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Gender differences in parent-reported age at diagnosis of children with autism spectrum disorder

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Abstract

Background

Autism spectrum disorders (ASD) are more commonly observed in boys than in girls. There is growing awareness of ASD in girls and recognition that under-diagnosis is common. The current study aimed to investigate any evidence of reduction in the average age at diagnosis for girls by assessing whether: 1) girls' age at diagnosis has reduced, compared to boys', across two age cohorts – children born between 1996–1999 and 2002–2005; 2) age at diagnosis differed between boys and girls diagnosed across childhood; 3) any characteristics are associated with earlier age at diagnosis in girls.

Methods

Data were available from large UK databases of children with ASD: The Database of Children with Autism Spectrum Disorder Living in the North East (http://daslne.org) and the Autism Spectrum Database–UK (www.asd-uk.com).

Results

There was no differential reduction of parent-reported age at diagnosis for girls over time. For children receiving their diagnosis at age ≥60 months, boys received diagnoses an average of one year earlier than did girls (98.2 months, SD=31.6 vs. 109.1 months, SD=36.4). For boys and girls, earlier diagnosis was associated with toileting problems and temper problems. Having additional diagnoses (e.g., dyslexia, dyspraxia, and epilepsy) was associated with later diagnosis.

Conclusions

Age at diagnosis has not decreased over time. Girls with ASD are diagnosed later than boys when aged 5 years or older. Health and education professionals would benefit from better understanding factors such as toileting problems, temper problems, and additional diagnoses that could potentially guide early identification of ASD in clinical practice for school-age girls.

Key words: Autism; ASD; girls; gender; age at diagnosis

The reported prevalence estimates of autism spectrum disorder (ASD) are always greater in males than females. The male to female ratio is around 4:1 (Baird et al., 2006; CDC, 2014; Fombonne, 2009) in the absence of intellectual impairment (see Rivet & Matson, 2011 for a review). Increased rates of ASD diagnoses in children over the last 15 years or so may be due to the broadening of, and changes to, ASD diagnostic criteria and practice, improved identification, earlier age at diagnosis in the teenage years, and different methodologies used to estimate prevalence (Russell, Collishaw, Golding, Kelly, & Ford, 2015).

Cognitively able girls may be diagnosed with ASD significantly less frequently and at an older age than boys despite there being no gender differences in the age at which parental concern is expressed (Giarelli et al., 2010). However, with the exception of learning/intellectual disability, there is little evidence to suggest what factors might be associated with earlier age at ASD diagnosis in girls. Indeed, several studies have suggested no gender difference in age at diagnosis (Mussey, Ginn, & Klinger, 2017). In a cross-cohort comparison study, Russell et al., (2015) found no gender difference in age at diagnosis nor differences in gender ratios of diagnosed children aged 7 years assessed in 1998/1999 (n = 96) and 2007/2008 (n = 209). Furthermore, in a large UK cohort study, Brett, Warnell, McConachie, and Parr (2016) found that the average age at diagnosis was 67.3 months for boys and 72.1 months for girls and had not decreased over the decade from 2004 to 2014. Although some children are now diagnosed by age 2 years, Brett and colleagues found no reduction in age at diagnosis for children diagnosed under age 3 years in the UK (Brett et al., 2016). While gender was not a significant influencing factor, earlier age at diagnosis was associated with language regression, lower socioeconomic status, greater degree of support required, greater symptom severity, and greater parental concern about initial symptoms (Brett et al., 2016; Daniels & Mandell, 2014).

There has been growing interest in the identification of ASD in girls, and it is becoming recognised that under-diagnosis or later diagnosis may be common (Dworzynski, Ronald, Bolton, & Happé, 2012; Van Wijngaarden-Cremers et al., 2014; Loomes, Hull, & Mandy, 2017). One way to measure whether there has been better detection of ASD in girls in recent years is to show whether there is evidence of change in the average age at diagnosis for girls. While Brett et al., (2016) assessed factors that influenced age at diagnosis, they did not specifically examine factors that are associated with earlier age at diagnosis independently for boys and girls. Thus, the current study

builds on that of Brett et al., (2016) to examine gender differences in parent-reported age at diagnosis in large UK databases of children with ASD.

We had the following aims: First, to assess whether girls' age at diagnosis has reduced, compared to boys', across two age cohorts – children who were born between 1996–1999 and 2002–2005. Changes in diagnostic practices have been shown to have a substantial effect on the increased prevalence of ASD (King & Bearman, 2009). Thus, this separation of birth cohorts was chosen to better control for this potential confound of changes over a decade, so that any evidence of reduced age at diagnosis in girls is less likely to be an artefact of general changes in diagnostic practices. If ASD diagnosis in girls has become more timely, we would expect a differential reduction in age at diagnosis, for girls compared to boys, between the age periods. Second, to investigate whether age at diagnosis differed between boys and girls diagnosed across childhood. We assessed gender differences in age at diagnosis across childhood by grouping the sample at the median age at diagnosis where any differences between boys and girls would most likely be salient (see below). Finally, to examine characteristics that might be associated with earlier age at diagnosis in girls.

Methods

Data were available from two large representative UK databases: The Database of children with autism spectrum disorder living in the North East of England (Dasl^{n}e, established in 2003; http://daslne.org) and the Autism Spectrum Database – UK (ASD–UK, established in 2011; www.asd-uk.com). Dasl^{n}e covers six areas around Newcastle upon Tyne, whilst ASD–UK covers the rest of the UK. By 2017, the databases held data from over 4000 families, including information on children's ASD and other medical diagnoses, behaviour problems, and language levels as reported by parents/carers and professionals.

Dasl^{n}e and ASD–UK share similar methodologies and type of data collected. Recruitment has been described previously (Warnell et al., 2012; Brett et al., 2016). Parents/carers are invited to join Dasl^{n}e shortly after their child (aged 2 to 18 years) receives an ASD diagnosis. For ASD–UK, parents/carers of children with a clinical diagnosis of ASD (aged 2 to 16 years) are invited to join through heath teams or self-referral.

Children enrolled in Dasl^{n}e and ASD–UK have been shown to be representative of children with ASD living in the North East of England (McConachie et al., 2009) and the rest of the UK (Warnell et al., 2012), respectively. These databases allow analyses based on good statistical power and sampling variation.

Validation of children's ASD diagnoses was examined previously for children enrolled in Dasl^{n}e (McConachie et al., 2009) and both Dasl^{n}e and ASD-UK (Warnell et al., 2015). Corroboration of diagnoses for a random sample of children enrolled in Dasl^{n}e was from information in their medical notes that was checked against questionnaires completed by their clinician. For a further sample, the Autism Diagnostic Observation Schedule-Generalised (Lord et al., 2000) was administered by a research associate and parents completed the Social Communication Questionnaire-Lifetime version (SCQ; Rutter, Bailey, & Lord, 2003) to give some standardised information about the children's ASD characteristics. The SCQ focuses on the child's entire developmental history and provides a total score that is interpreted in relation to specific ASD cut-off points. A score of 15 or greater is an indication of a possible ASD. These checks confirmed that all children met criteria for autism or ASD, or had this diagnosis documented in their medical notes. Parents/carers of children with ASD enrolled in ASD-UK completed the SCQ that has been used previously to investigate the reliability and validity of the parent-reported ASD diagnosis for children enrolled in ASD-UK (Warnell et al., 2015). When a professional report was available about a child, and the SCQ score was below 15, reports were checked for evidence that the child had ASD. However, IQ or language data from this corroboration were not available for use in the current study.

Informed consent was obtained from all participants included in the study. Parents/carers completed a paper or online questionnaire reporting on their child's gender, age at diagnosis, and type of ASD diagnosis within six categories: autism, Asperger syndrome, pervasive developmental disorder-not otherwise specified (PDD-NOS), autism spectrum disorder (ASD), atypical autism, and 'other'. The 'other' category allowed the opportunity for parents to report on any other term that was not listed but which they felt described their child's diagnosis, such as pathological demand avoidance, high-functioning autism, sensory autism etc. The categories were grouped as autism, Asperger syndrome, and 'ASD' that included PDD-NOS, atypical autism, and 'other'. These diagnostic terms were used at the time of data collection based on DSM-IV and ICD-10 diagnostic criteria by child health teams. Parents/carers reported on their child's language level (i.e., speaks in sentences

or lesser levels of competence), the presence of learning/intellectual disability, ADHD and other additional diagnoses. Other *additional diagnoses* includes other developmental diagnoses, such as dyslexia, dyspraxia, epilepsy (ASD–UK only) and any other diagnoses parents reported (e.g., Down's syndrome, global developmental delay, sensory processing disorder, severe learning disability).

Parents/carers also reported on the frequency and number of *co-existing conditions* experienced by their child that may or may not be formally diagnosed experienced (anxiety, aggression, eating problems, hyperactivity, reluctance to separate from parent, self-injury, sensory reactions, sleep problems, temper tantrums, and toileting problems). This was indicated as 'frequent' (i.e., behaviour is apparent three or more times a week), 'sometimes' (i.e., behaviour occurs once or twice a week), 'never or rare', or 'in the past only'. For the purpose of the current study, co-existing conditions were regarded as 'frequent' if reported to occur three or more times per week (Maskey, Warnell, Parr, Le Couteur, & McConachie, 2013).

The research was prospectively reviewed and approved by the local UK National Health Service Research Ethics Service Committee West Midlands – Black Country (reference number: 13/WM/0098) and the ASD–UK/Dasl^{n}e Research Committee. The work was carried out in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki as revised in 2000.

Samples

Parent-reported age at diagnosis was examined for 830 children enrolled in Dasl^{n}e by Year of Birth Group across two time periods: Children born between 1996–1999 (n = 482; 401 boys and 81 girls) were compared with children born between 2002–2005 (n = 348; 302 boys and 46 girls). These time periods were chosen opportunistically as they were some years apart to allow for possible changes in diagnostic practice over the decade from 1996 to 2005 inclusive (c. f., Russell et al., 2015). Indeed, King and Bearman (2009) found a 25% increase in ASD prevalence between 1992 and 2005 that was attributable to changes in diagnostic practice during this time period, suggesting that changes in diagnostic practices may also have a substantial impact on age at diagnosis. The proportion of boys to girls was 5.5:1 in Dasl^{n}e. Data for this analysis were available only from Dasl^{n}e as ASD–UK was not established until 2011.

Parent-reported age at diagnosis across childhood was then examined for 3335 children enrolled in both Dasl^{n}e and ASD–UK. In order to control for the potential confounds of the relationship between age and developmental milestones on age at diagnosis, we plotted and examined chronological age when data were provided and age at diagnosis for boys and girls (Figure 1). We identified that age at diagnosis starts to differ by gender at around 96 months chronological age and 60 months median diagnostic age. Therefore, we split the sample by gender into children who were under age 60 months when they received their diagnosis (*n* = 1873; 1549 boys and 324 girls) and compared them to children who had been diagnosed aged 60 months or older (*n* = 1462; 1198 boys and 264 girls) in order to increase the opportunity of finding observable differences in age at diagnosis, if indeed there were any. For children with ASD who were diagnosed at less than 60 months of age, the range of year of birth was from 1991–2013. For children with ASD who were diagnosed at 60 months of age or later, the range of year of birth was from 1989–2010. Therefore, the data examining diagnoses in both groups before 60 months of age and at, or after, 60 months of age, covers the 1990s and 2000s (Figure 2). The proportion of boys to girls was 4.7:1 in Dasl^{n}e/ASD–UK combined.

Data were included in analyses only where the child had a reported and valid age at diagnosis, and date of birth; as in Brett et al., (2016), parent data about perceived age at diagnosis were accepted as reported.

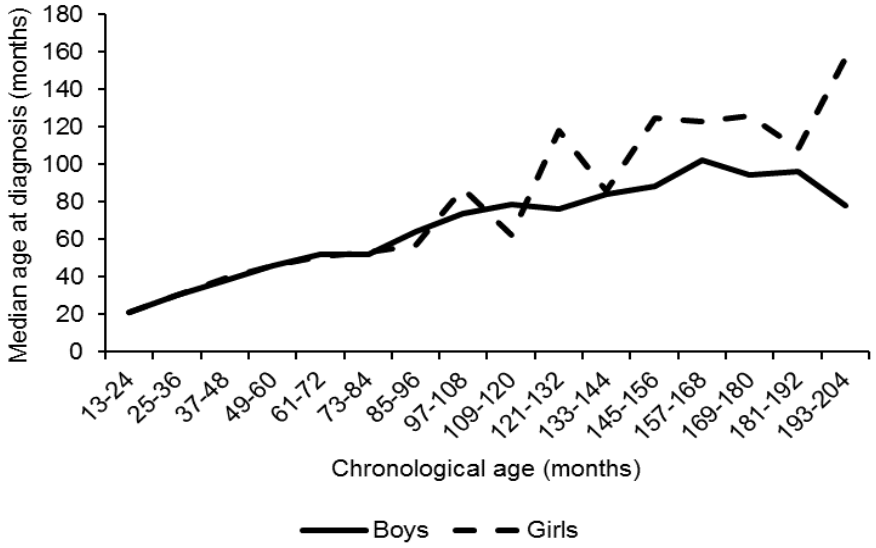

Figure 1. Median parent-reported age at diagnosis for boys and girls according to their chronological age group.

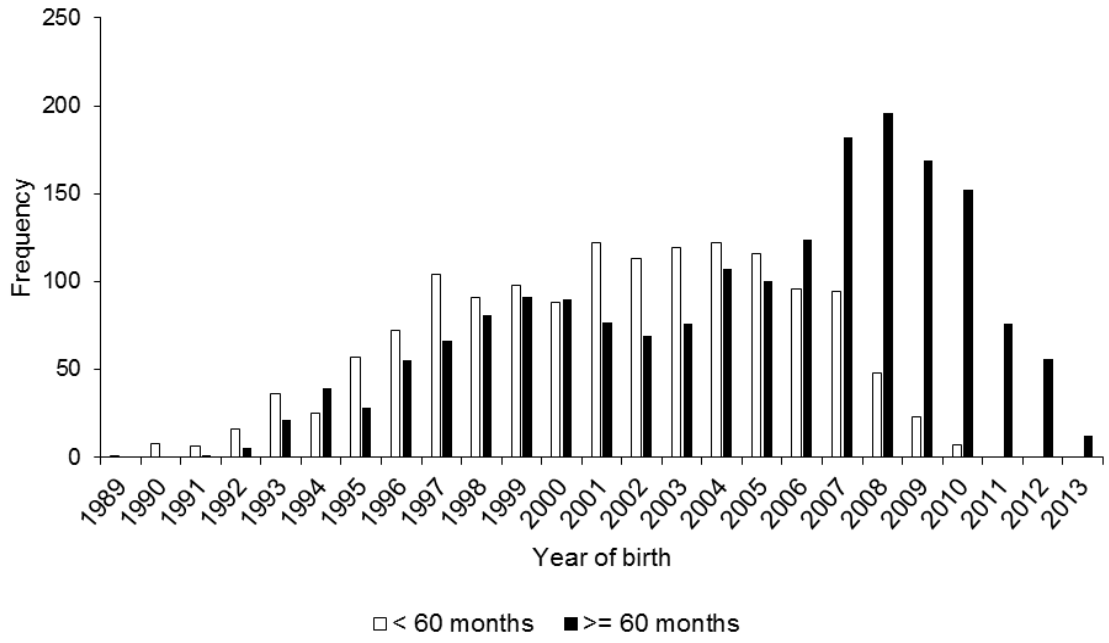

Figure 2. Frequency of year of birth for children by Age at Diagnosis Group.

Statistical analysis

All analyses used SPSS 22.0. The dependent variable was age at diagnosis, which was not normally distributed (skewness = 1.19, kurtosis = 0.86; Kolmogorov-Smirnov = 0.16 (3335), $p < .001$). Therefore, the variance was normalised by using a logarithmic (log10) transformation. This transformed dependent variable was used for the inferential statistics.

Gender differences in parent-reported age at diagnosis were analysed using two-way analyses of variance (ANOVA) with the between-subjects factors of Gender (2 levels: boys and girls) and Year of Birth Group (2 levels: 1996–1999 and 2002–2005), or Age at Diagnosis Group (2 levels: < 60 months and ≥ 60 months) and the within-subjects factor of the transformed age at diagnosis variable. Bonferroni post-hoc analyses were performed to locate differences and describe interactions more clearly.

The factors associated with age at diagnosis were assessed using one-way ANOVAs with the between-subjects factor of parent-reported ASD diagnosis type; independent samples t-tests for parent-reported learning/intellectual disability, ADHD and other additional diagnoses, language level, and the frequency of co-existing conditions. Pearson's Correlation coefficient was used to assess the relationship between age at diagnosis, the number of co-existing conditions, and the parent-reported SCQ score.

A stepwise multiple regression analysis was performed to determine variables that predicted parent-reported age at diagnosis. Standardised regression coefficients are reported for linear regression analyses, with beta values reporting the relative change between categories within factors in age at diagnosis. For dummy coded variables, this was the difference between each category and the reference category. All other statistical analyses were descriptive in nature.

For all statistical analyses, alpha was set to .05 and adjusted using Bonferroni correction for multiple comparisons. Effect sizes were reported using partial eta squared and Cohen's *d* as appropriate to describe the quantitative measure of the difference between groups (interpreted as .01 small, .06 medium, and .14 large for partial eta squared and .2 small, .5 medium, and .8 large for Cohen's *d*).

Results

Parent-reported age at diagnosis ranged from 7–213 months (mean = 67.0, SD = 37.2; median = 54, interquartile range = 46); only 5 parents reported an age at diagnosis below 12 months of age, therefore all parent-reported data were included. Chronological age at data collection ranged from 18–214 months (mean = 101.0, SD = 45.2; median = 94, interquartile range = 72). Table 1 shows descriptive statistics of chronological age and age at diagnosis of boys and girls with ASD by Year of Birth Group and Age at Diagnosis Group.

Gender difference in parent-reported age at diagnosis by Year of Birth Group (1996–1999 versus 2002–2005)

There was a significant main effect of Gender ($F(1, 826) = 10.71$, $p = .001$, $\eta^2p = .01$). Age at diagnosis was earlier for boys than for girls (boys mean = 66.5 months, SD = 36.8; median = 54, interquartile range = 46 vs. girls mean = 74.1 months, SD = 43.6; median = 58, interquartile range = 60). There was no significant main effect of Year of Birth Group ($F(1, 826) = 1.83$, $p = .176$, $\eta^2p = .00$) or a significant Gender x Year of Birth Group interaction ($F(1, 826) = 0.07$, $p = .798$, $\eta^2p = .00$).

Table 1. Chronological age and parent-reported age at diagnosis of the children with ASD by Year of Birth Group and Age at Diagnosis Group.

	Year of Birth Group (Dasl^{n}e only)				Age at Diagnosis Group (Dasl^{n}e and ASD-UK)			
	1996–1999 (*n* = 482)		2002–2005 (*n* = 348)		< 60 months (*n* = 1873)		≥ 60 months (*n* = 1462)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Number (%)	401 (83.2)	81 (16.8)	302 (86.8)	46 (13.2)	1549 (82.7)	324 (17.3)	1198 (81.9)	264 (18.1)
Age (months)								
Mean (SD)	126.4 (39.0)	137.8 (39.5)	89.9 (30.1)	95.4 (32.6)	82.8 (42.0)	78.2 (40.5)	123.5 (36.6)	133.6 (38.8)
Median	122	144	87	88	71	64	119	136.5
Interquartile range	62	72	42	52	56	47	56	64
Age at diagnosis (months)								
Mean (SD)	70.3 (37.8)	84.8 (47.5)	63.4 (30.9)	75.8 (36.6)	41.2 (10.2)	40.6 (10.4)	98.2 (31.6)	109.1 (36.4)
Median	57	72	55	62.5	42	41	90.5	102.5
Interquartile range	44	74	41	64	16	16	44	60

Gender differences and parent-reported age at diagnosis by Age at Diagnosis Group (< 60 months versus ≥ 60 months)

There was a significant main effect of Gender ($F(1, 3331) = 8.56$, $p = .003$, $\eta^2p = .00$) and Gender x Age at Diagnosis Group interaction ($F(1, 3331) = 18.49$, $p < .001$, $\eta^2p = .01$). (See Figure 3). Age at diagnosis was earlier for boys than for girls if they had received their diagnosis aged ≥ 60 months (boys mean = 98.2, SD = 31.6; median = 90.5, interquartile range = 44 vs. girls mean = 109.1, SD = 36.4; median = 102.5, interquartile range = 60) but not when diagnosed aged < 60 months (boys mean = 41.2, SD = 10.2; median = 42, interquartile range = 16 vs. girls mean = 40.6, SD = 10.4; median = 41, interquartile range = 16).

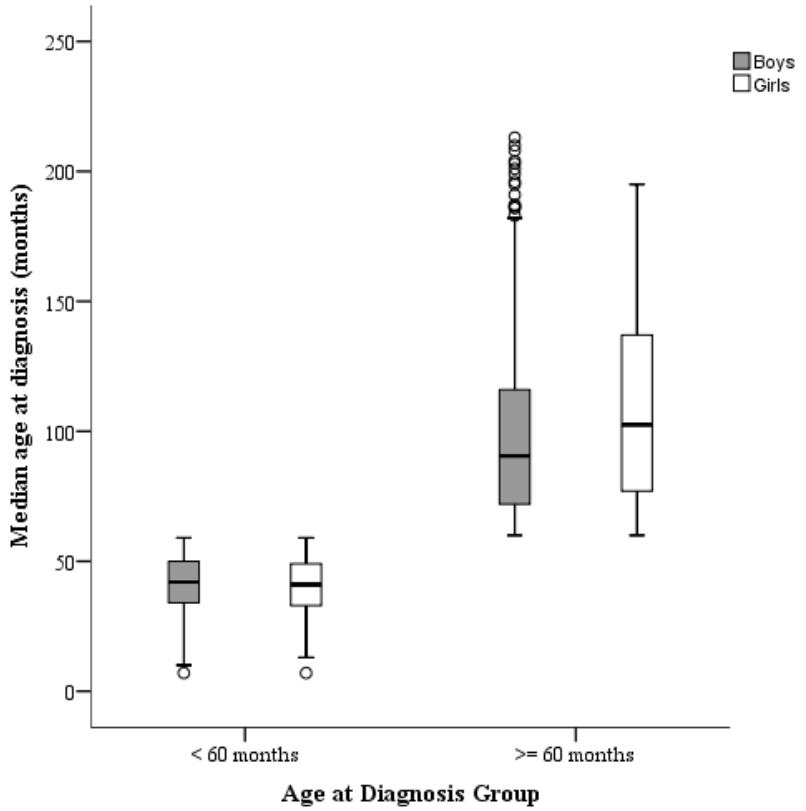

Figure 3. Median parent-reported age at diagnosis for boys and girls diagnosed < 60 months and ≥ 60 months of age.

Gender differences, parent-reported age at diagnosis, and factors associated with ASD

Since age at diagnosis was significantly earlier for boys than for girls if they had received their diagnosis aged ≥ 60 months but not < 60 months, we examined whether certain parent-reported characteristics were associated with age at diagnosis in girls who received their diagnosis at ≥ 60 months of age (*n* = 1462).

We first examined univariate associations between age at diagnosis and these characteristics in boys (*n* = 1198) and girls (*n* = 264) who had received their diagnosis at ≥ 60 months of age (Table 2). For both boys and girls, age at diagnosis was earlier for children who had toileting problems. Specifically for boys, age at diagnosis was earlier for those who: had a diagnosis of autism compared to Asperger syndrome, or a diagnosis of ASD compared to Asperger syndrome; had lower levels of language; and who had frequent co-existing conditions of hyperactivity, temper problems, eating

Table 2. Age at diagnosis and differences between parent-reported characteristics of boys and girls diagnosed at ≥ 60 months of age

Parent-reported characteristics		Boys						Girls					
		M (SD)	Median	Interquartile range	*n*	*n* (%)	Univariate association	M (SD)	Median	Interquartile range	*n*	*n* (%)	Univariate association
ASD diagnosis													
Autism	Yes	94.1 (30.9)	84	48	1198	127 (10.6)	$F(2, 1195) = 6.61$ $p = .001$ $\eta^2p = .01$	108.6 (41.3)	103	67	264	33 (12.5)	$F(2, 261) = 2.08$ $p = .13$ $\eta^2p = .02$
Asperger syndrome	Yes	102.3 (32.3)	97	46		424 (35.4)		116.0 (34.4)	116	55		65 (24.6)	
Other/ASD	Yes	96.2 (31.0)	88	42		647 (54.0)		106.4 (36.0)	99	56		166 (62.9)	
SCQ (ASD-UK only)		23.3 (6.9)	24	10	606	532 (87.8)	$r = -.02$ $p = .68$	21.7 (6.3)	21	8	139	119 (85.6)	$r = -.08$ $p = .42$
Language level													
Speaks in sentences	Yes	98.9 (31.0)	92	42	1186	947 (79.8)	$t(1184) = 2.41$ $p = .02$ $d = .13$	109.1 (35.6)	104	59	259	192 (74.1)	$t(257) = 0.43$ $p = .67$ $d = .03$
Lower levels of language	Yes	94.8 (33.4)	84	47		239 (20.2)		107.9 (38.7)	96	64		67 (25.9)	
Additional diagnoses													
Learning/intellectual disability	Yes	97.6 (32.6)	89	44	1198	261 (21.8)	$t(1196) = 0.50$ $p = .62$ $d = .02$	103.4 (34.6)	96	61	264	92 (34.8)	$t(262) = 1.87$ $p = .06$ $d = .24$
	No	98.3 (31.3)	92	43		937 (78.2)		112.1 (37.1)	108.5	60		172 (65.2)	
ADHD	Yes	98.5 (29.0)	92	38	1198	235 (19.6)	$t(1196) = 0.66$ $p = .51$ $d = .01$	111.3 (34.3)	112.5	59	264	46 (17.4)	$t(262) = 0.61$ $p = .54$ $d = .08$
	No	98.1 (32.2)	90	45		963		108.6 (36.9)	100	602		218	
Other	Yes	103.6 (34.3)	96	51	1198	399 (33.3)	$t(1196) = 4.02$ $p < .001$ $d = .25$	116.8 (37.3)	117.5	65	264	100 (37.9)	$t(262) = 2.73$ $p = .007$ $d = .32$
	No	95.5 (29.8)	88	42		799 (66.7)		104.4 (35.2)	98	56		164 (62.1)	
Co-existing conditions (number)[a]		4.4 (2.3)	4	4	1198	1062 (88.6)	$r = -.10$ $p = .001$	4.5 (2.3)	4	3	264	237 (89.8)	$r = -.13$ $p = .04$
Co-existing conditions (frequent)[b]													
Sleep problems	Yes	96.5 (30.9)	88	41	1182	580 (49.1)	$t(1180) = 1.71$ $p = .09$ $d = .10$	108.5 (37.5)	98.5	61	259	138 (53.3)	$t(257) = 0.34$ $p = .74$ $d = .03$
	No	99.7	94	47		602		109.5	108	59		121	

		(32.2)				(50.9)		(35.6)				(46.7)	
Toileting problems	Yes	93.5 (30.1)	85	42	1179	280 (23.7)	$t(1177) = 2.88$ $p = .004$ $d = .19$	93.0 (30.9)	81	45	258	54 (20.9)	$t(256) = 3.79$ $p < .001$ $d = .60$
	No	99.5 (32.0)	94	45		899 (76.3)		113.2 (36.7)	114.5	60		204	
Hyperactivity	Yes	95.4 (29.3)	88	40	1170	561 (47.9)	$t(1168) = 2.38$ $p = .02$ $d = .16$	107.4 (35.1)	99	53	255	116 (45.5)	$t(253) = 0.60$ $p = .55$ $d = .10$
	No	100.4 (33.2)	92	48		609 (52.1)		111.1 (38.0)	109	67		139 (54.5)	
Temper	Yes	94.3 (28.9)	87	40	1187	601 (50.6)	$t(1185) = 3.81$ $p < .001$ $d = .24$	103.9 (33.4)	96	53	262	129 (49.2)	$t(260) = 1.91$ $p = .06$ $d = .27$
	No	101.8 (33.7)	95.5	49		586 (49.3)		113.7 (38.7)	113	65		133 (50.8)	
Aggression	Yes	95.3 (29.3)	89	40	1187	339 (28.6)	$t(1185) = 1.67$ $p = .10$ $d = .13$	108.5 (36.7)	103	54	261	78 (29.9)	$t(259) = 0.13$ $p = .89$ $d = .02$
	No	99.2 (32.4)	90.5	47		848 (71.4)		109.2 (36.4)	101	61		183 (70.1)	
Injury	Yes	94.9 (31.8)	85.5	40	1179	160 (13.6)	$t(1177) = 1.46$ $p = .15$ $d = .12$	118.3 (40.8)	132	76	259	31 (12.0)	$t(257) = 1.40$ $p = .16$ $d = .28$
	No	98.6 (31.6)	92	44		1019 (86.4)		107.3 (35.9)	100	55		228 (88.0)	
Reluctant to separate	Yes	95.8 (28.4)	90	37	1175	215 (18.3)	$t(1173) = 0.76$ $p = .45$ $d = .09$	107.3 (36.6)	101	61	261	64 (24.5)	$t(259) = 0.37$ $p = .71$ $d = .05$
	No	98.5 (32.1)	90	46		960 (81.7)		109.1 (36.4)	102	60		197 (75.5)	
Anxiety	Yes	98.3 (30.5)	92	43	1184	611 (51.6)	$t(1182) = 0.50$ $p = .62$ $d = .01$	109.8 (34.8)	104	57	260	161 (61.9)	$t(258) = 1.06$ $p = .29$ $d = .09$
	No	98.1 (32.8)	89	46		573 (48.4)		106.3 (38.5)	98	60		99 (38.1)	
Eating problems	Yes	95.6 (30.7)	87	42	1182	617 (52.2)	$t(1180) = 3.05$ $p = .002$ $d = .17$	107.4 (34.1)	101	51	259	128 (49.4)	$t(257) = 0.34$ $p = .74$ $d = .08$
	No	101.0 (32.4)	96	44		565 (47.8)		110.3 (39.0)	102	68		131 (50.6)	
Sensory sensitivity	Yes	95.4 (29.6)	88	41	1184	652 (55.1)	$t(1182) = 2.95$ $p = .003$ $d = .18$	108.4 (35.8)	100	59	261	157 (60.2)	$t(259) = 0.14$ $p = .89$ $d = .04$
	No	101.2 (33.3)	95	46		532 (44.9)		109.9 (37.8)	111	63		104 (39.8)	

Note: [a]total number of co-existing conditions reported as frequent; [b]'frequent' = occurring 3 or more times per week.

problems, and sensory sensitivity. There were no univariate associations specific to girls. Age at diagnosis was later for both boys and girls who had another diagnosis (e.g., dyslexia, dyspraxia, epilepsy, and 'other'), and for children who had fewer co-existing conditions.

Regression analyses

To explore the predictive utility of the factors associated with parent-reported age at diagnosis and whether they were different for boys and girls when they were diagnosed ≥ 60 months, a stepwise multiple regression analysis was carried out with age at diagnosis as the dependent variable, separately for both boys and girls. The predictors chosen were those that had a significant univariate association with age at diagnosis for either boys or girls (Table 2).

Characteristics of children from both Dasl^{n}e and ASD–UK were included. The dummy coded ASD diagnosis variables (autism and Asperger syndrome) were entered in Step 1 (children with a reported 'ASD' diagnosis were the reference category) that resulted in two dummy coded variables (autism and Asperger syndrome). Language level was entered in Step 2. Other additional diagnoses were entered in Step 3. Frequency of co-existing conditions of toileting problems, hyperactivity, temper problems, eating problems, and sensory sensitivity, along with number of co-existing conditions, were entered in Step 4. Table 3 shows the results of this multiple regression separately for boys and girls.

Step 1 of the model, type of ASD diagnosis, was significant for boys ($F(2, 1007) = 6.38$, $p = .002$, $R^2 = .013$) but not for girls ($F(2, 215) = 0.94$, $p = .39$, $R^2 = .009$) and explained 1.3% and 0.9% of the variance, respectively. Age at diagnosis was earlier for boys who had a diagnosis of ASD compared to boys who had a diagnosis of Asperger syndrome ($\beta = .024$) whereas there was no significant difference between age at diagnosis for boys who had a diagnosis of autism and boys who had a diagnosis of ASD ($\beta = -.019$). Age at diagnosis did not differ for girls who had a diagnosis of ASD compared to girls who had a diagnosis of autism ($\beta = -.010$) or Asperger syndrome ($\beta = .029$).

Step 2 of the model, language level, was significant for boys ($F(3, 1006) = 6.23$, $p < .001$, $R^2 = .018$) but not for girls ($F(3, 214) = 0.63$, $p = .594$, $R^2 = .009$) and explained a further 0.5% and 0.0% of the variance, respectively. Boys whose language repertoire comprised only lower levels of language were diagnosed earlier than boys who spoke in sentences ($\beta = .025$) but this was not the case for girls ($\beta = -.004$).

Table 3. Results of the regression analysis for boys and girls diagnosed ≥ 60 months

Boys (n = 1009). Total variance explained = 5.2%		R^2	*B*	*Std. Error*	*Beta*	*t*	*p*
Step 1	(Constant)	.013	1.961	.005		356.99	<.001
	ASD (reference) vs Autism		-.019	.013	-.048	-1.48	=.140
	ASD (reference) vs Asperger syndrome		.024	.009	.089	2.76	=.006
Step 2	(Constant)	.018	1.942	.010		203.95	<.001
	ASD (reference) vs Autism		-.017	.013	-.042	-1.30	=.195
	ASD (reference) vs Asperger syndrome		.021	.009	.079	2.41	=.016
	Language level		.025	.010	.077	2.43	=.015
Step 3	(Constant)	.034	1.929	.010		193.83	<.001
	ASD (reference) vs Autism		-.019	.013	-.045	-1.41	=.158
	ASD (reference) vs Asperger syndrome		.022	.009	.080	2.46	=.014
	Language level		.026	.010	.080	2.55	=.011
	Other additional diagnoses		.034	.008	.125	4.02	<.001
Step 4	(Constant)	.052	1.958	.013		150.19	<.001
	ASD (reference) vs Autism		-.019	.013	-.032	-1.41	=.323
	ASD (reference) vs Asperger syndrome		.019	.009	.068	2.29	=.036
	Language level		.023	.010	.072	2.29	=.022
	Other additional diagnoses		.034	.008	.124	3.99	<.001
	Toileting problems		-.027	.010	-.092	-2.59	=.010
	Hyperactivity		-.009	.011	-.033	-.79	=.428
	Temper problems		-.030	.011	-.115	2.73	=.006
	Eating problems		-.019	.010	-.073	-1.51	=.044
	Sensory sensitivity		-.016	.010	-.059	-1.51	=.132
	Total number of co-existing conditions		.005	.004	.096	1.46	=.145
Girls (n = 217). Total variance explained = 12.6%		R^2	*B*	*Std. Error*	*Beta*	*t*	*p*
Step 1	(Constant)	.009	2.014	.012		162.40	<.001
	ASD (reference) vs Autism		-.010	.029	-.024	-.34	=.731
	ASD (reference) vs Asperger syndrome		.029	.024	.085	1.22	=.225
Step 2	(Constant)	.009	2.016	.020		99.43	<.001
	ASD (reference) vs Autism		-.010	.029	-.024	-.35	=.730
	ASD (reference) vs Asperger syndrome		.030	.024	.087	1.22	=.223
	Language level		-.004	.023	-.011	-.15	=.878
Step 3	(Constant)	.034	1.997	.022		92.00	<.001
	ASD (reference) vs Autism		-.008	.029	-.020	-.29	=.771
	ASD (reference) vs Asperger syndrome		.028	.024	.083	1.18	=.024
	Language level		-.002	.023	-.006	-.08	=.934
	Other additional diagnoses		.047	.020	.158	2.34	=.020
Step 4	(Constant)	.126	2.043	.030		67.95	<.001
	ASD (reference) vs Autism		-.018	.028	-.043	-.64	=.522
	ASD (reference) vs Asperger syndrome		.005	.024	.014	.19	=.848
	Language level		.011	.022	.034	-.50	=.617
	Other additional diagnoses		.047	.019	.159	2.41	=.017
	Toileting problems		-.100	.027	-.294	-3.76	=.001
	Hyperactivity		-.027	.025	-.094	-1.08	=.282
	Temper		-.063	.027	-.216	-2.35	=.020
	Eating problems		-.027	.022	-.094	-1.23	=.219
	Sensory sensitivity		-.022	.025	-.070	-.87	=.387
	Total number of co-existing conditions		.015	.009	.240	1.66	=.098

Step 3 of the model, other additional diagnoses, was also significant for boys ($F(4, 1005) = 8.77$, $p < .001$, $R^2 = .034$) and explained a further 1.6% of the variance. Boys who had an additional diagnosis were diagnosed later than boys who did not have an additional diagnosis ($\beta = .034$).

Although the model was not significant for girls ($F(4, 213) = 1.85$, $p = .120$, $R^2 = .034$) and did not explain any significant additional variance (2.5%), girls who had an additional diagnosis were also diagnosed later than girls who did not have an additional diagnosis ($\beta = .047$).

The final step of the model that included frequency and number of co-existing conditions, was significant for boys ($F(10, 999) = 5.45$, $p < .001$, $R^2 = .052$) and for girls ($F(10, 207) = 2.97$, $p = .002$, $R^2 = .126$) and explained a further 1.8% and 9.2% of the variance, respectively. Boys and girls were diagnosed earlier if children had toileting problems (boys, $\beta = -.027$; girls, $\beta = -.100$) and temper problems (boys, $\beta = -.030$; girls, $\beta = -.063$). Boys who had eating problems were diagnosed earlier ($\beta = -.019$) whereas eating problems did not explain any significant variance in age at diagnosis in girls ($\beta = -.027$). Hyperactivity, sensory problems, and the total number of co-existing conditions did not explain any significant additional variance for either boys or girls.

The model overall explained 5.2% and 12.6% of the variance in age at diagnosis in boys and girls, respectively.

Discussion

This large study found that, compared with boys, girls diagnosed with ASD at 5 years of age or older received their diagnosis an average of one year later. Whilst this was a small effect statistically, this difference can have a significant impact for children, families, and clinicians. This delay reduces opportunities for understanding girls' difficulties, and accessing community support and interventions, educational support and strategies at school and for older young people, the workplace. Although there was no statistically significant main effect of year of birth group for the periods 1996–1999 and 2002–2005, there appeared to be a trend where parent-reported age at diagnosis for both boys and girls was earlier for children born during the later time period. This trend is likely to be due to recent changes in clinical practice and the diagnostic processes.

It is not clear why girls are still being diagnosed relatively later, why they are overlooked or misdiagnosed, and why there is an under-identification of probable ASD in girls (Holtmann, Bölte, & Poustka, 2007; Loomes et al., 2017). It has been suggested by clinicians and researchers that this may be due to factors such as diagnostic criteria, concepts, and practices being biased towards 'male' presentation of ASD, that screening instruments may not be reliable for identifying probable ASD in

girls (Dworzynski et al., 2012), or the possibility that there is an altered clinical manifestation of the condition (Kirkovski, Enticott, & Fitzgerald, 2013). Also, where there is a broader autism phenotype or ASD in relatives, families may 'wait and see' whether their female child develops greater skills over time, rather than pursuing a diagnosis when difficulties are first suspected.

Furthermore, it is likely that girls may be better able than boys to compensate for, or adapt to, aspects of ASD characteristics, described as the 'camouflage' hypothesis (Dworzynski et al., 2012). Girls in social situations (e.g., at school age) may either intentionally or unconsciously 'mask' their limitations in social communication, understanding, and imagination, and thus not be considered to meet ASD diagnostic criteria. Girls are better able to follow social actions through observation and quicker to appease if they have made a social error. They are more likely to seek out interaction and play opportunities due to their increased tendency to be more socially aware and socially driven than boys (Gould & Ashton-Smith, 2011). It may be that girls receive a diagnosis later than boys because of gender differences in their school age presentation. Since this study did not find any gender differences in age at diagnosis before age 5 years, it may be that professionals attempt to make diagnoses earlier in order for girls to access intervention services sooner. Earlier support would assist with the social challenges that become evident within the school environment or before girls go on to develop compensatory strategies that may delay an ASD diagnosis.

In the regression analysis, although there were no factors that predicted age at diagnosis specific to girls, boys and girls diagnosed at 5 years of age or older received an ASD diagnosis earlier if they had toileting problems and temper problems and later if they had an additional diagnosis. Of note is that the strength of the associations between age at diagnosis and toileting problems, temper problems, and other additional diagnosis were larger for girls than for boys (Table 2). Indeed, these factors were somewhat better predictors for girls (12.6%) than for boys (5.2%) and may be stronger 'red flags' for parents to look out for and provide significant information for clinicians. This may lead to a greater awareness of possible clinical diagnosis in girls at school age. The clinical implications of camouflaging ASD symptomatology is that there is a greater chance that girls may be diagnosed with other internalising conditions that are not as visible such as anxiety, other mental health problems, or eating disorders (Hambrook, Tchanturia, Schmidt, Russell, & Treasure, 2007). This may then lead to 'diagnostic overshadowing' where difficulties are explained in terms of the first diagnosis. For example, Miodovnik, Harstad, Sideridis, and Huntington (2015) found that compared to children who

had received an ADHD diagnosis at the same time or after a diagnosis of ASD, children who had received an ADHD diagnosis first were diagnosed with ASD approximately 3 years later. Given the findings of the current study, it is possible that those school-age girls who do receive a diagnosis of ASD may be presenting with other externalising symptoms such as toileting problems and temper outbursts that are more 'obviously different', 'not typical for girls', or they are different from gender-based developmental expectations, resulting in referral for a diagnosis at an earlier age. It would be instructive in a different sample to follow up girls referred for diagnostic assessment who did not receive an ASD diagnosis and explore whether a diagnosis was given in the following years. Finally, it is important to acknowledge that despite the need for improving earlier diagnosis in school-age girls this study found girls received their diagnosis on average only one year later than boys; advances in clinical practice could go some way to reducing this difference.

Limitations

This study has strengths including the large number of children within representative databases. However, one important limitation is that Dasl^{n}e and ASD–UK do not have a direct measurement of children's IQ. The one factor that is known to predict age at diagnosis in girls is the presence of learning/intellectual disability. When girls do receive an earlier ASD diagnosis, they are likely to fall within the moderate to severe end of the spectrum (CDC, 2014; Munson et al., 2008; Dworzynski et al., 2012) although this finding is not consistent (see Coo et al., 2012). Cognitively able girls may be diagnosed with ASD significantly less frequently and later than boys despite no gender differences in the age when parental concern is expressed (Begeer et al., 2013), or the number of visits to a healthcare professional during the diagnostic process (Siklos & Kerns, 2007). Therefore, it is possible that there was no significant difference in parent-reported age at diagnosis for boys and girls diagnosed less than 5 years of age in the current study because girls may have had a particularly low IQ. Similarly, girls with ASD who had been diagnosed at 5 years of age or later may have been diagnosed significantly later than boys with ASD because they were more cognitively able. The level of both language and learning/intellectual ability were by parent report; ability was not a predictor of age at diagnosis for either boys or girls in this study, which is contrary to previous findings (Mandy et al., 2012; Daniels & Mandell, 2014). Age at diagnosis was also by parent report (though checked where possible when unusually early).

Implications

Health and education professionals would benefit from understanding better the subtle gender differences in autism characteristics especially for school-age girls, and to take note that specific characteristics may be used to guide identification of girls with ASD at an earlier age. For example, toileting problems, temper outbursts, and additional diagnoses in school-age girls may reinforce suspicion of probable ASD. Professionals can use this understanding to promote earlier identification in clinical practice.

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Author contributions

A. Petrou analysed the data and J. R. Parr, and H. McConachie conceptualised the study and contributed to conceptual analysis. A. Petrou, J. R. Parr, and H. McConachie co-wrote the paper, and had complete access to the study data that support the publication.

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