# PREVALENCE OF AUTISM SPECTRUM DISORDERS IN A BIRTH COHORT OF AN ENTIRE NATION

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# PREVALENCE OF AUTISM SPECTRUM DISORDERS IN A BIRTH COHORT OF AN ENTIRE NATION

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## ABSTRACT

**Objectives:** A steady increase in prevalence of autism spectrum disorders (ASD) has been reported in studies based on different methods, requiring adjustment for participation and missing data. Recent studies with high ASD prevalence rates rarely report on co-occurring medical conditions. The aim of the study was to describe the prevalence of clinically confirmed cases of ASD in a geographically defined population, concomitantly examining medical conditions.

**Design and participants:** The study is based on a nation-wide database on ASD for the cohort born 1994-98. All ASD cases (N=267) received physical and neurological examination, standardized diagnostic workup for ASD, as well as cognitive testing. ASD diagnosis was established by a multidisciplinary team. Information on medical conditions and chromosomal testing was obtained by record linkage with hospital registers.

**Setting:** Two tertiary institutions in Iceland. The population registry recorded 22,229 children in the birth cohort.

**Results:** Prevalence of all ASD was 120.1/10,000 (95% confidence interval (CI) 106.6 to 135.3), for boys 172.4/10,000 (95% CI 150.1 to 198.0) and for girls 64.8/10,000 (95% CI 51.3 to 81.8). Prevalence of all medical conditions was 17.2% (95% CI 13.2 to 22.2), including epilepsy of 7.1% (95% CI 4.6 to 10.8). The proportion of ASD cases with cognitive impairment (IQ <70) was 45.3%, but only 34.1% were diagnosed with intellectual disability (ID). Children diagnosed earlier or later did not differ on mean total score on a standardized interview for autism.

**Conclusions:** The number of clinically verified cases is larger than in previous studies, yielding a prevalence of ASD on a similar level as found in recent non-clinical studies. Prevalence of co-occurring medical conditions was high, considering the low proportion of

ASD cases that also had ID. Earlier detection is clearly desirable in order to provide counselling and treatment.

## ARTICLE SUMMARY

### Article focus

- Information on the prevalence of autism spectrum disorders (ASD) is important for effective service planning.
- Increases in prevalence of ASD have been found by different methods, and the procedures have required adjustments for low response rate or missing data. High rates of ASD need to be confirmed in studies based on clinical cases in well defined populations.

### Key messages

- High prevalence rate based on clinically verified cases of ASD was found in a nationwide birth cohort, and is on average comparable to recent studies.
- Hospital registries ensured accurate rates of co-occurring medical conditions and chromosomal aberrations.

### Strengths and limitations of this study

- The population is well defined and relatively homogenous. Good record keeping, easy access to health care, education free of charge, and the comprehensive social system have all ensured efficient case finding at tertiary institutions.
- Case finding was based on the presence of ASD in the records at tertiary level services. Thus the prevalence found should be regarded as minimum.

## INTRODUCTION

The earliest epidemiological studies on the prevalence of autism reported figures in the range of 3-5/10,000. In the eighties there was some evidence of increased prevalence of autism, but since the early nineties a steady increase has been apparent.[1] In a recent review of 43 studies, which provided estimates for the prevalence of autism and pervasive developmental disorders (PDDs), 19 were classified as newer epidemiological surveys of PDDs.[2] These were published between 2000 and 2008 and covered the ages 0-17 years. The prevalence figures were in the range of 30.0 to 67.4/10,000 except in two studies, one in South Thames (UK) with a prevalence of 116.1/10,000[3] and another from Toyota (Japan) with a prevalence of 181.1/10,000.[4] More recent studies have reported even higher prevalence, 157/10,000 and 260/10,000.[5,6] Whether this increase in prevalence through the decades reflects a true increase in incidence or is due to different methodological factors is a matter of debate.[2,5]

From the first prevalence studies on autism to the present, few studies have dealt with co-occurring medical conditions, some of which have recently been reviewed.[7] In studies involving the whole autism spectrum, medical conditions are rarely reported.[2]

In this study we present the prevalence of autism spectrum disorders (ASD) in a birth cohort of an entire nation with a clinical ascertainment of all cases at a tertiary institute. Co-occurring medical conditions of neuro-developmental origin obtained from hospital registers are reported.

## METHODS

This prevalence study was performed at the State Diagnostic and Counselling Centre (SDCC), which is a tertiary institute, serving children with serious neuro-developmental disorders in Iceland, and has had the responsibility of ASD diagnostics and services since 1997. For the purpose of this study, a database on ASD was kept at the SDCC.

The health care system, the educational system, and social services in Iceland are financed by governmental taxes and all residents are covered by national health insurance schemes. Since these services have an important role in case finding and referrals, a short description will be given. Primary health care centres manage a comprehensive maternity and child-care plan. The child health and developmental surveillance includes 11 visits to a general practitioner/paediatrician or a nurse during the preschool years where the children are vaccinated and clinically evaluated. The vaccination schedule includes the pertussis/diphtheria/tetanus immunization, which covers 97% of the children and the first measles/mumps/rubella immunization at the age of 18 months, which covers more than 92% according to the Chief Epidemiologist.[8] The first contact with the educational system is through preschool services, and approximately 90% of children aged 2 to 5 years attend preschools.[9] Education is compulsory for children aged 6 to 16 years, and includes special educational needs. The social services provide financial support to parents of children with serious developmental disorders or long-term illnesses, based on medical certificate.

Two specialized tertiary centres formally diagnose autism and ASD: the SDCC and the Department of Child and Adolescent Psychiatry at the Landspitali University Hospital (LUH), and records from the latter are included in the database of ASD at SDCC. An interdisciplinary team consisting of paediatricians or child psychiatrists, clinical child psychologists, and social workers reached consensus on the clinical diagnoses. Other

professionals involved in the diagnostic work-up included speech and language pathologists, special teachers, and occupational therapists.

All the children underwent a physical examination and a neurological evaluation. The Autism Diagnostic Interview-Revised (ADI-R)[10] and the Autism Diagnostic Observation Schedule (ADOS)[11] were administered, as well as cognitive tests and tests evaluating adaptive behaviour. Of the children classified as ASD cases, 94% received the ADI-R and 87.6% the ADOS. All received either the ADI-R or the ADOS. Intellectual quotient (IQ) or developmental quotient (DQ) data, henceforth both referred to as IQ, was available for all of the children and assessment of adaptive behaviour for 88.3%. The diagnoses were based on the above information as well as other information from hospitals, schools, and the referral services. The majority of children diagnosed early during the preschool years were reassessed before beginning elementary school.[12]

The classification of autism and ASD was based on the ICD-10.[13] To facilitate comparison with the DSM-IV[14] three diagnostic categories are reported: childhood autism (CA) ICD-10 F84.0 (DSM-IV Autistic Disorder), Asperger's Syndrome (AS) ICD-10 F84.5 (DSM-IV Asperger's Disorder), and other ASD including ICD-10 F84.1, F84.8, and F84.9 (DSM-IV Pervasive Developmental Disorder, Not Otherwise Specified). The ICD-10 F84.4 code was not used.

Cognitive ability was classified into three levels, IQ <50, 50-69, 70+, and cognitive impairment was defined as IQ <70. The diagnosis of intellectual disability (ID) was established according to ICD-10 criteria, taking into account the total score on standardized intellectual or developmental tests, the pattern of abilities, as well as measures of adaptive behaviour, and other relevant information.

As ASD is thought to result from a neurological abnormality, co-occurring medical conditions with neuro-developmental underpinnings were collected. Based on the personal

identifier, a record linkage was made between the ASD database and the electronic database containing all discharge diagnoses at the LUH, thus obtaining access to all medical diagnoses of these children up to the end of 2009. For increased precision of the medical data, we double-checked information regarding chromosomal testing by linking the personal identifier of the ASD cases to the records of the Dept. of Cytogenetics, LUH. A paediatrician (IG) selected the co-occurring medical conditions to be reported without assuming an etiological role between the condition and ASD for the individual case.[7]

For the calculation of prevalence, the numerator was children pertaining to the 1994-98 cohort diagnosed with ASD, while the denominator was all children residing in Iceland in the end of 2009, in total 22,229, 11,424 males and 10,805 females.[15] A calculation of 95% confidence intervals (CI) was based on a method proposed by Wilson.[16] A comparison was made between the group diagnosed by the end of 2005 and the group diagnosed during 2006 and 2009. *Chi*-square test was used to compare groups for categorical variables and *t*-test for differences in means. All p-values were two tailed and considered statistically significant at p-value less than 0.05.

## RESULTS

Among the birth cohort 1994-98 a total of 267 children were diagnosed with ASD, 197 males and 70 females. Table 1 shows the prevalence of ASD diagnoses, as well as the male/female ratio, cognitive level, and the number of children with medical conditions. The overall prevalence was 120.1 (95% CI 106.6 to 135.3), the prevalence for boys was 172.4/10,000 (95% CI 150.1 to 198.0) and for girls it was 64.8/10,000 (95% CI 51.3 to 81.8).

[Table 1 about here]

Of the cases, 17.2% tested below IQ 50, 28.1% in the 50-69 range, and 54.7% tested ≥70. The mean IQ for all ASD cases was 72.84 (SD=23.90, range <20-134), for boys 74.44 (SD=23.74), and for girls 68.31 (SD=23.91), $t(265)=1.85$, $p=0.065$. The male/female ratio was 2.1 for children with cognitive impairment (IQ <70) and 3.7 for those without such impairment, $\chi^2(1,N=267)=4.14$, $p=0.042$. The proportion of children with cognitive impairment using the IQ <70 classification was 45.3%, but only 34.1% of the ASD cases were formally diagnosed with ID. The proportion of children with ID in the CA group was 64%, and 29.9% for the other ASDs group. ID is by definition excluded in AS. The male/female ratio among those with ID was 1.8.

Chromosomal analyses were performed in 122 children (45.7%), and of these 78 were tested for fragile X. None of those tested was positive for fragile X. The prevalence of all medical conditions was 17.2% (95% CI 13.2 to 22.2), including epilepsy. Of the 46 children with a medical condition, 29 (63%) also had ID. The different medical conditions are shown in Table 2. The prevalence of epilepsy for all ASD was 7.1% (95% CI 4.6 to 10.8). Fourteen (73.7%) of those with epilepsy also had ID. The male/female ratio among those with medical conditions was 2.3, and among those with epilepsy it was 1.4.

[Table 2 about here]

The prevalence of ASD for the 1994-98 birth cohort at the end of 2005 was 56.7/10,000 (95% CI 47.6-67.4). During the four-year interval from 2006 to the end of 2009, more than twice as many children were diagnosed and the prevalence of ASD doubled. The comparison of the characteristics within the ASD group in the two time points (2005 and 2009) is shown in Table 3. The children diagnosed earlier were more often diagnosed with CA, while those diagnosed later were more often diagnosed with AS. No difference was found in the frequency of other ASD whether diagnosed earlier or later. However, the mean total score on ADI-R based on verbal cases (n=213) did not differ between groups, $t(211)=0.63$, $p=0.53$, not shown in the Table 3. More children diagnosed earlier had an IQ below 70 than those diagnosed later. This difference was also evident, when comparing mean IQ scores between groups, $t(264)=-3.37$, $p=0.001$, not shown in the Table. However, the proportion of children with a formal diagnosis of ID did not decrease significantly over time ($\chi^2(1, N=267)=2.45$, $p=0.117$, not shown in the Table. Medical conditions were not more common among children diagnosed earlier than later in the study period.

[Table 3 about here]

## DISCUSSION

In the present study the prevalence of all ASD was 1.2%. This prevalence is in concordance with the higher end of the range (0.3% to 1.8%) reported in the 19 newer surveys published 2000-2008, according to the review of Fombonne.[2] However, when considering more recent studies with ASD prevalence of approximately 1% or higher, our prevalence figure is in the lower end of the range from 0.9% to 2.6% (see Table 4).[3-6,17,18] The highest prevalences reported, 1.8% and 2.6%, are from Japan[4] and South Korea[6] respectively. It is notable that the gender ratio in these two studies is relatively low (2.5-2.8) and similar to the ratio reported in some of the other studies in Table 4.

[Table 4 about here]

In the discussion of these studies care must be taken, as there are considerable differences in the methods used as well as geographical, cultural, and ethnic differences. The studies from South Thames UK,[3] Cambridgeshire UK,[5] Goyang City South Korea,[6] and Bergen City Norway[17] were based on screening for ASD among children with special educational needs or who were on a disability registry, and/or screening among children in elementary schools, and/or among local clinicians. In these studies, different adjustments had to be made to estimate the prevalence due to sampling procedures and different responses and missing data. In the Autism and Developmental Disabilities Monitoring Network USA surveillance,[18] the prevalence of ASD was estimated at 0.90% in children aged 8 years, through a systematic retrospective review by examining records from areas of 11 states. The prevalence of 1.81% in the study from Toyota, Japan,[4] was based on screening and advice to parents to consult, while the diagnosis was founded on a clinical interview with parents and observation of the child.

In the present study, the diagnostic category of CA represented a relatively small proportion (28%) of the total number of cases, even if the prevalence is high (0.34%). This

prevalence is 7.7 times higher than reported in the first study on autism published in Iceland[19] and almost four times that reported in a more recent study.[20]

None of the 19 studies selected by Fombonne[2] were included in a review on medical condition in ASD population samples,[7] and none of the studies in Table 4 reported on medical conditions, except for the present one. In the above review, the rate of medical conditions varied from 8% to 25% in studies published between 1996 and 2007.[7] The comparison of the proportion of medical conditions found in the present study to the findings of other studies is difficult because a generally accepted definition of the phenomenon is lacking.[7] Our estimate of 17.2% may seem high, considering how large a proportion (65.9%) of our ASD cases did not have diagnosed ID.[21] No case with fragile X was identified, although the literature predicts fragile X to be in the range of 2% to 8% with autism when DNA testing is utilized.[22]

Epilepsy in our ASD group was associated with ID and the female gender as demonstrated in a meta-analysis.[23] The lifetime prevalence of epilepsy for all ASD in the present study was 7.1%, which is low compared to other studies on the subject.[24,25] In this context, it is of paramount importance to distinguish between studies on autism in adulthood on the one hand[24] and studies on all ASD in childhood on the other hand.[25] In fact, the literature on the incidence and prevalence of epilepsy is sparse in relation to high ASD prevalence.

In a four-year period, from the end of 2005 to the end of 2009, the prevalence of ASD in the cohort studied doubled, moving from 0.6% to 1.2%. This increase cannot be explained by external migration, and internal migration is irrelevant since the area studied and the whole country are the same. As expected, children diagnosed earlier (by 2005) were more likely to have CA than AS and were generally more impaired than those diagnosed later (2006-2009), although the groups did not differ regarding the frequency of ID and medical conditions. In order to examine symptom severity from another angle than diagnostic classification, we

compared the earlier and later diagnosed groups on ADI-R total score. This comparison did not reveal differences between groups. High scores on the ADI-R for those diagnosed later indicate serious autistic symptoms, possibly in association with co-occurring developmental and psychiatric disorders. Another point of interest is that the number of boys did not increase, contrary to what is suggested by some investigators.[26] One interpretation of these results is simply that as the cohort studied grows older, more girls are identified with ASD,[27] and because girls with ASD are more likely to be cognitively impaired, it would counteract the predicted trend for fewer children with co-occurring ID as the prevalence of ASD increases. Comparing the distribution of boys and girls in the group of children with ID (n=91) diagnosed earlier or later with ASD revealed some support for this hypothesis, as the gender ratio was 2.8 and 1.2 respectively, although this difference fell short of statistical significance.

Of our ASD cases, 54.7% were classified with IQ of 70 or above. This proportion ranged from 30.0% to 74.2% in the studies selected by Fombonne,[2] where IQ data was reported (13/19). The studies in Table 4, which present comparable data, show this proportion to be from 44.0% to 66.4%.[3,4] These figures indicate that as the prevalence of ASD increases, the proportion of children with cognitive impairment decreases. However, important as the classification of cognitive level above or below IQ 70 may be for comparing epidemiological samples with ASD, it should not be overlooked that IQ <70 simply serves as a proxy for ID. For instance, it is possible to arrive at a full-scale score on a Wechsler test of IQ below 70 in various ways, notably when severe language impairments or non-verbal learning disabilities are present. From this perspective, there is a notable difference between the proportion of children with IQ <70 (45.3%) and the proportion receiving a formal diagnosis of ID (34.1%) in the present study. Thus, the IQ <70 classification may provide an inaccurate estimate of how many individuals actually have ID in addition to ASD.

In the present study, case finding was based on the presence of ASD in the records at tertiary level services, and hence prospective screening identifying potential cases followed by clinical examination did not take place. Thus, the clinical source of the data indicates that the prevalence reported should be regarded as minimum. However, the prevalence of ASD found is based on the exact number of clinically confirmed cases and definite number of the population derived from a population register of a whole nation. Also, based on record linkage, co-occurring medical conditions were obtained for ASD cases from electronic hospital records. The population is well defined and relatively homogenous. Good record keeping, easy access to health care, education free of charge, and the comprehensive social system have all ensured efficient case finding at tertiary institutions, which have the purpose to serve the diagnostic and counselling needs of children with serious developmental disorders. The referral and diagnostic process in the country has been fairly standardized and is relatively transparent, compared to larger societies where a multitude of record sources is to be expected, behind which there may be widely different diagnostic practices. Only two tertiary instances offered diagnostic services for ASD and these have worked in close cooperation regarding diagnostic procedures. The ADI-R was used for 94% of the children by qualified clinicians, all had formal cognitive or developmental testing and consensus diagnoses were reached within an interdisciplinary team. In addition, the majority of children diagnosed during their early preschool years were reassessed before entering elementary school.

## CONCLUSION

The number of clinically verified cases is larger than in previous studies, yielding a prevalence rate of ASD on a similar level as found in recent non-clinical studies. The tertiary level of services diagnosed a fair number of ASD cases; however, it may be considered a public health issue how many children are diagnosed after they enter the elementary school system.

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**Contributors** Evald Saemundsen (ES), Vilhjálmur Rafnsson (VR), and Páll Magnússon designed the study. ES and PM oversaw the data entry. Ingibjörg Georgsdóttir and VR oversaw the gathering of data on medical conditions. Erlendur Egilsson assisted with quality control regarding data entry and the statistical analysis with ES and VR. ES did the literature review and wrote the first draft with the assistance of VR. All authors read and commented on the content of the manuscript and agreed on the final version and approved its submission.

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**Ethics approval** The study was approved by the Data Protection Authority, the National Bioethics Committee (VSNb2009100017/03.1), and the Scientific Committee of Landspitali University Hospital.

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Table 1 Prevalence of childhood autism, Asperger's Syndrome, other autism spectrum disorders, and all autism spectrum disorders, 95% confidence intervals, male/female ratio, cognitive level, and medical conditions in an Icelandic cohort born in 1994-98

| ASD Diagnoses | No. of Cases | Rate per 10,000 | 95% CI Lower/Upper | Male/Female Ratio | IQ ≥ 70 (%) | MC (%) |
|---|---|---|---|---|---|---|
| CA | 75 | 33.7 | 26.9 to 42.3 | 2.1 | 21 (28.0) | 22 (29.3) |
| AS | 48 | 21.6 | 16.3 to 28.6 | 3 | 48 (100) | 4 (8.3) |
| Other ASD | 144 | 64.8 | 55.1 to 76.2 | 3.2 | 77 (53.5) | 20 (13.9) |
| All ASD | 267 | 120.1 | 106.6 to 135.3 | 2.8 | 146 (54.7) | 46 (17.2) |

Abbreviations: ASD, autism spectrum disorder; CI, confidence interval; IQ, intelligence quotient; MC, medical conditions; CA, childhood autism; AS, Asperger's syndrome.

Table 2 Medical conditions in children (n=46) with childhood autism, Asperger's syndrome, and other autism spectrum disorders in an Icelandic cohort born in 1994-98[a]

| | CA | AS | Other ASD | All ASD (%) |
|---|---|---|---|---|
| Genetic and congenital syndromes[b] | 8 | 2 | 4 | 14 (5.2) |
| Chromosomal aberrations[c] | 3 | 0 | 3 | 6 (2.2) |
| Congenital CNS malformations[d] | 3 | 1 | 2 | 6 (2.2) |
| Other neurological conditions[e] | 6 | 1 | 9 | 16 (6.0) |
| Epilepsy[f] | 10 | 0 | 9 | 19 (7.1) |

Abbreviations: CA, childhood autism; AS, Asperger's syndrome; ASD, autism spectrum disorders.

[a] Some children had more than one condition.

Figures in brackets indicate the number of cases: [b] Down syndrome [3], Arnold-Chiari malformation [2], Ehlers-Danlos syndrome [1], homocystinuria [1], neurofibromatosis [1], Prader-Willi syndrome [1], Saethre-Chotzen syndrome [1], Smith-Magenis syndrome [1], Sotos syndrome [1], Sturge-Weber syndrome [1], Turner syndrome [1]; [c] inversion 9 (p11q12) [2], balanced autosomal rearrangements t4;14 (p11;q11) [1], microdeletion 3 (p26.3-pter) [1], partial duplication 8 (q1-q22) [1], partial duplication 20 (q12-q13.13) [1]; [d] microcephaly [3], agenesis of corpus callosum [1], macrogyria [1], cerebral cyst [1]; [e] cerebral palsy [5], asphyxia/intracranial hemorrhage [3], CNS infections [3], hearing impairment [2], CNS tumor [1], extrapyramidal motor disorder [1], vision impairment [1];

[f] six children had seizure onset in the first year of life.

Table 3 Icelandic children born in 1994-98 with autism spectrum disorders diagnosed until the end of 2005 compared to those diagnosed 2006 to 2009 with respect to diagnostic subtypes, gender, cognitive level, medical conditions, and epilepsy

| | 2005 n=26 (%) | 2009 n=141 (%) | Rate Ratio | 95% CI Lower/Upper | p Value |
|---|---|---|---|---|---|
| CA | 49 (38.9) | 26 (18.4) | 2.11 | 1.40 to 3.18 | 0.0002 |
| AS | 13 (10.3) | 35 (24.8) | 0.42 | 0.23 to 0.75 | 0.002 |
| Other ASD | 64 (50.8) | 80 (56.7) | 0.90 | 0.72 to 1.12 | 0.331 |
| Males | 96 (76.2) | 101 (71.6) | 1.06 | 0.92 to 1.23 | 0.398 |
| IQ ≥ 70 | 60 (47.6) | 86 (61.0) | 0.78 | 0.62 to 0.98 | 0.028 |
| All MCs | 26 (20.6) | 20 (14.2) | 1.45 | 0.86 to 2.47 | 0.163 |
| Epilepsy[a] | 13 (10.3) | 6 (4.3) | 2.42 | 0.95 to 6.19 | 0.054 |

Abbreviations: CI, confidence interval; CA, childhood autism; AS, Asperger's syndrome; ASD, autism spectrum disorders; IQ, intelligence quotient; MCs, medical conditions.

[a] Subcategory of MCs.

Table 4 Recent studies on the prevalence of autism spectrum disorders in children estimated at approximately 1% or higher

| Study and Location | Age groups | Method | No. of clinically verified cases | Target population | Prev. % | Male / female ratio |
|---|---|---|---|---|---|---|
| Baird (2006)[3] UK | 9-10 | Records / Survey | 158 | 56,946 | 1.16[a] | 3.3 |
| Kawamura (2008)[4] Japan | 1-7 | Clinical | 228 | 12,589 | 1.81[b] | 2.8 |
| ADDM (2009)[18] USA | 8 | Records | NA | 307,790 | 0.90[c] | 3.2-7.6 |
| Baron-Cohen (2009)[5] UK | 5-9 | Records / Survey | NA | 8,824 | 1.57[a] | Not reported |
| Posserud (2010) [17] Norway | 7-9 | Survey | 14 | 6,609 | 0.87[a] | Not reported |
| Kim (2011)[6] South-Korea | 7-12 | Records / Survey | 201 | 55,266 | 2.64[a] | 2.5 |
| Present study Iceland | 11-15 | Clinical | 267 | 22,229 | 1.20[b] | 2.8 |

Abbreviations: ADDM, Autism and Developmental Disabilities Monitoring Network, USA; NA, not applicable.

[a] Estimated prevalence taking non-responders into consideration.

[b] Calculated from raw numbers.

[c] An overall average across 11 ADDM sites

**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies***

| Section/Topic | Item # | Recommendation | Reported on page # |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 and 3 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 5 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 5 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | 6 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 6 and 8 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | 7 |
| | | (*b*) For matched studies, give matching criteria and number of exposed and unexposed | NA |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 7 and 8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6, 7, and 8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | 7 and 14 |
| Study size | 10 | Explain how the study size was arrived at | 7 and 8 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 7 and 8 |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | 8 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | 8 |
| | | (*c*) Explain how missing data were addressed | 14 |
| | | (*d*) If applicable, explain how loss to follow-up was addressed | NA |
| | | (*e*) Describe any sensitivity analyses | NA |
| **Results** | | | NA |

| | | | |
|---|---|---|---|
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | 9 and 10 |
| | | (b) Give reasons for non-participation at each stage | NA |
| | | (c) Consider use of a flow diagram | NA and 22, table 3 |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | 9 and 20, 21, and 22 |
| | | (b) Indicate number of participants with missing data for each variable of interest | 7 and 9 |
| | | (c) Summarise follow-up time (eg, average and total amount) | 9 and 10 |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time | 9 and 10 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 9 and 10, table 1, 2, and 3 |
| | | (*b*) Report category boundaries when continuous variables were categorized | 10 |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | 9 and 10 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 10 |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 11, and 4 |
| **Limitations** | | | |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 11, and 14, 15, and 4 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 11, and 12, and 4 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 16 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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# PREVALENCE OF AUTISM SPECTRUM DISORDERS IN AN ICELANDIC BIRTH COHORT



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| | |

# PREVALENCE OF AUTISM SPECTRUM DISORDERS IN AN ICELANDIC BIRTH COHORT

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Running title: Prevalence of ASD in an Icelandic birth cohort

Key words: Epidemiology, public health, developmental neurology and neurodisability, autism spectrum disorders

Word count: 3493

Tables: 4

## ABSTRACT

**Objectives:** A steady increase in prevalence of autism spectrum disorders (ASD) has been reported in studies based on different methods, requiring adjustment for participation and missing data. Recent studies with high ASD prevalence rates rarely report on co-occurring medical conditions. The aim of the study was to describe the prevalence of clinically confirmed cases of ASD in Iceland, and concomitantly examining medical conditions.

**Design and participants:** The study is based on a nation-wide database on ASD for the cohort born 1994-98. All ASD cases (N=267) received physical and neurological examination, standardized diagnostic workup for ASD, as well as cognitive testing. ASD diagnosis was established by a multidisciplinary team. Information on medical conditions and chromosomal testing was obtained by record linkage with hospital registers.

**Setting:** Two tertiary institutions in Iceland. The population registry recorded 22,229 children in the birth cohort.

**Results:** Prevalence of all ASD was 120.1/10,000 (95% confidence interval (CI) 106.6 to 135.3), for boys 172.4/10,000 (95% CI 150.1 to 198.0) and for girls 64.8/10,000 (95% CI 51.3 to 81.8). Prevalence of all medical conditions was 17.2% (95% CI 13.2 to 22.2), including epilepsy of 7.1% (95% CI 4.6 to 10.8). The proportion of ASD cases with cognitive impairment (IQ <70) was 45.3%, but only 34.1% were diagnosed with intellectual disability (ID). Children diagnosed earlier or later did not differ on mean total score on a standardized interview for autism.

**Conclusions:** The number of clinically verified cases is larger than in previous studies, yielding a prevalence of ASD on a similar level as found in recent non-clinical studies. Prevalence of co-occurring medical conditions was high, considering the low proportion of ASD cases that also had ID. Earlier detection is clearly desirable in order to provide counselling and treatment.

## ARTICLE SUMMARY

### Article focus

- Information on the prevalence of autism spectrum disorders (ASD) is important for effective service planning.
- Increases in prevalence of ASD have been found by different methods, and the procedures have required adjustments for low response rate or missing data. High rates of ASD need to be confirmed in studies based on clinical cases in well defined populations.

### Key messages

- High prevalence rate based on clinically verified cases of ASD was found in a nationwide birth cohort, and is on average comparable to recent studies.
- Hospital registries ensured accurate rates of co-occurring medical conditions and chromosomal aberrations.

### Strengths and limitations of this study

- The population is well defined and relatively homogenous. Good record keeping, easy access to health care, education free of charge, and the comprehensive social system have all ensured efficient case finding at tertiary institutions.
- Case finding was based on the presence of ASD in the records at tertiary level services. Thus the prevalence found should be regarded as minimum.

## INTRODUCTION

The earliest epidemiological studies on the prevalence of autism reported figures in the range of 3-5/10,000. In the eighties there was some evidence of increased prevalence of autism, but since the early nineties a steady increase has been apparent.[1] In a recent review of 43 studies, which provided estimates for the prevalence of autism and pervasive developmental disorders (PDDs), 19 were classified as newer epidemiological surveys of PDDs.[2] These were published between 2000 and 2008 and covered the ages 0-17 years. The prevalence figures were in the range of 30.0 to 67.4/10,000 except in two studies, one in South Thames (UK) with a prevalence of 116.1/10,000[3] and another from Toyota (Japan) with a prevalence of 181.1/10,000.[4] More recent studies have reported even higher prevalence, 157/10,000 and 260/10,000.[5,6] Whether this increase in prevalence through the decades reflects a true increase in incidence or is due to different methodological factors is a matter of debate.[2,5]

From the first prevalence studies on autism to the present, few studies have dealt with co-occurring medical conditions, some of which have recently been reviewed.[7] In studies involving the whole autism spectrum, medical conditions are rarely reported.[2]

In this study we present the prevalence of autism spectrum disorders (ASD) in a birth cohort of an entire nation with a clinical ascertainment of all cases at a tertiary institute. Co-occurring medical conditions of neuro-developmental origin obtained from hospital registers are reported.

## METHODS

This prevalence study was performed at the State Diagnostic and Counselling Centre (SDCC), which is a tertiary institute, serving children with serious neuro-developmental disorders in Iceland, and has had the responsibility of ASD diagnostics and services since 1997. For the purpose of this study, a database on ASD was kept at the SDCC.

The health care system, the educational system, and social services in Iceland are financed by governmental taxes and all residents are covered by national health insurance schemes and these services have an important role in case finding and referrals. Primary health care centres manage a comprehensive maternity and child-care plan. The child health and developmental surveillance includes 11 visits to a general practitioner/paediatrician or a nurse during the preschool years where the children are vaccinated and clinically evaluated. The vaccination schedule includes the pertussis/diphtheria/tetanus immunization, which covers 97% of the children and the first measles/mumps/rubella immunization at the age of 18 months, which covers more than 92% according to the Chief Epidemiologist.[8] The first contact with the educational system is through preschool services, which approximately 90% of children attend .[9] Education is compulsory for children aged 6 to 16 years, and includes special educational needs. The social services provide financial support to parents of children with serious developmental disorders or long-term illnesses, based on medical certificate.

Two specialized tertiary centres formally diagnose autism and ASD: the SDCC and the Department of Child and Adolescent Psychiatry at the Landspitali University Hospital (LUH), and records from the latter are included in the database of ASD at SDCC. An interdisciplinary team consisting of paediatricians or child psychiatrists, clinical child psychologists, and social workers reach consensus on the clinical diagnoses. Other professionals involved in the diagnostic work-up include speech and language pathologists, special teachers, and occupational therapists.

All the children in the study underwent a physical examination and a neurological evaluation. The Autism Diagnostic Interview-Revised (ADI-R)[10] and the Autism Diagnostic Observation Schedule (ADOS)[11] were administered, as well as cognitive tests and tests evaluating adaptive behaviour. Of the children classified as ASD cases, 94% received the ADI-R and 87.6% the ADOS. All received either the ADI-R or the ADOS. Intellectual quotient (IQ) or developmental quotient (DQ) data, henceforth both referred to as IQ, was available for all of the children and assessment of adaptive behaviour for 88.3%. The diagnoses were based on the above information as well as other information from hospitals, schools, and the referral services. The majority of children diagnosed early during the preschool years were reassessed before beginning elementary school at 6 years of age.[12]

The classification of autism and ASD was based on the ICD-10.[13] To facilitate comparison with the DSM-IV[14] three diagnostic categories are reported: childhood autism (CA) ICD-10 F84.0 (DSM-IV Autistic Disorder), Asperger's Syndrome (AS) ICD-10 F84.5 (DSM-IV Asperger's Disorder), and other ASD including ICD-10 F84.1, F84.8, and F84.9 (DSM-IV Pervasive Developmental Disorder, Not Otherwise Specified). The ICD-10 F84.4 code was not used.

Cognitive ability was classified into three levels, IQ <50, 50-69, 70+, and cognitive impairment was defined as IQ <70. The diagnosis of intellectual disability (ID) was established according to ICD-10 criteria, taking into account the total score on standardized intellectual or developmental tests,[15-19] the pattern of abilities, as well as measures of adaptive behaviour,[20,21] and other relevant information. Diagnosis of ID was only made after two successive cognitive tests.

As ASD is thought to result from a neurological abnormality, co-occurring medical conditions with neuro-developmental underpinnings were collected. Based on the personal identifier, a record linkage was made between the ASD database and the electronic database

containing all discharge diagnoses at the LUH, thus obtaining access to all medical diagnoses of these children up to the end of 2009. For increased precision of the medical data, we double-checked information regarding genetic testing by linking the personal identifier of the ASD cases to the records of the Dept. of Cytogenetics, LUH. The genetic testing and the related results were a product of different routine tests used for clinical evaluation through the years. A paediatrician (IG) selected the medical conditions to be reported from diagnoses obtained by record linkage with the hospital registry and the records at the SDCC. This was done by taking into consideration neurological abnormalities, neuro-developmental conditions, genetic and congenital syndromes, and epilepsy without assuming an etiological role between the condition and ASD for the individual case.[7] The definition of epilepsy was two unprovoked seizures.

For the calculation of prevalence, the numerator was children pertaining to the 1994-98 cohort diagnosed with ASD, while the denominator was all children born in Iceland during this period and residing in Iceland in the end of 2009, in total 22,229, 11,424 males and 10,805 females according to the National Registry.[22] A calculation of 95% confidence intervals (CI) was based on a method proposed by Wilson.[23] A comparison was made between the group diagnosed by the end of 2005 and the group diagnosed during 2006 and 2009. *Chi*-square test was used to compare groups for categorical variables and *t*-test for differences in means. All p-values were two tailed and considered statistically significant at p-value less than 0.05.

The study was approved by the Data Protection Authority, the National Bioethics Committee (VSNb2009100017/03.1), and the Scientific Committee of LUH.

## RESULTS

Among the birth cohort 1994-98 a total of 267 children were diagnosed with ASD, 197 males and 70 females. Table 1 shows the prevalence of ASD diagnoses, as well as the male/female ratio, cognitive level, and the number of children with medical conditions. The overall prevalence was 120.1 (95% CI 106.6 to 135.3), the prevalence for boys was 172.4/10,000 (95% CI 150.1 to 198.0) and for girls it was 64.8/10,000 (95% CI 51.3 to 81.8).

[Table 1 about here]

Of the cases, 17.2% tested below IQ 50, 28.1% in the 50-69 range, and 54.7% tested ≥70. The mean IQ for all ASD cases was 72.84 (SD=23.90, range <20-134), for boys 74.44 (SD=23.74), and for girls 68.31 (SD=23.91), $t(265)=1.85$, $p=0.065$. The male/female ratio was 2.1 for children with cognitive impairment (IQ <70) and 3.7 for those without such impairment, $\chi^2(1,N=267)=4.14$, $p=0.042$. The proportion of children with cognitive impairment using the IQ <70 classification was 45.3%, but only 34.1% of the ASD cases were formally diagnosed with ID. The proportion of children with ID in the CA group was 64%, and 29.9% for the other ASDs group. ID is by definition excluded in AS. The male/female ratio among those with ID was 1.8.

Chromosomal analyses were performed in 122 children (45.7%), and of these 78 were tested for fragile X. None of those tested was positive for fragile X. The prevalence of all medical conditions was 17.2% (95% CI 13.2 to 22.2), including epilepsy. Of the 46 children with a medical condition, 29 (63%) also had ID. The different medical conditions are shown in Table 2. The prevalence of epilepsy for all ASD was 7.1% (95% CI 4.6 to 10.8). Fourteen (73.7%) of those with epilepsy also had ID. The male/female ratio among those with medical conditions was 2.3, and among those with epilepsy it was 1.4.

[Table 2 about here]

The prevalence of ASD for the 1994-98 birth cohort at the end of 2005 was 56.7/10,000 (95% CI 47.6-67.4). During the four-year interval from 2006 to the end of 2009, more than twice as many children were diagnosed and the prevalence of ASD doubled. The comparison of the characteristics within the ASD group in the two time points (2005 and 2009) is shown in Table 3. The children diagnosed earlier were more often diagnosed with CA, while those diagnosed later were more often diagnosed with AS. No difference was found in the frequency of other ASD whether diagnosed earlier or later. However, the mean total score on ADI-R based on verbal cases (n=213) did not differ between groups, $t(211)=0.63$, $p=0.53$, not shown in the Table 3. More children diagnosed earlier had an IQ below 70 than those diagnosed later. This difference was also evident, when comparing mean IQ scores between groups, $t(264)=-3.37$, $p=0.001$, not shown in the Table. However, the proportion of children with a formal diagnosis of ID did not decrease significantly over time ($\chi^2(1, N=267)=2.45$, $p=0.117$, not shown in the Table. Medical conditions were not more common among children diagnosed earlier than later in the study period.

[Table 3 about here]

## DISCUSSION

In the present study the prevalence of all ASD was 1.2%. This prevalence is in concordance with the higher end of the range (0.3% to 1.8%) reported in the 19 newer surveys published 2000-2008, according to the review of Fombonne.[2] However, when considering more recent studies with ASD prevalence of approximately 1% or higher, our prevalence figure is in the lower end of the range from 0.9% to 2.6% (see Table 4).[3-6,24,25] The highest prevalences reported, 1.8% and 2.6%, are from Japan[4] and South Korea[6] respectively. It is notable that the gender ratio in these two studies is relatively low (2.5-2.8) and similar to the ratio reported in some of the other studies in Table 4.

[Table 4 about here]

In the discussion of these studies care must be taken, as there are considerable differences in the methods used as well as geographical, cultural, and ethnic differences. The studies from South Thames UK,[3] Cambridgeshire UK,[5] Goyang City South Korea,[6] and Bergen City Norway[24] were based on screening for ASD among children with special educational needs or who were on a disability registry, and/or screening among children in elementary schools, and/or among local clinicians. In these studies, different adjustments had to be made to estimate the prevalence due to sampling procedures and different responses and missing data. In the Autism and Developmental Disabilities Monitoring Network USA surveillance,[25] the prevalence of ASD was estimated at 0.90% in children aged 8 years, through a systematic retrospective review by examining records from areas of 11 states. The prevalence of 1.81% in the study from Toyota, Japan,[4] was based on screening and advice to parents to consult, while the diagnosis was founded on a clinical interview with parents and observation of the child.

In the present study, the diagnostic category of CA represented a relatively small proportion (28%) of the total number of cases, even if the prevalence is high (0.34%). This

prevalence is 7.7 times higher than reported in the first study on autism published in Iceland[26] and almost four times that reported in a more recent study. [27]

None of the 19 studies selected by Fombonne[2] were included in a review on medical condition in ASD population samples,[7] and none of the studies in Table 4 reported on medical conditions, except for the present one. In the above review, the rate of medical conditions varied from 8% to 25% in studies published between 1996 and 2007.[7] The comparison of the proportion of medical conditions found in the present study to the findings of other studies is difficult because a generally accepted definition of the phenomenon is lacking.[7] Our estimate of 17.2% may seem high, considering how large a proportion (65.9%) of our ASD cases did not have diagnosed ID.[28] No case with fragile X was identified, although the literature predicts fragile X to be in the range of 2% to 8% with autism when DNA testing is utilized.[29]

Epilepsy in our ASD group was associated with ID and the female gender as demonstrated in a meta-analysis.[30] The lifetime prevalence of epilepsy for all ASD in the present study was 7.1%, which is low compared to other studies on the subject.[31,32] It should be noted that the follow up in the hospital registry, and thus the registration of medical conditions, was up to the end of 2009 when the children were 11-15 years old. In this context, it is of paramount importance to distinguish between studies on autism in adulthood on the one hand[31] and studies on all ASD in childhood on the other hand.[32] In fact, the literature on the incidence and prevalence of epilepsy is sparse in relation to high ASD prevalence.

In a four-year period, from the end of 2005 to the end of 2009, the prevalence of ASD in the cohort studied doubled, moving from 0.6% to 1.2%. This increase cannot be explained by immigration to Iceland, confirmed by the National Registry,[22] and migration of people from one part of the country to another is irrelevant since the area studied and the whole country are the same. As expected, children diagnosed earlier (by 2005) were more likely to have CA than AS and were generally more impaired than those diagnosed later (2006-2009),

although the groups did not differ regarding the frequency of ID and medical conditions. In order to examine symptom severity from another angle than diagnostic classification, we compared the earlier and later diagnosed groups on ADI-R total score. This comparison did not reveal differences between groups. High scores on the ADI-R for those diagnosed later indicate serious autistic symptoms, possibly in association with co-occurring developmental and psychiatric disorders. Another point of interest is that the number of boys did not increase, contrary to what is suggested by some investigators.[33] One interpretation of these results is simply that as the cohort studied grows older, more girls are identified with ASD,[34] and because girls with ASD are more likely to be cognitively impaired, it would counteract the predicted trend for fewer children with co-occurring ID as the prevalence of ASD increases. Comparing the distribution of boys and girls in the group of children with ID (n=91) diagnosed earlier or later with ASD revealed some support for this hypothesis, as the gender ratio was 2.8 and 1.2 respectively, although this difference fell short of statistical significance.

Of our ASD cases, 54.7% were classified with IQ of 70 or above. This proportion ranged from 30.0% to 74.2% in the studies selected by Fombonne,[2] where IQ data was reported (13/19). The studies in Table 4, which present comparable data, show this proportion to be from 44.0% to 66.4%.[3,4] These figures indicate that as the prevalence of ASD increases, the proportion of children with cognitive impairment decreases. However, important as the classification of cognitive level above or below IQ 70 may be for comparing epidemiological samples with ASD, it should not be overlooked that IQ <70 simply serves as a proxy for ID. For instance, it is possible to arrive at a full-scale score on a Wechsler test of IQ below 70 in various ways, notably when severe language impairments or non-verbal learning disabilities are present. From this perspective, there is a notable difference between the proportion of children with IQ <70 (45.3%) and the proportion receiving a formal diagnosis of ID (34.1%)

in the present study. Thus, the IQ <70 classification may provide an inaccurate estimate of how many individuals actually have ID in addition to ASD.

In the present study, case finding was based on the presence of ASD in the records at tertiary level services, and hence prospective screening identifying potential cases followed by clinical examination did not take place. Thus, the clinical source of the data indicates that the prevalence reported should be regarded as minimum. However, the prevalence of ASD found is based on the exact number of clinically confirmed cases and definite number of the population derived from a population register of a whole nation. Also, based on record linkage, co-occurring medical conditions were obtained for ASD cases from electronic hospital records. Nevertheless, this follow-up ended when the children were 11-15 years of age and other conditions, for example epilepsy, maybe diagnosed later during their lifetime. The population is well defined and relatively homogenous. Good record keeping, easy access to health care, education free of charge, and the comprehensive social system have all ensured efficient case finding at tertiary institutions, which have the purpose to serve the diagnostic and counselling needs of children with serious developmental disorders. The referral and diagnostic process in the country has been fairly standardized and is relatively transparent, compared to larger societies where a multitude of record sources is to be expected, behind which there may be widely different diagnostic practices. Only two tertiary instances offered diagnostic services for ASD and these have worked in close cooperation regarding diagnostic procedures. The ADI-R was used for 94% of the children by qualified clinicians, all had formal cognitive or developmental testing and consensus diagnoses were reached within an interdisciplinary team. In addition, the majority of children diagnosed during their early preschool years were reassessed before entering elementary school.

## CONCLUSION

The number of clinically verified cases is larger than in previous studies, yielding a prevalence rate of ASD on a similar level as found in recent non-clinical studies. The tertiary level of services diagnosed a fair number of ASD cases; however, it may be considered a public health issue how many children are diagnosed after they enter the elementary school system.

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**Contributors** Evald Saemundsen (ES), Vilhjálmur Rafnsson (VR), and Páll Magnússon designed the study. ES and PM oversaw the data entry. Ingibjörg Georgsdóttir and VR oversaw the gathering of data on medical conditions. Erlendur Egilsson assisted with quality control regarding data entry and the statistical analysis with ES and VR. ES did the literature review and wrote the first draft with the assistance of VR. All authors read and commented on the content of the manuscript and agreed on the final version and approved its submission.

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**Competing interests** None.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** no additional data available.

**Ethics approval** The study was approved by the Data Protection Authority, the National Bioethics Committee (VSNb2009100017/03.1), and the Scientific Committee of Landspitali University Hospital.

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Table 1 Prevalence of childhood autism, Asperger's Syndrome, other autism spectrum disorders, and all autism spectrum disorders, 95% confidence intervals, male/female ratio, cognitive level, and medical conditions in an Icelandic cohort born in 1994-98

| ASD Diagnoses | No. of Cases | Rate per 10,000 | 95% CI Lower/Upper | Male/Female Ratio | IQ ≥ 70 (%) | MC (%) |
|---|---|---|---|---|---|---|
| CA | 75 | 33.7 | 26.9 to 42.3 | 2.1 | 21 (28.0) | 22 (29.3) |
| AS | 48 | 21.6 | 16.3 to 28.6 | 3 | 48 (100) | 4 (8.3) |
| Other ASD | 144 | 64.8 | 55.1 to 76.2 | 3.2 | 77 (53.5) | 20 (13.9) |
| All ASD | 267 | 120.1 | 106.6 to 135.3 | 2.8 | 146 (54.7) | 46 (17.2) |

Abbreviations: ASD, autism spectrum disorder; CI, confidence interval; IQ, intelligence quotient; MC, medical conditions; CA, childhood autism; AS, Asperger's syndrome.

Table 2 Medical conditions in children (n=46) with childhood autism, Asperger's syndrome, and other autism spectrum disorders in an Icelandic cohort born in 1994-98[a]

| | CA | AS | Other ASD | All ASD (%) |
|---|---|---|---|---|
| Genetic and congenital syndromes[b] | 8 | 2 | 4 | 14 (5.2) |
| Chromosomal aberrations[c] | 3 | 0 | 3 | 6 (2.2) |
| Congenital CNS malformations[d] | 3 | 1 | 2 | 6 (2.2) |
| Other neurological conditions[e] | 6 | 1 | 9 | 16 (6.0) |
| Epilepsy[f] | 10 | 0 | 9 | 19 (7.1) |

Abbreviations: CA, childhood autism; AS, Asperger's syndrome; ASD, autism spectrum disorders.

[a] Some children had more than one condition.

Figures in brackets indicate the number of cases: [b] Down syndrome [3], Arnold-Chiari malformation [2], Ehlers-Danlos syndrome [1], homocystinuria [1], neurofibromatosis [1], Prader-Willi syndrome [1], Saethre-Chotzen syndrome [1], Smith-Magenis syndrome [1], Sotos syndrome [1], Sturge-Weber syndrome [1], Turner syndrome [1]; [c] inversion 9 (p11q12) [2], balanced autosomal rearrangements t4;14 (p11;q11) [1], microdeletion 3 (p26.3-pter) [1], partial duplication 8 (q1-q22) [1], partial duplication 20 (q12-q13.13) [1]; [d] microcephaly [3], agenesis of corpus callosum [1], macrogyria [1], cerebral cyst [1]; [e] cerebral palsy [5], asphyxia/intracranial hemorrhage [3], CNS infections [3], hearing impairment [2], CNS tumor [1], extrapyramidal motor disorder [1], vision impairment [1];

[f] six children had seizure onset in the first year of life.

Table 3 Icelandic children born in 1994-98 with autism spectrum disorders diagnosed until the end of 2005 compared to those diagnosed 2006 to 2009 with respect to diagnostic subtypes, gender, cognitive level, medical conditions, and epilepsy

| | 2005 n=126 (%) | 2009 n=141 (%) | Rate Ratio | 95% CI Lower/Upper | p Value |
|---|---|---|---|---|---|
| CA | 49 (38.9) | 26 (18.4) | 2.11 | 1.40 to 3.18 | 0.0002 |
| AS | 13 (10.3) | 35 (24.8) | 0.42 | 0.23 to 0.75 | 0.002 |
| Other ASD | 64 (50.8) | 80 (56.7) | 0.90 | 0.72 to 1.12 | 0.331 |
| Males | 96 (76.2) | 101 (71.6) | 1.06 | 0.92 to 1.23 | 0.398 |
| IQ ≥ 70 | 60 (47.6) | 86 (61.0) | 0.78 | 0.62 to 0.98 | 0.028 |
| All MCs | 26 (20.6) | 20 (14.2) | 1.45 | 0.86 to 2.47 | 0.163 |
| Epilepsy[a] | 13 (10.3) | 6 (4.3) | 2.42 | 0.95 to 6.19 | 0.054 |

Abbreviations: CI, confidence interval; CA, childhood autism; AS, Asperger's syndrome; ASD, autism spectrum disorders; IQ, intelligence quotient; MCs, medical conditions.

[a] Subcategory of MCs.

Table 4 Recent studies on the prevalence of autism spectrum disorders in children estimated at approximately 1% or higher

| Study and Location | Age groups | Method | No. of clinically verified cases | Target population | Prev. % | Male / female ratio |
|---|---|---|---|---|---|---|
| Baird (2006)[3] UK | 9-10 | Records / Survey | 158 | 56,946 | 1.16[a] | 3.3 |
| Kawamura (2008)[4] Japan | 1-7 | Clinical | 228 | 12,589 | 1.81[b] | 2.8 |
| ADDM (2009)[25] USA | 8 | Records | NA | 307,790 | 0.90[c] | 3.2-7.6 |
| Baron-Cohen (2009)[5] UK | 5-9 | Records / Survey | NA | 8,824 | 1.57[a] | Not reported |
| Posserud (2010) [24] Norway | 7-9 | Survey | 14 | 6,609 | 0.87[a] | Not reported |
| Kim (2011)[6] South-Korea | 7-12 | Records / Survey | 201 | 55,266 | 2.64[a] | 2.5 |
| Present study Iceland | 11-15 | Clinical | 267 | 22,229 | 1.20[b] | 2.8 |

Abbreviations: ADDM, Autism and Developmental Disabilities Monitoring Network, USA; NA, not applicable.

[a] Estimated prevalence taking non-responders into consideration.

[b] Calculated from raw numbers.

[c] An overall average across 11 ADDM sites

# PREVALENCE OF AUTISM SPECTRUM DISORDERS IN AN ICELANDIC BIRTH COHORT ~~OF AN ENTIRE NATION~~

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Running title: Prevalence of ASD in an Icelandic birth cohort ~~of an entire nation~~

Key words: Epidemiology, public health, developmental neurology and neurodisability, autism spectrum disorders

Word count: ~~3030~~

Tables: 4

## ABSTRACT

**Objectives:** A steady increase in prevalence of autism spectrum disorders (ASD) has been reported in studies based on different methods, requiring adjustment for participation and missing data. Recent studies with high ASD prevalence rates rarely report on co-occurring medical conditions. The aim of the study was to describe the prevalence of clinically confirmed cases of ASD in Iceland ~~in a geographically defined population~~, and concomitantly examining medical conditions.

**Design and participants:** The study is based on a nation-wide database on ASD for the cohort born 1994-98. All ASD cases (N=267) received physical and neurological examination, standardized diagnostic workup for ASD, as well as cognitive testing. ASD diagnosis was established by a multidisciplinary team. Information on medical conditions and chromosomal testing was obtained by record linkage with hospital registers.

**Setting:** Two tertiary institutions in Iceland. The population registry recorded 22,229 children in the birth cohort.

**Results:** Prevalence of all ASD was 120.1/10,000 (95% confidence interval (CI) 106.6 to 135.3), for boys 172.4/10,000 (95% CI 150.1 to 198.0) and for girls 64.8/10,000 (95% CI 51.3 to 81.8). Prevalence of all medical conditions was 17.2% (95% CI 13.2 to 22.2), including epilepsy of 7.1% (95% CI 4.6 to 10.8). The proportion of ASD cases with cognitive impairment (IQ <70) was 45.3%, but only 34.1% were diagnosed with intellectual disability (ID). Children diagnosed earlier or later did not differ on mean total score on a standardized interview for autism.

**Conclusions:** The number of clinically verified cases is larger than in previous studies, yielding a prevalence of ASD on a similar level as found in recent non-clinical studies. Prevalence of co-occurring medical conditions was high, considering the low proportion of

ASD cases that also had ID. Earlier detection is clearly desirable in order to provide counselling and treatment.

## ARTICLE SUMMARY

### Article focus

- Information on the prevalence of autism spectrum disorders (ASD) is important for effective service planning.
- Increases in prevalence of ASD have been found by different methods, and the procedures have required adjustments for low response rate or missing data. High rates of ASD need to be confirmed in studies based on clinical cases in well defined populations.

### Key messages

- High prevalence rate based on clinically verified cases of ASD was found in a nationwide birth cohort, and is on average comparable to recent studies.
- Hospital registries ensured accurate rates of co-occurring medical conditions and chromosomal aberrations.

### Strengths and limitations of this study

- The population is well defined and relatively homogenous. Good record keeping, easy access to health care, education free of charge, and the comprehensive social system have all ensured efficient case finding at tertiary institutions.
- Case finding was based on the presence of ASD in the records at tertiary level services. Thus the prevalence found should be regarded as minimum.

## INTRODUCTION

The earliest epidemiological studies on the prevalence of autism reported figures in the range of 3-5/10,000. In the eighties there was some evidence of increased prevalence of autism, but since the early nineties a steady increase has been apparent.[1] In a recent review of 43 studies, which provided estimates for the prevalence of autism and pervasive developmental disorders (PDDs), 19 were classified as newer epidemiological surveys of PDDs.[2] These were published between 2000 and 2008 and covered the ages 0-17 years. The prevalence figures were in the range of 30.0 to 67.4/10,000 except in two studies, one in South Thames (UK) with a prevalence of 116.1/10,000[3] and another from Toyota (Japan) with a prevalence of 181.1/10,000.[4] More recent studies have reported even higher prevalence, 157/10,000 and 260/10,000.[5,6] Whether this increase in prevalence through the decades reflects a true increase in incidence or is due to different methodological factors is a matter of debate.[2,5]

From the first prevalence studies on autism to the present, few studies have dealt with co-occurring medical conditions, some of which have recently been reviewed.[7] In studies involving the whole autism spectrum, medical conditions are rarely reported.[2]

In this study we present the prevalence of autism spectrum disorders (ASD) in a birth cohort of an entire nation with a clinical ascertainment of all cases at a tertiary institute. Co-occurring medical conditions of neuro-developmental origin obtained from hospital registers are reported.

## METHODS

This prevalence study was performed at the State Diagnostic and Counselling Centre (SDCC), which is a tertiary institute, serving children with serious neuro-developmental disorders in Iceland, and has had the responsibility of ASD diagnostics and services since 1997. For the purpose of this study, a database on ASD was kept at the SDCC.

The health care system, the educational system, and social services in Iceland are financed by governmental taxes and all residents are covered by national health insurance schemes and~~. Since~~ these services have an important role in case finding and referrals~~, a short description will be given.~~ Primary health care centres manage a comprehensive maternity and child-care plan. The child health and developmental surveillance includes 11 visits to a general practitioner/paediatrician or a nurse during the preschool years where the children are vaccinated and clinically evaluated. The vaccination schedule includes the pertussis/diphtheria/tetanus immunization, which covers 97% of the children and the first measles/mumps/rubella immunization at the age of 18 months, which covers more than 92% according to the Chief Epidemiologist.[8] The first contact with the educational system is through preschool services, ~~and~~ which approximately 90% of children ~~aged 2 to 5 years~~ attend ~~preschools~~.[9] Education is compulsory for children aged 6 to 16 years, and includes special educational needs. The social services provide financial support to parents of children with serious developmental disorders or long-term illnesses, based on medical certificate.

Two specialized tertiary centres formally diagnose autism and ASD: the SDCC and the Department of Child and Adolescent Psychiatry at the Landspitali University Hospital (LUH), and records from the latter are included in the database of ASD at SDCC. An interdisciplinary team consisting of paediatricians or child psychiatrists, clinical child psychologists, and social workers reach~~ed~~ consensus on the clinical diagnoses. Other

professionals involved in the diagnostic work-up included speech and language pathologists, special teachers, and occupational therapists.

All the children in the study underwent a physical examination and a neurological evaluation. The Autism Diagnostic Interview-Revised (ADI-R)[10] and the Autism Diagnostic Observation Schedule (ADOS)[11] were administered, as well as cognitive tests and tests evaluating adaptive behaviour. Of the children classified as ASD cases, 94% received the ADI-R and 87.6% the ADOS. All received either the ADI-R or the ADOS. Intellectual quotient (IQ) or developmental quotient (DQ) data, henceforth both referred to as IQ, was available for all of the children and assessment of adaptive behaviour for 88.3%. The diagnoses were based on the above information as well as other information from hospitals, schools, and the referral services. The majority of children diagnosed early during the preschool years were reassessed before beginning elementary school at 6 years of age.[12]

The classification of autism and ASD was based on the ICD-10.[13] To facilitate comparison with the DSM-IV[14] three diagnostic categories are reported: childhood autism (CA) ICD-10 F84.0 (DSM-IV Autistic Disorder), Asperger's Syndrome (AS) ICD-10 F84.5 (DSM-IV Asperger's Disorder), and other ASD including ICD-10 F84.1, F84.8, and F84.9 (DSM-IV Pervasive Developmental Disorder, Not Otherwise Specified). The ICD-10 F84.4 code was not used.

Cognitive ability was classified into three levels, IQ <50, 50-69, 70+, and cognitive impairment was defined as IQ <70. The diagnosis of intellectual disability (ID) was established according to ICD-10 criteria, taking into account the total score on standardized intellectual or developmental tests,[15-19] the pattern of abilities, as well as measures of adaptive behaviour,[20,21] and other relevant information. Diagnosis of ID was only made after two successive cognitive tests.

As ASD is thought to result from a neurological abnormality, co-occurring medical conditions with neuro-developmental underpinnings were collected. Based on the personal identifier, a record linkage was made between the ASD database and the electronic database containing all discharge diagnoses at the LUH, thus obtaining access to all medical diagnoses of these children up to the end of 2009. For increased precision of the medical data, we double-checked information regarding genetic~~chromosomal~~ testing by linking the personal identifier of the ASD cases to the records of the Dept. of Cytogenetics, LUH. The genetic testing and the related results were a product of different routine tests used for clinical evaluation through the years. A paediatrician (IG) selected the medical conditions to be reported from diagnoses obtained by record linkage with the hospital registry and the records at the SDCC. This was done by taking into consideration neurological abnormalities, neuro-developmental conditions, genetic and congenital syndromes, and epilepsy without assuming an etiological role between the condition and ASD for the individual case.[7] The definition of epilepsy was two unprovoked seizures.

For the calculation of prevalence, the numerator was children pertaining to the 1994-98 cohort diagnosed with ASD, while the denominator was all children born in Iceland during this period and residing in Iceland in the end of 2009, in total 22,229, 11,424 males and 10,805 females according to the National Registry.[22] A calculation of 95% confidence intervals (CI) was based on a method proposed by Wilson.[23] A comparison was made between the group diagnosed by the end of 2005 and the group diagnosed during 2006 and 2009. *Chi*-square test was used to compare groups for categorical variables and *t*-test for differences in means. All p-values were two tailed and considered statistically significant at p-value less than 0.05.

The study was approved by the Data Protection Authority, the National Bioethics Committee (VSNb2009100017/03.1), and the Scientific Committee of LUH.

## RESULTS

Among the birth cohort 1994-98 a total of 267 children were diagnosed with ASD, 197 males and 70 females. Table 1 shows the prevalence of ASD diagnoses, as well as the male/female ratio, cognitive level, and the number of children with medical conditions. The overall prevalence was 120.1 (95% CI 106.6 to 135.3), the prevalence for boys was 172.4/10,000 (95% CI 150.1 to 198.0) and for girls it was 64.8/10,000 (95% CI 51.3 to 81.8).

[Table 1 about here]

Of the cases, 17.2% tested below IQ 50, 28.1% in the 50-69 range, and 54.7% tested ≥70. The mean IQ for all ASD cases was 72.84 (SD=23.90, range <20-134), for boys 74.44 (SD=23.74), and for girls 68.31 (SD=23.91), $t(265)=1.85$, $p=0.065$. The male/female ratio was 2.1 for children with cognitive impairment (IQ <70) and 3.7 for those without such impairment, $\chi^2(1,N=267)=4.14$, $p=0.042$. The proportion of children with cognitive impairment using the IQ <70 classification was 45.3%, but only 34.1% of the ASD cases were formally diagnosed with ID. The proportion of children with ID in the CA group was 64%, and 29.9% for the other ASDs group. ID is by definition excluded in AS. The male/female ratio among those with ID was 1.8.

Chromosomal analyses were performed in 122 children (45.7%), and of these 78 were tested for fragile X. None of those tested was positive for fragile X. The prevalence of all medical conditions was 17.2% (95% CI 13.2 to 22.2), including epilepsy. Of the 46 children with a medical condition, 29 (63%) also had ID. The different medical conditions are shown in Table 2. The prevalence of epilepsy for all ASD was 7.1% (95% CI 4.6 to 10.8). Fourteen (73.7%) of those with epilepsy also had ID. The male/female ratio among those with medical conditions was 2.3, and among those with epilepsy it was 1.4.

[Table 2 about here]

The prevalence of ASD for the 1994-98 birth cohort at the end of 2005 was 56.7/10,000 (95% CI 47.6-67.4). During the four-year interval from 2006 to the end of 2009, more than twice as many children were diagnosed and the prevalence of ASD doubled. The comparison of the characteristics within the ASD group in the two time points (2005 and 2009) is shown in Table 3. The children diagnosed earlier were more often diagnosed with CA, while those diagnosed later were more often diagnosed with AS. No difference was found in the frequency of other ASD whether diagnosed earlier or later. However, the mean total score on ADI-R based on verbal cases (n=213) did not differ between groups, $t(211)=0.63$, $p=0.53$, not shown in the Table 3. More children diagnosed earlier had an IQ below 70 than those diagnosed later. This difference was also evident, when comparing mean IQ scores between groups, $t(264)=-3.37$, $p=0.001$, not shown in the Table. However, the proportion of children with a formal diagnosis of ID did not decrease significantly over time ($\chi^2(1, N=267)=2.45$, $p=0.117$, not shown in the Table. Medical conditions were not more common among children diagnosed earlier than later in the study period.

[Table 3 about here]

## DISCUSSION

In the present study the prevalence of all ASD was 1.2%. This prevalence is in concordance with the higher end of the range (0.3% to 1.8%) reported in the 19 newer surveys published 2000-2008, according to the review of Fombonne.[2] However, when considering more recent studies with ASD prevalence of approximately 1% or higher, our prevalence figure is in the lower end of the range from 0.9% to 2.6% (see Table 4).[3-6,24,25] The highest prevalences reported, 1.8% and 2.6%, are from Japan[4] and South Korea[6] respectively. It is notable that the gender ratio in these two studies is relatively low (2.5-2.8) and similar to the ratio reported in some of the other studies in Table 4.

[Table 4 about here]

In the discussion of these studies care must be taken, as there are considerable differences in the methods used as well as geographical, cultural, and ethnic differences. The studies from South Thames UK,[3] Cambridgeshire UK,[5] Goyang City South Korea,[6] and Bergen City Norway[24] were based on screening for ASD among children with special educational needs or who were on a disability registry, and/or screening among children in elementary schools, and/or among local clinicians. In these studies, different adjustments had to be made to estimate the prevalence due to sampling procedures and different responses and missing data. In the Autism and Developmental Disabilities Monitoring Network USA surveillance,[25] the prevalence of ASD was estimated at 0.90% in children aged 8 years, through a systematic retrospective review by examining records from areas of 11 states. The prevalence of 1.81% in the study from Toyota, Japan,[4] was based on screening and advice to parents to consult, while the diagnosis was founded on a clinical interview with parents and observation of the child.

In the present study, the diagnostic category of CA represented a relatively small proportion (28%) of the total number of cases, even if the prevalence is high (0.34%). This

prevalence is 7.7 times higher than reported in the first study on autism published in Iceland[26] and almost four times that reported in a more recent study.[27]

None of the 19 studies selected by Fombonne[2] were included in a review on medical condition in ASD population samples,[7] and none of the studies in Table 4 reported on medical conditions, except for the present one. In the above review, the rate of medical conditions varied from 8% to 25% in studies published between 1996 and 2007.[7] The comparison of the proportion of medical conditions found in the present study to the findings of other studies is difficult because a generally accepted definition of the phenomenon is lacking.[7] Our estimate of 17.2% may seem high, considering how large a proportion (65.9%) of our ASD cases did not have diagnosed ID.[28] No case with fragile X was identified, although the literature predicts fragile X to be in the range of 2% to 8% with autism when DNA testing is utilized.[29]

Epilepsy in our ASD group was associated with ID and the female gender as demonstrated in a meta-analysis.[30] The lifetime prevalence of epilepsy for all ASD in the present study was 7.1%, which is low compared to other studies on the subject.[31,32] It should be noted that the follow up in the hospital registry, and thus the registration of medical conditions, was up to the end of 2009 when the children were 11-15 years old. In this context, it is of paramount importance to distinguish between studies on autism in adulthood on the one hand[31] and studies on all ASD in childhood on the other hand.[32] In fact, the literature on the incidence and prevalence of epilepsy is sparse in relation to high ASD prevalence.

In a four-year period, from the end of 2005 to the end of 2009, the prevalence of ASD in the cohort studied doubled, moving from 0.6% to 1.2%. This increase cannot be explained by ~~external migration~~ immigration to Iceland, confirmed by the National Registry,[22] and ~~internal~~ migration of people from one part of the country to another is irrelevant since the area studied and the whole country are the same. As expected, children diagnosed earlier (by 2005) were more likely to have CA than AS and were generally more impaired than those diagnosed

later (2006-2009), although the groups did not differ regarding the frequency of ID and medical conditions. In order to examine symptom severity from another angle than diagnostic classification, we compared the earlier and later diagnosed groups on ADI-R total score. This comparison did not reveal differences between groups. High scores on the ADI-R for those diagnosed later indicate serious autistic symptoms, possibly in association with co-occurring developmental and psychiatric disorders. Another point of interest is that the number of boys did not increase, contrary to what is suggested by some investigators.[33] One interpretation of these results is simply that as the cohort studied grows older, more girls are identified with ASD,[34] and because girls with ASD are more likely to be cognitively impaired, it would counteract the predicted trend for fewer children with co-occurring ID as the prevalence of ASD increases. Comparing the distribution of boys and girls in the group of children with ID (n=91) diagnosed earlier or later with ASD revealed some support for this hypothesis, as the gender ratio was 2.8 and 1.2 respectively, although this difference fell short of statistical significance.

Of our ASD cases, 54.7% were classified with IQ of 70 or above. This proportion ranged from 30.0% to 74.2% in the studies selected by Fombonne,[2] where IQ data was reported (13/19). The studies in Table 4, which present comparable data, show this proportion to be from 44.0% to 66.4%.[3,4] These figures indicate that as the prevalence of ASD increases, the proportion of children with cognitive impairment decreases. However, important as the classification of cognitive level above or below IQ 70 may be for comparing epidemiological samples with ASD, it should not be overlooked that IQ <70 simply serves as a proxy for ID. For instance, it is possible to arrive at a full-scale score on a Wechsler test of IQ below 70 in various ways, notably when severe language impairments or non-verbal learning disabilities are present. From this perspective, there is a notable difference between the proportion of children with IQ <70 (45.3%) and the proportion receiving a formal diagnosis of ID (34.1%)

in the present study. Thus, the IQ <70 classification may provide an inaccurate estimate of how many individuals actually have ID in addition to ASD.

In the present study, case finding was based on the presence of ASD in the records at tertiary level services, and hence prospective screening identifying potential cases followed by clinical examination did not take place. Thus, the clinical source of the data indicates that the prevalence reported should be regarded as minimum. However, the prevalence of ASD found is based on the exact number of clinically confirmed cases and definite number of the population derived from a population register of a whole nation. Also, based on record linkage, co-occurring medical conditions were obtained for ASD cases from electronic hospital records. Nevertheless, this follow-up ended when the children were 11-15 years of age and other conditions, for example epilepsy, maybe diagnosed later during their lifetime. The population is well defined and relatively homogenous. Good record keeping, easy access to health care, education free of charge, and the comprehensive social system have all ensured efficient case finding at tertiary institutions, which have the purpose to serve the diagnostic and counselling needs of children with serious developmental disorders. The referral and diagnostic process in the country has been fairly standardized and is relatively transparent, compared to larger societies where a multitude of record sources is to be expected, behind which there may be widely different diagnostic practices. Only two tertiary instances offered diagnostic services for ASD and these have worked in close cooperation regarding diagnostic procedures. The ADI-R was used for 94% of the children by qualified clinicians, all had formal cognitive or developmental testing and consensus diagnoses were reached within an interdisciplinary team. In addition, the majority of children diagnosed during their early preschool years were reassessed before entering elementary school.

## CONCLUSION

The number of clinically verified cases is larger than in previous studies, yielding a prevalence rate of ASD on a similar level as found in recent non-clinical studies. The tertiary level of services diagnosed a fair number of ASD cases; however, it may be considered a public health issue how many children are diagnosed after they enter the elementary school system.

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**Contributors** Evald Saemundsen (ES), Vilhjálmur Rafnsson (VR), and Páll Magnússon designed the study. ES and PM oversaw the data entry. Ingibjörg Georgsdóttir and VR oversaw the gathering of data on medical conditions. Erlendur Egilsson assisted with quality control regarding data entry and the statistical analysis with ES and VR. ES did the literature review and wrote the first draft with the assistance of VR. All authors read and commented on the content of the manuscript and agreed on the final version and approved its submission.

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Table 1 Prevalence of childhood autism, Asperger's Syndrome, other autism spectrum disorders, and all autism spectrum disorders, 95% confidence intervals, male/female ratio, cognitive level, and medical conditions in an Icelandic cohort born in 1994-98

| ASD Diagnoses | No. of Cases | Rate per 10,000 | 95% CI Lower/Upper | Male/Female Ratio | IQ ≥ 70 (%) | MC (%) |
|---|---|---|---|---|---|---|
| CA | 75 | 33.7 | 26.9 to 42.3 | 2.1 | 21 (28.0) | 22 (29.3) |
| AS | 48 | 21.6 | 16.3 to 28.6 | 3 | 48 (100) | 4 (8.3) |
| Other ASD | 144 | 64.8 | 55.1 to 76.2 | 3.2 | 77 (53.5) | 20 (13.9) |
| All ASD | 267 | 120.1 | 106.6 to 135.3 | 2.8 | 146 (54.7) | 46 (17.2) |

Abbreviations: ASD, autism spectrum disorder; CI, confidence interval; IQ, intelligence quotient; MC, medical conditions; CA, childhood autism; AS, Asperger's syndrome.

Table 2 Medical conditions in children (n=46) with childhood autism, Asperger's syndrome, and other autism spectrum disorders in an Icelandic cohort born in 1994-98[a]

| | CA | AS | Other ASD | All ASD (%) |
|---|---|---|---|---|
| Genetic and congenital syndromes[b] | 8 | 2 | 4 | 14 (5.2) |
| Chromosomal aberrations[c] | 3 | 0 | 3 | 6 (2.2) |
| Congenital CNS malformations[d] | 3 | 1 | 2 | 6 (2.2) |
| Other neurological conditions[e] | 6 | 1 | 9 | 16 (6.0) |
| Epilepsy[f] | 10 | 0 | 9 | 19 (7.1) |

Abbreviations: CA, childhood autism; AS, Asperger's syndrome; ASD, autism spectrum disorders.

[a] Some children had more than one condition.

Figures in brackets indicate the number of cases: [b] Down syndrome [3], Arnold-Chiari malformation [2], Ehlers-Danlos syndrome [1], homocystinuria [1], neurofibromatosis [1], Prader-Willi syndrome [1], Saethre-Chotzen syndrome [1], Smith-Magenis syndrome [1], Sotos syndrome [1], Sturge-Weber syndrome [1], Turner syndrome [1]; [c] inversion 9 (p11q12) [2], balanced autosomal rearrangements t4;14 (p11;q11) [1], microdeletion 3 (p26.3-pter) [1], partial duplication 8 (q1-q22) [1], partial duplication 20 (q12-q13.13) [1]; [d] microcephaly [3], agenesis of corpus callosum [1], macrogyria [1], cerebral cyst [1]; [e] cerebral palsy [5], asphyxia/intracranial hemorrhage [3], CNS infections [3], hearing impairment [2], CNS tumor [1], extrapyramidal motor disorder [1], vision impairment [1];

[f] six children had seizure onset in the first year of life.

Table 3 Icelandic children born in 1994-98 with autism spectrum disorders diagnosed until the end of 2005 compared to those diagnosed 2006 to 2009 with respect to diagnostic subtypes, gender, cognitive level, medical conditions, and epilepsy

| | 2005 n=126 (%) | 2009 n=141 (%) | Rate Ratio | 95% CI Lower/Upper | p Value |
|---|---|---|---|---|---|
| CA | 49 (38.9) | 26 (18.4) | 2.11 | 1.40 to 3.18 | 0.0002 |
| AS | 13 (10.3) | 35 (24.8) | 0.42 | 0.23 to 0.75 | 0.002 |
| Other ASD | 64 (50.8) | 80 (56.7) | 0.90 | 0.72 to 1.12 | 0.331 |
| Males | 96 (76.2) | 101 (71.6) | 1.06 | 0.92 to 1.23 | 0.398 |
| IQ ≥ 70 | 60 (47.6) | 86 (61.0) | 0.78 | 0.62 to 0.98 | 0.028 |
| All MCs | 26 (20.6) | 20 (14.2) | 1.45 | 0.86 to 2.47 | 0.163 |
| Epilepsy[a] | 13 (10.3) | 6 (4.3) | 2.42 | 0.95 to 6.19 | 0.054 |

Abbreviations: CI, confidence interval; CA, childhood autism; AS, Asperger's syndrome; ASD, autism spectrum disorders; IQ, intelligence quotient; MCs, medical conditions.

[a] Subcategory of MCs.

Table 4 Recent studies on the prevalence of autism spectrum disorders in children estimated at approximately 1% or higher

| Study and Location | Age groups | Method | No. of clinically verified cases | Target population | Prev. % | Male / female ratio |
|---|---|---|---|---|---|---|
| Baird (2006)[3] UK | 9-10 | Records / Survey | 158 | 56,946 | 1.16[a] | 3.3 |
| Kawamura (2008)[4] Japan | 1-7 | Clinical | 228 | 12,589 | 1.81[b] | 2.8 |
| ADDM (2009)[25] USA | 8 | Records | NA | 307,790 | 0.90[c] | 3.2-7.6 |
| Baron-Cohen (2009)[5] UK | 5-9 | Records / Survey | NA | 8,824 | 1.57[a] | Not reported |
| Posserud (2010)[24] Norway | 7-9 | Survey | 14 | 6,609 | 0.87[a] | Not reported |
| Kim (2011)[6] South-Korea | 7-12 | Records / Survey | 201 | 55,266 | 2.64[a] | 2.5 |
| Present study Iceland | 11-15 | Clinical | 267 | 22,229 | 1.20[b] | 2.8 |

Abbreviations: ADDM, Autism and Developmental Disabilities Monitoring Network, USA; NA, not applicable.

[a] Estimated prevalence taking non-responders into consideration.

[b] Calculated from raw numbers.

[c] An overall average across 11 ADDM sites