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ORIGINAL ARTICLE

Time Trends in Treated Incidence, Socio-demographic Risk Factors, and Co-occurring Psychiatric Disorders in Diagnosed Autism Spectrum Disorder With or Without Intellectual Disability: A Finnish Nationwide Register Study

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Abstract

Purpose Research on Autism spectrum disorder (ASD) trends and risk factors, particularly relating to by intellectual disability (ID), is limited. This study examined the incidence, sociodemographic risk factors and co-occurrence conditions of ASD, including categorization by ID, using national registers.

Methods This study included singletons born in Finland between 1998 and 2015 who had been diagnosed with ASD by 2018, with cases categorized into ASD with ID and ASD without ID. We divided the study sample into four birth cohorts (1998–2002, 2003–2007, 2008–2011 and 2012–2015) to analyze changes in incidence over time. Cases (n = 10,171) were matched with controls (n = 49,391) by age, gender, and birthplace. Associations between sociodemographic risk factors and ASD were analyzed using conditional logistic regression. Co-occurrence with other psychiatric disorders was examined only in the oldest cohort (1992–2002).

Results The cumulative incidence of ASD without ID increased from 0.52 to 0.89% by age 10, while ASD with ID remained stable at 0.17%. Several socio-demographic risk factors were associated with both groups, while parental immigration status was only associated with cases with ID. A total of 59.0% of cases had one co-occurring psychiatric disorder, with a significant difference in prevalence between the groups (p < .05).

Conclusion The increase in diagnosed ASD, particularly without ID, recorded by specialized services in Finland between 1998 and 2018 may reflect a real increase in incidence, or changes in diagnostic criteria and practices, improved mental health services, greater public and professional awareness or treatment seeking behavior.

Keywords ASD with and without ID · Incidence · Sociodemographic risk factors · Co-occurrence

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder marked by deficits in social communication, restricted interests and repetitive behavior (Hodges et al., 2020). Both genetic and environmental risk factors play crucial roles in the etiology of ASD (Bai et al., 2019), and may also influence its heterogeneity (Neri de Souza Reis et al., 2021), including the frequent co-occurrence of intellectual disability (ID). This co-occurrence is substantial, with a median rate of 33% (Zeidan et al., 2022) and allows clinicians to specify diagnoses as ASD with or without ID (Oliveras-Rentas et al., 2012). Cases of ASD with ID experience greater functional impairment, highlighting the need

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for additional support and intervention compared to cases without ID (Bertelli et al., 2023; Matthews et al., 2018). The convergence of specific deficits and high co-occurrence rates makes ASD one of the most disabling developmental disorders, resulting in a substantial economic burden (Talantseva et al., 2023).

The global prevalence of ASD showed considerable variation both within and across regions, with a median of approximately 1 in 100 children, reported ranging from 0.01% to 4.36% (Zeidan et al., 2022), and significantly higher rates among children aged between 6 and 12 years old (Talantseva et al., 2023). Time trend studies on ASD have demonstrated a notable increase in incidence during the last decade (Avlund et al., 2021; Jensen et al., 2014; Sasayama et al., 2021). However, only two of those studies have specifically investigated the co-occurrence of ID (Idring et al., 2015; Shenouda et al., 2023), and only one was a register-based study (Idring et al., 2015). A population-based study in the US reported that, from 2000 to 2016, the prevalence of ASD with ID increased twofold, from 2.9 to 7.3 per 1,000 persons, whereas ASD without ID increased approximately fivefold, within the same time span, from 3.8 to 18.9 per 1,000 persons; the boy-to-girl ratio ranged from 3.9 in ASD with ID to 4.4 in ASD without ID (Shenouda et al., 2023). A register-based study from Sweden reported an eightfold increase in ASD without ID (from 0.14 to 1.10%) between 2001 and 2011, while the prevalence of ASD with ID showed only a slight increase, from 0.28 to 0.34% during the same period (Idring et al., 2015).

Several studies have examined the association between ASD and psychosocial risk factors, including family income, region of birth, maternal marital status, maternal socioeconomic status (SES), parental immigration status and parental age (Crafa & Warfa, 2015; Idring et al., 2015; Lampi et al., 2013; Lauritsen et al., 2005; Maenner, 2023; Rai et al., 2012; Sandin et al., 2016). However, few have studied the relationship between these risk factors and ASD, with and without ID. To our knowledge, only six studies have explored these associations based on this categorization (Delobel-Ayoub et al., 2015; Idring et al., 2014, 2015; Pinborough-Zimmerman et al., 2011; Rai et al., 2012; Shenouda et al., 2023), and among them, four were population-based studies and two were register-based studies from Sweden (Idring et al., 2014, 2015). None of these studies included information about the severity of ID. The register-based studies found that ASD was more prevalent among certain groups of migrants and less prevalent with increasing familial income levels, especially for ASD with ID (Idring et al., 2015). Advancing parental age showed a stronger association with ASD cases with ID than cases without ID. When using maternal age 29 as a reference, the odds ratio (OR) of ASD with ID was 2.04 for mothers aged 40–45, compared to 1.54 for ASD without ID. Similarly, using paternal age 32 as a reference, the OR for ASD with ID was 1.52 for fathers aged 55–59, compared to 1.19 for ASD without ID (Idring et al., 2014).

Individuals with ASD often present with a wide range of co-occurring psychiatric conditions (Barlattani et al., 2023; Hossain et al., 2020; Lai et al., 2019). However, few studies have examined the co-occurrence of psychiatric disorders and ASD, with and without ID. Only two register-based studies have focused on the co-occurrence of depression and attention deficit hyperactivity disorder (ADHD) in these groups. These studies found that the risk of ADHD and depression co-occurrence was higher among ASD without ID compared to cases with ID (Ghirardi et al., 2018; Rai et al., 2018).

The main aim of the current study was to report the incidence and cumulative incidence of diagnosed ASD among boys and girls aged 3 to 20 years in Finland. We also aimed to report the incidence and cumulative incidence of ASD with and without ID. In addition, we examined several socio-demographic risk factors and co-occurring psychiatric disorders associated with ASD overall as well as with ASD with and without ID. While a few register-based studies from Nordic countries have addressed similar questions, our use of Finnish nationwide register-based data, combined with the analysis of cumulative incidence rather than prevalence and inclusion of several sociodemographic risk factors provides a detailed comparison of ASD with and without ID over time. This information could support public health authorities in better planning resources, designing more targeted interventions, and improving healthcare service planning.

Materials and Methods

This study was a part of the Finnish Prenatal Study of Autism and Autism Spectrum Disorder (FIPS-A). The study population consisted of all children born in Finland as single births from 1 January 1998 to 31 December 2015 (N = 1,044,102), who were followed up until 31 December 2018. We censored individuals who emigrated from Finland or died during the follow up period. The study design is further detailed in Fig. S1. FIPS-A received approval from the Finnish Institute for Health and Welfare (Dnro THL/463/5.05.00/2019).

FIPS-A and National Registers

The FIPS-A study is based on register linkages between the Finnish Care Register for Health Care (CRHC), the Finnish Medical Birth Register (FMBR) and the Digital and Population Services Agency (DVV). A detailed description of these

registers has previously been published (Lampi et al., 2011). The CRHC includes information on patients discharged from inpatient care since 1998 as well as information on outpatient care, dates of all admissions and discharges, and clinical diagnoses. In Finland, ASD is typically diagnosed in an inpatient or outpatient clinic of child neurology or child psychiatry. Since 1996, all diagnoses have been based on the ICD-10. The majority of ASD cases in Finland are diagnosed and treated in the public healthcare system, and diagnoses are routinely registered in the CRHC by physicians. The FMBR consists of detailed and standardized information regarding pregnancy, the prenatal period, and the neonatal period of all births in Finland up to the age of 7 days. Variables including maternal SES, marital status, parental age and immigration were acquired from the FMBR, and region of birth and urbanicity information was obtained from the DVV. The DVV is a registered population information system that contains basic information about Finnish and foreign citizens residing in Finland, which can be used in healthcare and statistical purposes(*Digital and Population Data Services Agency | Digital and Population Data Services Agency*, n.d.).

Study Participants

Cases and Controls

Cases of ASD ($n = 10{,}171$) included all children born in Finland between 1998 and 2015 who had been diagnosed with ASD in the CRHC with ICD-10 codes (F84.0, F84.5, F84.8/F84.9 and F84.1) by the end of 2018. The ASD sample was categorized into four birth cohort groups: 1998–2002, 2003–2007, 2008–2011 and 2012–2015. These individuals were followed until reaching the ages of 20, 15, 10 and 6, respectively. The cut-offs for birth cohort categorization reflect key developmental transitional phases, including the transition to school (age 6 years), pre-puberty (10 years), mid-puberty (15 years) and the transition to adulthood (20 years). This stratification provided an understanding of potential cohort effects on the incidence of ASD and enabled investigation of changes in incidence over time. We also classified ASD into two categories, ASD with and without ID, based on co-occurrence with ID (ICD 10 codes: F70–F79). We excluded all cases diagnosed with ASD before the age of 3 years, but not after that ($n = 132$), to ensure the inclusion of only stable and reliable diagnosis (Fig. S1). We also excluded cases whose latest ASD diagnosis was Rett's syndrome (F84.2), other childhood disintegrative disorders (F84.3), or an overactive disorder associated with mental retardation and stereotyped movements (F84.4).

Controls ($n = 49{,}391$) were defined as individuals without ASD (F84.x) or ID (F70–79). Each case was matched with five controls on date of birth (±30 days), sex and place of birth. Date of birth was included as a matching factor to control for secular changes in prevalence of exposures and ASD outcomes as well as to control for potential confounding by season of birth. In our study, we calculated the "yearly incidence" as the number of new diagnosed ASD cases per 100 persons at risk among boys and girls separately. "Cumulative incidence" was defined as the proportion of new diagnosed cases per 100 persons over the period from 1998 to 2018, and this was calculated separately for each cohort. Additionally, we stratified the cumulative incidence by ASD with and without ID for both boys and girls in each cohort.

Demographic Variables

Maternal SES was divided into five categories: upper white-collar workers, lower white-collar workers, blue-collar workers, others and unknown and missing data. Maternal marital status was divided into married or in a relationship and single. Previous studies have shown a non-linear association between parental age and risk of ASD, with increased risk observed when the maternal age is under age 20 or over 40 (Idring et al., 2014), and when the paternal age exceeds 55 (Reichenberg et al., 2010). We examined parental age as a categorical variable, analyzing maternal and paternal ages separately to identify specific age ranges associated with a significant increased risk of ASD. Due to this, maternal age was categorized as: <20, 20–24, 25–29, 30–34, 35–39, ≥40 years and paternal age as: <20, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, ≥50 years. Parental immigration status was categorized as both parents were born in Finland, both parents were immigrants, or either the mother or the father was an immigrant. Region of birth was classified as Southern, Western, Northern or Eastern Finland. Urbanicity was divided into urban, semi-urban and rural categories.

Co-occurring with Another Psychiatric Disorders

We limited our examination of co-occurrence with other psychiatric disorders to the oldest birth cohort, born 1998–2002, in order to extend the follow-up period. We examined the prevalence of these disorders in all cases and compared them with the controls, and examined the differences in prevalence between individuals with ASD with and without ID. The co-occurring disorders were identified using the ICD-10 classification of mental disorders, schizophrenia (F20–F25, F28 and F29), bipolar disorder (F31), depressive disorder (F32, F33), anxiety disorder (F40, F41), obsessive-compulsive disorder (OCD) (F42), sleep disorders (F51, excluding F51.3 and F51.4), ADHD (F90) and Tourette syndrome (F95.1, F95.2).

Statistical Analysis

We analyzed time trends of yearly and cumulative incidence of diagnosed ASD and ASD with and without ID among the whole population born in Finland during the specified years. We calculated the yearly incidence of new ASD cases per 100 persons at risk separately by biological sex. Similarly, we computed cumulative incidence per 100 persons along with 95% confidence intervals (95% CI), separately by sex and birth cohort, using the Kaplan-Meier method. We conducted the same analyses for ASD cases with and without ID. To account for the occurrence and absence of ID as competing outcomes, we estimated cumulative incidence as the marginal probability of each outcome. We compared the statistical difference between the treated incidence rates for boys and girls using the log-rank test. In addition, we used binominal tests to compare the proportion of individuals diagnosed with ASD with and without ID at specific points.

We analyzed the association between sociodemographic risk factors and ASD cases in the total sample and separately for ASD with and without ID. We used conditional logistic regression to examine the unadjusted associations between outcomes and risk factors, including maternal SES, place of birth, region of birth, maternal marital status, parental immigration status and maternal and paternal age. For each risk factor and outcome, we calculated unadjusted ORs and 95% CIs. We then conducted multivariate conditional logistic regression for all variables that showed a statistically significant association with ASD in univariate analyses ($p<.05$). To assess the interaction effect of risk factors and sex, we used conditional logistic regression for all ASD cases. When interactions were significant, we conducted both unadjusted and adjusted conditional logistic regressions separately by sex. We applied a similar approach to explore interactions between the risk factors and the birth cohort. We excluded subjects with missing data on any explanatory variables from the models. We assessed the prevalence of other psychiatric disorders among the oldest birth cohort (born between 1998 and 2002). To compare the prevalence of co-occurrence with other psychiatric disorders, we used Chi-squared test between all cases and controls, between ASD with or without ID and their matched controls, as well as between ASD with ID and ASD without ID. We also performed these analyses separately by biological sex. Finally, we conducted a logistic regression to examine the association between ASD with and without ID and the risk of comorbidity with other psychiatric disorders. In this model, we adjusted for sex, birth year and sociodemographic risk factors, including maternal SES, region of birth, urbanicity, maternal marital status, parental immigration status, and maternal and paternal age. We conducted all statistical analyses using SAS statistical software, version 9.4.

Results

Characteristics of the Study Population

The median age at first diagnosis of ASD was 8 years (interquartile range (IQR): 5–11). Of all cases, 77.1% were boys. The median age at first diagnosis was 8 years (IQR: 5–11) for boys and 9 years (IQR 5–13) for girls. Of all ASD cases, 83.3% were diagnosed without ID. A total of 38.0% of the cases were in the oldest birth cohort (1998–2002). The first cohort was followed up until the age of 20 years, and the other cohorts were followed up until 15, 10 and 6 years, respectively. The majority of diagnosed ASD cases were born into families with mothers whose SES was lower white-collar worker (31.9%), who were aged 25–29 years (31.3%) and who were either married or in a relationship (84.9%). Furthermore, most diagnosed cases had non-immigrant parents (86.8%) and fathers who were 30–34 years old (31.7%). The age at first diagnosis was 9 years (IQR: 6 −12) among ASD cases without ID, and 4 years (IQR: 3–6) among ASD cases with ID. The age at first diagnosis was significantly different between the two groups, as determined by the Mann-Whitney U test ($p<.001$).

Yearly Incidence by Age and Gender

Figure S2 shows the yearly incidence of total ASD cases for boys and girls. Among the boys, the incidence rapidly increased between ages 3 and 9, while among the girls, it steadily increased from ages 3 to 15. After these age ranges, the incidence decreased for both genders. The boy-to-girl ratio in ASD diagnoses was 4.18:1 at age 6, decreasing to 1.52:1 by age 15.

Figure S3 presents the yearly incidence of ASD without ID and ASD with ID among girls and boys. The yearly incidence trend for ASD without ID was similar to that of the total cases. In contrast, the trend for ASD with ID showed an increase from age 1 to 3, followed by a decrease. These changes in yearly incidence were more pronounced among the boys than among the girls. At age 10, the boy-to-girl ratio was 4.50:1 among individuals with ASD without ID, and 3.17:1 among those with ASD with ID.

Cumulative Incidence by Birth Cohorts

Total Cases of ASD

Figure 1 shows the cumulative incidences of diagnosed ASD cases for boys and girls by birth cohort (1998–2002, 2003–2007, 2008–2011, 2012–2015). In the 1998–2002 cohort, the cumulative incidence of ASD increased from 0.48%, 95% (CI 0.44–0.51) among boys and 0.16%, 95%

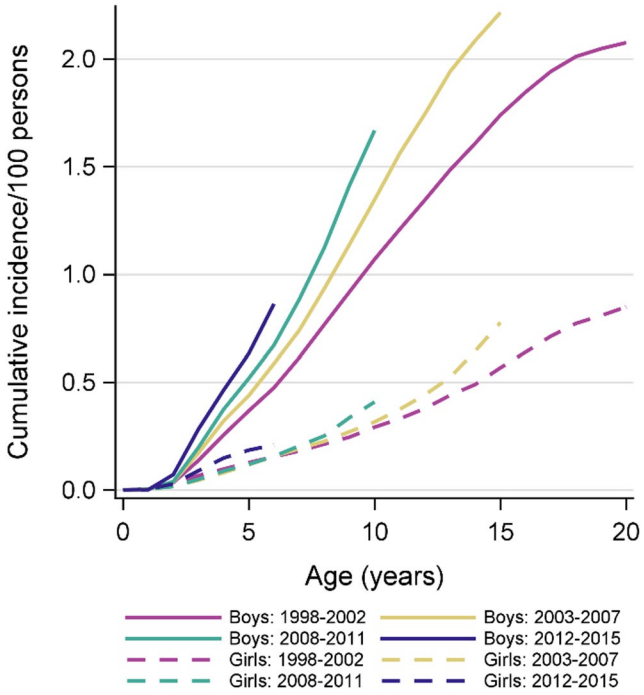

Fig. 1 Cumulative incidence of ASD per 100 persons among boys and girls for birth cohorts

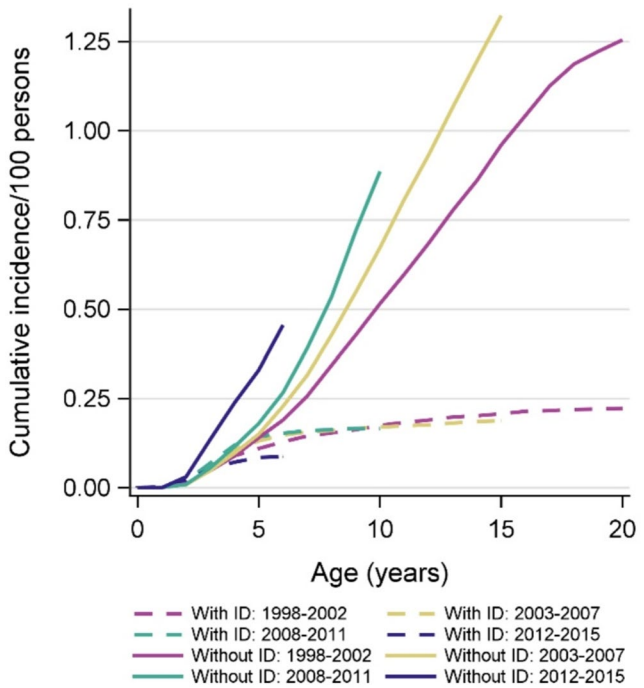

Fig. 2 Cumulative incidence of ASD with and without ID per 100 persons among different birth cohorts

(CI 0.14–0.18) among girls at age 6 to 2.08%, 95% (CI 1.99–2.16) and 0.85%, 95% (CI 0.79–0.91), respectively, by age 20.

To analyze the trend across cohorts, we focused on a maximum age of 6 in each cohort. Among boys, the cumulative incidence increased from 0.48%, 95% (CI 0.44–0.51) in the 1998–2002 cohort to 0.59%, 95% (CI 0.55–0.63) in the 2003–2007 cohort, rose further to 0.67%, 95% CI (0.63–0.72) in the 2008–2011 cohort, and reached 0.86%, 95% CI (0.79–0.94) in the 2012–2015 cohort. Among girls, the incidence remained stable at 0.16%, 95% CI (0.14–0.18) in the first three cohorts but increased slightly to 0.21%, 95% CI (0.18–0.25) in the 2012–2015 cohort. The differences between groups by birth year and gender were statistically significant, $p<.001$.

ASD With and Without ID

In comparing the 1998–2002 and 2008–2011 cohorts, the cumulative incidence of ASD without ID at age 10 increased from 0.52%, 95% CI (0.49–0.54) to 0.89%, 95% CI (0.84–0.94). However, the cumulative incidence of ASD with ID remained stable at the age of 10, at 0.17%, 95% CI (0.16–0.19) (Fig. 2). The cumulative incidence over time were significantly different between the two groups, when comparing the proportion of individuals at age 5 and age 15, $p<.001$.

Sociodemographic Factors

Total Cases

Table 1 shows the sociodemographic factors and associations between all ASD cases and the risk factors in the study population. In the multivariate model, the sociodemographic risk factors associated with ASD were: maternal SES (blue-collar, others, unknown, $p<.001$), single motherhood ($p<.001$) and paternal age (35–39 years, 40–44 years, 45–49 years, ≥50 years, $p<.001$). Table 1 shows the associations between all ASD cases and sociodemographic risk factors.

There was significant interaction by biological sex between region of birth and ASD, $p=.02$ (Table S3). When those born in Southern Finland were selected as a reference, the odds of ASD increased among both girls, OR 1.30, 95% CI (1.10–1.53), $p=.002$ and boys OR 1.12, 95% CI (1.02–1.23), $p=.016$, who were born in Eastern Finland (Table S4).

Birth cohort and parental immigration status were both found to significantly interact with ASD, $p<.001$ (Table S3). In the youngest birth cohort, born between 2012 and 2015, children with immigrant parents were significantly more likely to get diagnosed with ASD, compared to those whose

Table 1 Association between sociodemographic factors in total ASD cases and controls

Sociodemographic factor		Cases (*N*=10,171)	Controls (*N*=49,391)	Multivariate[b]
		n (%)	*n* (%)	OR (95%CI)
Maternal SES	Upper white-collar workers	1,514 (14.9)	83,508 (16.9)	Ref.
	Unknown	1,745 (17.2)	7,063 (14.3)	**1.33 (1.22–1.45)** ***
	Lower white-collar workers	3,254 (31.9)	17,884 (36.2)	1.04 (0.977–1.12)
	Blue-collar workers	1,566	7,294 (14.8)	**1.21 (1.11–1.32)** ***
	Others[a]	2,092	8,800 (17.8)	**1.34 (1.24–1.45)** ***
Birth region	Southern Finland	4,400 (43.3)	20,505 (41.5)	Ref.
	Western Finland	3,414 (33.6)	17,384 (35.2)	**0.89 (0.84–0.95)** **
	Northern Finland	1,270 (12.5)	6,884 (13.9)	**0.88 (0.81–0.95)** **
	Eastern Finland	1,087 (10.7)	4,618 (9.3)	**1.12 (1.03–1.23)** **
Place of birth	Urban	7,058 (69.4)	32,220 (65.2)	Ref.
	Semi-urban	1,474 (14.5)	8,040 (16.3)	**0.86 (0.80–0.92)** ***
	Rural	1,577 (15.5)	8,800 (17.8)	**0.81 (0.76–0.87)** ***
Marital status	Married/in relationship	8,634 (84.9)	43,864 (88.8)	Ref.
	Single	816 (80.2)	2,692 (5.5)	**1.29 (1.16–1.43)** ***
Parental immigration status	Both parents Finnish	8,827 (86.8)	44,863 (90.8)	Ref.
	Mother immigrant	269 (2.6)	974 (2.0)	1.13 (0.95–1.35)
	Father immigrant	300 (2.9)	1,260 (2.6)	1.13 (0.96–1.32)
	Both parents immigrants	500 (4.9)	1,624 (3.3)	1.09 (0.94–1.27)
Maternal age (years)	<20	368 (3.6)	1,315 (2.7)	1.08 (0.89–1.32)
	20–24	1,798 (17.7)	8,077 (16.4)	1.04 (0.95–1.13)
	25–29	3,037 (29.9)	15,586 (31.6)	Ref.
	30–34	2,868 (28.2)	15,198 (30.8)	0.93 (0.87–1.00)
	35–39	1,602 (15.8)	7,385 (15.0)	0.99 (0.90–1.09)
	≥40	481 (4.7)	1,777 (3.6)	1.06 (0.91–1.22)
Paternal age (years)	<20	116 (1.2)	441 (0.9)	0.96 (0.71–1.31)
	20–24	1,033 (10.4)	4,746 (9.7)	0.99 (0.88–1.12)
	25–29	2,400 (24.3)	12,411 (25.5)	0.96 (0.89–1.04)
	30–34	2,918 (29.5)	15,689 (32.2)	Ref.
	35–39	2,027 (20.5)	9,872 (20.3)	**1.11 (1.03–1.20)** **
	40–44	903 (9.1)	3,903 (8.0)	**1.25 (1.13–1.39)** ***
	45–49	326 (3.3)	1,214 (2.5)	**1.40 (1.20–1.65)** ***
	≥50	173 (1.7)	455 (0.9)	**1.84 (1.47–2.31)** ***

The bolded values are statistically significant (p<.05)

Ref=reference category, OR=odds ratio, CI=confidence interval, SES=socioeconomic status

Number of missing: Maternal SES: 1745 (17.2%), Urbanicity: 62 (0.6%), Marital status: 721 (7.1%), Parental immigration status: 275 (2.7%), Maternal age: 17 (0.2%), Paternal age: 275 (2.7%)

[a]Students, pensioners, unemployed, small business entrepreneurs, housewives and househusbands

[b]The multivariate model included maternal SES class, region of birth, urbanicity, maternal marital status, parental immigration status, maternal and paternal age

*** $p<.001$, ** $p<.01$, * $p<.05$

both parents were born in Finland. The odds were higher when only the mother was an immigrant, OR 2.61, 95% CI (1.77–3.85), $p<.001$, and when both parents were immigrants, OR 6.67, 95% CI (5.21–8.54), $p<.001$, (Table S5).

ASD With and Without ID

The frequencies of sociodemographic risk factors for ASD with and without ID cases and for controls are presented in Table 2.

Table 3 shows the associations between sociodemographic factors and ASD with and without ID (Table 3). Several sociodemographic risk factors showed statistically significant interaction with ASD with and without ID ($p<.1$) (Table 3). In the multivariate model, the sociodemographic risk factors associated with increased odds of ASD without ID were: lower maternal SES (blue-collar, $p=.05$), single motherhood ($p<.001$), younger maternal age (less than 20 years, $p=.006$) and older paternal age (40–44 years, $p=.014$; 45–49 years, $p<.001$; ≥50 years, $p<.001$).

Similarly, the sociodemographic risk factors associated with increased odds of ASD with ID were: lower maternal SES (lower white-collar, $p=.001$; blue-collar, $p<.001$), being born in Eastern Finland ($p<.001$), single motherhood ($p<.001$), immigrant parents (only the mother was an immigrant, $p=.006$; only the father was an immigrant, $p=.016$;

Table 2 Frequencies of sociodemographic risk factors in ASD with and without ID cases and controls

Sociodemographic factor		ASD without ID[b]		ASD with ID[c]	
		Cases (*N*=8,474)	Controls (*N*=41,167)	Cases (*N*=1,697)	Controls (*N*=8,224)
		n (%)	*n* (%)	*n* (%)	*n* (%)
Maternal SES	Upper white-collar workers	1,307 (15.4)	6,939 (16.9)	207 (12.2)	1,411 (17.2)
	Unknown	1,426 (16.8)	5,749 (14.0)	319 (18.8)	1,314 (16.0)
	Lower white-collar workers	2,713 (32.0)	14,994 (36.4)	541 (31.9)	2,890 (35.1)
	Blue-collar workers	1,271 (15.0)	6,114 (14.9)	295 (17.4)	1,180 (14.3)
	Others[a]	1,757 (20.7)	7,371 (17.9)	335 (19.7)	1,429 (17.4)
Birth region	Southern Finland	3,685 (43.5)	16,960 (41.2)	715 (42.1)	3,545 (43.1)
	Western Finland	2,886 (34.1)	14,527 (35.3)	528 (31.1)	2,857 (34.7)
	Northern Finland	1,065 (12.6)	5,801 (14.1)	205 (12.1)	1,083 (13.2)
	Eastern Finland	838 (9.9)	3,879 (9.4)	249 (14.7)	739 (9.0)
Place of birth	Urban	5,917 (69.8)	26,774 (65.0)	1,141 (67.2)	5,446 (66.2)
	Semi-urban	1,232 (14.5)	6,730 (16.3)	242 (14.3)	1,310 (15.9)
	Rural	1,277 (15.1)	7,383 (17.9)	300 (17.7)	1,417 (17.2)
Marital status	Married/in relationship	7,193 (84.9)	36,518 (88.7)	1,441 (84.9)	7,346 (89.3)
	Single	666 (7.9)	2,275 (5.5)	150 (8.8)	417 (5.1)
Parental immigration status	Both parents Finnish	7,448 (87.9)	37,461 (91.0)	1,379 (81.3)	7,402 (90.0)
	Mother immigrant	214 (2.5)	828 (2.0)	55 (3.2)	146 (1.8)
	Father immigrant	241 (2.8)	1,047 (2.5)	59 (3.5)	213 (2.6)
	Both parents immigrants	338 (4.0)	1,291 (3.1)	162 (9.5)	333 (4.0)
Maternal age (years)	<20	319 (3.8)	1,104 (2.7)	49 (2.9)	211 (2.6)
	20–24	1,517 (17.9)	6,760 (16.4)	281 (16.6)	1,317 (16.0)
	25–29	2,527 (29.8)	12,930 (31.4)	510 (30.1)	2,656(32.3)
	30–34	2,405 (28.4)	12,668 (30.8)	463 (27.3)	2,530 (30.8)
	35–39	1,312 (15.5)	6,183 (15.0)	290 (17.1)	1,202 (14.6)
	≥40	381 (4.5)	1,477 (3.6)	100 (5.9)	300 (3.6)
Paternal age (years)	<20	100 (1.2)	366 (0.9)	16 (0.9)	75 (0.9)
	20–24	878 (10.4)	4,022 (9.8)	155 (9.1)	724 (8.8)
	25–29	2,003 (23.6)	10,267 (24.9)	397 (23.4)	2,144 (26.1)
	30–34	2,476 (29.2)	13,090 (31.8)	442 (26.0)	2,599 (31.6)
	35–39	1,667 (19.7)	8,243 (20.0)	360 (21.2)	1,629 (19.8)
	40–44	715 (8.4)	3,268 (7.9)	188 (11.1)	635 (7.7)
	45–49	262 (3.1)	1,002 (2.4)	64 (3.8)	212 (2.6)
	≥50	140 (1.7)	378 (0.9)	33 (1.9)	77 0.9)

SES = socioeconomic status

[a]Students, pensioners, unemployed, small business entrepreneurs, housewives and househusbands

Number of missing: [b]ASD without ID: Maternal SES: 1426 (16.8%), Urbanicity: 48 (0.6%), Marital status: 615 (7.3%), Parental immigration status: 233 (2.7%), Maternal age: 13 (0.2%), Paternal age: 233 (2.7%)

[c]ASD with ID: Maternal SES: 319 (18.8%), Urbanicity: 14 (0.8%), Marital status: 106 (6.2%), Parental immigration status: 42 (2.5%), Maternal age: 4 (0.2%), Paternal age: 42 (2.5%)

both parents were immigrants, $p<.001$) and older maternal age (≥40 years, $p=.024$), and older paternal age (35–39 years, $p=.002$; 40–44 years, $p<.001$); 45–49 years, $p=.028$; ≥50 years, $p=.038$).

Co-occurring With Another Psychiatric Disorder

We limited the co-occurring analyses to the oldest birth cohort, born between 1998 and 2002 ($n=3,867$). A total of 59.0% cases had at least one co-occurring diagnosis. Among the cases of ASD without ID, 64.1% had co-occurring diagnoses, and among the cases ASD of with ID, the respective percentage was 31.9%. The most common frequent co-occurring diagnoses among the cases of ASD without ID were ADHD (33.9%), depressive disorder (25.4%) and anxiety disorder (23.9%). Among the cases of ASD with ID, the most prevalent diagnoses were ADHD (17.2%), anxiety disorder (10.5%) and schizophrenia (5.2%) (Table S6). ASD cases without ID were more likely to have been diagnosed with other psychiatric disorders compared to those with ID,

Table 3 Association between sociodemographic factors in ASD with and without ID cases and controls

Sociodemographic factor		Interaction with comorbid ID[b]	ASD without ID	ASD with ID
		p–value	Multivariate[c]	Multivariate[c]
			OR (95%CI)	OR (95%CI)
Maternal SES	Upper white-collar workers	**0.002****	Ref.	Ref.
	Unknown		**1.29 (1.18–1.42)** ***	**1.53 (1.24–1.90)** ***
	Lower white-collar workers		0.99 (0.91–1.06)	**1.36 (1.13–1.63)** **
	Blue-collar workers		**1.10 (1–1.20)** *	**1.75 (1.42–2.16)** ***
	Others[a]		**1.24(1.14–1.36)** ***	**1.44 (1.17–1.78)** ***
Birth region	Southern Finland	**<.001*****	Ref.	Ref.
	Western Finland		**0.93 (0.88–0.99)** *	0.90 (0.78–1.03)
	Northern Finland		**0.90 (0.83–0.97)** **	1.03 (0.86–1.24)
	Eastern Finland		1.04 (0.96–1.14)	**1.87 (1.56–2.24)** ***
Place of birth	Urban	**0.005****	Ref.	Ref.
	Semi-urban		**0.84 (0.78–0.90)** ***	1.02 (0.87–1.20)
	Rural		**0.79 (0.73–0.85)** ***	1.00 (0.87–1.20)
Marital status	Married/in a relationship	**0.053***	Ref.	Ref.
	Single		**1.29 (1.16–1.42)** ***	**1.75 (1.40–2.20)** ***
Parental immigration status	Both parents Finnish	**<.001*****	Ref.	Ref.
	Mother immigrant		1.09 (0.92–1.28)	**1.67 (1.16–2.41)** **
	Father immigrant		1.02 (0.87–1.19)	**1.49 (1.08–2.06)** *
	Both parents immigrants		1.13 (0.99–1.30)	**2.91 (2.33–3.64)** ***
Maternal age (years)	<20	**0.097***	**1.28 (1.07–1.52)** **	0.95 (0.61–1.48)
	20–24		**1.09 (1.01–1.19)** *	1.02 (0.84–1.24)
	25–29		Ref.	Ref.
	30–34		0.93 (0.87–1.00)	0.98 (0.83–1.15)
	35–39		0.98 (0.89–1.07)	1.17 (0.95–1.44)
	≥40		1.08 (0.93–1.25)	**1.42 (1.05–1.93)** *
Paternal age (years)	<20	**0.010****	0.95 (0.73–1.25)	1.20 (0.60–2.39)
	20–24		0.93 (0.84–1.04)	1.20 (0.93–1.30)
	25–29		0.95 (0.88–1.02)	1.10 (0.93–1.30)
	30–34		Ref.	Ref.
	35–39		1.05 (0.98–1.14)	**1.30 (1.10–1.55)** **
	40–44		**1.14 (1.03–1.27)** *	**1.60 (1.28–2.00)** ***
	45–49		**1.33 (1.13–1.55)** ***	**1.47 (1.04–2.08)** *
	≥50		**1.86 (1.50–2.31)** ***	**1.67 (1.03–2.73)** *

The bolded values are statistically significant (p<.05)

[a]Students, pensioners, unemployed, small business entrepreneurs, housewives and househusbands

[b]Chi-square test

[c]The multivariate model included maternal SES class, region of birth, urbanicity, maternal marital status, parental immigration status, maternal and paternal age

Ref = reference category, OR = odds ratio, CI = confidence interval, SES = socioeconomic status

*** $p<.001$, ** $p<.01$, * $p<.05$

with the exception of bipolar disorder and schizophrenia. After adjusting for sex, birth year and all sociodemographic risk factors, these differences remained statistically significant ($p<.05$) (Table S7). Among the girls, those with ASD without ID were more likely to have received diagnoses of anxiety and depressive disorders compared to those with ASD with ID. Among the boys, ASD without ID was more likely to have been diagnosed with ADHD, depressive disorder, anxiety disorder, OCD or Tourette syndrome compared to those with ASD with ID (Table S7).

Discussion

This study utilized nationwide register-based data, including inpatient and outpatient records from all specialized healthcare clinics in Finland. We identified four main key findings. First, girls are typically diagnosed with ASD later (by age 15) than boys (by age 9). Second, the cumulative incidence among ASD without ID notably increased over the study period, but for ASD with ID, the cumulative incidence remained stable after age 5. Third, several socio-demographic risk factors were associated with both

ASD cases with and without ID. Fourth, ADHD, depressive disorder and anxiety disorder were the most common psychiatric disorders among the cases of ASD without ID, and ADHD, anxiety disorder and schizophrenia were most common for ASD cases with ID.

First, the general later diagnosis of girls was reflected in the boy-to-girl ratio, which decreased from 4.18:1 at age 6 to 1.52:1 at age 15. This finding aligns with previous research indicating that the incidence of ASD increases with age, specifically among girls (Idring et al., 2015; Jensen et al., 2014; Russell et al., 2022; Surén et al., 2012). Two register-based studies in Sweden and Denmark found an increase in ASD incidence, most prominently among girls (Idring et al., 2015; Jensen et al., 2014). This trend may be explained by an increased awareness of ASD in girls in recent decades (Solmi et al., 2022). Additionally, diagnosing ASD in girls can be more complicated as they often mask their symptoms through better social-communication and imitation skills (Dean et al., 2017), leading to detection only when impairments become more severe. Girls may also present more internalizing symptoms such as anxiety or depression, which can lead to misdiagnosis of ASD traits. In contrast, boys typically exhibit more externalizing behaviors such as aggression and motor problems, resulting in earlier diagnosis (Santos et al., 2022). Therefore, detecting ASD in both genders requires considering sex differences in clinical characteristics (Delobel-Ayoub et al., 2020). Another finding in the current study is that the boy-to-girl ratio was greater among cases of ASD without ID compared to the group with ID. The presence of ID may moderate the female phenotype of ASD. Previous studies have shown that girls who have ASD without ID exhibit fewer repetitive behaviors and interests and fewer linguistic problems compared to boys, potentially contributing to the underdiagnosis of girls who have ASD without ID (Saure et al., 2023). Conversely, girls with ASD with ID experience greater social difficulties, repetitive behaviors, poorer linguistic abilities and more motor problems, leading to higher referral and diagnosis rates (Rynkiewicz et al., 2019). According to our findings, although the health care utilization has improved over time, the diagnosis of ASD—particularly ASD without ID—among girls still requires greater attention and awareness. Enhancing early screening protocols to identify these cases more effectively may reduce diagnostic delays and support earlier, more tailored interventions (Sheldrick et al., 2022; Lindly et al., 2025).

Second, the cumulative incidence of ASD without ID increased over time during childhood and adolescence in both boys and girls, while it remained almost stable around age 5 for ASD cases with ID. These findings are consistent with a previous register-based study in Sweden: there was an eightfold increase in the prevalence of ASD without ID among children aged 2–17 years, whereas the prevalence of ASD with ID slightly increased among this group (Idring et al., 2015). A time-trend study in the US revealed a fivefold increase in ASD without ID and a twofold increase in ASD with ID from 2000 to 2016, based on diagnosis at age 8 years (Shenouda et al., 2023). Changes in diagnostic criteria, increased awareness among parents and professionals (Olfson et al., 2014), improved access to services (Mishina et al., 2024), and increasing parental age at childbirth (Kiuru et al., 2020) may have contributed to the rise in diagnosed cases of ASD without ID (Katusic et al., 2021). Additionally, most cases of ASD with ID may be identified by age 5 due to well-established early childhood screening programs, which could result in better identification.

Third, we found that cases of ASD with ID as well as those without ID were associated with several sociodemographic risk factors, including low maternal SES, single motherhood, and a paternal age of over 40. The risk factors were similar for both groups, except for parental immigration status and being born in Eastern Finland, which were associated only with ASD with ID. Mothers with lower income may experience higher levels of stress, leading to neuroinflammatory abnormalities that can potentially affect their offspring's brain development (Blair & Raver, 2016; Koyama et al., 2023). Furthermore, single motherhood increased the odds of ASD with and without ID, but the risk of ASD with ID was found to be greater. Single mothers tend to have a lower income and education levels and less support, which can further increase levels of stress (Behere et al., 2017; Delobel-Ayoub et al., 2015). Fathers over 40, but not mothers, were more likely to have a child with ASD with or without ID. However, a Swedish register-based study found associations between a maternal age of over 30 and a paternal age of over 50 and ASD (Idring et al., 2014). The difference between our findings and the Swedish study may be attributed to sample size, as our study includes a sample nearly 2.5 times larger. The association between a paternal age of over 40 and an increased risk of ASD with or without ID may be explained by the quality of sperm, which is affected by age with de novo mutations that increase the likelihood of neurodevelopmental disorders such as autism and ID (Kaltsas et al., 2023; Sanders et al., 2012).

In our study, we observed a higher prevalence of ASD among children with immigrant parents, particularly when both parents were immigrants. Upon adjusting for other sociodemographic risk factors, we found that only ASD with ID remained significantly associated with parental immigration status. This finding also aligns with prior research (Becerra et al., 2014; Crafa & Warfa, 2015; Delobel-Ayoub et al., 2015; Idring et al., 2015; Ng et al., 2017). A population-based study in Sweden revealed that children of migrant parents were more likely to have ASD with ID

compared to cases without ID, with a greater risk when migration happened during pregnancy (Magnusson et al., 2012). A 2015 case-control study in Finland demonstrated that the risk of Asperger's syndrome was significantly lower among children whose parents were both immigrants compared to those with two Finnish parents (Lehti et al., 2015). Another case-control study involving 1,132 cases in 2013 using FIPS-A data showed that the risk of childhood autism increased among children with immigrant mothers, but not those with immigrant fathers (Lehti et al., 2013). Our study, however, found that both maternal and paternal immigration backgrounds were individually associated with an increased risk of ASD with ID. It is important to note that the ASD categorization in the previous studies differed from that of our study, as we included all the cases of ASD and categorized them based on co-occurrence of ID. One significant factor contributing to our findings may have been the higher prevalence of consanguineous marriages among immigrants, which is associated with an elevated risk of novel mutations in genes linked to ID (Barnevik–Olsson et al., 2008). Another explanation for this finding is that there could have been immunological factors due to early pathogen exposure in the mother or neonate, which may be associated with the risk of both ID and ASD (Gillberg & Gillberg, 1996). Stressful life events, including poverty, war and immigration, have also been linked to gene mutations (Havdahl et al., n.d.; Ronald et al., 2011). Additionally, help-seeking behaviors may have changed among immigrants, possibly due to reduced stigma, or increased access to healthcare services (Paananen et al., 2013). Regional disparities also played a role in the differences in the sociodemographic risk factors between ASD with and without ID cases. Previous register-based studies in Finland have reported geographic variations in the prevalence of mental disorders, with higher rates of anxiety in the southern region (Khanal et al., 2022) and higher rates of bipolar disorder (Chudal et al., 2014), ADHD (*Lasten ja nuorten ADHD-diagnoosien yleisyys 2022*, 2022) and schizophrenia (Suokas et al., 2024) in the eastern part of country. These regional differences may be partially explained by disparities in healthcare access, which may contribute to an underdiagnosis of milder cases in this area.

In this study we focused on examining the prevalence of other psychiatric disorders in cases of ASD with and without ID. We found clear differences, with individuals diagnosed with ASD without ID being more likely to receive diagnoses of ADHD, depressive disorder, anxiety disorder, OCD, sleep disorder and Tourette syndrome. These differences between the two groups were statistically significant. Additionally, we observed that both girls and boys with ASD without ID were at greater risk of being diagnosed with anxiety and depressive disorders compared to those with ASD with ID. These findings are consistent with previous research (Rai et al., 2018), which suggests that individuals with higher cognitive functioning may have greater awareness of their difficulties. This increased insight, along with experience of social isolation, bullying and feeling different, may contribute to a heightened vulnerability to internalizing problems, such as anxiety and depression. Furthermore, delayed diagnosis of ASD in individuals without ID may lead to prolonged psychological stress due to lack of understanding and appropriate support during childhood and adolescence. These findings underscore the importance of raising awareness about the diagnosis of ASD without ID, specifically among girls, as their diagnosis often occurs later than boys. This delayed diagnosis may be due to ASD co-occurring with other disorders, which can mask the signs of ASD. Therefore, it is crucial for healthcare professionals to be vigilant and consider the possibility of ASD, even in cases where symptoms may be overshadowed by other conditions. Early detection and intervention can lead to better outcomes for individuals with ASD, highlighting the need for increased awareness and understanding of the disorder, particularly among girls.

Strengths and Limitations

The register-based case-control study included a large sample size, and categorized cases based on high-functioning and low-functioning. A key advantage was the use of cumulative incidence rather than prevalence, reflecting changes in the rate of ASD diagnoses over time. There are number of limitations in this study that should be considered when interpreting the findings. First, since the registers only recorded individuals who sought specialized mental health services, cases with milder symptoms or those treated in private health clinics were likely missed. Consequently, our reliance on register-based data might be an underestimation of accurate ASD incidence. Therefore, our rates should be interpreted as treated incidence rates and not as population-based incidence rates. Second, ASD diagnoses obtained from the CRHC are based on clinical diagnoses, not on standardized interviews, possibly resulting in misclassification. However, the validity of the CRHC has previously been shown to be good in the diagnoses of mental disorders in childhood autism (Lampi et al., 2010). Third, we did not consider the level of intellectual disability (e.g., mild, moderate, severe, or profound) in our study. Finally, the sociodemographic data used in this study were collected at the time of birth, does not account for any changes in factors over time or include additional sociodemographic variables that may emerge later in life.

Conclusion

This nationwide register-based study with a large sample size reveals that the incidence of ASD without ID increased from 1998 to 2015. However, it remains unclear whether this result reflects a real increase in incidence or if it is due to improvements in the service system, and help-seeking, changes in diagnostic criteria or greater awareness among population and professionals. The mean age for ASD without ID was relatively high for boys and very high for girls. This highlights the importance of further improving the service system in detecting ASD without ID. Furthermore, co-occurring psychiatric disorders were common, and early detection could prevent secondary disorders from developing. Whereas socio-demographic factors were mostly shared by both groups, parental immigration status was associated only with ASD with ID. This finding highlights the importance of ensuring mental health services for immigrants. Further research is needed to find out the underlying causes of the high incidence of ASD without ID.

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Declarations

Competing Interests The authors have no relevant financial or non-financial interests to disclose.

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