Among the differences found, it is striking that in both age groups, children with subclinical ASD tend to consume more legumes than children with ASD or even with TD, and this is the one group that reached the recommended number of servings. The consumption of legumes is recommended by public health agencies around the world on the basis that they are a good source of protein, fibre, and several micronutrients, including iron and zinc (Venn, Thies and O'Neil 2020). In our study, the lowest consumption of legumes was found among children with ASD, in contrast to the data presented by Mari-Bauset et al. (2017), which was also collected from a Spanish population in a Mediterranean environment. The joint analysis of the consumption of sweets/beverages was not differently significant between groups but favourably children with subclinical ASD consumed fewer sweets than children with ASD. Other differences in food consumption between subclinical ASD and other groups are related to age group. Preschool children with subclinical ASD had higher consumption in the protein groups than ASD children in the same age group, specifically related to the reduced consumption of fish and eggs, while primary school children with subclinical ASD consumed less meats than those with ASD. Our data did not support the hypothesis of a consistent eating pattern within the broad autism phenotype. We did not find a progression in food consumption according to the level of severity of ASD (from diagnostic to subclinical). Only in raw vegetables did preschool children with ASD and subclinical ASD consume significantly less than children with TD, and the same trend was observed among primary school children. However, although a low degree of acceptance of vegetables has been referred to in several studies with ASD children (Chistol et al. 2018; Dickerson Mayes and Zickgraf 2019; Tsujigushi et al. 2020), the small sample size of subclinical ASD children and the non-generalisation with other foods does not allow us to draw conclusions in this case.

We found that the differences between children along the entire autism disorder spectrum and those with TD occur mainly with children diagnosed with ASD and not with the subclinical ASD group. However,

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although it should be noted that the consumption of most food groups is quite similar between children with ASD and those with TD, some interesting peculiarities emerged when comparing food subgroups. Our data were not consistent with those of Mari-Bauset et al. (2017), who, also in Spain, found a healthy eating index for children with ASD and no significant differences in the food variety score. In the current study, differences between food subgroups may be related to the sensory characteristics of the food, which, together with the clinical characteristics of children with ASD, such as disordered sensorial processing, inflexible adherence to routines and gastrointestinal disturbances (Cemark, Curtin and Bandini 2010; Hubbart et al. 2014; Ranjan and Nasser, 2015; Santocchi et al. 2016; Smith et al. 2020), may give rise to the food preferences and aversions typical in this population (Emond et al. 2010; Evans et al. 2012; Graf-Myles et al. 2013; Liu et al. 2016). In addition, as mentioned in Schreck and Williams (2006), along with the diagnostic characteristics of autism, family food preferences could also influence the food selection of the children.

In addition, we observed specific differences in dietary patterns by age. We found an evolutionary change in dietary protein sources: preschool children with ASD consumed less protein groups than TD children (-35.3 g; -22.5%) ($p=0.002$), and this is opposite to the consumption of primary school children (22.5 g; 11.7%) ($p=0.058$), which is related to the high consumption of meats in this age group. Vissoker et al. (2018), working with a group of preschool children, and Malhi et al. (2017), with children between 4-10 years old, found that ASD children consume less protein food groups than TD children. However, neither Williams, Gibbons and Schreck (2005) nor Diolordi et al. (2014) found any differences with samples of a wide age range (2–12 years old and 6–9.5 years old, respectively). In our study, the lower consumption of protein found in preschool children with ASD was due to the reduced consumption of fish and eggs. In different cultural settings, Al-Farsi et al. (2013) also found a lower consumption of fish, eggs, legumes and vegetables in Egyptian ASD preschool children than in TD preschool children, and Hertz-Picciotto et al. (2010) found a lower consumption of fish in Californian ASD preschool children than in TD children. The reduced consumption of fish could be related to the particular smell and flavour of fish or to its bones (Chistol et al. 2018; Diolordi et al. 2014). In contrast, Zhu et al. (2020) in China and other authors in the USA (Berding and Donovan 2018; Graf-Myles et al. 2013) found only a lower consumption of dairy in ASD preschool children compared to their TD peers, which is not supported by our data. Unlike some of

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these authors, the children with autism in our sample were not reported to follow intentional diets, such as casein-free diets. We found that primary school children with ASD consumed less cheese and yogurt than their peers with TD, which does not coincide with the lesser consumption of dairy described by Marí-Bauset et al. (2017) in Spanish children aged 6 to 9. Furthermore, the high consumption of meats within the protein food groups found in the sample of 10–11 years old in our study is not consistent with the data of other researchers, in which the consumption of meat was lower in children with ASD (Diolordi et al. 2014; Vissoker et al. 2019) or was the same in ASD and TD children (Zhu et al. 2020). Our data are similar to those of Huxham (2012), who found that in the UK 69.2% of children with ASD had preferences for processed meat products. Apart from these age differences in the consumption of proteins, primary school children with ASD also consumed fewer citrus fruits and less natural fruit juice, which in our country comes mainly from citrus fruit (oranges). This reduced consumption may be related to the acidic taste of these fruits, which may make them less accepted by children with ASD who present higher oral sensory sensitivity (Cermak, Curtin and Bandini 2010; Chistol et al. 2018). On the other hand, the consumption of other fruits was higher in primary school children with ASD, which means that overall, no significant differences were detected in the total consumption of fruits. The higher consumption of non-citrus fruits could be related to their sweet and savoury taste (Diolordi et al. 2014; Schreck, Williams and Smith 2004). The preference for these tastes may also be one reason for the higher consumption of sweets and commercial fruit juices in ASD children compared to the other diagnosis groups. Most studies have considered fruit consumption as a global value without differentiating fruit types. So, like us, the meta-analysis by Esteban et al. (2019) did not find any differences in overall fruit consumption, although only three studies could be analysed. However, other authors (Araujo et al. 2018; Evans et al. 2012; Smith et al. 2020; Vissoker et al. 2019; Zhu et al. 2020) found that fruit and vegetables were the least consumed foods among children with ASD. To promote the acceptance of fruit and vegetables, a recent study (Chung, Law, Fong 2020) physically changed these foods, improving impaired sensory processing and consequently increasing their consumption in children with ASD. In the fat group, primary school children with ASD consumed less olive oil than their peers with TD. We think that this slight decrease in oil consumption may be associated with a stronger dislike of stews; however, olive oil consumption is very common in Spain and specifically in the Mediterranean region, and we have not found other studies including this analysis to date.

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Regardless of age group, children with ASD consumed fewer raw vegetables. These foods are characterised by strong flavours and tough textures, which make them less accepted by children with ASD (Chistol et al. 2018; Dickerson, Mayes and Zickgraf 2019; Tsujigushi et al. 2020). Another possible reason for this food selectivity may be gastrointestinal disturbances, as described in Santocchi et al. (2016). Other authors (Al-Farsi et al. 2013; Bandini et al. 2010; Diolordi et al. 2014; Vissoker et al. 2019; Wallace et al. 2020; Zhu et al. 2020) have also observed a reduced consumption of vegetables, but they did not explore subgroups within vegetables. Only Al-Thbiany et al. (2017) described non-significant differences in raw and boiled vegetable consumption between children with ASD and TD. Lastly, and in agreement with previous data (Berding and Donovan 2018; Evans et al. 2012; Vissoker et al. 209; Wallace et al. 2020), we found that the children with ASD consumed more sweets and sweetened beverages than children with TD. This excessive consumption has often been attributed to these children's preference for sweet flavours (Schreck, Williams and Smith 2004), but Wallace et al. (2020) found that among children with ASD, emotional over-eating was related to the increased consumption of sweet foods. This eating behaviour linked to negative emotions like anxiety may have both immediate and eventual health effects. On the other hand, the diet of children with ASD in our study, rich in simple sugars, added sugars and saturated fatty acids and low in fibre and antioxidants, may have consequences at the neurological level. This dietary pattern, as described Martínez Leo and Segura Campos (2020) in a neurobiological model, favours the dysbiosis of the gut microbiota and, through a series of systemic repercussions, facilitates the neuroinflammation process.

2) Diets of ASD and TD children and their alignment with recommendations

We compared our subjects' food consumption with the serving/days recommended in the dietary guidelines to evaluate the degree of dietary adequacy. In general, we observed that the children in the different subject groups met the R-DG in terms of average values in the starch (with a lower consumption of legumes in children with ASD), dairy, oil (with a lower consumption in children with ASD), and protein groups (with lower fish and egg consumption in preschool children with ADS). The adequate consumption of these food groups ensures an adequate average supply of energy, proteins, carbohydrates, fats and MUFAs, calcium, fat-soluble vitamins and some minerals in the children.

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However, we also observed some risky dietary behaviours among the children due to their very low consumption of legumes (between 0.19–0.31 s/w vs 2–4 s/w R-DG), vegetables (between 1.08–1.49 s/d vs 2–3 s/d R-DG) and fruit (between 1.36–1.74 s/d vs 2–3 s/d R-DG), and their higher consumption of sweet foods and sugary beverages (4.17–7.65 s/d vs occasionally R-DG), sweet cereals (between 0.86–1.33 s/d vs occasionally R-DG) compared to the R-DG.

Like other authors, we also observed that children with ASD generally consume a lower quantity of some foods than the R-DG in some food groups, almost all coinciding with a reduced consumption of fruits and vegetables (Araujo et al. 2018; Berding and Donovan 2018; Diolordi et al. 2014; Evans et al 2012; Graf-Myles et al. 2013; Malhi et al. 2017; Sharp et al. 2013), but not the other food groups. However, our study did not reveal a lower consumption of dairy products or protein than that recommended in the dietary guidelines, nor a reduced consumption in children with ASD in relation to TD children, though other authors have observed a lower consumption of dairy products among children with ASD (Al-Thbiany et al. 2017; Berding and Donovan 2018; Diolordi et al 2014; Graf-Myles et al. 2013; Malhi et al. 2017; Mari-Bauset et al. 2017) proteins (Al-Thbiany et al. 2017; Malhi et al. 2017; Sharp et al. 2013), and fish (Al-Thbiany et al. 2017; Berding and Donovan 2018). Nevertheless, the samples used in most studies come from a clinical population, which may represent a greater severity of autism than in this study (severity in ADOS is low). In our sample, only the preschool children with ASD failed to meet the recommendations for fish consumption, while the fish consumption habits of all the other groups aligned with the guidelines. Our data are consistent with those of most studies conducted with children from developed countries, in which the consumption of sweet food products and sugary drinks is much higher than the recommended occasional consumption (Araujo et al. 2018; Berding and Donovan 2018; Evans et al. 2012; Sharp et al. 2013). It has been well established that a higher consumption of sugary products is associated with the development of obesity, type 2 diabetes mellitus and cardiovascular diseases (Ludwing et al. 2018; Makarem et al. 2018; WHO 2015).

In general, a dietary pattern with a low content of fibres from legumes, nuts, fruits and vegetables is related to a decreased feeling of satiety during meals (Clark & Slavin 2013). This, together with an excess intake of high energy density food, such as sweet cereals, sweets and sugary drinks, constitute an eating pattern of high energy intake in all children. However, it is important to note that this high-risk eating pattern is

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more pronounced among children with ASD, since their specificities in the consumption of some food groups leads them to an eating pattern that diverges even further from the R-DG. This is the case of the reduced consumption of legumes, raw vegetables, some types of fruit, and fish (in preschool children) and the higher consumption of sweets among children with ASD compared to children with TD.

This pattern coincides with the higher percentage of obesity observed in children with ASD versus TD children (preschool: 16.7% vs 7.0%; $p=0.240$; primary school: 29.3% vs 19.3 %; $p=0.046$). Other authors have also observed this relationship between the eating patterns in ASD subjects and the higher prevalence of obesity (Araujo et al. 2018; Evans et al. 2012).

3) Strengths and limitations

One of the strengths of the design of this study is that the participants come from a representative school sample from a Spanish province. The two-phase design allowed us to detect both children at risk and not at risk of ASD, all of whom underwent the diagnostic procedure, which yielded three groups: ASD, subclinical ASD and TD. In addition, the study of two age groups allowed us to explore differences related to age. Most published studies come from clinical samples, so it is difficult to include children with subclinical ASD and children with TD with equivalent age and geographical characteristics. However, our results cannot be generalised for ASD and subclinical ASD, because the number of subjects in these age subgroups was not very high.

At a methodological level, the diagnostic procedure for ASD was very rigorous, and both validated techniques and questionnaires were used to determine the anthropometric and nutritional variables, specifically, the CFCA has been validated in the Spanish population for both age groups participating in the study.

Conclusion

The consumption habits of children with ASD, subclinical ASD and TD present no differences in the major food groups. However, the consumption of some food subgroups is different between children with ASD and TD and undergoes changes with age. Preschool children with ASD eat fewer raw vegetables, fish, and

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eggs, and primary school children with ASD consume fewer legumes, raw vegetables, citrus fruits and natural juices, cheese and yogurt and olive oil and more meat (red and processed meat) than children with TD. Both age groups with ASD consumed more sugar than the TD group. None of the children met the recommended dietary guidelines for fruit, vegetables, legumes or eggs, but children with ASD diverged even further from the recommendations than the TD group. Their eating pattern (poor in legumes, fruit, vegetables, and rich in sugary cereals, red and processed meat, sweets and sugary drinks) puts them at higher risk of developing obesity than TD children. Children in general, and especially children with autism, would benefit from the promotion of a healthy diet. It would be interesting to confirm the health risk that their eating habits may have through follow-up studies.

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Table 1. Sociodemographic, anthropometrical and psychological characteristics by age group and ASD diagnosis

	Preschool-age children			Primary-school-age children			
	ASD ^a (n=86)	SUBCLINICAL ^b (n=21)	TD ^c (n=142)	ASD ^a (n=41)	SUBCLINICAL ^b (n=19)	TD ^c (n=191)	P
Age (years)*	5.07 (0.67)	4.79 (0.40)	5.09 (0.51)	11.19 (1.48)	10.96 (0.54)	11.06 (0.52)	0.499
Gender (males) (%)	80.6 (29)	71.4 (15)	57.7 (82)	85.4 (95)	84.2 (16)	56.0 (107)	<0.001 (<0.001) ^{ns} (0.017) ^{ns}
Ethnicity (Autocthon) (%)	83.3 (30)	95.2 (20)	74.6 (106)	87.8 (96)	78.9 (15)	85.3 (163)	0.665
Hollingshead classification (%)							
Low	22.2 (8)	23.8 (5)	12.00 (17)	9.8 (4)	36.8 (7)	15.2 (29)	0.064
Medium	50.0 (18)	57.1 (12)	66.9 (95)	65.9 (27)	57.9 (11)	63.4 (121)	(0.019) ^{ns}
High	27.8 (10)	19.0 (4)	21.1 (30)	24.4 (10)	5.3 (1)	21.5 (41)	(0.029) ^{ns}
SQDI classification (%)							
Unhealthy	25.0 (9)	4.8 (1)	6.3 (9)	24.4 (10)	5.3 (1)	8.9 (17)	0.012
Need to improve	75.0 (27)	90.5 (19)	93.0 (132)	75.6 (31)	94.7 (18)	91.1 (174)	(0.005) ^{ns}
Healthy	-	4.8 (1)	0.7 (1)	-	-	-	(0.019) ^{ns}
BMI (kg/m ²)*	16.11 (2.35)	16.15 (1.94)	15.94 (2.17)	21.17 (4.16)	19.20 (3.79)	19.77 (3.97)	0.087 (0.043) ^{ns}
Total IQ (WISC/WPPSI) (Score)*	89.44 (20.87)	89.20 (17.60)	100.51 (14.35)	97.14 (17.55)	98.47 (18.27)	103.92 (16.28)	0.046 (0.025) ^{ns}
ADHD Comorbidity (%)	22.2 (8)	19.0 (4)	-	36.6 (15)	47.4 (9)	-	<0.001 (<0.001) ^{ns}
ADOS-2 severity (Score)*	5.53 (1.91)	3.43 (1.91)	1.44 (1.00)	5.12 (2.10)	3.68 (1.74)	1.19 (0.60)	<0.001 (<0.001) ^{ns} (0.012) ^{ns}

Values are expressed in: *Mean (SD) or in Percentage (n). ASD: Autism Spectrum Disorder; TD: Children with typical development; SQDI: Spanish Quality of Life Index; IQ: Intelligence quotient; WISC: Wechsler Intelligence Scales for Children; WPPSI: Wechsler Preschool and Primary Scale of Intelligence; ADHD: Attention Deficit Hyperactivity Disorder; ADOS: Autism Diagnostic Observation Schedule

Table 2. Food Consumption by age group and ASD diagnosis

	Preschool-age children				School-age Children				Recommended servings	
	ASD ^a (n=36)	SUBCLINICAL ^b (n=21)	TD ^c (n=142)	P	ASD ^a (n=41)	SUBCLINICAL ^b (n=19)	TD ^c (n=191)	P		
STARCH	g/d	193.14 (77.71)	177.91 (50.08)	183.43 (79.75)	0.728	232.14 (85.27)	197.48 (60.66)	214.51 (75.72)	0.228	4-6 s/d
	s/d	4.65 (1.99)	4.12 (0.99)	4.36 (1.85)	0.534	4.45 (1.56)	3.80 (1.29)	4.26 (1.54)	0.313	
Savoury cereals & tubers	g/d	142.08 (59.93)	130.47 (45.32)	135.17 (64.86)	0.494	183.92 (85.92)	145.21 (66.25)	164.72 (62.16)	0.095	Occasionally
	s/d	2.78 (0.96)	2.39 (0.74)	2.61 (1.30)	0.766	2.89 (1.19)	2.43 (1.28)	2.77 (1.15)	0.359	
Sweet cereals	g/d	39.11 (29.37)	32.82 (28.53)	36.48 (28.85)	0.729	34.57 (28.35)	31.62 (21.56)	31.66 (24.76)	0.795	Occasionally
	s/d	1.33 (1.01)	1.16 (1.10)	1.31 (0.97)	0.798	1.18 (0.97)	0.86 (0.56)	1.03 (0.69)	0.261	
Legumes*	g/d	6.82 (6.43)	10.73 (7.40)	8.95 (5.95)	0.058 (0.04) ^{ns}	10.82 (9.01)	17.32 (8.69)	14.95 (9.93)	0.020 (0.015) ^{ns}	2-4 s/w
	s/d	0.19 (0.18)	0.31 (0.21)	0.26 (0.17)	0.058 (0.04) ^{ns}	0.20 (0.18)	0.29 (0.14)	0.25 (0.17)	0.093	
Nuts	g/d	5.13 (15.66)	3.89 (6.24)	2.83 (3.66)	0.251	2.82 (4.30)	3.33 (3.60)	3.17 (3.67)	0.843	3-7 s/w
	s/d	0.34 (1.04)	0.26 (0.42)	0.19 (0.24)	0.251	0.18 (0.27)	0.22 (0.24)	0.21 (0.25)	0.688	
VEGETABLES	g/d	77.88 (77.02)	97.01 (61.38)	94.24 (48.91)	0.268	104.76 (86.60)	98.32 (57.59)	109.30 (67.68)	0.776	2-3 s/d
	s/d	1.49 (1.52)	1.87 (1.15)	1.72 (0.87)	0.365	1.10 (0.89)	1.08 (0.65)	1.21 (0.77)	0.584	
Boiled Vegetables	g/d	66.24 (75.48)	85.10 (50.31)	64.79 (35.59)	0.179 (0.023) ^{ns}	88.04 (68.73)	75.43 (43.35)	81.23 (50.87)	0.657	2-3 s/d
	s/d	1.32 (1.51)	1.70 (1.01)	1.30 (0.71)	0.179 (0.023) ^{ns}	0.88 (0.69)	0.75 (0.48)	0.81 (0.51)	0.657	
Raw Vegetables	g/d	11.64 (17.66)	11.90 (21.59)	29.45 (29.18)	<0.001 (0.001) ^{ns}	16.72 (29.57)	22.89 (21.94)	28.07 (26.89)	0.047 (0.017) ^{ns}	2-3 s/d
	s/d	0.17 (0.25)	0.17 (0.31)	0.42 (0.42)	<0.001 (0.001) ^{ns}	0.22 (0.36)	0.33 (0.31)	0.40 (0.38)	0.018 (0.006) ^{ns}	

Table 2. Continued

FRUIT	g/d	233.18 (158.14)	181.07 (138.22)	232.34 (135.45)	0.284	245.62 (155.81)	227.55 (101.86)	226.66 (153.98)	0.765	3-4 s/d
	s/d	1.64 (1.05)	1.36 (0.87)	1.68 (0.87)	0.323	1.74 (1.03)	1.68 (0.76)	1.59 (1.02)	0.669	
FRESH FRUIT	g/d	93.77 (83.77)	88.23 (58.23)	99.85 (57.70)	0.680	122.13 (87.75)	130.24 (78.24)	105.33 (69.23)	0.184	3-4 s/d
	s/d	0.92 (0.78)	0.88 (0.58)	1.00 (0.58)	0.680	1.11 (0.77)	1.18 (0.72)	0.96 (0.63)	0.184	
Citrus fruit	g/d	22.79 (33.72)	29.73 (32.00)	35.09 (31.85)	0.117	25.74 (53.23)	52.49 (48.18)	46.32 (42.54)	0.020 (0.008) ^{ns}	3-4 s/d
	s/d	0.23 (0.34)	0.30 (0.32)	0.35 (0.32)	0.117	0.23 (0.48)	0.48 (0.44)	0.42 (0.39)	0.020 (0.008) ^{ns}	
Other fruit	g/d	70.81 (77.70)	58.50 (39.36)	64.76 (42.97)	0.664	96.39 (71.75)	77.74 (50.91)	59.01 (40.30)	<0.001 (0.002) ^{ns}	3-4 s/d
	s/d	0.71 (0.78)	0.59 (0.39)	0.65 (0.43)	0.664	0.88 (0.65)	0.71 (0.46)	0.54 (0.37)	<0.001 (0.002) ^{ns}	
PRESERVED FRUIT	g/d	3.10 (8.84)	2.36 (6.88)	2.82 (7.58)	0.940	2.59 (5.46)	2.78 (5.26)	5.81 (17.40)	0.386	3-4 s/d
	s/d	0.03 (0.09)	0.02 (0.07)	0.03 (0.08)	0.940	0.02 (0.06)	0.03 (0.05)	0.06 (0.17)	0.386	
FRUIT JUICE	g/d	136.31 (140.83)	90.48 (124.65)	129.67 (113.56)	0.330	120.91 (124.66)	94.54 (77.45)	115.52 (112.25)	0.688	Occasionally
	s/d	0.68 (0.70)	0.45 (0.62)	0.65 (0.57)	0.330	0.60 (0.62)	0.47 (0.39)	0.58 (0.56)	0.688	
Natural fruit juice	g/d	41.30 (77.27)	24.49 (42.65)	42.66 (59.02)	0.448	28.83 (42.75)	55.99 (74.71)	55.51 (81.52)	0.122 (0.003) ^{ns}	3-4 s/d
	s/d	0.20 (0.37)	0.12 (0.21)	0.21 (0.30)	0.448	0.14 (0.21)	0.28 (0.37)	0.28 (0.41)	0.122 (0.003) ^{ns}	
Commercial fruit juice	g/d	95.01 (97.36)	65.99 (114.15)	87.02 (93.38)	0.541	92.08 (125.07)	38.55 (53.93)	60.01 (69.91)	0.027 (0.024) ^{ns}	3-4 s/d
	s/d	0.48 (0.49)	0.33 (0.57)	0.44 (0.47)	0.541	0.46 (0.63)	0.19 (0.27)	0.30 (0.35)	0.027 (0.024) ^{ns}	

Table 2. Continued

DAIRY PRODUCTS	g/d	429.40 (175.97)	433.73 (212.80)	416.31 (160.99)	0.855	370.02 (186.34)	349.15 (161.52)	369.14 (160.94)	0.877	2-3 s/d
	s/d	2.84 (1.15)	2.83 (1.31)	2.85 (1.02)	0.996	2.41 (1.27)	2.59 (1.12)	2.77 (1.12)	0.184	
Cheese and yogurt	g/d	118.01 (91.78)	94.51 (71.39)	103.59 (59.89)	0.392	95.29 (68.93)	97.82 (76.71)	98.69 (66.72)	0.958 (0.001) ^{ns}	
	s/d	1.13 (0.85)	0.98 (0.63)	1.15 (0.62)	0.535	0.77 (0.64)	1.07 (0.77)	1.18 (0.68)	0.003 (0.001) ^{ns}	
Milk	g/d	260.26 (152.27)	287.07 (159.71)	267.49 (143.03)	0.796	222.24 (138.93)	198.50 (104.97)	223.63 (130.33)	0.724	
	s/d	1.30 (0.76)	1.44 (0.80)	1.34 (0.72)	0.796	1.11 (0.69)	0.99 (0.52)	1.12 (0.65)	0.724	
Dairy desserts	g/d	51.13 (46.96)	52.14 (46.96)	45.22 (44.07)	0.669	52.50 (57.99)	52.84 (53.04)	46.82 (38.48)	0.667	
	s/d	0.41 (0.38)	0.42 (0.37)	0.36 (0.35)	0.669	0.53 (0.58)	0.52 (0.53)	0.47 (0.38)	0.667	Occasionally
FATS-Olive oil	g/d	30.16 (9.02)	32.14 (7.93)	31.53 (8.00)	0.600	37.71 (12.34)	40.51 (5.80)	42.54 (9.13)	0.012 (0.004) ^{ns}	
	s/d	3.02 (0.90)	3.21 (0.79)	3.15 (0.80)	0.600	3.14 (1.03)	3.38 (0.48)	3.55 (0.76)	0.012 (0.004) ^{ns}	3-4 s/d
PROTEIN GROUPS	g/d	136.87 (53.06)	176.71 (77.47)	172.21 (63.58)	0.009 (0.002) ^{ns} (0.025) ^{ns}	217.20 (84.92)	185.39 (62.19)	191.70 (59.74)	0.058	
	s/d	1.11 (0.58)	1.58 (0.78)	1.52 (0.56)	0.001 (0.001) ^{ns} (0.013) ^{ns}	1.54 (0.60)	1.52 (0.65)	1.47 (0.54)	0.751	1-3 s/d
MEATS	g/d	91.15 (41.48)	102.96 (43.53)	96.43 (41.44)	0.582	142.99 (80.90)	109.31 (43.98)	115.83 (41.16)	0.005 (0.042) ^{ns} (0.042) ^{ns}	
	s/w	7.71 (3.67)	8.60 (3.79)	8.03 (3.50)	0.658	9.56 (4.71)	7.79 (3.19)	8.28 (2.98)	0.057	3-4 s/w
Poultry	g/d	31.49 (31.22)	36.57 (18.20)	31.82 (16.59)	0.583	51.05 (40.70)	43.96 (23.88)	41.48 (19.99)	0.083	
	s/w	2.76 (2.73)	3.20 (1.59)	2.78 (1.45)	0.583	3.24 (2.42)	3.08 (1.67)	2.90 (1.40)	0.463	3 s/w
Red and processed meat	g/d	59.66 (32.79)	66.38 (29.82)	64.62 (31.47)	0.653	91.95 (59.47)	65.35 (31.54)	74.34 (31.43)	0.010 (0.028) ^{ns}	
	s/w	4.96 (2.90)	5.40 (2.57)	5.24 (2.63)	0.794	6.32 (3.82)	4.72 (2.34)	5.37 (2.33)	0.049	Occasionally

Table 2. Continued

FISH	g/d	26.75 (21.76)	44.56 (30.25)	49.04 (29.56)	<0.001 ^{ns} (0.024) ^{ns}	42.22 (26.59)	38.08 (28.36)	43.52 (28.07)	0.710	
	s/w	2.17 (1.70)	3.37 (2.10)	3.82 (2.23)	<0.001 ^{ns} (0.033) ^{ns}	3.43 (2.33)	2.89 (2.17)	3.41 (2.16)	0.599	
Oily Fish	g/d	8.81 (10.48)	11.16 (11.59)	17.37 (16.79)	0.006 (0.004) ^{ns}	15.61 (19.35)	16.89 (18.91)	16.14 (15.25)	0.959	
	s/w	0.62 (0.73)	0.78 (0.81)	1.22 (1.18)	0.006 (0.004) ^{ns}	1.09 (1.35)	1.18 (1.32)	1.13 (1.07)	0.959	
White Fish	g/d	16.13 (17.13)	31.90 (24.80)	29.31 (20.92)	0.001 ^{ns} (0.015) ^{ns}	19.76 (16.97)	18.03 (13.48)	22.15 (16.24)	0.440	
	s/w	1.13 (1.20)	2.23 (1.74)	2.05 (1.46)	0.002 (0.015) ^{ns}	1.38 (1.19)	1.26 (0.94)	1.55 (1.14)	0.440	
Seafood	g/d	1.80 (3.20)	1.50 (2.71)	2.36 (2.97)	0.338	6.84 (10.75)	3.16 (4.10)	5.23 (5.39)	0.114	
	s/w	0.42 (0.75)	0.35 (0.63)	0.55 (0.69)	0.338	0.96 (1.50)	0.44 (0.57)	0.73 (0.75)	0.114	
EGGS	g/d	12.15 (9.13)	18.46 (14.17)	17.79 (11.16)	0.022 (0.006) ^{ns} (0.046) ^{ns}	21.16 (15.04)	20.68 (13.15)	17.40 (8.89)	0.068	
	s/w	1.55 (1.16)	2.35 (1.80)	2.26 (1.42)	0.022 (0.006) ^{ns} (0.046) ^{ns}	2.69 (1.91)	2.63 (1.63)	2.21 (1.13)	0.068	
SWEETS/BEVERAGES	g/d	48.63 (80.44)	50.34 (109.11)	33.25 (46.54)	0.267	72.28 (108.54)	39.27 (45.05)	55.94 (67.23)	0.242	
	s/w	5.79 (5.63)	4.17 (4.42)	4.21 (3.40)	0.100	7.65 (8.73)	4.54 (3.48)	5.04 (4.70)	0.018	
Sweets	g/d	16.18 (15.15)	8.01 (7.56)	12.10 (8.97)	0.013 (0.025) ^{ns} (0.049) ^{ns}	19.30 (22.00)	10.04 (9.79)	11.61 (10.33)	0.002 (0.034) ^{ns} (0.028) ^{ns}	
	s/w	4.65 (3.97)	2.69 (2.70)	3.47 (2.80)	0.041 (0.031) ^{ns}	5.80 (7.05)	3.52 (3.49)	3.50 (3.60)	0.009 (0.041) ^{ns}	
Sweetened beverages	g/d	32.45 (70.99)	42.34 (110.15)	21.15 (44.85)	0.238	52.98 (101.82)	29.22 (46.96)	44.33 (63.92)	0.476	
	s/w	1.14 (2.48)	1.48 (3.86)	0.74 (1.57)	0.238	1.85 (3.56)	1.02 (1.64)	1.55 (2.24)	0.476	
									Occasionally	
										Occasionally
										Occasionally

Food groups with recommended consumption. ASD: Autism Spectrum Disorder; TD: Children with typical development. Mean (SD), g/d: grams/day; s/d: servings/day; s/w: servings/week.*Legumes are also included in protein group.